U.S. Department
Of Transportation

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FINAL REGULATORY IMPACT ANALYSIS

CORPORATE AVERAGE FUEL ECONOMY and CAFE REFORM FOR MY 2008-2011 LIGHT TRUCKS

Office of Regulatory Analysis and Evaluation
National Center for Statistics and Analysis
March 2006

TABLE OF CONTENTS

TABLE OF CONTENTS cont.

EXECUTIVE SUMMARY

This assessment examines the costs and benefits of improving the fuel economy of light trucks for model years (MY) 2008-2011. It includes a discussion of the technologies that can improve fuel economy, analysis of the potential impact on light truck retail prices, safety, lifetime fuel savings and their value to consumers, and other societal benefits such as improved energy security and reduced emissions of pollutants and greenhouse gases.

The agency is reforming the corporate average fuel economy (CAFE) standards for light trucks with a size-based standard. Manufacturers will have the choice of complying with standards established under either the traditional system (Unreformed CAFE) or the Reformed CAFE system during a transition period spanning MYs 2008-2010. In MY 2011, all manufacturers will be required to comply with the Reformed CAFE standard. Under Reformed CAFE, the agency is setting standards based on a vehicle attribute referred to as footprint[1]. A continuous mathematical function provides a separate fuel economy target for each footprint. Different parameters for the continuous mathematical function are derived for each model year. Individual manufacturers will be required to comply with a single fuel economy level that is based on the distribution of its production among the footprints of its vehicles in each particular model year.

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[1] Vehicle Footprint is defined as the wheelbase (the distance from the center of the front axle to the center of the rear axle) times the average track width (the distance between the center line of the tires) of the vehicle (in square feet).

Four alternatives are examined in the analysis. The alternatives are:

1: Unreformed CAFE system for MY 2008-2010

2: Reformed CAFE system for MY 2008-2011 (Continuous Function)

3: The NPRM proposed Step Function (using the boundaries and targets proposed in the NPRM)

4: A Revised Step Function (using the boundaries proposed in the NPRM with re-optimized targets based on the latest data available)

In addition, in Model Year 2011, the agency is requiring medium duty passenger vehicles[2] (MDPVs) to meet fuel economy standards for the first time. Alternative analyses show the impact of the inclusion of MDPVs in the standards.

Costs: Costs were estimated based on the specific technologies that were applied to improve each manufacturer's fuel economy up to the level required under each alternative. Table 1 provides those cost estimates on an average per-vehicle basis, and Table 2 provides those estimates on a fleet-wide basis in millions of dollars.

Benefits: Benefits are determined mainly from fuel savings over the lifetime of the vehicle, but also include externalities such as reductions in criteria pollutants. Table 3 provides those estimates on an industry-wide basis.

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[2] MDPVs are light trucks that have a gross vehicle weight rating (GVWR) less than 10,000 lbs., a GVWR greater than 8,500 lbs. or a curb weight greater than 6,000 lbs, and primarily used to transport passengers. EPA has identified these vehicles as being primarily to transport passengers, not cargo.

Net Benefits: Table 4 compares costs and benefits of each alternative. The values in Table 4 indicate the extent to which societal benefits exceed the costs of each alternative, since all the values are net benefits.

Fuel Savings: Table 5 shows the lifetime fuel savings in millions of gallons.

Table 1
Incremental Cost
Per Vehicle
(In Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	64	185	195	N.A.	N.A.
Reformed CAFE	66	201	213	271	255
NPRM Step Function	21	137	129	N.A.	185
Revised Step Function	68	189	205	264	251

* By policy design, the mpg levels under Reformed CAFE are set so that the industry-wide costs of Reformed CAFE are roughly equal to the industry-wide costs of Unreformed CAFE for MY 2008-2010.

Table 2
Incremental Total Cost
(In Millions of Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	536	1,621	1,752	N.A.	N.A.
Reformed CAFE	553	1,724	1,903	2,531	2,301
NPRM Step Function	171	1,194	1,144	N.A.	1,665
Revised Step Function	575	1,658	1,832	2,461	2,265

* By policy design, the mpg levels under Reformed CAFE are set so that the industry-wide costs of Reformed CAFE are roughly equal to the industry-wide costs of Unreformed CAFE for MY 2008-2010.

Table 3
Present Value of Lifetime Societal Benefits by Alternative
(Millions of $2003)
(Discounted **3%**)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	704	2,291	2,587	N.A.	N.A.
Reformed CAFE	968	2,492	2,857	3,676	3,356
NPRM Step Function	530	1,906	1,934	N.A.	2,613
Revised Step Function	1,066	2,460	2,815	3,581	3,315

(Discounted **7%**)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	577	1,876	2,109	N.A.	N.A.
Reformed CAFE	782	2,015	2,336	2,992	2,726
NPRM Step Function	411	1,561	1,576	N.A.	2,146
Revised Step Function	887	2,018	2,288	2,934	2,703

Table 4
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of $2003)

(Discounted **3%**)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	168	670	835	N.A.	N.A.
Reformed CAFE	415	768	954	1,145	1,055
NPRM Step Function	359	712	790	N.A.	948
Revised Step Function	491	802	983	1,120	1,050

(Discounted **7%**)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	41	255	357	N.A.	N.A.
Reformed CAFE	229	291	433	461	425
NPRM Step Function	240	367	432	N.A.	481
Revised Step Function	312	360	456	473	438

Table 5
Savings in Millions of Gallons of Fuel
Undiscounted Over the Lifetime of the Model Year

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	555	1,813	2,023	NA	NA
Reformed CAFE	746	1,940	2,230	2,834	2,583
NPRM Step Function	390	1,505	1,511	NA	2,043
Revised Step Function	848	1,944	2,190	2,786	2,572

All of the alternatives provide net benefits for both consumers and society. The Unreformed CAFE alternative provides the lowest net benefits and the Revised Step Function provides slightly higher net benefits than the Reformed CAFE alternative.

The Reformed CAFE and Revised Step Function alternatives provide roughly equivalent fuel savings over the four years combined.

Including MDPVs in MY 2011 increases both net benefits and fuel savings.

I. INTRODUCTION

The purpose of this study is to analyze the effects of changes in the fuel economy standards for light trucks from MY 2008 to MY 2011. It includes a discussion of the technologies that can improve fuel economy, the potential impacts on light truck retail prices, safety, the discounted lifetime net benefits of fuel savings, and the potential gallons of fuel saved.

The agency issued a final rule on April 7, 2003 (68 FR 16868), setting the CAFE standard applicable to light trucks for MY 2005 at 21.0 mpg, for MY 2006 at 21.6 mpg, and for MY 2007 at 22.2 mpg.

On February 7, 2002 (67 FR 5767), the agency issued a Request for Comments (RFC), seeking information upon which it could assess the viability of a reinvigorated CAFE program. The Request for Comments also sought comment on the findings and recommendations arising from the National Academy of Sciences study[3] published in January 2002. We also sought comments on possible reforms to the CAFE program, as it applies to both passenger cars and light trucks, to protect passenger safety, advance fuel-efficient technologies, and obtain the benefits of market-based approaches. While we have considered the comments, the original Request for Comments was quite general and the comments received tended to focus on the various alleged shortcomings of the current program or the generic admonishment against CAFE reform--and not on specific potential options.

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[3] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", National Research Council, 2002. The link for the NAS report is http://www.nap.edu/books/0309076013/html/

On December 29, 2003, the agency published an advanced notice of proposed rulemaking (ANPRM) seeking comment on various issues relating to reforming the CAFE program (68 FR 74908). The agency sought comment on possible enhancements to the program that would assist in further fuel conservation while protecting motor vehicle safety and the economic vitality of the automobile industry. This document, while not espousing any particular reform, sought more specific input than the 2002 RFC on various options set forth in an effort to adapt CAFE to today's vehicle fleet. A detailed summary of comments can be found in the docket to the ANPRM (Docket No. 2003-16128).

On August 30, 2005, the agency published a notice of proposed rulemaking (NPRM) to establish CAFE standards for model years (MYs) 2008 through 2011, and more importantly to reform the CAFE program (70 FR 51414). At the same time, we asked all manufacturers to update their fuel economy product plans. The data provided by vehicle manufacturers in response to this later request and data from the NAS Report were used in developing the basis for the final rule levels.

In the NPRM, we proposed fuel economy standards for light trucks in MYs 2008-2010, established under the traditional CAFE system (Unreformed CAFE system). We also proposed standards for MYs 2008-2010 under a proposed reformed CAFE system (Reformed CAFE system). During MYs 2008-2010, manufacturers would have an option of complying with standards established under the Unreformed or the Reformed CAFE system. We proposed that this period would serve as a transition period to provide manufacturers an opportunity to adjust to changes in the CAFE system. For MY 2011, we proposed standards established under Reformed CAFE only.

The NPRM proposed a new attribute-based Reformed CAFE system. The attribute-based system is based on the vehicle footprint (wheel base[4] x average wheel track width[5]). In the NPRM, the Reformed CAFE standard was based on fuel economy targets set for each of 6 footprint "categories", like a Step-Function. As the footprint category increased in size, the target mpg decreased. So, larger light trucks were compared to lower mpg targets. A single composite standard would then be calculated based on a manufacturer's production level in each category and would represent the required fuel economy for that manufacturer.

Need for Reform

The ANPRM discussed the principal criticisms of the current CAFE program that led the agency to explore light truck CAFE reform. They relate to energy security, traffic safety, and economic practicability.

First, concern has been raised that the energy-saving potential of the CAFE program is hampered by the current regulatory structure. Manufacturers who offer predominately small light trucks have little or no regulatory incentive to enhance fuel economy, because their vehicles tend to be more fuel efficient than the Unreformed CAFE level. Moreover, the difference between the fuel economy standards for passenger cars and light trucks (27.5 mpg and 20.7 mpg, respectively, for MY 2004) encourages vehicle manufacturers to offer vehicles classified as light trucks for

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[4] "Wheel base" is essentially the distance between the centers of the axles

[5] "Track width" is the lateral distance between the centerline of the tires.

purposes of CAFE, possibly inducing design changes that hurt overall fuel economy. A CAFE system that more closely links fuel economy standards to the various market segments and their fuel economy performance may reduce the incentive to design vehicles which are functionally similar to passenger cars but are classified as light trucks.

Second, concern has been raised that the current light truck CAFE standards (called "Unreformed CAFE" in this document) could create safety risks. Vehicle manufacturers are encouraged to achieve greater fuel economy by downsizing and downweighting. Alternatively, manufacturers may offer small light trucks to offset their offerings of large light trucks. The resulting increase in the disparity between the smallest and largest vehicle sizes and weights in the on-road vehicle fleet is widely believed to have increased the number of fatalities in crashes involving light-duty trucks. The NAS report and a more recent NHTSA study[6] have suggested that if downweighting were concentrated on the heaviest light trucks in the fleet, there could be a small fleetwide safety benefit. An alternative CAFE system may allow more energy savings while protecting and enhancing the safety of the motoring public.

A third reason for considering CAFE reform relates to the adverse economic impacts that may result from such future increases in the stringency of CAFE standards. Rapid increases in the level of the CAFE standard could have substantial economic consequences on manufacturers,

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[6] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, Ph.D., NHTSA, October 2003, DOT HS 809-662.

especially those full-line manufacturers with product mixes dominated by large heavier light trucks. For example, full-line manufacturers – especially those with substantial sales in the heavier end of the light truck market – may generate fewer CAFE credits and incur larger compliance costs than vehicle manufacturers who focus their sales in the smaller, lighter end of the light truck market. As CAFE standards become more stringent under the current structure, the full-line manufacturers may experience adverse financial consequences, with resulting disruptions for employees in these firms and their suppliers.

The dual fuel incentive program, through which manufacturers may improve their calculated fuel economies by producing vehicles capable of operating on alternative fuels, is not considered in this analysis. By law, the agency has always analyzed fuel economy without considering the dual fuel credits, since it is an incentive program designed to increase the availability of alternative fuel vehicles.

Throughout this document, confidential information is presented in brackets [ ].

II. NEED OF THE NATION TO CONSERVE ENERGY

The Environmental Policy and Conservation Act (EPCA) specifically directs the Department to balance the technological and economic challenges related to fuel economy with the nation's need to conserve energy. While EPCA grew out of the energy crisis of the 1970s, the United States still faces considerable energy challenges today. U.S. energy consumption has been outstripping U.S. energy production at an increasing rate. This imbalance, if allowed to continue, will undermine our economy, our standard of living, and our national security. (May 2001 National Energy Policy (NEP) Overview, p. viii)

As was made clear in the first chapter of the NEP, efficient energy use and conservation are important elements of a comprehensive program to address the nation's current energy challenges:

> America's current energy challenges can be met with rapidly improving technology, dedicated leadership, and a comprehensive approach to our energy needs. Our challenge is clear--we must use technology to reduce demand for energy, repair and maintain our energy infrastructure, and increase energy supply. Today, the United States remains the world's undisputed technological leader: but recent events have demonstrated that we have yet to integrate 21st-century technology into an energy plan that is focused on wise energy use, production, efficiency, and conservation.

The concerns about energy security and the effects of energy prices and supply on national economic well-being that led to the enactment of EPCA persist today. The demand for petroleum is steadily growing in the U.S. and around the world.

The Energy Information Administration's International Energy Outlook 2005 (IEO2005)[7] and Annual Energy Outlook 2006 (Early Release) (AEO2006) indicate growing demand for petroleum in the U.S. and around the world. U.S. demand for oil is expected to increase from 21 million barrels per day in 2004 to 28 million barrels per day in 2030. In the AEO2006 reference case, world oil demand increases through 2030 at a rate of 1.4 percent annually, from 82 million barrels per day in 2004 to 118 million barrels per day in 2030 (AEO2006). Approximately 67 percent of the increase in world demand is projected to occur in North America and emerging Asia. Energy use in the transportation sector is projected to increase at an annual rate of 1.8 percent through 2025 (AEO2006).

To meet this projected increase in demand, worldwide production capacity would have to increase by more than 36 million barrels per day over current levels. OPEC producers are expected to supply 40 percent of the increased production. In contrast, U.S. crude oil production is projected to increase from 8.4 million barrels per day in 2004 to 9.62 million in 2015, and then begin declining, falling to 8.9 million barrels per day in 2025. By 2025, 60 percent of the oil consumed in the U.S. would be imported oil. [8]

Energy is an essential input to the U.S. economy, and having a strong economy is essential to maintaining and strengthening our national security. Secure, reliable, and affordable energy sources are fundamental to economic stability and development. Rising energy demand poses a challenge to energy security, given increased reliance on global energy markets. As noted above, U.S. energy consumption has increasingly been outstripping U.S. energy production.

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[7] See http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2005).pdf.

[8] AEO2006, Table A20, International Petroleum Supply and Disposition Summary

Conserving energy, especially reducing the nation's dependence on petroleum, benefits the U.S. in several ways. Improving energy efficiency has benefits for economic growth and the environment, as well as other benefits, such as reducing pollution and improving security of energy supply. More specifically, reducing total petroleum use decreases our economy's vulnerability to oil price shocks. Reducing dependence on oil imports from regions with uncertain conditions enhances our energy security and can reduce the flow of oil profits to certain states now hostile to the U.S. Reducing the growth rate of oil use will help relieve pressures on already strained domestic refinery capacity, decreasing the likelihood of product price volatility.

We believe that the continued development of advanced technology, such as fuel cell technology, and an infrastructure to support it, may help in the long term to achieve reductions in foreign oil dependence and stability in the world oil market. The continued infusion of advanced diesels and hybrid propulsion vehicles into the U.S. light truck fleet may also contribute to reduced dependence on petroleum. In the shorter term, our Reformed CAFE proposal would encourage broader use of fuel saving technologies, resulting in more fuel-efficient vehicles and greater overall fuel economy.

We have concluded that the increases in the light truck CAFE standards that will result from today's final rule will contribute appropriately to energy conservation and the comprehensive energy program set forth in the NEP. In assessing the impact of the standards, we accounted for the increased vehicle mileage that accompanies reduced costs to consumers associated with greater fuel economy and have concluded that the final rule will lead to considerable fuel savings. While increasing fuel economy without increasing the cost of fuel will lead to some additional vehicle travel, the overall impact on fuel conservation remains decidedly positive.

We acknowledge that, despite the CAFE program, the United States' dependence on foreign oil and petroleum consumption has increased in recent years. Nonetheless, data suggest that past fuel economy increases have had a major impact on U.S. petroleum use. The NAS determined that if the fuel economy of the vehicle fleet had not improved since the 1970s, U.S. gasoline consumption and oil imports would be about 2.8 million barrels per day higher than they are today.

III. CAFE REFORM

The CAFE system has long been the subject of public debate. Currently, there are separate standards for passenger cars and light trucks. Each manufacturer's light truck fleet must meet the CAFE standard for light trucks, based on a harmonic average of the fuel economy for each light truck model. This can be considered a "one size fits all" standard (every manufacturer is required to meet the same fuel economy level, e.g., 22.2 mpg for MY 2007 light trucks). Thus, the level of the standard doesn't vary with a manufacturer's product mix.

The NPRM discussed the principal criticisms of the current CAFE program that led the agency to explore light truck CAFE reform. First, the energy-saving potential of the CAFE program is hampered by the current regulatory structure. The Unreformed approach to CAFE does not distinguish between the various market segments of light trucks, and therefore does not recognize that some vehicles designed for classification purposes as light trucks may achieve fuel economy similar to that of passenger cars. The Unreformed CAFE approach instead applies a single standard to the light truck fleet as a whole, encouraging manufacturers to offer small light trucks that will offset the larger vehicles that get lower fuel economy. A CAFE system that more closely links fuel economy standards to the various market segments reduces the incentive to design vehicles that are functionally similar to passenger cars but classified as light trucks.

Second, because weight strongly affects fuel economy, the current light truck CAFE program encourages vehicle manufacturers to reduce weight in their light truck offerings to achieve greater fuel economy.[9] As the NAS report and a more recent NHTSA study have found, downweighting of the light truck fleet, especially those trucks in the low and medium weight ranges, creates more safety risk for occupants of light trucks and all motorists combined.[10]

Third, the agency noted the adverse economic impacts that might result from steady future increases in the stringency of CAFE standards under the current regulatory structure. Rapid increases in the light truck CAFE standard could have economic consequences.

The vulnerability of full-line firms to tighter CAFE standards does not arise primarily from poor fuel economy ratings within weight classes, i.e., from less extensive use of fuel economy improving technologies. Their overall CAFE averages are low, compared to manufacturers that produce more relatively light vehicles, because their sales mixes service a market demand for bigger and heavier vehicles capable of more demanding utilitarian functions. An attribute-based (Reformed CAFE) system could avoid disparate impacts on full-line manufacturers that could result from a sustained increase in CAFE standards.

The ANPRM discussed a number of reforms, primarily attribute-based systems that classify vehicles by either weight and/or size. As weight or size increases, the level of the required fuel economy level would decline. This can be accomplished by either segmenting vehicles based on the desired attribute or by adopting a system proposed by NAS that specifies a continuous

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[9] Manufacturers can reduce weight without changing the fundamental structure of the vehicle by using lighter materials or eliminating available equipment or options. It is more difficult to reduce vehicle size, and particularly footprint, because that attribute is more closely associated with the basic architecture of the vehicle.

[10] However, both studies also suggest that if downweighting is concentrated on the heaviest light trucks in the fleet there would be no net safety impact, and there might even be a small fleet-wide safety benefit. There is substantial uncertainty about the curb weight cut-off above which this would occur.

relationship between fuel economy and the vehicle attribute that is represented by a mathematical formula or function.

In an attribute-based standard, vehicles that share the same level of one or more attributes would face the same required level of CAFE.

Similar vehicles would be grouped into the same fleet segment, or lie near each other on a continuous mathematical function. If a manufacturer only produces certain types of vehicles, these vehicles would have to meet fuel economy levels set for that fleet segment of vehicles rather than a standard set for all light trucks. Such attribute-based systems remove the incentive for a manufacturer to down-weight or downsize vehicles (depending on the particular attribute used for the standard) because doing so would result in the vehicle facing a more stringent required CAFE level. Therefore, these types of systems address the safety criticism of the current system. Attribute-based systems also remove the incentive to comply with CAFE standards by “mix shifting.” Manufacturing small light trucks to balance out larger vehicles would be much less attractive under this system than under the current unreformed CAFE system. Also, the incentive to produce light trucks rather than cars is much less under an attribute-based system because it narrows the disparity between fuel economy standards of passenger cars and small light trucks.

An attribute-based system would also be more equitable to all manufacturers. Unlike the current standard, attribute based systems would require action to achieve compliance by both full-range and specialized manufacturers. In an attribute-based system, each segment of the vehicle fleet would face differing stringency levels. Manufacturers of predominantly larger or heavier vehicles would face less stringent required CAFE levels than manufacturers of smaller or lighter vehicles. Each manufacturer would have a required fuel economy level that reflects their fleet. But virtually all manufacturers would be required to improve the fuel economy of their vehicles under an attribute-based system.

Reformed CAFE is more market-oriented in the way it more fully respects economic conditions and consumer choice. Reformed CAFE does not force vehicle manufacturers to adjust fleet mix toward smaller vehicles unless that is what consumers are demanding. As the industry's sales volume and mix changes in response to economic conditions (e.g., gasoline prices and household income) and consumer preferences (e.g., desire for seating capacity or hauling capability), the level of CAFE required of manufacturers under Reformed CAFE will, at least partially, adjust automatically to these changes. Accordingly, Reformed CAFE may reduce the need for the agency to revisit previously established standards in light of changed market conditions, a difficult process that undermines regulatory certainty for the industry.

Vehicle Weight and Safety

The ANPRM presented examples of attribute-based systems using both curb weight and vehicle shadow (size)[11]. Both the NAS report and a more recent NHTSA safety study[12] made explicit links between weight and vehicle safety. It is important to note that both of these studies linking

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[11] Vehicle Shadow: the shadow of a vehicle, as if a light were shining from directly above (measured in square inches), essentially the overall width times the overall length of the vehicle.
Vehicle Footprint: the wheelbase times the average track width (the distance between the center line of the tires) of the vehicle (in square feet).

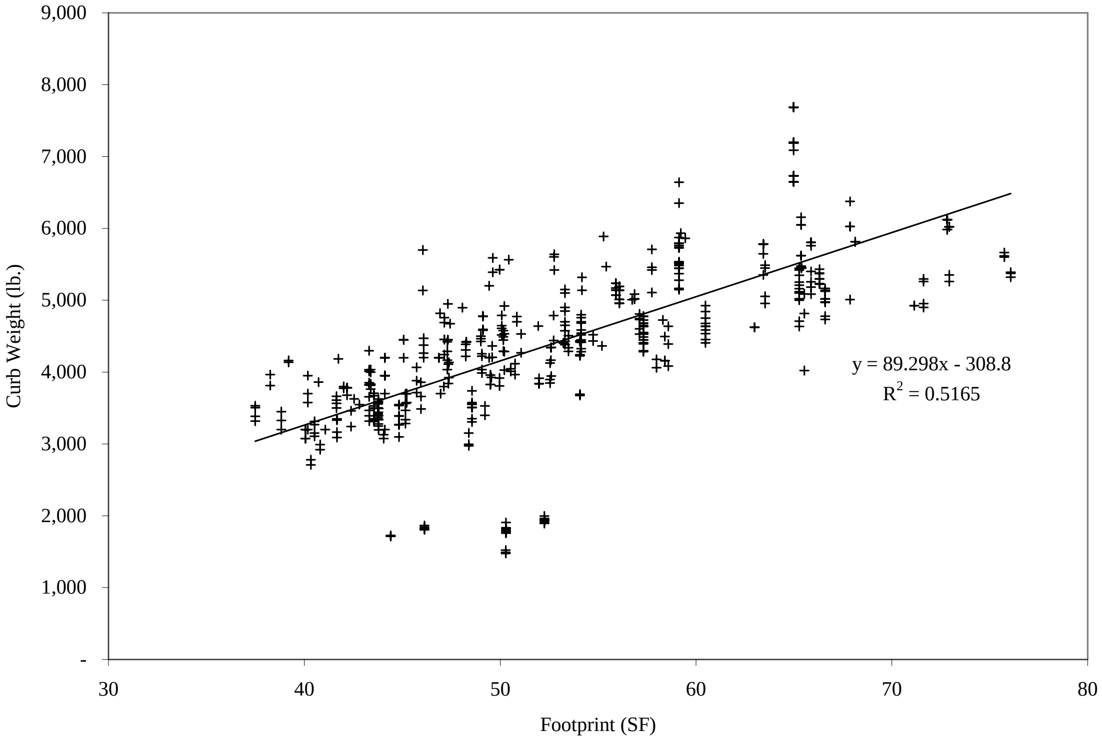
[12] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, PH.D., NHTSA, October 2003, DOT HS 809-662.

weight and safety are historical in nature. That is, these relationships are based on data observed at the time of the study (in the mid 1980's for the NAS study and 1991-1999 for the NHTSA study), but may not necessarily persist into the future. During this time period, vehicle size and weight were highly correlated.

Figure III-1 shows a least-squares regression of vehicle size (foot print) on vehicle weight (curb weight) for model year 2002 data. This figure clearly shows a positive linear relationship between these two attributes. Since size is a good predictor of weight, and weight is good measure of safety, it follows that size should also be a good measure of safety, at least in the historical data that have been analyzed. This is mentioned in Dr. Kahane's response to a safety study submitted by Dynamic Research, Inc., Marc Ross (University of Michigan) and Tom Wenzel (Lawrence Berkeley National Laboratory), and William E. Wecker Associates.

Dr. Kahane wrote:

Figure III-1


9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
-
30
40
50
60
70
80
Curb Weight (lb.)
Footprint (SF)
y = 89.298x - 308.8
R2 = 0.5165

”The objective of the NHTSA study was to calibrate the historical (MY 1991-99) relationships of vehicle mass and fatality risk, after controlling for driver age/gender, geographical location, and vehicle equipment. In this type of analysis, “vehicle mass” incorporates not only the effects of mass per se but also the effects of many other size attributes that are historically and/or causally related to mass, such as wheelbase, track width and structural integrity. (As vehicles get longer and wider, they almost always get heavier.)

The study does not claim that mass per se is the specific factor that increases or decreases fatality risk (except in its role in determining the relative Delta V of two vehicles that collide). On the contrary, Chapter 5 of the NHTSA report shows that certain 4,000-pound SUVs have significantly higher fatal-crash rates than 3,500-pound cars. The study only shows the historical relationship between mass – taking into account all the other size attributes that have typically varied with mass – and fatality risk, for vehicles of the same type. If historical relationships between mass and other size attributes continue, in the absence of compelling reasons that would change those relationships, future changes in mass are likely to be associated with similar changes in fatality risk. (However, the increased use of advanced restraint systems and sophisticated crash avoidance safety devices in recent and future production vehicles could have a noticeable impact on the historical relationship between vehicle mass and fatality risk in future vehicle fleets.)

In that sense, it is irrelevant whether mass, wheelbase, track width or some other attribute is the principal causal factor on fatality risk. If you decrease mass, you will also tend to

> reduce wheelbase, track width and other dimensions of size. If manufacturers respond to this proposal by building lighter vehicles of constant size, the historical relationship between mass and safety would gradually weaken."

Changes in technology could influence the relationship between weight and size. Several comments to the ANPRM claim that there is emerging evidence that vehicle weight can be reduced without reductions in size or safety through the use of high strength, lightweight materials. Currently, we do not observe many vehicles built with lightweight materials in the historical data and therefore cannot separate the impact of size versus weight when lightweight materials are utilized.

A 2001 study by Dr. Leonard Evans,[13] modeled the risk of driver fatality in car 1 in a head-on collision with car 2. The equations in the report indicate that reducing the curb weight of car 1 would increase the risk to the driver of car 1, while reducing the curb weight of car 2 would decrease the risk to the driver of car 1. However, the equations also indicate that reducing the wheelbase of either car increases the total risk to both drivers, supporting DRI's findings.

- A 2004 SAE paper by Dr. Leonard Evans, found that increasing the amount of lightweight materials in vehicle design can provide reduced occupant risk both in two-vehicle and single-vehicle crashes, and also reduce risk for occupants in other vehicles[14].

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[13] Evans, L., "Causal Influence of Car Mass and Size on Driver Fatality Risk", American Journal of Public Health, Vol. 91, No**.** 7, July 2001, pp 1076-1081.

[14] Evans, L., "How to make a car lighter and safer," SAE 2004-01-1 172, Society of Automotive Engineers, 11 March 2004.

- Advocates for Highway and Auto Safety submitted comments to the Docket that Kahane's (NHTSA's) 2003 analysis may not apply if the effects of size and weight reductions are disaggregated, "weight reductions without corresponding reductions in vehicle wheelbase length and track width could be expected to produce net benefits in reducing occupant crash risks."

Adding a significant amount of size to a vehicle is much more difficult and costly than adding weight to a vehicle. This is especially true if the measure of size is vehicle footprint – the product of track width and wheelbase. Although vehicle shadow (vehicle length time width) was described as a potential choice of a size measure in the ANPRM, the agency believes footprint has advantages over shadow. These two measures are highly correlated (as shown in Figures III-2 and III-3). A manufacturer could simply add body panels or bumper extensions to increase a vehicle's shadow. Increasing footprint, however, would involve redesigning the vehicle platform – a much more costly option, especially with the current trend of producing several model lines from a single platform. Vehicle footprint is more integral to a vehicle's design than either vehicle weight or shadow and cannot easily be altered between model years in order to move a vehicle into a different category with a lower fuel economy target.

Footprint (especially track width) is an important variable in terms of a vehicle's propensity for rollovers, a type of crash that accounts for approximately one-third of all light vehicle occupant traffic fatalities. Track width is one of the two vehicle properties that define Static Stability Factor (SSF). SSF was used as a single predominant factor to predict rollover rate in the agency's original rollover NCAP, and it is still the most powerful element in the agency's current rollover NCAP risk model that also factors in a road maneuver test. Wheelbase does not have a direct effect on rollover resistance. However, there are hypotheses that an increase in wheelbase could reduce loss-of-control crashes by making the vehicle react slower in yaw and thereby reduce the number of single-vehicle pavement departure crashes that produce most rollovers. Unfortunately, the agency does not have any data to substantiate this theory.

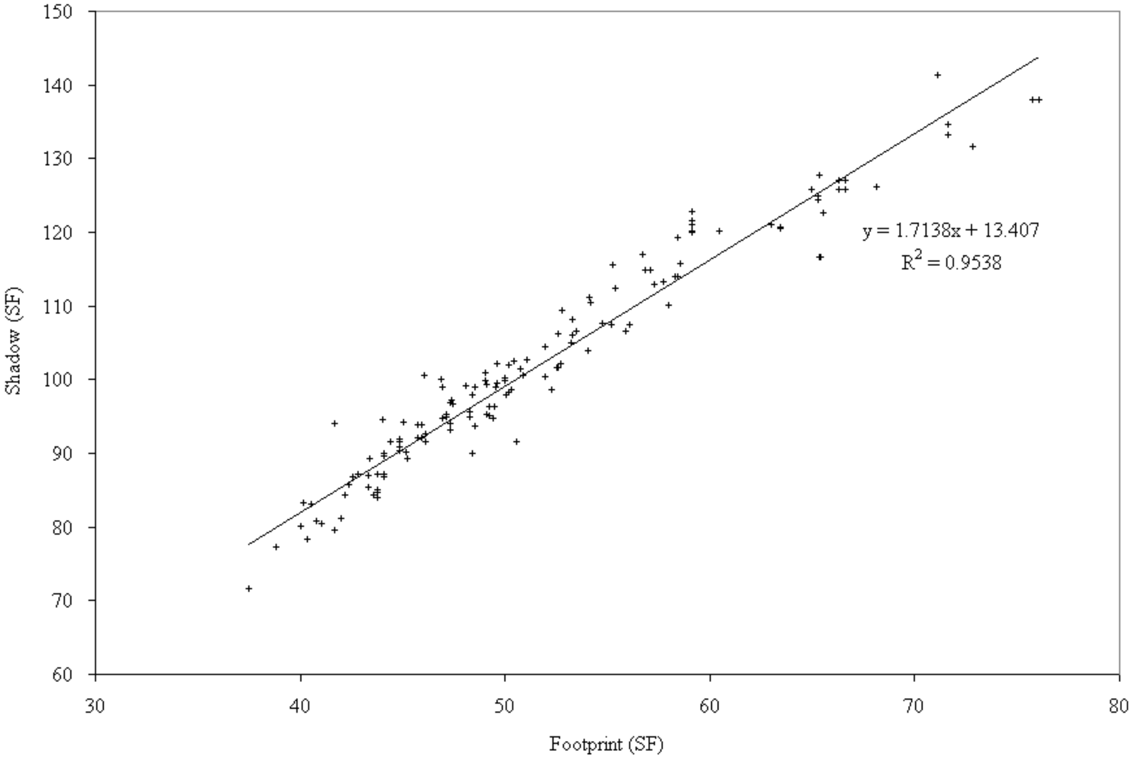
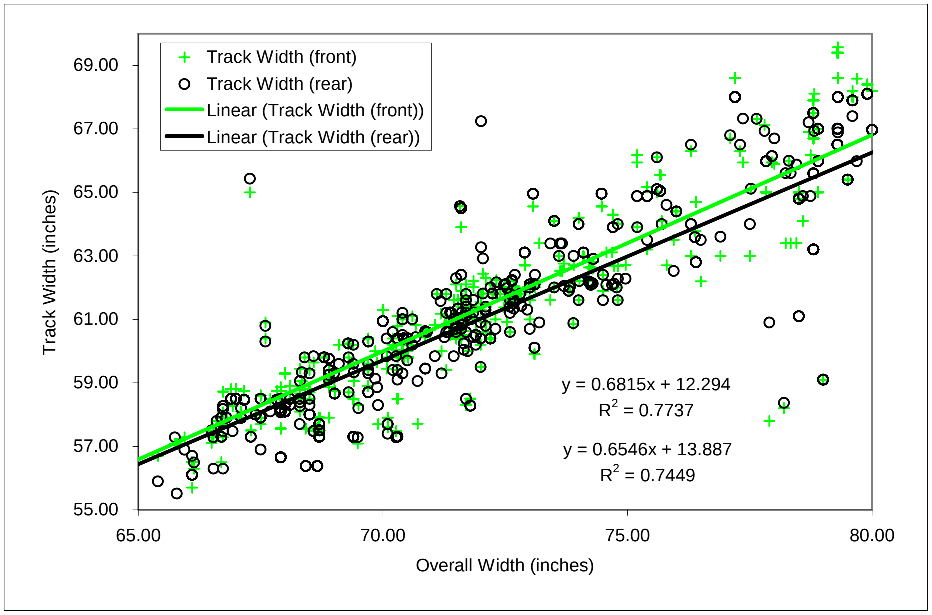


Figure III-2


Track Width (front)
Track Width (rear)
Linear (Track Width (front))
Linear (Track Width (rear))
69.00
67.00
65.00
63.00
61.00
59.00
57.00
55.00
Track Width (inches)
y = 0.6815x + 12.294
R^2 = 0.7737
y = 0.6546x + 13.887
R^2 = 0.7449
65.00
70.00
75.00
80.00
Overall Width (inches)

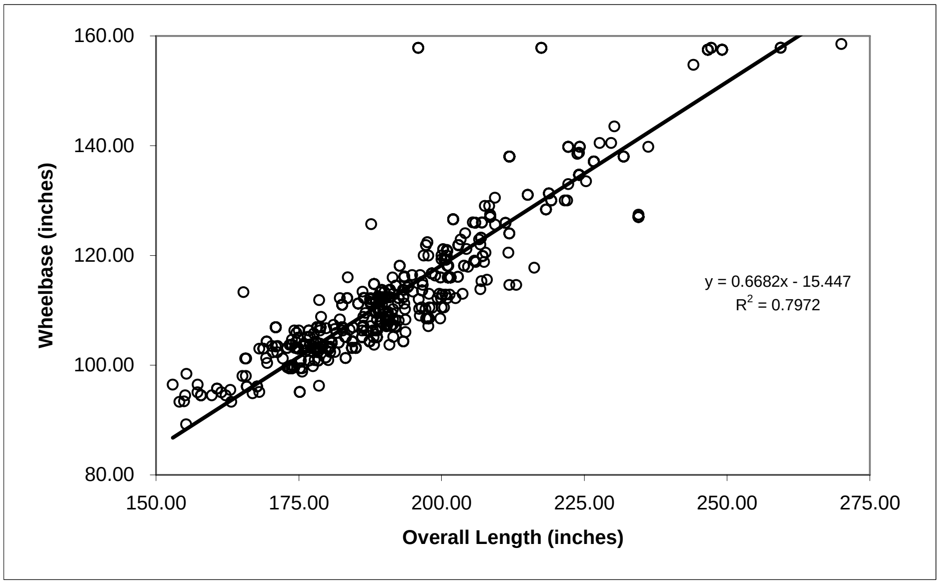

160.00
140.00
120.00
100.00
80.00
Wheelbase (inches)
y = 0.6682x - 15.447
R^2 = 0.7972
150.00
175.00
200.00
225.00
250.00
275.00
Overall Length (inches)

Figure III-3

Analysis indicates that there is a relationship between footprint and fuel economy. A DOE analysis demonstrates a moderate correlation between vehicle wheelbase times track width and fuel economy.[15] Confidential data from a vehicle manufacturer regarding the relationship between fuel economy, consumption, and footprint (wheelbase times track width) showed correlation coefficients on the order of 0.5 for light-duty vehicles, with the coefficients for light trucks higher than those for cars.

NHTSA notes that size is not as well correlated with fuel economy as is weight. However, this should not necessarily disqualify size as the basis for a fuel economy system. Some commenters stated that the curb weight is far better correlated with fuel consumption, with a correlation coefficient of the order of 0.7. Commenters argued that the stronger correlation of weight makes reliance on size inappropriate. However, neither of these correlations is strong (a strong correlation would be above 0.9). While it is true that weight is somewhat better correlated with fuel economy than vehicle size, both attributes are correlated with fuel economy, though neither attribute comes close to fully explaining the relationship between fuel economy and vehicle characteristics. In choosing an attribute to use for the proposal, the agency considered a variety of factors, including the correlation with fuel economy, safety impacts, difficulty in "gaming" the system, preservation of fuel-saving compliance options, and we determined that footprint is the best of the available attributes.

In the analyses for the NPRM, we included the possibility of limited vehicle weight reduction for vehicles over 5,000 lbs. curb weight where we determined that weight reduction would not

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[15] Plotkin, S., Greene, D., and Duleep, K.G., Examining the Potential for Voluntary Fuel Economy Standards in the United States and Canada, Argonne National Laboratory report ANL/ESD/02-5, October 2002.

reduce overall safety and would be a cost-effective choice.[16] Use of the 5,000 lbs cut-off point was based on analysis in the Kahane study. The Kahane study found that the net safety effect of removing 100 pounds from a light truck is zero for light trucks with a curb weight greater than 3,900 lbs.[17] However, given the significant statistical uncertainty around that figure, we assumed a confidence bound of approximately 1,000 lbs. and used 5,000 lbs. as the threshold for considering weight reduction.[18]

Several commenters supported our assumption that manufacturers could respond to the CAFE standards with limited weight reductions that would not reduce safety. Conversely, several commenters stated that any weight reduction will lead to a reduction in safety. Environmental Defense stated that previously manufacturers have relied upon weight reduction without regard to vehicle safety, and therefore the agency should expand consideration of weight reduction in our analysis. These comments are discussed below.

Before discussing the comments, we would like to clarify that our analysis does not mandate weight reduction, or any specific technology application for that matter. We performed the analysis for the NPRM and the final rule on the assumption that manufacturers would find it cost-effective to reduce the weight of light trucks that have a curb weight greater than 5,000 lbs. Our analysis relied exclusively on other fuel-saving technologies for lighter light trucks to

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[16] The amount of projected weight reduction was two percent for light trucks with a curb weight between 5,000 and 6,000 lbs and up to four percent for light trucks with a curb weight over 6,000 lbs.

[17] Kahane, Charles J., PhD, Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks, October 2003. DOT HS 809 662. Page 161. Docket No. NHTSA-2003-16318 (http://www.nhtsa.dot.gov/cars/rules/regrev/evaluate/pdf/809662.pdf)

[18] See the discussion of “Effect of Weight and Performance Reductions on Light Truck Fuel Economy” in Chapter V of the PRIA.

demonstrate that manufacturers can comply with the required fuel economy levels established today without the need for potentially unsafe compliance measures.

Honda cited several reports, which it asserted demonstrated that limited weight reductions would not reduce safety and could possibly decrease overall fatalities. Honda stated that the 2003 study by DRI found that reducing weight without reducing size slightly decreased fatalities, and that this was confirmed in a 2004 study by DRI that assessed new data and methodology changes in the 2003 Kahane Study. Honda asserted that the DRI results tend to confirm “that curb weight reduction would be expected to decrease the overall number of fatalities.”

DRI submitted an additional study, <u>Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track Width on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1985-1997 Model Year LTVs</u>, Van Auken, R.M. and J. W. Zellner, May 20, 2005. This DRI study concluded that reductions in footprint are harmful to safety, whereas reductions in mass while holding footprint constant would benefit safety. The DRI study disagreed with NHTSA’s finding that mass had greater influence than track width or wheelbase on the fatality risk of passenger cars in non-rollover crashes.

The Union of Concerned Scientists stated that recent studies indicate that increases in weight have very little impact on safety. However, the Union of Concerned Scientists did not cite any specific study. Further, Environmental Defense stated that the Kahane study on which the agency relied for determining the weight reduction limitations was flawed. Environmental Defense stated that the Kahane study does not adequately distinguish between the effects of size and weight on motor vehicle accident mortality, despite the large body of evidence suggesting that other factors besides vehicle weight, such as vehicle size and design, have critical implications for vehicle safety.

While NHTSA agrees that limited weight reduction to heavier vehicles will not reduce safety, we continue to disagree with DRI's overall conclusion, cited by Honda, that weight reductions while holding footprint constant would significantly benefit safety in lighter vehicles. NHTSA's analyses of the relationships between fatality risk, mass, track width and wheelbase in 4-door 1991-1999 passenger cars (Docket No. 2003-16318-16) found a strong relationship between track width and the rollover fatality rate, but only a modest (although significant) relationship between track width and fatality rate in non-rollover crashes. Even controlling for track width and wheelbase – e.g., by holding footprint constant – weight reduction in the lighter cars is strongly, significantly associated with higher non-rollover fatality rates in the NHTSA analysis. By contrast, the DRI study of May 20, 2005 analyzed 4-door cars and found a strong relationship between track width and fatality risk, and non-significant associations of mass and wheelbase with fatality risk (Docket No. 2005-22223-78, p. 31). In other words, when DRI analyzed the same group of vehicles as NHTSA, they did not get the same results. This difference indicates that DRI's analytical method and/or database are not the same as NHTSA's.

The agency continues to stand by our analytical method and database, and we continue to believe that weight reduction in lighter vehicles would reduce safety. However, we also continue to believe that weight reductions in the heavier light trucks, while holding footprint constant, will not likely result in a net reduction in safety.

The Insurance Institute for Highway Safety (IIHS) expressed similar concern with weight reduction as the agency, stating that the safety cost of reduced mass would be most apparent if the weight reductions were to occur among the smallest and lightest vehicles. Referencing the 2003 Kahane report, IIHS indicated that decreases in mass among vehicles weighing more than 5,000 pounds could result in a net safety benefit. However, IIHS continued to caution that reducing mass reduces, on average, a vehicle's ability to protect its occupants, noting that the effects of mass on vehicle crashworthiness have been observed and documented (Kahane, 1997; Partyka, 1996; O'Neill et al., 1974).

General Motors and the Alliance were more explicit in their concerns over the safety impact associated with weight reduction. The Alliance stated that the fundamental laws of physics dictate that smaller and/or lighter vehicles are less safe than larger/heavier counterparts with equivalent safety designs and equipment. General Motors agreed that improvements in material strength, flexibility, and vehicle design have helped improve overall vehicle and highway safety. But, General Motors added, for a given vehicle, reducing mass generally reduces net safety. Further, General Motors stated that it does not intentionally reduce mass by replacing it with advanced materials, presuming that such action alone will result in improved protection for the occupants in a lighter vehicle; instead GM continues to believe that vehicles with larger mass will provide better protection to occupants involved in a crash than a vehicle of the same design with less mass, given equivalent crashes.

General Motors also questioned the agency's reliance on a 5,000 lbs. minimum vehicle weight for considering weight reduction, which was based on the finding of the 2003 Kahane report that reducing curb weight negatively impacts safety only at curb weights under 3,900 pounds. General Motors stated that the agency's conclusion is inconsistent with the sensitivity analysis performed by William E. Wecker Associates, Inc. and submitted to the ANPRM docket. General Motors stated that the inflection point on the Wecker report's graph for General Motors light trucks in both the periods of MYs 1991-1995 and MYs 1996-1999 is higher than 5,000 pounds.

Additionally, General Motors stated that the NPRM did not acknowledge or rationally respond to the main point of the Wecker report, which was that Dr. Kahane's "analysis alone does not support the proposition that a crossover weight at or near 5,085 pounds is a robust, accurate description of the field performance of the [ ] fleet."

We believe that General Motors is confusing the 5,085 lbs. crossover weight (where the safety effect of mass reduction in a vehicle weighing exactly 5,085 lbs., is zero) with the breakeven point described in the NPRM, which is the point where the total effect of reducing all vehicles heavier than the breakeven weight by an equal amount is zero. NHTSA estimated that the breakeven point as described in the NPRM is 3,900 lbs., if footprint is held constant.

If the 3,900 lbs. estimate were perfectly accurate, we would be confident that weight reductions in vehicles down to 3,900 pounds would not result in net harm to safety. However, we agree with commenters that there is considerable uncertainty about the crossover weight and also the breakeven point. Therefore, in our analysis, we limited weight reduction to vehicles with a curb weight greater than 5,000 pounds. We believe that the 5,000 lbs. limit is sufficient so that we can be confident that such weight reductions will not have net harm on safety.

SUVOA encouraged NHTSA to emphasize the importance of making sure that CAFE requirements do not encourage vehicle downsizing "or any other action that might have an adverse effect on safety." SUVOA cited several reports in support of its assertion that downsizing harms safety[19]. As explained above, the agency has applied weight reduction only to those vehicles for which we are confident that such reduction will not negatively impact safety, however, our analysis does not mandate the use of specific technologies or weight reductions.

The Competitive Enterprise Institute stated that the agency's own rulemaking demonstrates the safety of weight, specifically the FMVSS No. 216, <u>Roof crush,</u> rulemaking (see 70 FR 49223, August 23, 2005). The Competitive Enterprise Institute noted that in that rulemaking, NHTSA determined that the proposed requirement of more protective roofs would "add both cost and weight" to the vehicles. This commenter also stated that NHTSA found that the stronger the roof crush standard, the more added weight it would entail. The Competitive Enterprise Institute also cited the IIHS, March 19, 2005 *Status Report* on fatality risks in different vehicles, which the commenter stated concluded that in each vehicle group, "the heavier vehicles, like bigger ones, generally had lower death rates."

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[19] SUVOA provided the following cites in support of its assertion:

- 2001, the National Academy of Sciences affirmed that earlier downsizing of vehicles following the imposition of CAFE regulations resulted in an additional 1,300 to 2,600 deaths and an additional 20,000 serious injuries per year.
- A Harvard School of Public Health-Brookings Institution study in the 1990s found that vehicle downsizing due to federal fuel economy mandates increased occupant deaths by 14 to 27 percent.
- An in-depth analysis by *USA Today* in 1999, using NHTSA and auto insurance industry data, found that since 1975, 7,700 additional deaths occurred for every mile per gallon gained. By 1999, vehicle downsizing had killed more than 46,000 Americans. Factoring in the ensuing six years through 2005, the total conservatively eclipses 55,000 deaths.

The weight safety analysis performed by the agency for this rulemaking accounted for not only the occupant safety (crashworthiness) of the vehicle, but also the rollover propensity of the vehicle, and the safety of the occupants of other vehicles it strikes. While in some instances, the crashworthiness of a vehicle can be improved through design changes that add weight to a vehicle, design changes can also reduce a vehicle's weight without reducing crashworthiness, and may in some instances improve the safety of a vehicle (e.g., reduce rollover propensity).

Environmental Defense commented that by limiting the use of weight reduction to heavier vehicles, the agency disregarded the likelihood that manufacturers would rely on weight reduction in smaller, lighter vehicles. Environmental Defense suggested that the improved baselines should reflect this weight reduction strategy.

Environmental Defense asserted that weight reduction is among the most common and cost-effective options available to manufacturers for improving vehicle fuel economy across the light truck fleet. Environmental Defense referenced estimates presented in DeCicco (2005) that suggest that the cost per pound of weight reduced through use of high-strength steel and advanced engineering techniques has been as low as, or lower than, 31 cents per pound reduced.

Moreover, Environmental Defense stated, the exclusion of mass reduction in NHTSA's analysis bears no relation to what will actually happen in the marketplace when standards are implemented. Environmental Defense argued that absent safety regulations prohibiting the use of mass reductions, manufacturers are likely to choose this compliance alternative in vehicles of all weights as a cost-effective way to comply with CAFE. Environmental Defense stated that

NHTSA should consider the potential for mass reduction among its compliance alternatives for *all* light trucks.

As stated above, the agency does not dictate which fuel-savings technologies must be applied to vehicles. Mass reduction is a compliance alternative for all light trucks. However, one of the considerations in setting fuel economy standards is to set standards that will not lead to a reduction in the safety of the light truck fleet. The standards established by the agency are those capable of being achieved by the manufacturers without the need to reduce safety. If the agency were to consider weight reduction as a compliance option for all light trucks, we are concerned that the resulting increased stringency would force unsafe downweighting.

Footprint and safety

The impact of CAFE standards on motor vehicle and passenger safety has long been recognized as an integral part of the agency's process of determining maximum feasible average fuel economy. The agency notes that there are no compelling studies that quantify the precise and separate effects of vehicle size and weight on safety, in part because there is a high degree of correlation between size and weight among vehicles now in widespread use. The agency has determined that an attribute system based on footprint with the continuous function would minimize incentives for design changes that would reduce motor vehicle safety. In a weight-based system, a manufacturer can add weight to a vehicle in order to take advantage of a category with a lower fuel economy target. As discussed above, this up-weighting can have positive and negative safety implications, with possibly negative impacts for the fleet as a whole if weight is added to heavier light trucks. A manufacturer could not as readily increase footprint as it could vehicle weight.

In order to increase footprint, a manufacturer would have to either extend a vehicle's track width, wheelbase, or both. Maintaining and increasing track width should play a positive role in limiting rollover vulnerability, whereas maintaining and increasing wheelbase should play a positive role in improving handling – especially directional stability, which is crucial in preventing unintended off-road excursions that often lead to rollovers – and maximizing crush space (though total length is probably more closely correlated with crush space than is wheelbase).

Baseline and Alternatives

The baselines, against which costs and benefits are estimated for all the scenarios, are the manufacturer's plans for each model year 2008-2011 or the MY 2007 standard of 22.2 mpg, whichever is higher. The manufacturer's plans were updated based on the manufacturer's comments to the NPRM. This is named the "Adjusted Baseline". In addition, several of the technology applications were changed based on comments to the NPRM and all of the alternatives examined in this analysis include these updated technology applications. A separate calculation was performed for each manufacturer for each year and compared to the Adjusted Baseline.

A number of alternatives are examined in this analysis. The two Alternatives presented first are the compliance options provided in the final rule for manufacturers. These are named:

“**Unreformed CAFE**”, which is the flat standard of 22.5 mpg for MY 2008, 23.1 mpg for MY 2009, and 23.5 mpg for MY 2010. The Unreformed CAFE compliance option is not allowed in MY 2011.

“**Reformed CAFE**”, which is based on a continuous function and is applicable for MY 2008 to MY 2011. The Reformed CAFE system is also applicable to MDPVs[20] in MY 2011.

The Unreformed CAFE standards for MYs 2008-2010 are set in the same manner that NHTSA has set standards for many years. They are based on NHTSA’s “Stage Analysis” projections of technologies available for the model years in question for individual manufacturers and the “Volpe Analysis” projections of their incremental costs and fuel savings. Chapters V and VI provide detailed information about those projections. The level of the Unreformed CAFE standards is set with particular regard to the capabilities of and impacts on the “least capable” full-line manufacturer (i.e., one that produces a wide variety of types and sizes of vehicles) with a significant share of the market. The Unreformed CAFE standards establish a single CAFE level, applicable to each manufacturer, for each model year.

The Reformed CAFE standards for MYs 2008 - 2010 are set at levels intended to ensure that the industry-wide cost of those standards, based on the overall fleet technology costs for the seven largest manufacturers (not on an individual basis), are roughly equivalent to the industry-wide cost of the Unreformed CAFE standards for those model years. This approach promotes an

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[20] The EPA defines “MPDV” as a light truck related at more than 8,500 lbs GVWR, or that has a vehicle curb weight of more than 6,000 pounds, or that has a basic vehicle frontal are in excess of 45 squire feet. “MDPV” does not include a vehicle that:
The EPA defines “MPDV” as a light truck related at more than 8,500 lbs GVWR, or that has a vehicle curb weight of more than 6,000 pounds, or that has a basic vehicle frontal are in excess of 45 squire feet. “MDPV” does not include a vehicle that:

orderly and effective transition to the Reformed CAFE system since experience with the new system will be gained prior to full implementation in MY 2011.

The strategy for the Reformed CAFE system for MY 2011 is different, since there is no Unreformed CAFE system to compare it to. For MY 2011, we set the continuous function at a point that maximizes fuel savings and would be the socially optimal level based on marginal cost/benefit considerations. Socially optimal is defined as a set of target mpg levels where the marginal cost of achieving the target levels just equals the marginal societal benefit derived from improving fuel economy. Social costs and social benefits are defined as both private consumer costs or benefits plus externalities as discussed later in this analysis.

During a transition period of MYs 2008-2010, manufacturers may comply with CAFE standards established in the traditional way (Unreformed CAFE) or with standards established under the reformed structure (Reformed CAFE). This will permit manufacturers to gain experience with the Reformed CAFE standards. The additional lead time provided by the transition period will aid, for example, those manufacturers that, for the first time, face a binding CAFE constraint necessitating actions beyond the fuel economy improvements that they planned on their own to make. In MY 2011, all manufacturers are required to comply with a Reformed CAFE standard.

Final Rule Unreformed CAFE Levels

Table III-1 shows the Manufacturer's Plans and the Adjusted Baseline for MY 2008 to 2011, as well as the Unreformed CAFE final rule levels, all harmonically averaged[21], for MY 2008-2010. The harmonic average measures gallons per mile, rather than miles per gallon, and thus averages actual fuel use, rather than miles per gallon.

Table III-1
Unreformed CAFE Levels
(in mpg)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Manufacturer's Plans	21.94	22.02	22.37	22.41	22.62
Adjusted Baseline	22.40	22.42	22.73	22.75	22.97
Unreformed CAFE Final Rule	22.5	23.1	23.5	N.A.	N.A.

Final Rule Reformed CAFE Continuous Function

Figure III-4 depicts the continuous function as compared to the proposed Step Function. The continuous function is defined by the following mathematical function:

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[21] This is an example of a harmonic average. Total sales on top, divided by the sum of individual make/models divided by their fuel economy.

$$\frac{400,000}{\frac{100,000}{27.0mpg}+\frac{100,000}{24.0mpg}+\frac{100,000}{22.0mpg}+\frac{100,000}{19.0mpg}} = 22.6 \text{ mpg}$$

$$Required\_Fuel\_Economy\_Level = \frac{N}{\sum_i \frac{N_i}{T_i}}$$

Where:

N is the total number (sum) of light trucks produced by a manufacturer,
N_i is the number (sum) of the i^{th} model light truck produced by the manufacturer, and
T_i is fuel economy target of the i^{th} model light truck, which is determined according to the

following formula, rounded to the nearest hundredth:

$$mpg = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)/d}}{1+e^{(x-c)/d}}}$$

where,

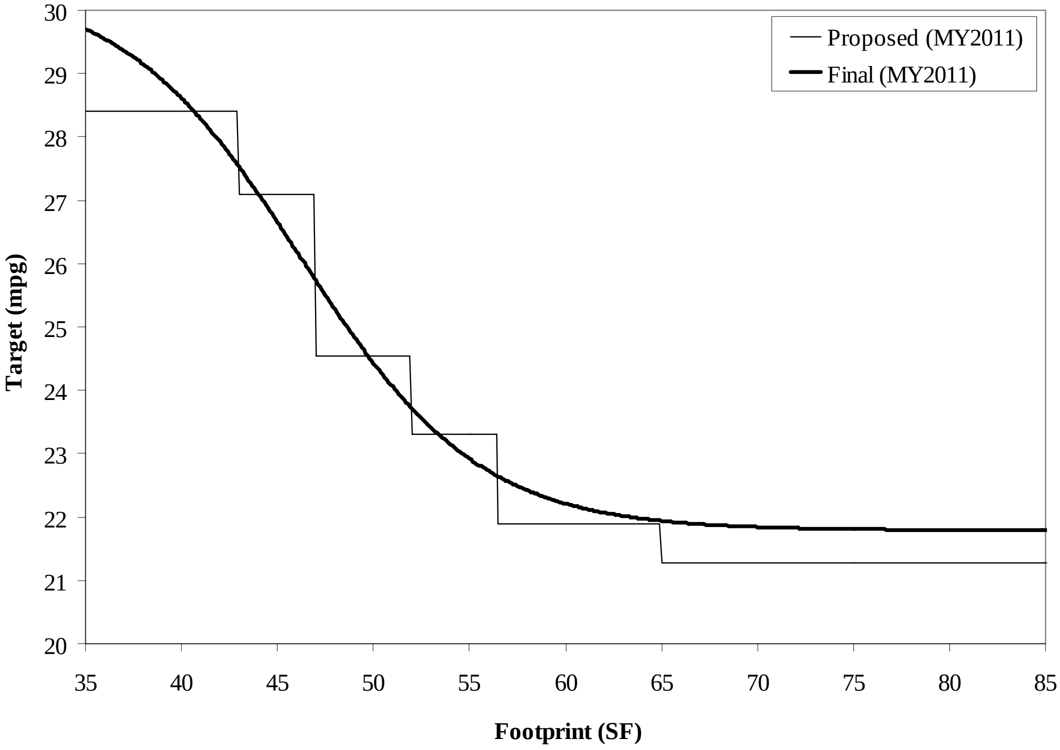
a = the maximum fuel economy target (in mpg)
b = the minimum fuel economy target (in mpg)
c = the footprint value (in square feet, rounded to the nearest tenth) at which the fuel economy target is midway between a and b
d = the parameter (in square feet) defining the rate at which the value of targets decline from the largest to smallest values
e = 2.718
x = footprint (in square feet, rounded to the nearest tenth) of the vehicle model

The values for each model year in that function are:

Table III-2
Continuous Function Parameters

Logistic area-based function	**MY 2008**	**MY 2009**	**MY 2010**	**MY 2011**
a: mpg ("ceiling")	28.56	30.07	29.96	30.42
b: mpg ("floor")	19.99	20.87	21.20	21.79
c: square feet ("midpoint")	49.30	48.00	48.49	47.74
d: square feet ("width")	5.58	5.81	5.50	4.65

Figure III-4: Example of the Continuous Function curve compared to the proposed step function



Under Reformed CAFE, each manufacturer's required level of CAFE is based on target levels set according to vehicle size based on the continuous function curve for that model year. The targets are assigned according to a vehicle's "footprint" – the product of the average track width (the distance between the centerline of the tires on the same axle) and wheelbase (basically, the distance between the centers of the axles). Each footprint value is assigned a target specific to that footprint value. This differs from what we proposed. The proposed reform segmented the light truck fleet into categories (a Step-Function) based on footprint and assigned a target fuel economy value for each category. Under the final rule adopted today, targets are assigned along the continuum of footprint values in the light truck fleet. The target values reflect the technological and economic capabilities of the industry. The target for a given footprint value is the same for all manufacturers, regardless of differences in their overall fleet mix. Compliance is determined by comparing a manufacturer's harmonically averaged fleet fuel economy in a model year with a required fuel economy level calculated using the manufacturer's actual production levels and the targets levels for each vehicle.

The agency believes that the Reformed CAFE approach has four basic advantages over the Unreformed CAFE approach.

First, Reformed CAFE enlarges energy savings. The energy-saving potential of Unreformed CAFE is limited because only a few full-line manufacturers are required to make improvements. In effect, the capabilities of these full-line manufacturers, whose offerings include larger and heavier light trucks, constrain the stringency of the uniform, industry-wide standard. As a result, the Unreformed CAFE standard is generally set below the capabilities of limited-line manufacturers, who sell predominantly lighter and smaller light trucks. Under Reformed CAFE, which accounts for size differences in product mix, virtually all light-truck manufacturers will be required to improve the fuel economy of their vehicles. Thus, Reformed CAFE will continue to require full-line manufacturers to improve the overall fuel economy of their fleets, while also requiring limited-line manufacturers to enhance the fuel economy of the vehicles they sell.

Second, Reformed CAFE offers enhanced safety. As past actions have demonstrated, vehicle manufacturers constrained by Unreformed CAFE standards have often pursued the following compliance strategies that entail safety risks: (1) downsizing of vehicles, (2) redesign of some vehicles to permit classification as "light trucks" for CAFE purposes, and (3) offering smaller and lighter vehicles to offset sales of larger and heavier vehicles. The adverse safety effects of downsizing and downweighting have already been documented in the CAFE program for passenger cars. In addition, when a manufacturer designs or redesigns a vehicle to permit its classification as a light truck, it may increase the vehicle's propensity to roll over.

Reformed CAFE is designed to lessen each of these safety risks. Downsizing of vehicles is discouraged under Reformed CAFE since smaller vehicles are expected to achieve greater fuel economy. Moreover, Reformed CAFE lessens the incentive to design smaller vehicles to achieve a "light truck" classification, since small light trucks are regulated at roughly the same degree of stringency as passenger cars.

Third, Reformed CAFE provides a more equitable regulatory framework for different vehicle manufacturers. Under Unreformed CAFE, the cost burdens and compliance difficulties have been imposed primarily on the full-line manufacturers who have large sales volumes at the larger and heavier end of the light-truck fleet. Reformed CAFE spreads the regulatory cost burden for fuel economy more broadly across vehicle manufacturers within the industry.

Fourth, Reformed CAFE is more market-oriented because it more fully respects economic conditions and consumer choice. Reformed CAFE does not force vehicle manufacturers to adjust fleet mix toward smaller vehicles unless that is what consumers are demanding. As the industry's sales volume and mix changes in response to economic conditions (e.g., gasoline prices and household income) and consumer preferences (e.g., desire for seating capacity or hauling capability), the level of CAFE required of manufacturers under Reformed CAFE will, at least partially, adjust automatically to these changes. Accordingly, Reformed CAFE reduces the need for the agency to revisit previously established standards in light of changed market conditions, a difficult process that undermines regulatory certainty for the industry.

The continuous function standard is developed using the same three-phase process used to establish the step-function described in the proposed standard In “phase one,” the agency adds fuel saving technologies to each manufacturer’s fleet until the cost of improving its fuel economy further just equals the value of fuel savings and other benefits from doing so. Data points representing each vehicle’s size and “optimized” fuel economy from the light truck fleets of the seven largest light truck manufacturers are then plotted on a graph.

In “phase two,” a preliminary continuous function is statistically fitted through these data points, subject to constraints on its upper and lower limits as described below. This contrasts with the proposed step function, in which the improved fleets were distributed among the pre-defined footprint categories and the harmonic average fuel economy of models assigned to each category was used to determine the preliminary target for that category. With a continuous function, the agency sets different fuel economy targets for each value of vehicle footprint, rather than setting targets that would each apply to a range of footprint values.

Once a preliminary continuous function has been statistically fitted to data for a model year, it is then adjusted just as the step function is in “phase three” of the proposed rule. That is, the preliminary continuous function is then raised or lowered until industry-wide net benefits (based on the seven largest manufacturers) are maximized, which occurs when the change in industry-wide compliance costs (based on the seven largest manufacturers) from adjusting it further would be exactly offset by the resulting change in benefits.

Under a continuous function, the level of CAFE required for each manufacturer (and its compliance with that level) is determined in exactly the same fashion as under the proposed step function. Each manufacturer’s required CAFE level is the sales-weighted harmonic average of the fuel economy targets corresponding to the footprint of each of its light truck models, and its compliance is assessed by comparing the sales-weighted harmonic average of each of its models’ actual fuel economy to this required level. The key difference is that under the continuous function, any change in a vehicle’s footprint subjects it to a new fuel economy target, thus changing a manufacturer’s required CAFE level slightly. Conversely, under the step function, changing a vehicle’s footprint would subject it to a new target – and thus change a manufacturer's required CAFE level – only if that change moved it to a smaller or larger footprint category.

Defining the Function and the Shape of the Curve

In the second phase, we plotted the results of phase one (i.e., the light truck fleets of the seven largest manufacturers, each separately "socially optimized"). Then, we calculated a statistical relationship through the plotted data points (using production-weighted nonlinear least squares regression). This relationship defines a preliminary continuous function (a "curve") that, upon being adjusted, determines the fuel economy targets for light trucks based on vehicle footprint. Although adjusted, the shape of the curve remains unchanged throughout the equal-increment adjustments in phase three below, because the absolute differences (on a gallon-per-mile basis) between the targets are unaffected by those adjustments.

In its report, NAS illustrated a function that set fuel economy targets for vehicle based on weight. Under the NAS function, fuel consumption increased in a linear manner as vehicle weight increased up to 4,000 lbs. At 4,000 lbs, the function leveled-off. The leveling of the function at 4,000 lbs represented a "safety threshold," i.e., the NAS report determined that there was a safety benefit in minimizing the incentive to up-weight vehicles beyond 4,000 lbs. Under the NAS function, increasing a vehicles weight beyond 4,000 lbs did not subject a vehicle to a less stringent fuel consumption value.

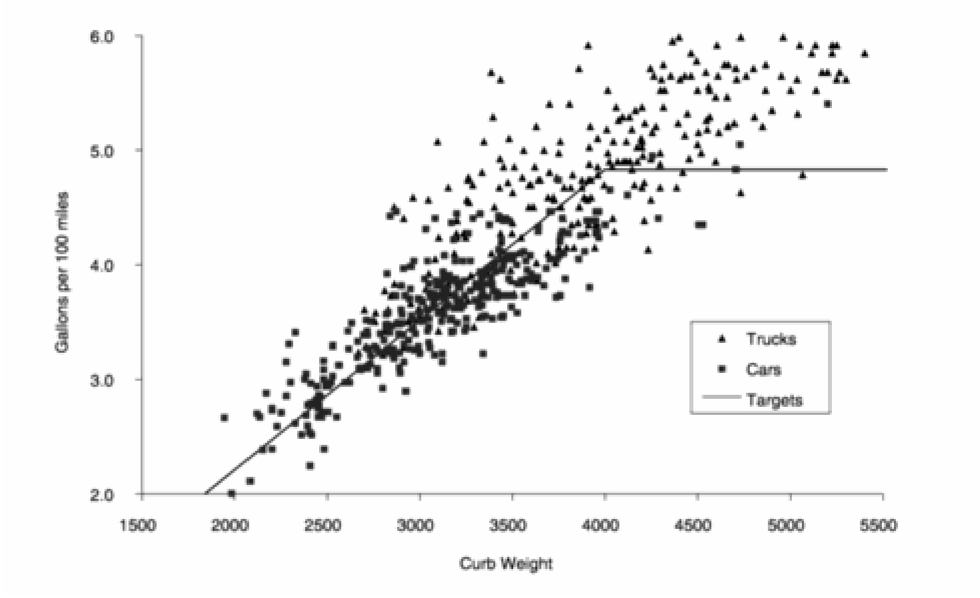


Figure III-5: Illustration of the fuel economy function under the NAS alternative attribute system example (NAS report, p. 109).

The agency considered relying on a function as illustrated by NAS, but determined that the NAS function presented several problems. First, the flattening of the function would be expected to produce a milder form of the “edge effects” that are of concern under the step function. At the “safety threshold” there would be an abrupt change in the rate at which size increases are rewarded. This abrupt change could distort the production of vehicles located near the threshold and encourage manufacturers to potentially downsize some vehicles to the threshold point. Second, it is not clear whether and, if so, where, in terms of footprint, a true "safety threshold" occurs. Without a “safety threshold” the NAS function would be a simple linear function, which as discussed below introduces several potential problems. Finally, there is a possibility that a function based on the NAS illustration could extrapolate to unreasonably high levels for small vehicles.

As discussed below, the agency has decided to use a constrained logistic function to set the targets. We have determined that a constrained logistic function provides a good fit to the optimized light truck fleet data, while not resulting in potentially impracticable high targets for very small vehicles, or unreasonably low targets for very large vehicles.

The agency evaluated a variety of mathematical forms to estimate the relationship between vehicle footprint and fuel economy. The agency considered a simple linear function, a quadratic function, an exponential function, and an unconstrained logistic function. Each of these relationships was estimated in gallons per mile (gpm) rather than miles per gallon (mpg). As explained in the NPRM, the relationship between fuel economy measured in mpg and fuel savings is not linear. An increase in one mpg in a vehicle with low fuel economy (e.g., 20 mpg to 21 mpg) results in higher fuel savings than if the change occurs in a vehicle with high fuel economy (e.g., 30 mpg to 31 mpg). Increasing fuel economy by equal increments of gallons per mile provides equal fuel savings regardless of the fuel economy of a vehicle. Increasing the fuel economy of a vehicle from 0.06 gpm to 0.05 gpm saves exactly the same amount of fuel as increasing the fuel economy of a vehicle from 0.03 gpm to 0.02 gpm.[22]

Given that the agency is concerned with fuel savings, gpm is a more appropriate metric for evaluating the functions. Therefore, we plotted the "socially optimized" fleets in terms of footprint versus gpm. Once a shape of a function was determined in terms of "gallons per mile," the agency then converted the function to mpg for the purpose of evaluating the potential target values. The figures below illustrate each of the functions as sales weighted estimates of the

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[22] Lower fuel consumption represents a more stringent value (i.e., a low gpm value equates to a high mpg value).

relationship between fuel economy of the “socially optimized” fleets and foot print, which were considered by the agency, as calculated with the data of the “socially optimized” fleet.

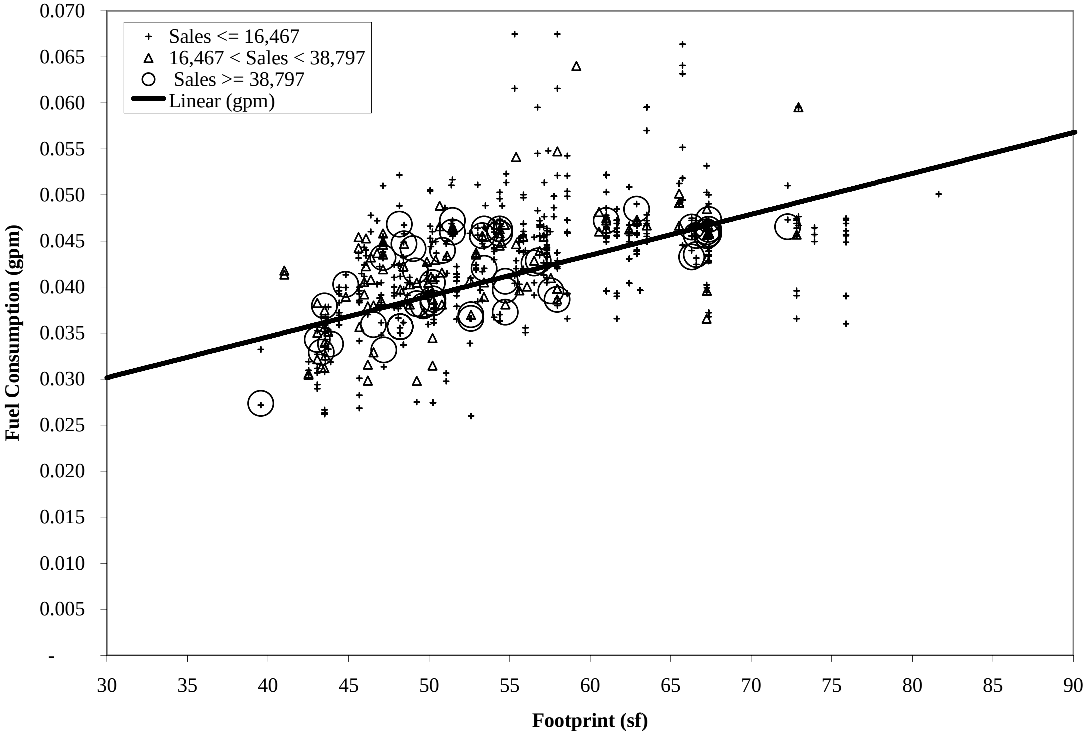

Figure 1A: Linear function fit through sales weighted “socially optimized” light truck fleet (gpm as a function of footprint)

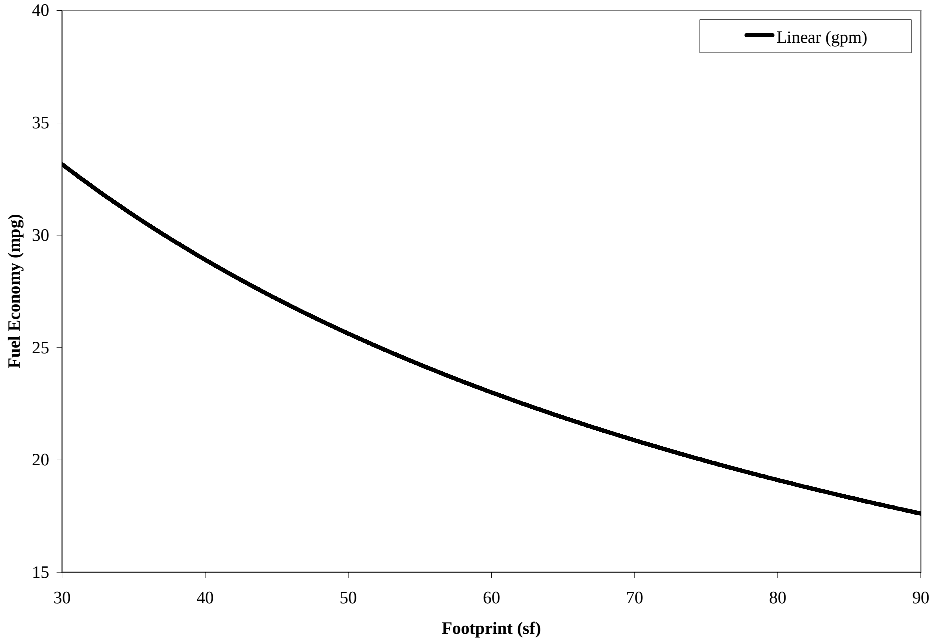

Figure 1B: Linear function fit through sales weighted "socially optimized" light truck fleet (mpg as a function of footprint)

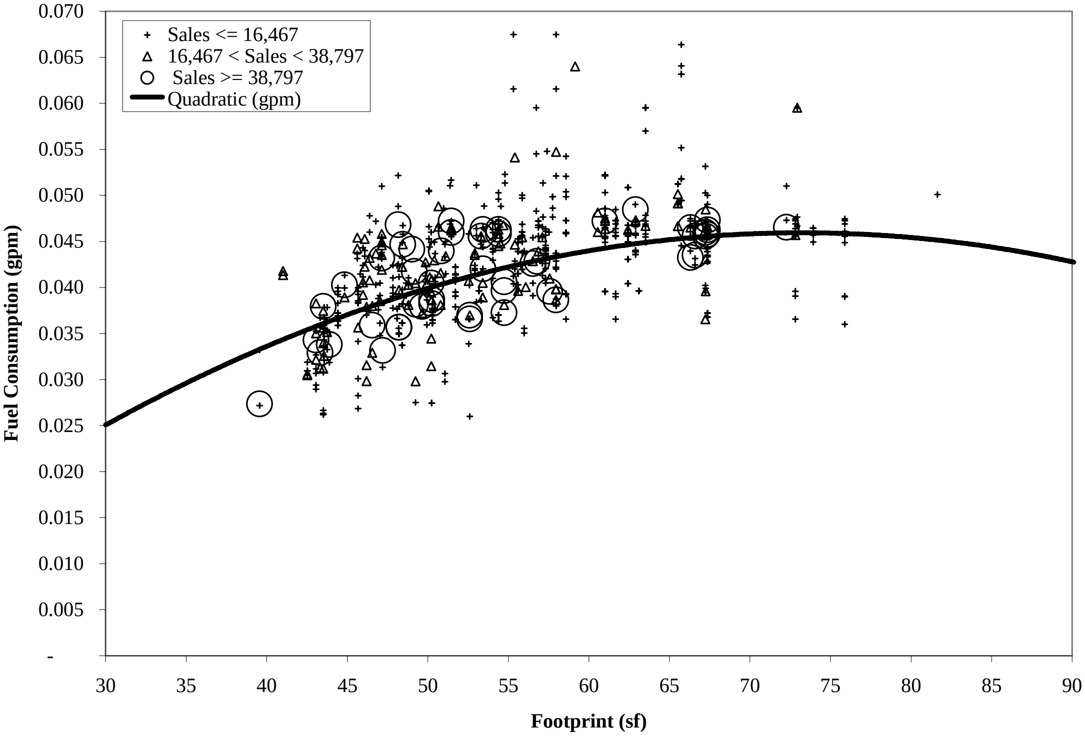

Figure 2A: Quadratic function fit through sales weighted "socially optimized" light truck fleet (gpm as a function of footprint)

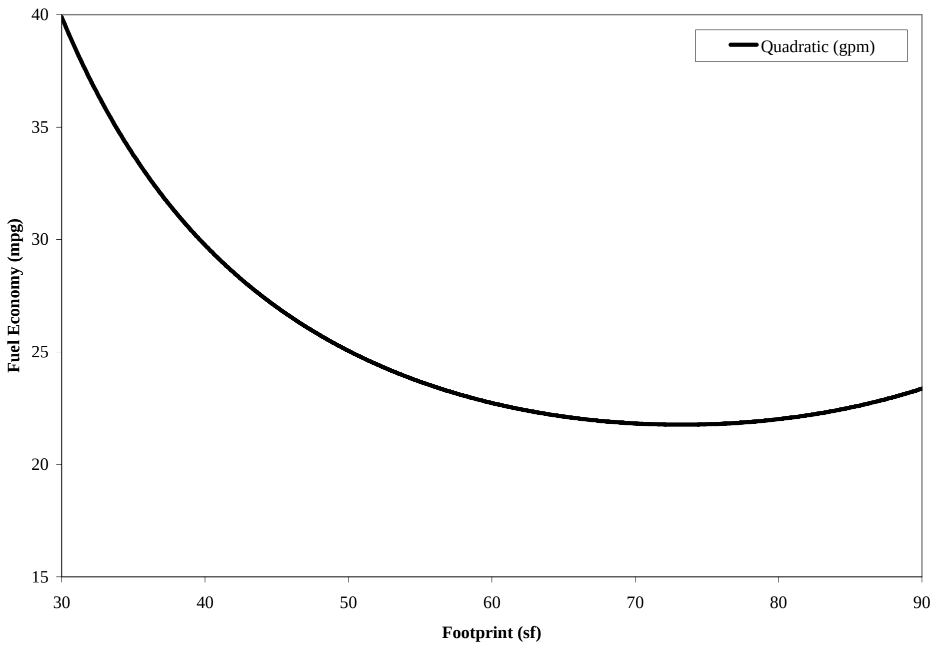

Figure 2B: Quadratic function fit through sales weighted "socially optimized" light truck fleet (mpg as a function of footprint)

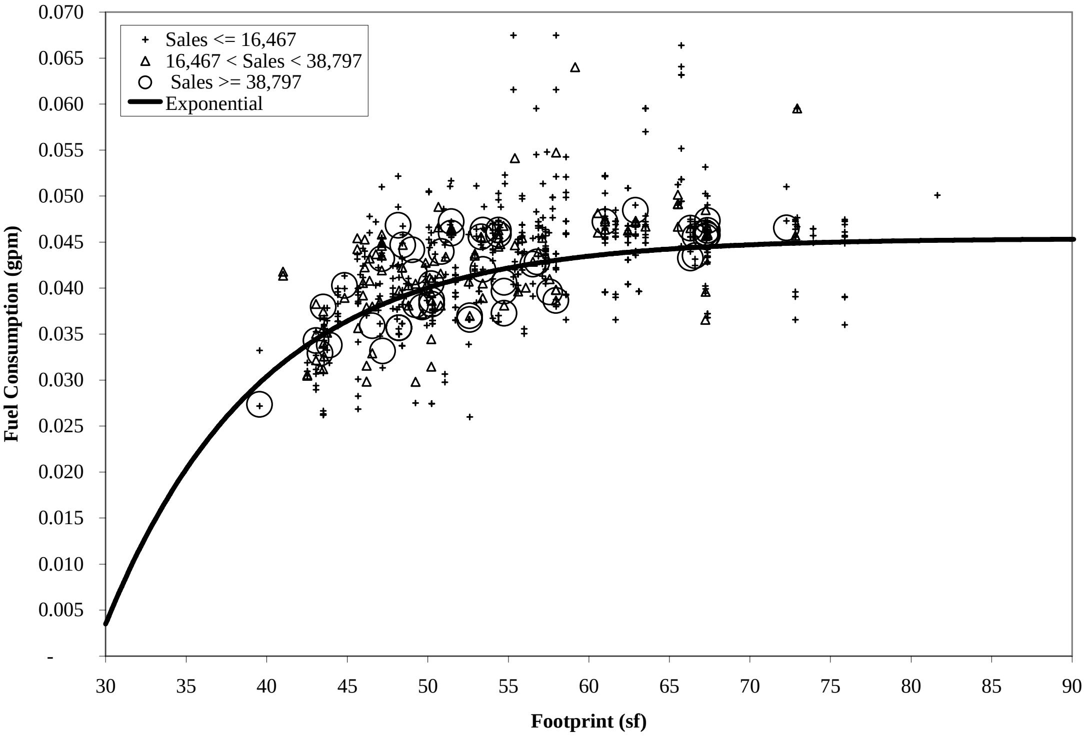

Figure 3A: Exponential function fit through sales weighted "socially optimized" light truck fleet (gpm as a function of footprint)

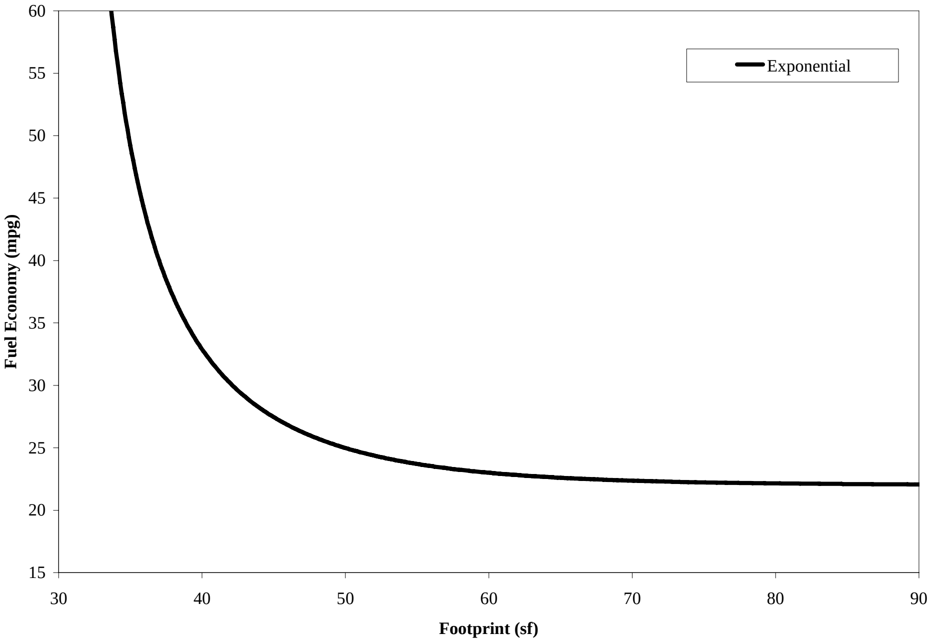

Figure 3B: Exponential function fit through sales weighted "socially optimized" light truck fleet (mpg as a function of footprint)

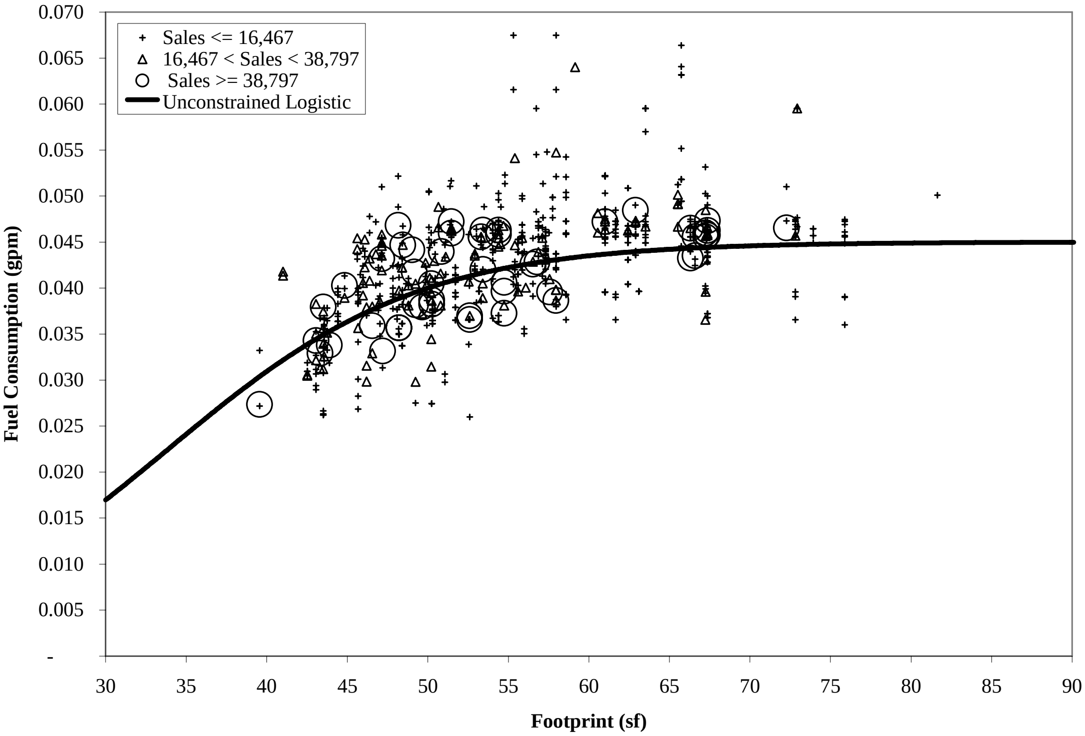

Figure 4A: Logistic function fit through sales weighted "socially optimized" light truck fleet (gpm as a function of footprint)

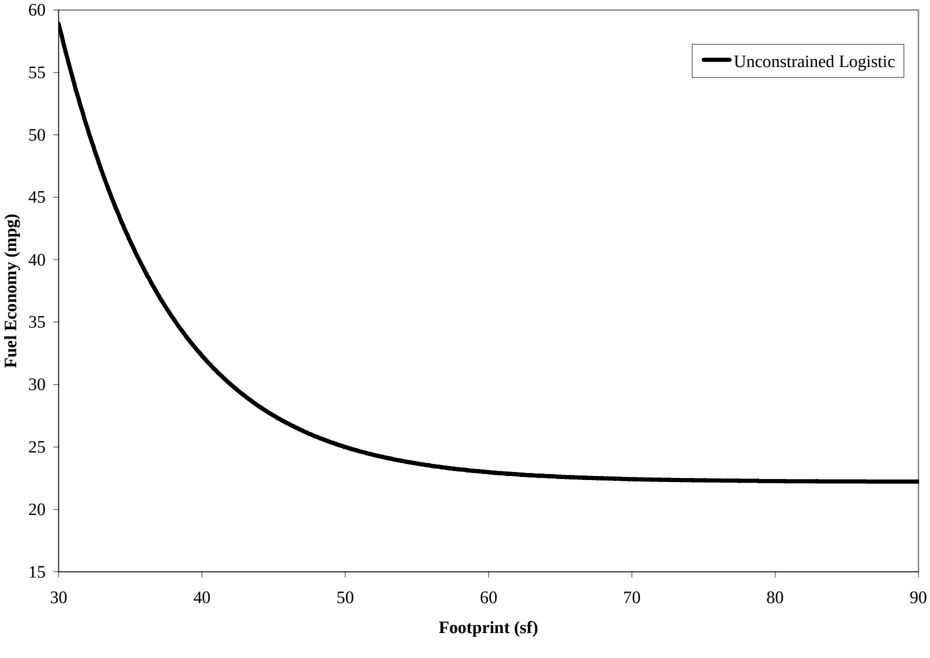

Figure 4B: Logistic function fit through sales weighted "socially optimized" light truck fleet (mpg as a function of footprint)

After evaluating the functions above, we determined that none of the functions as presented would be appropriate for the CAFE program. Each of the four forms fit the data relatively well within the footprint range observed in the manufacturers' product plans (from about 40 square feet to about 85 square feet). However, at slightly beyond the endpoints of the observed range, the functional forms tended towards excessively high stringency levels at the smaller end of the footprint range, excessively low stringency levels at the higher end of the footprint end, or both. Excessively high stringency levels at the smaller end of the footprint range potentially could result in target values beyond the technological capabilities of manufacturers. Excessively low stringency levels at the higher end of the footprint range standards would reduce fuel savings below that of the socially optimized fleet.

As Figure 1A shows, a simple linear functional form provides a reasonably good fit for small vehicles, but results in very low stringency for vehicles above 80 square feet and would correspond to fuel consumption values for very large vehicles greater than the fuel consumption for those vehicles under the optimized fleet. Reliance on a linear function would result in targets for large light trucks that are well below the optimized fuel economy, in terms of mpg, for those vehicles. These low target values would reduce fuel savings and provide a fuel economy incentive for upsizing. Additionally, depending on the distribution of the fleet, a simple linear relationship could also produce targets for very small vehicles well above the corresponding data points.

Polynomial relationships between footprint and fuel economy, such as a quadratic function, result in fuel consumption values that deviate substantially from the data points at either end of the footprint range. Further, because of their inherent curvature, polynomial functions often result in less stringent mpg targets for the smallest models than for slightly larger vehicles, or mpg targets for the largest models that are more stringent than those for slightly smaller models. As illustrated in Figure 2B the convex curvature of the function results in increases in stringency for vehicles with a footprint larger than about 70 square feet. This increase is contrary to the data points of the socially optimized fleet.

Under an exponential relationship, the fuel economy targets tend towards very high levels of stringency as footprint declines below 40 square feet (see Figure 3B). Under the exponential function for footprint values smaller than the smallest vehicle in the planned fleet are more a characteristic of the function, as opposed to representing the technological capabilities of such vehicles. A similar increase in targets occurs under a logistic function, although not to the extent as with an exponential function (see Figure 4B).

Under either an unconstrained exponential or an unconstrained logistic function, if a manufacturer were to introduce a vehicle with a footprint smaller than that considered in the optimized fleet, that vehicle would be compared to a fuel economy target potentially beyond the level that would be achieved had the agency “optimized” that vehicle. Such a target likely would be difficult to achieve using available technology. If a market demand were to develop for light trucks smaller than the smallest light truck currently planned by manufacturers, targets based on an exponential relationship or a logistic relationship could be technologically infeasible and limit consumer choice.

To address this issue the agency determined that it is necessary to constrain the chosen function at the end points of the footprint range. However, imposing a constraint on an exponential function prevents the curve from closely fitting the actual relationship between vehicle footprint and fuel economy across much of the size spectrum. In addition, exponential functions constrained to reach a maximum mpg value tended to have inconsistent shapes when fitted to light truck data for different model years.[23] Therefore, the agency decided to use a constrained logistic function to fit the target curve to the data points. The constrained logistic function is illustrated below in gallons per mile and inverted in miles per gallon:

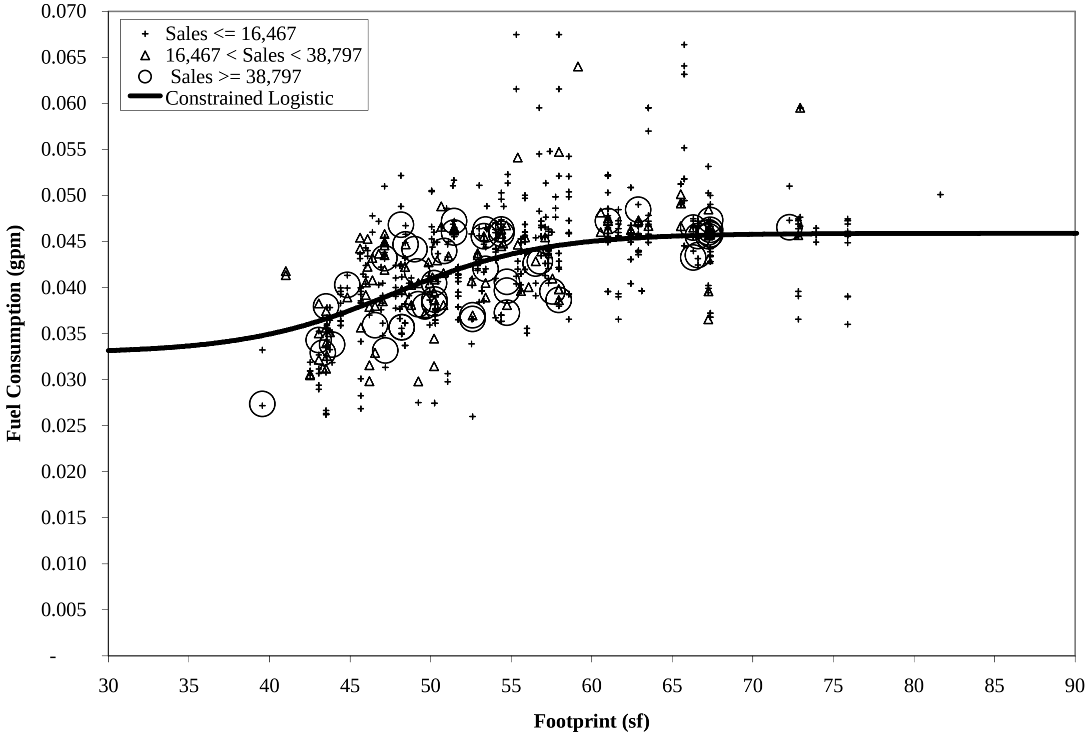

Figure 5: Constrained logistic function fit through sales weighted "socially optimized" light truck fleet (gpm as a function of footprint)

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[23] That is, the targets they established for models for some footprint values declined rather than increased between successive model years.

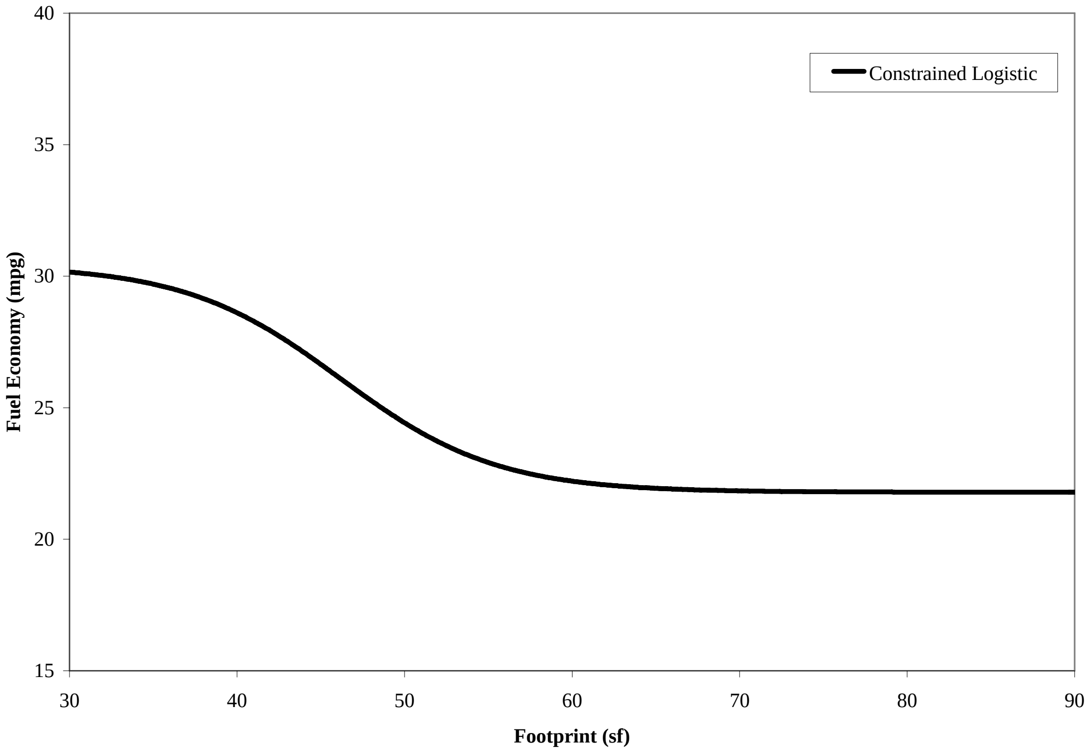

FIGURE 6: CONSTRAINED LOGISTIC FUNCTION (MPG)

The constrained logistic function provides a relatively good fit to the data points without creating excessively high targets for small vehicles, excessively low targets for large vehicles, or regions in which targets for large vehicles exceed those for small vehicles. The constrained logistic function also produces a curve that provides an acceptable fit to the light truck data across all four model years.

Further, by constraining the function at the ends of the footprint range, we limit the potential for the curve to be disproportionately influenced by a single vehicle model located at either end of the range. The vehicle population decreases as the curve moves away from the middle of the footprint range. The low vehicle population levels provide for a single vehicle model located at either end of the range to have a greater influence on its target, than a vehicle with comparable production numbers located in the middle of the range. This greater influence translates to greater influence on the shape of the curve. As demonstrated in the unconstrained logistic function, at a footprint value of 40 square feet a single model produced in larger numbers than other vehicles at or near this footprint value causes associated fuel consumption values to sharply decrease. This translates to rapidly increasing targets as footprint decreases below 40 square feet. Constraining the function also minimizes the potential for a disproportionate influence from a single vehicle model on the curve. The agency has constrained the target values at the ends of the range.

Constraining the upper and lower bounds in this manner has the additional benefit of generating a curve that closely tracks the shape of the proposed step-function. We have constrained this function so that the smallest/largest vehicles face similar stringency that was found in the smallest/largest categories in the step function.

The constrained logistic function selected by the agency is defined by four parameters. Two parameters establish the function's upper and lower bounds, respectively. A third parameter specifies the footprint at which the function is halfway between the upper and lower bounds. The last parameter establishes the rate or "steepness" of the function’s transition between the upper (at low footprint) and lower (at high footprint) boundaries.

The agency determined the values of the parameters establishing the function's upper and lower bounds by calculating the sales-weighted harmonic average values of optimized fuel economy levels for light trucks with footprints below 43 square feet and above 65 square feet, respectively. Because these ranges respectively include the smallest and largest models represented in the current light truck fleet, the agency determined that these two segments of the light truck fleet are appropriate for establishing the upper and lower fuel economy bounds of a continuous function.

The remaining two parameters (i.e., the "midpoint" and "curvature" parameters) were estimated using production-weighted nonlinear least-squares regression to achieve the closest fit to data on footprint and optimized fuel economy for all light truck models expected to be produced during each of model years 2008-2011.[24] Described mathematically, the logistic function is as follows:

$$T = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)/d}}{1+e^{(x-c)/d}}}$$

where,

T = the fuel economy target (in mpg)
a = the maximum fuel economy target (in mpg)
b = the minimum fuel economy target (in mpg)
c = the footprint value (in square feet) at which the fuel economy target is midway between a and b
d = the parameter (in square feet) defining the rate at which the value of targets decline from the largest to smallest values
e = 2.718[25]
x = footprint (in square feet, rounded to the nearest tenth) of the vehicle model

The resulting curve is an elongated “S”-shape, with fuel economy targets decreasing as footprint increases.

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[24] More precisely, these two parameters determine the range between the vehicle footprints where the upper and lower limits of fuel economy are reached, and the value of footprint for which the value of fuel economy is midway between its upper and lower bounds.

[25] For the purpose of the Reformed CAFE standard, we are carrying *e* out to only three decimal places.

Final level of the curve (and targets)

The final step in the process is to adjust the level of the preliminary curve defined in step two above is then "optimized" for the entire fleet produced by the seven largest manufacturers. The preliminary curve is gradually adjusted, by adjusting the initial values of parameters (a) and (b) by equal increments of fuel savings until the change in total costs incurred by all manufacturers for complying with their respective CAFE requirements (the sales-weighted harmonic averages of the mpg targets for their individual models specified by the function) from a further adjustment would exactly (within precision limits of the analysis) offset the resulting change in the value of fuel savings and associated benefits. Each light truck model's final fuel economy target can be determined by entering its footprint (in square feet) into the function with these revised parameter values appropriate for its model year, and calculating the resulting value of fuel economy in miles per gallon.

The parameter values for MYs 2008-2011 are as follows:

Table III-3
Optimized Parameter Values for Logistic Function

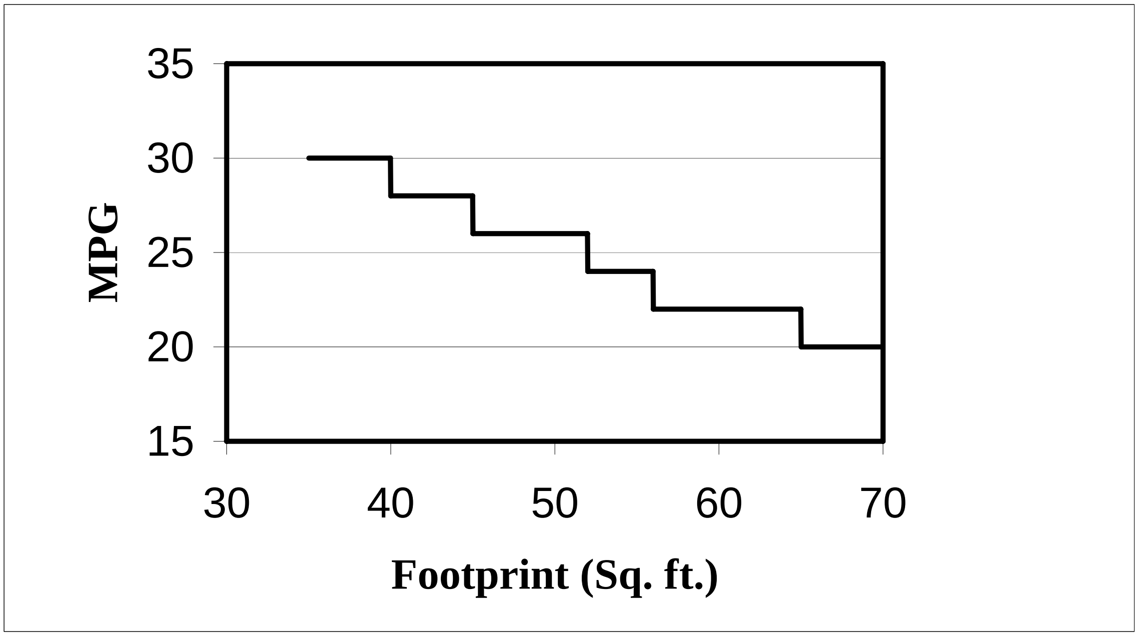
Parameter	Model Year			
	2008	**2009**	**2010**	**2011**
a	28.56	30.07	29.96	30.42
b	19.99	20.87	21.20	21.79
c	49.30	48.00	48.49	47.74
d	5.58	5.81	5.50	4.65

Once targets are calculated for each vehicle in a manufacturer's fleet under the continuous function, the corporate average fuel economy level required of the manufacturer is calculated using a harmonic average, as under the proposed step function. A manufacturer's actual fuel economy is calculated according to the procedure used in the current CAFE system. Penalties and credits are also determined and applied as under the current CAFE systems.

Step Function

In the NPRM, we proposed a step-function based on footprint target categories. Figure III-6 depicts the shape of the step function, as proposed.

Figure III-6—Illustration of the "shape" of the step function



The NPRM's proposed category boundaries (step boundaries) were defined after placing planned light truck production data points onto a distribution plot by footprint. We then sought to place the category boundaries generally at points indicating low volume immediately to the left and high volume immediately to the right. Our intent in doing so was to avoid providing an incentive to increase vehicle size in order to move a model into a category with a lower target. We sought to create a reasonable number of categories that would also combine, to the extent practicable, similar vehicle types into the same category structures. Each category was then assigned a fuel economy target.

The proposed targets were determined by a three-step process. First, the agency applied feasible technology to each of the seven largest manufacturers' fleets individually until the marginal cost of the added technology equaled the marginal benefit of the additional technology. Next, initial targets were determined by placing all of the improved mpg levels by footprint into the six categories and calculating the production-weighted fuel economy average within each category. Finally, the initial targets were adjusted by equal increments of fuel savings to a level at which marginal cost equaled marginal benefit for industry as a whole. This final level provided the targets as proposed, which would be used to determine a manufacturer's required fuel economy level.

Under the NPRM's proposed Step Function, the required level of CAFE for a particular manufacturer for a model year would be calculated after inserting the following data into the standard for that model year: (1) that manufacturer's actual total production, and (2) its production in each footprint category for that model year.[26] The calculation of the required level

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[26] Since the calculation of a manufacturer's required level of average fuel economy for a particular model year would require knowing the final production figures for that model year, the final formal calculation of that level would not occur until after those figures are submitted by the manufacturer to EPA. That submission would not, of course, be made until after the end of that model year.

would be made by dividing the manufacturer’s total production for the model year by the sum of the six fractions (one for each category) obtained by dividing the manufacturer’s production in a category by the category’s target.

As proposed, a manufacturer’s required fuel economy was represented as the following formula:

$$\frac{\text{Manufacturer X's Total Production of Light Trucks}}{\frac{\text{X's production in category 1}}{\text{Target for category 1}} + \frac{\text{X's production in category 2}}{\text{Target for category 2}} + \text{etc}} = \text{X's required level of CAFE}$$

The method of assessing compliance under the proposed Reformed CAFE system can be illustrated using an example of a manufacturer that produces four models in two of the proposed footprint categories with targets assumed for the purposes of the example shown in Table III-4:

Table III-4
Illustrative Example of Method of Assessing
Compliance under a Step Function

Model	**Fuel Economy (mpg)**	**Production (units)**	**Footprint (sq. ft.)**	**Footprint category**	**Footprint category Target (mpg)**
A	27	100,000	43	1	27.3
B	24	100,000	42	1	27.3
C	22	100,000	52	4	22.9
D	19	100,000	54	4	22.9

Under the NPRM proposed Step Function CAFE, the manufacturer would be required to achieve an average fuel economy level of:

$$\text{Required CAFE Level} = \frac{400{,}000}{\dfrac{200{,}000}{27.3\,mpg} + \dfrac{200{,}000}{22.9\,mpg}} = 24.9 \text{ mpg}$$

This fuel economy figure would be compared with the manufacturer's actual CAFE for its entire fleet, i.e., the production-weighted harmonic mean fuel economy level for four models in its fleet:

$$\text{Actual CAFE} = \frac{400{,}000}{\dfrac{100{,}000}{27.0\,mpg} + \dfrac{100{,}000}{24.0\,mpg} + \dfrac{100{,}000}{22.0\,mpg} + \dfrac{100{,}000}{19.0\,mpg}} = 22.6 \text{ mpg}$$

In the illustrative example, the manufacturer's actual CAFE (22.6 mpg) is less than the required level (24.9 mpg), indicating that the manufacturer is not in compliance.

Application of the continuous-function based standard

The Reformed CAFE standard establishes a relationship between vehicle footprint and the fuel economy target for light trucks with different footprint values. The final rule establishes a category system like that proposed in the NPRM, in which each vehicle model has an associated fuel economy target based on its footprint.

The required level of CAFE for each manufacturer during a model year is the production-weighted harmonic average of the fuel economy targets for each model in its product line for that model year. While individual manufacturers may face different requirements for their overall CAFE levels depending on the distribution of footprint values for the models making up their respective product lines, each manufacturer is subject to identical fuel economy target for light truck models with the same footprint value. Moreover, the same formula is used to determine each manufacturer's required level of CAFE using the fuel economy targets for different footprint values, footprint values for its individual models, and the production levels of each of its models. Individual manufacturers face different required CAFE levels only to the extent that they produce different size mixes of vehicle models, and in this respect, today's final rule is no different than if the agency established multiple classes of vehicles with different CAFE standards for each class. Under such a multiple-class system, manufacturers would implicitly face different CAFE requirements at the fleet level as a result of differences in their fleet mixes.

To determine whether it has achieved its required overall CAFE level, each manufacturer's production-weighted harmonic average of the actual fuel economy levels for each model in its entire product line is compared to this required CAFE level. If the weighted average of its models' actual fuel economy levels is at least equal to the manufacturer's required level of average fuel economy, then it has complied with the Reformed CAFE standard. If its actual fleet-wide average fuel economy level is greater than its required CAFE level, the manufacturer earns credits equal to that difference that can be used in any of the three preceding or following model years.

More specifically, the manner in which a manufacturer's required overall CAFE for a model year under the Reformed system is computed is similar to the way in which its actual CAFE for a model year has always been calculated. Its required CAFE level is computed on the basis of the production and the footprint target as follows:

$$\frac{\text{Manufacturer X's Total Production of Light Trucks}}{\dfrac{\text{X's production of model } m}{\text{Target for model } m} + \dfrac{\text{X's production of model } n}{\text{Target for model } n} + \text{etc}} = \text{X's required level of CAFE}$$

This formula can be restated as follows:

$$Required\_Fuel\_Economy\_Level = \frac{N}{\sum_i \frac{N_i}{T_i}}$$

Where:

N is the total number (sum) of light trucks produced by a manufacturer,
N_i is the number (sum) of the i^{th} model light truck produced by the manufacturer, and
T_i is fuel economy target of the i^{th} model light truck.

The required level is then compared to the CAFE that the manufacturer actually achieves in the model year in question:

$$CAFE = \frac{N}{\sum_i \frac{N_i}{mpg_i}}$$

Where,
N is the total number (sum) of light trucks produced by the manufacturer,
N_i is the number (sum) of the i^{th} model light trucks produced by the manufacturer,
mpg_j is the fuel economy of the i^{th} model light truck.

A manufacturer is in compliance if the actual CAFE meets or exceeds the required CAFE.

The method of assessing compliance under Reformed CAFE can be further explained using an illustrative example of a manufacturer that produces four models in two footprint categories with fuel economy targets assumed for the purposes of the example shown in Table III-5:

Table III-5
Illustrative Example of Method of Assessing
Compliance under a Continuous Function

Model	**Fuel Economy (mpg)**	**Production (units)**	**Footprint (sq. ft.)**	**Footprint Target (mpg)**
A	27.0	100,000	43.00	27.5
B	24.0	100,000	42.00	27.8
C	22.0	100,000	52.00	23.7
D	19.0	100,000	54.00	23.2

Under Reformed CAFE, the manufacturer would be required to achieve an average fuel economy level of:

Required CAFE Level = $$\frac{400,000}{\frac{100,000}{27.5mpg}+\frac{100,000}{27.8mpg}+\frac{100,000}{23.7mpg}+\frac{100,000}{23.2mpg}}$$ = 25.4 mpg

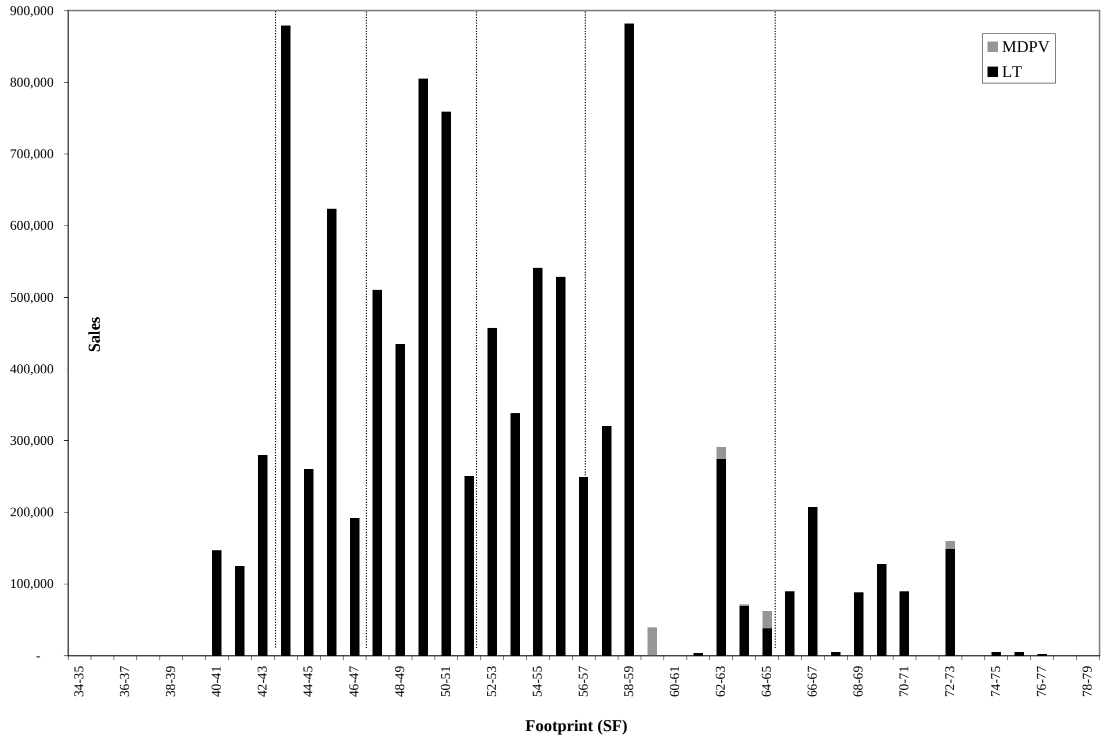
This fuel economy figure would be compared with the manufacturer’s actual CAFE for its entire fleet (i.e., the production-weighted harmonic mean fuel economy level for four models in its fleet):

Actual CAFE = $$\frac{400,000}{\frac{100,000}{27.0mpg}+\frac{100,000}{24.0mpg}+\frac{100,000}{22.0mpg}+\frac{100,000}{19.0mpg}}$$ = 22.6 mpg

In the illustrative example, the manufacturer’s actual CAFE (22.6 mpg) is less than the required level (25.4 mpg), indicating that the manufacturer is not in compliance.

In the NPRM, we set the boundaries of the step function standard at footprint levels intending to address the potential for “upsizing.” We discussed the potential for manufacturers to “upsize” their vehicles for the primary purpose of subjecting that vehicle to a less stringent target and noted the increased potential for upsizing vehicles located near an upper boundary of a category. In order to minimize this potential, we established the proposed boundaries generally at points indicating low volume immediately to the left and high volume immediately to the right. Identification of points between low and high volume was based on the distribution of vehicles from the product plans provided to the agency in response to the 2003 ANPRM. Based on this distribution, the agency was able to readily identify boundaries, as illustrated in the figure below.

Figure III-7: Sales Distribution of Light Truck Fleet by Footprint Used in the NPRM



A variety of commenters also recognized the potential for "upsizing" vehicle designs that influenced the agency's proposed boundaries. The Alliance asserted that the agency's selection of boundaries under the step function effectively addressed the potential problem of vehicle upsizing under its proposed category system, noting that it "agrees with the agency's assessment that both the number and the location of the boundaries for the footprint categories would likely minimize any such edge effects."

However, the boundaries set in the NPRM did not align to similar low and high volume points for the updated fleets, based on revised product plans submitted by the manufacturers in response to the Request for Comments issued at the time of the NPRM. Distribution of the light truck fleet represented in the updated product plans provided by manufacturers for development of the final rule differs from that of the light truck fleet reflected in the product plans submitted in response to the ANPRM. When these updated data are factored in, the boundaries set in the NPRM are not located at points with low volume to the left of the boundary and high volume to the right of the boundary. The implication of the updated distribution is that the boundaries set in the NPRM do longer minimize the potential for "edge effects" as was the agency's intent in the NPRM (see Figure III-8 as an example).

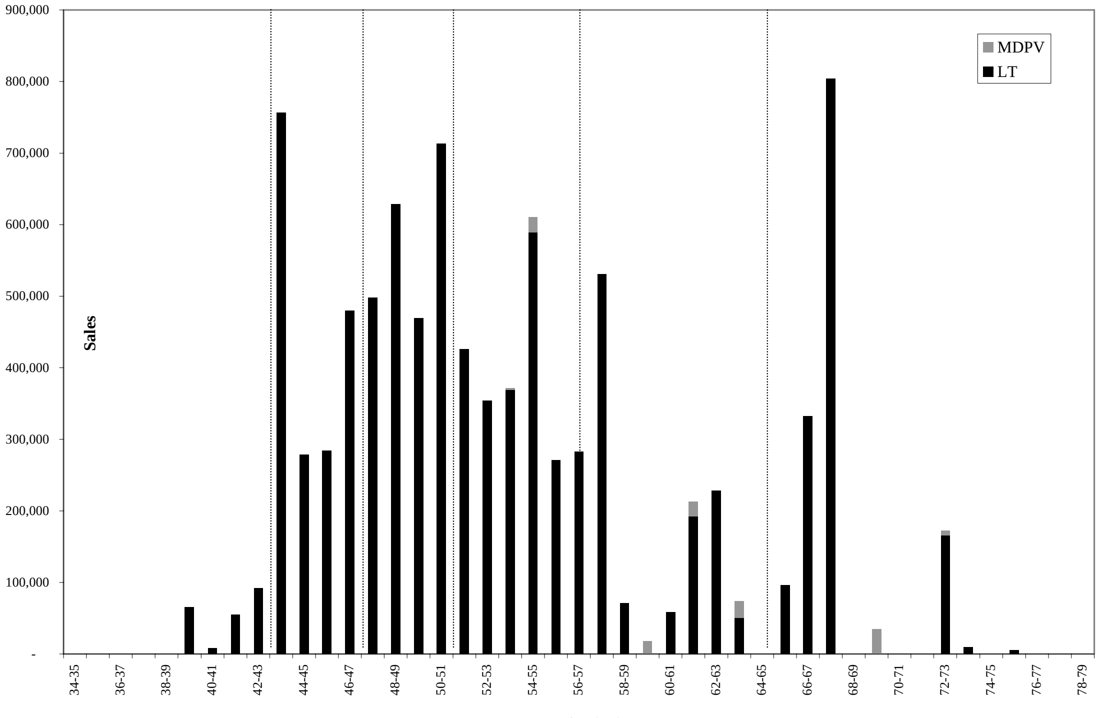


Figure III-8

In order for the agency to attempt to minimize the potential for vehicle "upsizing" under a step-function system, we would need to relocate the category boundaries. By utilizing a continuous function, the agency eliminates boundaries and thus the potential difficulties associated with defining and redefining category boundaries.

Alternatives Examined

Besides the final rule’s compliance options described above (Unreformed and Reformed CAFE), the agency examined a number of other alternatives. All of the alternatives examined in this analysis are variations of setting a reformed standard. These alternatives are all analyzed using the same technology applications and values that were applied to the final rule. These alternatives are:

The continuous function without MDPVs in MY 2011

This requires a new set of equations for the continuous function for MY 2011 as follows:

Table III-6
Continuous Function Parameters
Without MDPVs for MY 2011

Logistic area-based function	**MY 2008**	**MY 2009**	**MY 2010**	**MY 2011 Without MDPVs**
a: mpg ("ceiling")	28.56	30.07	29.96	30.46
b: mpg ("floor")	19.99	20.87	21.20	22.03
c: square feet ("midpoint")	49.30	48.00	48.49	47.23
d: square feet ("width")	5.58	5.81	5.50	4.59

The Proposed NPRM Step Function targets, without MDPVs in MY 2011

This alternative keeps the bin boundaries and the proposed bin targets as in the NPRM, but uses updated production data.

Table III-7
Proposed NPRM Step Function Targets
(in mpg)

NPRM Step Function Targets				
Category	**2008**	**2009**	**2010**	**2011 without MDPVs**
1 < 43.0 square feet	26.8	27.4	27.8	28.4
2 43.0 to < 47.0	25.6	26.4	26.4	27.1
3 47.0 to < 52.0	22.3	23.5	24.0	24.5
4 52.0 to < 56.5	22.2	22.7	22.9	23.3
5 56.6 to < 65.0	20.7	21.0	21.6	21.9
6 ≥ 65.0	20.4	21.0	20.8	21.3

Revised Step Function Targets with and without MDPVs in MY 2011

These step functions keeps the category boundaries as proposed in the NPRM, but the targets for each category are changed based on the new technology data used in setting the final rule.

Table III-8
Category Target under Revised Step Function

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011**	**MY 2011**
Category				**With MDPVs**	**Without MDPVs**
1 < 43.0 square feet	28.56	29.72	29.87	30.32	30.37
2 43.0 to < 47.0	25.94	26.66	26.96	27.20	27.17
3 47.0 to < 52.0	22.74	23.28	23.82	24.24	24.19
4 52.0 to < 56.5	22.45	23.04	23.32	23.51	23.51
5 56.6 to < 65.0	20.96	21.73	22.09	22.11	22.48
6 ≥ 65.0	19.99	20.70	21.16	21.74	21.98

These alternatives, which will be examined throughout the rest of the analysis, allow an examination of the differences between the stepwise function and the continuous function and between alternatives with and without MDPVs, as well as the differences if we used the NPRM stepwise function for the final rule.

IV. IMPACT OF OTHER FEDERAL MOTOR VEHICLE STANDARDS ON LIGHT TRUCK FUEL ECONOMY

Introduction

The Energy Policy and Conservation (EPCA or the Act) requires that fuel economy standards be set at the maximum feasible level after taking into account the following criteria: (1) technological feasibility, (2) economic practicability, (3) the impact of other Federal Motor Vehicle Standards on fuel economy, and (4) the need of the Nation to conserve energy. This section discusses the effects of other government regulations on model year (MY) 2008-2011 light truck fuel economy.

The Impact of Safety Standards and Voluntary Safety Improvements

The fuel economy impact of safety improvements will typically take the form of increased vehicle weight, which reduces the fuel economy of the vehicle. The manufacturer's estimates of weight and fuel economy impact have already been included in their baseline fuel economy projections. In some instances the manufacturers' weight estimates are similar to NHTSA's, in some instances they are less than NHTSA's, but often they are more than NHTSA's. The agency's estimates are based on cost and weight tear-down studies of a few vehicles and cannot possibly cover all the variations in the manufacturers' fleets. The manufacturers' estimates of the fuel economy impact of added weight on mpg have typically been less than NHTSA's estimates. NHTSA estimated that an increase of 3-4 pounds[27] results in a decrease of 0.01 mpg, the manufacturer's data show that an increase of up to 7 pounds results in a decrease of 0.01 mpg. The combination of the manufacturers estimating more safety weight impacts, but at the

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[27] In reality, the fuel economy impact depends on the baseline weight of the vehicle.

same time estimating weight having less impact on miles-per-gallon, has resulted in similar impacts being estimated by NHTSA and the manufacturers. The agency has not questioned the manufacturers' estimates closely because the differences in the overall fuel economy impact due to required safety standards as estimated by Ford, General Motors, and NHTSA is small.

We have broken down our analysis of the impact of safety standards that might affect the MY 2008-2011 fleets into two parts, those final rules with known effective dates, and proposed rules without final effective dates or currently voluntary safety improvements.

Baseline Weights

The average test weight (curb weight plus 300 pounds) of the light truck fleet is expected to be 4,744 pounds for MY 2008, 4,800 pounds for MY 2009, 4,792 pounds for MY 2010, and 4,786 pounds for MY 2011 (excluding MDPVs). Thus, overall, weight in light trucks is anticipated to change very little during this timeframe. The change in weight includes all factors, such as changes in the fleet mix of vehicles, required safety improvements, voluntary safety improvements, and other changes for marketing purposes.

Weight Impacts of Required Safety Standards (Final Rules)

The National Highway Traffic Safety Administration (NHTSA) has issued five final rules (two in FMVSS 208) on safety standards that become effective for light trucks between MY 2008-2011, using MY 2007 as a baseline. These have been analyzed for their potential impact on light truck fuel economy weights for MY 2008-2011.

1. FMVSS 138, Tire Pressure Monitoring System
2. FMVSS 202, Head Restraints
3. FMVSS 208, Rear Seat Lap/Shoulder Belts and 35 mph Testing
4. FMVSS 301, Fuel System Integrity

FMVSS 138, Tire Pressure Monitoring System

As required by the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act, NHTSA is requiring a tire pressure monitoring system (TPMS) to be installed in all passenger cars, multipurpose passenger vehicles, trucks, and buses that have a Gross Vehicle Weight Rating (GVWR) of 10,000 pounds or less. Compliance is based on the following phase-in schedule:

20 percent of light vehicles produced between October 5, 2005 and August 31, 2006,
70 percent of light vehicles produced between September 1, 2006 and August 31, 2007,
All light vehicles produced after September 1, 2007 must meet the final rule.

Thus, for Model Year 2008, an additional 30 percent of the fleet will be required to meet the standard. We estimate from a cost tear-down study that the added weight for an indirect TPMS system is about 0.156 lbs. and for a direct TPMS system is 0.275 to 0.425 lbs. Initially, direct systems will be more prevalent; thus, the increased weight attributable to TPMS is estimated to average 0.35 lbs. (0.16 kilograms). For MY 2008, the weight increase associated with meeting FMVSS 138 is anticipated to be 0.11 pounds [ ] or 0.05 kilograms [ ]. Beyond its weight, operation of the TPMS system would not affect new vehicle CAFE, since the testing is performed with tires fully inflated. Instead, we expect that TPMS will increase in-service fuel economy by warning drivers when their tire pressure is low and reminding drivers to inflate their tires.

FMVSS 202, Head Restraints

The final rule requires an increase in the height of front seat outboard head restraints in pickups, vans, and utility vehicles, effective September 1, 2008 (MY 2009)[28]. If the vehicle has a rear seat head restraint, it is required to be at least a certain height. The initial (1969) head restraint requirement resulted in the average front seat head restraints being 3 inches taller than pre-standard head restraints and adding 5.63 pounds[29] to the weight of a passenger car. With the new final rule, we estimate the increase in height for the front seats to be 1.3 inches and for the rear seat to be 0.26 inch, for a combined average of 1.56 inches[30]. Based on the relationship of pounds to inches from current head restraints, we estimate the average weight gain across light trucks would be 2.9 pounds (1.3 kilograms). (5.63/3 * 1.56 = 2.93 lbs.)

FMVSS 208, Occupant Crash Protection, (Rear Center Seat Lap/Shoulder Belts)

This final rule requires a lap/shoulder belt in the center rear seat of light trucks. There are an estimated 5,061,079[31] seating positions in light trucks needing a lap/shoulder belt, where they currently have just a lap belt. This estimate of seating positions is an aggregation of light trucks, SUVs, minivans and 15 passenger vans that have either no rear seat, or 1 to 4 rear seats that need

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[28] The compliance date for the upgraded requirements applicable to head restraints voluntarily installed at rear outboard seating positions recently was amended from September 1, 2008, to September 1, 2010 (see, 71 FR 12415; March 9, 2006).

[29] "Cost and Weight Added by Federal Motor Vehicle Safety Standards for Model Years 1968-2001 in Passenger Cars and Light Trucks", NHTSA, December 2004, DOT-HS-809-834. Pg. 51.

[30] "Final Regulatory Impact Analysis, FMVSS No. 202 Head Restraints for Passenger Vehicles", NHTSA, November 2004, Docket No. 19807-1, pg. 74.

[31] "Final Economic Assessment and Regulatory Flexibility Analysis, Cost and Benefits of Putting a Shoulder Belt in the Center Seats of Passenger Cars and Light Trucks", NHTSA, June 2004, Docket No. 18726-2, pg. 33.

shoulder belts. This estimate was based on sales of 7,521,302 light trucks in MY 2000. Thus, the average light truck needs 0.67 shoulder belts. The average weight of a rear seat lap belt is 0.92 lbs. and the average weight of a manual lap/shoulder belt with retractor is 3.56 lbs[32]. Thus, the anticipated weight gain is 2.64 pounds per shoulder belt. We estimate the average weight gain per light truck for the shoulder belt would be 1.8 pounds (0.8 kilograms). (2.64 * .67 = 1.77 lbs.)

A second, potentially more important, weight increase depends upon how the center seat lap/shoulder belt is anchored. The agency has allowed a detachable shoulder belt in this seating position, which could be anchored to the ceiling or other position, without a large increase in weight (less than 1 lb.). If the center seat lap/shoulder belt is anchored to the seat itself, typically the seat would need to be strengthened to handle this load (the agency requested comments on this weight increase). If the manufacturer decides to change all of the seats to integral seats, having all three seating positions anchored through the seat, then both the seat and flooring would need to be strengthened (again the agency requested comments on this weight increase). Comments were received from General Motors and Ford, which ranged from [ ].

Compliance is based on the following phase-in schedule:

50 percent of light vehicles produced between September 1, 2005 and August 31, 2006,
80 percent of light vehicles produced between September 1, 2006 and August 31, 2007,
100 percent of light vehicles produced after September 1, 2007 must meet the final rule.

Thus, for Model Year 2008, an additional 20 percent of the fleet will be required to meet the standard. We estimate the average weight gain per light truck for the shoulder belt would be

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[32] "Cost and Weight Added by Federal Motor Vehicle Safety Standards for Model Years 1968-2001 in Passenger Cars and Light Trucks", NHTSA, December 2004, DOT-HS-809-834. Pg. 84.

0.36 lbs (0.16 kg) {1.8 pounds (0.8 kg) * 0.2} compared to MY 2007. For the anchorage, the average weight increase would be 0.2 pounds (0.09 kg) or more. [ ].

FMVSS 208, Occupant Crash Protection, (35 mph Frontal Impact Testing)

The advanced air bag rule requires 35 mph belted testing with the 50th percentile male dummy with a phase-in schedule of:

35 percent of light vehicles produced between September 1, 2007 and August 31, 2008,
65 percent of light vehicles produced between September 1, 2008 and August 31, 2009,
100 percent of light vehicles produced after September 1, 2009 must meet the final rule,

Small volume manufacturers, multi-stage manufacturers, and alterers must comply with the final rule on September 1, 2010.

About 85 percent of the fleet already meets the test based on NCAP results. It is assumed that pretensioners and load limiters would be the countermeasures used to pass the test. The estimated combined weight of these features is 2.4 pounds for the two front outboard seats. Thus, the average incremental weight increase would be 0.36 pounds or 0.16 kg.

FMVSS 301, Fuel System Integrity

This final rule amends the testing standards for rear end crashes and resulting fuel leaks. Many vehicles already pass the more stringent standards, and those affected are not likely to be pick-up trucks or vans. It is estimated that weight added will be only light-weight items such as a flexible filler neck. We estimate the average weight gain across this vehicle class would be 0.24 pounds (0.11 kilograms).

Compliance is based on the following phase-in schedule:

40 percent of light vehicles produced between September 1, 2006 and August 31, 2007,
70 percent of light vehicles produced between September 1, 2007 and August 31, 2008,
100 percent of light vehicles produced after September 1, 2008 must meet the final rule.

Thus, 60 percent of the fleet must meet FMVSS 301 during the MY 2008-2010 time period.

Thus, the average weight gain during this period would be 0.14 pounds (0.07 kilograms).

Weight Impacts of Potential Future Safety Standards and Voluntary Safety Improvements

There are several safety standards that have recently been proposed, or that the agency is required by Congress to propose in the near future that could impact on some of the MY 2008-2011 vehicles. In most cases, these proposals or future proposals are already being met voluntarily by a part of the fleet. In addition, there are improvements that are being made voluntarily to meet market demand and/or to perform better on government or insurance industry tests involving vehicle ratings. These have been combined without regard to effective date, even though the final effective dates may be later than MY 2011.

Anti-lock Brakes and Electronic Stability Control (ESC)

NHTSA and the Insurance Institute for Highway Safety have both released analyses indicating significant avoidance of single vehicle run-off-road crashes with Electronic Stability Control. Many manufacturers are planning to install ESC on all of their light vehicles. Recent congressional legislation contained in section 10301 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users of 2005 (SAFETEA-LU)[33] requires the Secretary of Transportation to "establish performance criteria to reduce the occurrence of rollovers consistent with stability enhancing technologies" and to "issue a proposed rule … by

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[33] Pub. L. 109-59, 119 Stat. 1144 (2005).

October 1, 2006, and a final rule by April 1, 2009." A requirement by NHTSA in this area could potentially be effective by MY 2011. In the meantime, voluntarily installed ESC systems are adding weight to vehicles. The ESC system needs anti-lock brakes to work appropriately. Anti-lock brakes add about 20 pounds to the weight of a light truck. Currently, about 91 percent of all light trucks have anti-lock brakes. Thus, if all light trucks added anti-lock brakes, average light truck weight would increase by 1.8 pounds. ESC is estimated to add about 9 pounds to a vehicle's weight. In 2005, an estimated 23 percent of light trucks had ESC. Thus, if all light trucks added ESC, average light truck weight would increase by 6.9 pounds. So, the total weight increase would average 8.7 pounds (3.95 kg.).

Roof Crush, (FMVSS 216)

On August 23, 2005, NHTSA published an NPRM (70 FR 49223) proposing to upgrade the agency's safety standard on roof crush resistance (FMVSS 216).[34] The NPRM proposed to extend the standard to vehicles with a GVWR of 10,000 pounds or less, increase the force applied to 2.5 times each vehicle's unloaded weight and amend the current limit on the amount of roof crush with a requirement to maintain enough headroom for a mid-size adult male occupant.

The Alliance, Ford, DaimlerChrysler and Toyota commented that the agency should have included the weight impact of FMVSS 216 in its analysis. The agency agrees. Manufacturers' estimates of the weight implications of compliance with the proposed FMVSS No. 216 ranged from minimal to tens of pounds.

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[34] "Preliminary Regulatory Impact Analysis, FMVSS 216, Upgrade Roof Crush Resistance", August 2005, Docket No. 22143-2, page V-19.

As estimated at the time of the FMVSS 216 NPRM, the proposed upgrade was estimated to increase average vehicle weight by 6.07 pounds. The proposed effective date was the first September 1 occurring three years after publication of the final rule.

In addition to the comments on the CAFE NPRM, NHTSA received a number of comments on the weight estimates in response to the Roof Crush NPRM. Other manufacturers commented to the Roof Crush NPRM that the agency's weight estimates were too low. However, other commenters indicated that weight estimates were too high because the agency failed to consider alternative, lighter, materials manufacturers could use to comply with the standard. The agency is still evaluating all of the comments to the Roof Crush NPRM and estimates that if a final rule were issued it would be in 2007. Therefore, for purposes of this CAFE rule the agency is using the estimates made at the time of the Roof Crush NPRM and assuming an effective date of September 1, 2010.

Side Impact and Ejection Mitigation Air Bags (Thorax and Head Air Bags)

Many manufacturers are installing side impact air bags (thorax bags, combination head/thorax bags, or window curtains). NHTSA proposed an oblique pole test as part of FMVSS 214 (Side Impact Protection) on May 17, 2004, (69 FR 27990). Based on current technology, this NPRM would result in head protection by either a combination head/thorax side air bag or window curtains. SAFETEA-LU is also mandating ejection mitigation. The most likely countermeasure is the use of a rollover sensor and window curtain air bags, which would result in taller and wider window curtains that would be tethered or anchored low to keep occupants in the vehicle.

A teardown study of 5 thorax air bags resulted in an average weight increase per vehicle of 4.77 pounds (2.17 kg).[35] A second teardown study of 3 combination head/thorax air bags resulted in a similar average weight increase per vehicle of 4.38 pounds (1.99 kg).[36] This second study also performed teardowns of 5 window curtain systems. One of the window curtain systems was very heavy (23.45 pounds). The other four window curtain systems had an average weight increase per vehicle of 6.78 pounds (3.08 kg), a figure which is assumed to be average for all vehicles in the future. We expect rollover curtains for ejection mitigation to be a few pounds heavier than window curtains for side impact, but the agency does not have a weight estimate at this time.

Assuming in the future that the typical system used to comply with the requirements of FMVSS No. 214 will be thorax bags with a window curtain, the average weight increase would be 11.55 pounds (4.77 + 6.78) or 5.25 kg (2.07 + 3.08). In MY 2005, about 31 percent of the fleet had thorax air bags, 7 percent had combination air bags and, and 25 percent had window curtains. The combined average weight for these systems in MY 2005 was 3.49 pounds (1.59 kg). Thus, the future increase in weight for side impact air bags and window curtains compare to MY 2005 installations is 8.06 pounds (11.55 – 3.49) or 3.66 kg (5.25 – 1.59).

As a related matter, another area that could result in an increase in weight is if the manufacturers include structure to get a higher score in the IIHS side impact barrier test. The IIHS side barrier is physically taller than NHTSA's barrier. The agency has no data to determine what, if any,

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[35] Khadilkar, et al. "Teardown Cost Estimates of Automotive Equipment Manufactured to Comply with Motor Vehicle Standard – FMVSS 214(D) – Side Impact Protection, Side Air Bag Features", April 2003, DOT HS 809 809.

[36] Ludtke & Associates, "Perform Cost and Weight Analysis, Head Protection Air Bag Systems, FMVSS 201", page 4-3 to 4-5, DOT HS 809 842.

voluntary weight increases have been added or will be added to obtain a better score in this test.

[ ]

Offset Frontal Crash Testing

The Insurance Institute for Highway Safety (IIHS) has been testing and rating vehicles using an offset deformable barrier crash test at 64 km/h. Many manufacturers have redesigned their vehicles to do better in these tests and have increased the weight of their vehicles. Four light trucks that the agency has tested, which improved from a poor rating to a marginal or good rating in the IIHS testing, increased their weights (some with other redesigns) as follows:

Table IV-1
Increases in Weight to Improve in
Offset Frontal Testing

	Before	**After Redesign**	**Increase in Weight**
SUV	1997 Chevrolet Blazer (4,686 lbs.)	2002 Trailblazer (5,181 lbs.)	495 lbs.
SUV	1999 Mitsubishi Montero Sport (4,646 lbs.)	2001 Mitsubishi Montero Sport (4,715 lbs.)	69 lbs.
Pickup	2001 Dodge Ram 1500 (4,930 lbs.)	2002 Dodge Ram 1500 (4,969 lbs.)	39 lbs.
Minivan	1996 Toyota Previa (3,810 lbs.)	1998 Toyota Sienna (3,937 lbs.)	127 lbs.

These weight increases have an affect on the vehicle's fuel economy. However, many vehicles have already been redesigned with this offset frontal test in mind. Whether increases in weight like this will continue for other vehicles in the future is unknown.

FMVSS 206 and FMVSS 208

There are two other standards that might have a small impact on vehicle weight, but the agency believes that the overall weight increase of these for the fleet will be small. These include: FMVSS 206 (Door Locks and Door Retention Components), sliding door latch requirements will add a small weight to van doors that do not have two latches (essentially the addition of an additional latch). We estimate about 1.2 million doors would need to be changed, but we have not estimated the weight increase.

FMVSS 208 (Occupant Crash Protection), a 35 mph test belted test with 5th female dummies will be added to the standard, but this is not anticipated to require an increase in weight.

Summary – Overview of Anticipated Weight Increases

The following two tables summarize estimates made by NHTSA regarding the weight added in MY 2008 –2011 to institute the above discussed standards or potential voluntary safety improvements. Table IV-2 presents the actions that are required of the manufacturers by changes in the safety standards   that are already final rules compared to a baseline of MY 2007. Table IV-3 presents proposed rules and other voluntary actions compared to a baseline of MY 2005.

Table IV-2
Weight Additions Due to Required FMVSS Regulations
Already Issued Final Rules

Standard No.	Effective Date	Added Weight in pounds	Added Weight in kilograms
138	Last 30% in MY 2008	0.11	0.05
202	MY 2009	2.9	1.3
208 (belts)	Last 20% in MY 2008	0.36	.16
208 (anchorages)	Last 20% in MY 2008	0.2 - ? [ ]	0.09 - ? [ ]
208 (pretensioners and load limiters)	Phase-in starts in MY 2008, affects all by MY 2011	0.36	0.16
301	Affect 60% total, Middle 30% in MY 2008, and Last 30% in MY 2009	0.14	0.07
Total		4.07 - ? [ ]	1.83 - ? [ ]

Table IV-3
Weight Additions Due to Future Final Rules
And Possible Voluntary Safety Improvements

	Added Weight in pounds	Added Weight in kilograms
Anti-lock Brakes and ESC	8.7	3.95
Side Impact Air Bags (Thorax and Head Air Bags)	8.06	3.66
Improve Offset Frontal Crash Ratings	?	?
Roof Crush Upgrade	6.07	2.76
Total	22.83 - ?	10.37 - ?

In summary, NHTSA estimates that weight additions required by final rule FMVSS regulations that will be effective in MY 2008-2011, compared to the MY 2007 fleet, will increase light truck weight by an average of 4.07 pounds or more (1.83 kg or more). Likely weight increases from future safety standards or voluntary safety improvements will add 22.83 pounds or more (10.37 kg or more) compared to MY 2005 installations. Using the confidential data, the results are [

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Based on NHTSA's weight-versus-fuel-economy algorithms, a 3-4 pound increase in weight equates to a loss of 0.01 mpg in fuel economy. Thus, the agency's estimate of the safety/weight effects are 0.01 mpg or more for already issued final rules and 0.057 mpg or more for future safety standards or voluntary safety improvements, for a total of 0.067 mpg or more. Using the confidential data, the results are [

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Docket Comments

The Alliance commented that the PRIA's estimated weight increase of 3.71 pounds or more for final rules and 11.75 pounds or more for voluntary safety improvements are substantially underestimated and that weight estimates provided by several manufacturers were up to ten times the NHTSA estimate. The individual manufacturers' actual estimates were not provided as part of the Alliance's docket comments. Ford and General Motors did provide confidential information as discussed below.

CONFIDENTIAL SUBMISSIONS

Information on the fuel economy impacts of safety standards and voluntary safety improvements were submitted by Ford and General Motors. These are summarized in the table below:

[Table IV-4
Confidential Submissions on Safety Standards and Voluntary Safety Improvements

Table IV-5
MPG Effect of Safety Weight Increases

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The Impact of Emission Standards

1. Tier 2 Requirements

On February 10, 2000, the Environmental Protection Agency (EPA) published a final rule (65 FR 6698) establishing new Federal emissions standards for passenger cars and light trucks. These new emissions standards, known as Tier 2 standards, are designed to focus on reducing the emissions most responsible for the ozone and particulate matter (PM) impact from these vehicles (nitrogen oxides (NOx) and non-methane organic gases (NMOG), consisting primarily of hydrocarbons (HC)) and contributing to ambient volatile organic compounds (VOC).

For new passenger cars and light trucks, rated at less than 6,000 pounds GVWR, the Tier 2 standards phase-in began in 2004, and are to be fully phased-in by 2007. The phase-in schedule for MDPVs under the Tier 2 Program requires that 50% of the fleet must comply in MY 2008 and 100% by MY 2009.

Prior to model year 2008, EPA also regulates MDPVs under "Interim-Non-Tier 2" standards, applicable to MDPVs on a phase-in schedule beginning with MY 2004. The phase-in schedule requires compliance at the following levels: 25% in 2004, 50% in 2005, 75% in 2006, and 100% in 2007. Thus, beginning in 2008, half the MDPVs are expected to comply with Tier 2 and the other half with "Interim Non-Tier 2 Standards," with implementation expanding in succeeding years.

In addition to establishing new emissions standards for vehicles, the Tier 2 standards also establish standards for the sulfur content of gasoline.

When issuing the Tier 2 standards, EPA responded to comments regarding the Tier 2 standard and its impact on CAFE by indicating that it believed that the Tier 2 standards would not have an adverse effect on fuel economy.

2. **California Air Resources Board - Clean Air Act § 209 standards**

The Clean Air Act (CAA) generally prohibits States or any other political subdivision from adopting any standard relating to the control of emissions from new motor vehicles (CAA § 209(a); 42 USC § 7543(a)). However, the statute provides that the State of California may issue such standards upon obtaining a waiver from the EPA (CAA § 209(b); 42 USC § 7543(b)). The State of California has established several emission requirements under § 209(b) of CAA as part of its Low Emission Vehicle (LEV) program. California initially promulgated these § 209(b) standards in its LEV I standards, and it has subsequently adopted more stringent requirements under § 209(b) of the CAA in its LEV II regulations. The relevant LEV II regulations are being phased in for passenger cars and light trucks during the 2004-2007 model years.[37]

The LEV II amendments restructure the light-duty truck category so that trucks with a GVWR rating of 8,500 pounds or less are subject to the same low-emission vehicle standards as passenger cars. The LEV II Program also includes more stringent (than LEV I) emission standards for passenger car and light-duty truck LEVs and establishes standards for “ultra low emission vehicles” (ULEVs).

The LEV II Program also has requirements for “zero emission vehicles” (ZEVs) that apply to passenger cars and light trucks up to 3,750 lbs. loaded vehicle weight (LVW), beginning in MY 2005. Trucks between 3,750 lbs. LVW and 8,500 lbs. GVWR are phased in to the ZEV regulation from 2007-2012. The ZEV requirements begin at 10 percent in 2005 and ramp up to 16 percent for 2018 under different paths.

Compliance with more stringent emission requirements of the § 209 CAA requirements in the LEV II program is most often achieved through more sophisticated combustion management. The associated improvements and refinement in engine controls generally improve fuel efficiency and have a positive impact on fuel economy.[38] However, such gains may be

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[37] As of the end of 2005, ten other states have adopted the LEV II program, including Connecticut, Maine, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington.

[38] Northeast States for Coordinated Air Use Management, “White Paper: Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program,” October 2003.

diminished because the advanced technologies required by the program can affect the impact of other fuel-economy improvements (primarily due to increase weight). The agency has considered this potential impact in our evaluation of manufacturers' product plans.

3. Onboard Vapor Recovery

On April 6, 1994, EPA published a final rule (59 FR 16262) controlling vehicle-refueling emissions through the use of onboard refueling vapor recovery (ORVR) vehicle-based systems. These requirements applied to light-duty vehicles beginning in the 1998 model year, and were phased-in over three model years. The ORVR requirements also apply to light-duty trucks with a GVWR of 6,000 pounds or less beginning in model year 2001 and phasing-in over three model years. For light-duty trucks with a GVWR of 6,001-8,500 lbs, the ORVR requirements first apply in the 2004 model year and were phased-in over three model years.

The ORVR requirements impose a weight penalty on vehicles, as they necessitate the installation of vapor recovery canisters and associated tubing and hardware. However, the operation of the ORVR system results in fuel vapors being made available to the engine for combustion while the vehicle is being operated. As these vapors provide an additional source of energy that would otherwise be lost to the atmosphere through evaporation, the ORVR requirements do not have a negative impact on fuel economy, despite the associated weight increase.

V. FUEL ECONOMY ENHANCING TECHNOLOGIES

Available Technologies

A variety of vehicle technologies could conceivably be applied in many potential combinations to increase the fuel economy of light trucks. This chapter provides a short description of the nature of each technology. This information was derived from confidential data provided by the manufacturers as well as information publicly available in the literature. The technologies relied upon in this analysis, in the order that they are presented in Table VI-4 are as follows:

Low-Friction Lubricants

The use of lower viscosity engine and transmission lubricants can reduce fuel consumption. The NAS report projected that low-friction lubricants could reduce fuel consumption by 1 percent at a cost impact of $8 to $11[39]. However, even without any changes to fuel economy standards, most MY 2008-2010 light trucks are likely to use 5W-30 motor oil, and some will use even less viscous oils, such as 5W-20 or possibly even 0W-20. Most manufacturers therefore attributed smaller potential fuel economy reductions and cost increases to lubricant improvements.

Rolling Resistance Reduction

Tire characteristics (e.g., materials, construction, and tread design) influence durability, traction control, vehicle handling, and comfort. They also influence rolling resistance and, therefore, fuel consumption. This technology is applicable to light trucks with unibody construction and all passenger cars. The NAS report projected that vehicles using tires with lower rolling resistance

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[39] The price increases noted in this chapter are slightly higher than shown in the NAS study, since they have been converted into calendar year 2003 prices.

could achieve fuel consumption reductions of 1.0 to 1.5 percent, while keeping similar traction and handling characteristics, at a retail price equivalent (RPE) cost of $15 to $58. Many manufacturers have already adopted rolling resistance reductions.

Low Drag Brakes

Low drag brakes reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake shoes are pulled away from the rotating disc. The latest available information to the agency (not NAS data) [ ] predicts that low drag brakes could reduce fuel consumption by 1 percent to 2 percent at a cost of $50 to $125.

Electric Power Steering

In a vehicle with a 42 V electrical system, it may be feasible to replace a hydraulic power steering system that consumes energy even under straight-line driving conditions with a more efficient electric power steering system that only consumes energy when required to meet steering loads. However, a 42-Volt electrical system is not a prerequisite for electric power steering. The NAS report projected that electric power steering could reduce fuel consumption by 1.5 to 2.5 percent at a cost of $109 to $156.

Aerodynamic Drag Reduction

A vehicle's size and shape determine the amount of power needed to push the vehicle through the air at different speeds. Changes in vehicle shape or frontal area can therefore reduce fuel consumption. Areas for potential aerodynamic drag improvements include skirts, air dams, underbody covers, and more aerodynamic side view mirrors. The NAS report projected that further reductions in light truck aerodynamic drag could reduce fuel consumption by 1.0 to 2.0 percent at a cost of $0 to $146.

Weight Reduction

The term "weight reduction" encompasses a variety of techniques with a variety of costs and lead times. These include lighter-weight materials, higher-strength materials, component redesign, and size matching of components. Lighter-weight materials involve using lower density materials in vehicle components, such as replacing steel parts with aluminum or plastic. The use of higher-strength materials involves the substitution of one material for another that possesses higher strength and less weight. An example would be using high-strength alloy steel versus cold-rolled steel.   Component redesign is an on-going process to reduce costs and/or weight of components, while improving performance and reliability. An example would be a subsystem replacing multiple components and mounting hardware.

The cost of reducing weight is difficult to determine and is dependent upon the methods used. For example, a change in design that reduces weight on a new model may or may not save money. On the other hand, material substitution can result in an increase in price per application of the technology if more expensive materials are used. See Table VI-4 for the range of improvements and costs ($0.75 to $1.25 per pound reduced).

Engine Accessory Improvement

Internal combustion engines rely on a number of accessory components, such as coolant, oil, and power steering fluid pumps. Incremental improvements to such components could help to reduce overall fuel consumption. Further reductions could be achieved by replacing mechanically driven accessories with electrically powered counterparts. However, the potential for such replacement will be greater for vehicles with 42-Volt electrical systems. The NAS report projected that engine accessory improvement could reduce fuel consumption by 1.0 to 2.0 percent at a cost of $87 to $116.

Reduction of Engine Friction Losses

The amount of energy an engine loses to friction can be reduced in a variety of ways. Improvements in the design of engine components and subsystems will result in friction reductions, improved engine operation, greater fuel economy, and reduced emissions. Examples include low-tension piston rings, roller cam followers, material substitution, more optimal thermal management, and piston surface treatments, as well as lubricant friction reduction. The NAS report predicted that such technologies could reduce fuel consumption by 1 percent to 5 percent, at a cost of $36 to $146. However, even without any changes to fuel economy standards, most MY 2008-2011 light trucks are likely to employ one or more such techniques to reduce engine friction and other mechanical and hydrodynamic losses.

Cylinder Deactivation

For the vast majority of light trucks, each cylinder is always active while the engine is running. Under partial load conditions, the engine's specific fuel consumption could be reduced if some cylinders could be disabled, such that the active cylinders operate at higher load. Thus an eight-cylinder engine could disable four cylinders under light loads, such as when the vehicle is cruising at highway speed. This technology could be applied to four and six cylinder engines as well. The NAS report projected that cylinder deactivation could reduce fuel consumption by 3.0 to 6.0 percent at a cost of $116 to $262. Some manufacturers are getting results in excess of 6 percent and most are at the high end of the range.

Multi-valve Overhead Camshaft Engine

Without changes to fuel economy standards, it appears likely that many MY 2008 light trucks would use overhead valve (OHV) engines with pushrods and one intake and one exhaust valve per cylinder. Engines with overhead cams (OHC) and more than two valves per cylinder achieve increased airflow at high engine speeds and reduction of the valve train's moving mass and enable central positioning of spark plugs. Such engines, which are already used in some light trucks, typically develop higher power at high engine speeds. The NAS report projected that multi-valve OHC engines could reduce fuel consumption by 2 percent to 5 percent at a cost of $109 to $146. However, some of this reduction is attributed to engine downsizing that would reduce available torque at low engine speeds. For multi-valve OHC engines, manufacturers provided fuel consumption reduction estimates that were similar and cost estimates that were more divergent.

Variable Valve Timing

Some light trucks currently use variable valve timing (VVT) on overhead cam engines, which is a system that provides for some optimization of valve opening and closing over the engine's operating region. VVT reduces pumping losses when the engine is lightly loaded by positioning the valve at the optimum position needed to sustain horsepower and torque. VVT can also improve thermal efficiency at higher engine speeds and loads. The NAS report projected that VVT could reduce fuel consumption by 2.0 to 3.0 percent at a cost of $36 to $146. Manufacturers are currently using many different types of variable valve timing, which have a variety of different names and methods. All of these are considered to be forms of variable valve timing by NHTSA.

Variable Valve Lift and Timing

Some light trucks use overhead cam engines for which both valve timing and lift can be at least partially optimized based on engine operating conditions. Engines with variable valve timing and lift (VVLT) can achieve further reductions in pumping losses and further increases in thermal efficiency. The NAS report projected that VVLT could reduce fuel consumption by 1.0 to 2.0 percent over VVT alone at a cost of $73 to 218.

Intake Valve Throttling

VVLT engines reduce pumping losses and increase thermal efficiency by providing some optimization of valve timing and lift. Intake valve throttling (IVT) would use more complex systems of sensors, electronic controls, and variable valve lifts to enable further optimization of valve timing and lift. The NAS report estimates that IVT on overhead cam engines could achieve a 3.0 to 6.0 percent reduction in fuel consumption at a cost of $218 to $437 when compared to VVLT.

Camless Valve Actuation

When electromechanical actuators are used to replace cams and coupled with sensors and microprocessor controls, valve timing and lift can be optimized over all conditions. This level of control can enable even further incremental reductions in fuel consumption. The NAS report projected that camless valve actuation could reduce fuel consumption by 5.0 to 10.0 percent over VVLT at a cost of $291 to $582.

Variable Compression Ratio

A spark-ignited engine's specific power is limited by the engine's compression ratio, which is, in turn, currently limited by the engine's susceptibility to knock, particularly under high load conditions. Engines with variable compression ratio (VCR) improve fuel economy by the use of higher compression ratios at lower loads and lower compression ratios under higher loads. The NAS report projected that VCR could reduce fuel consumption by 2.0 to 6.0 percent over 4-valve VVT at a cost of $218 to $510.

Direct Injection Spark Ignition

With direct fuel injection, spark ignition engines can utilize well-controlled lean mixtures, resulting in higher thermodynamic efficiency. This can be done under stoichiometric or lean burn conditions. This technology yields 10 percent or more improvement in fuel consumption in European applications. Some passenger cars sold in Europe and in Japan use this technology.

However, the more stringent NOx and particulate emissions standards in the U.S. limit the improvement for light trucks to 1.0 to 3.0 percent at a cost of $200 to $250. These are NHTSA estimates, not NAS estimates [ ].

Engine Downsizing and Supercharging

The specific power of a naturally aspirated engine is limited, in part, by the rate at which the engine is able to draw air into the combustion chambers. By increasing the pressure differential between the atmosphere and the charging cylinders, superchargers and turbochargers increase this available airflow, and thereby the engine's specific power. Like other technologies that increase specific power, superchargers and turbochargers make it possible to reduce engine size while maintaining performance. Assuming such engine downsizing, the NAS report projected that supercharging could reduce fuel consumption by 5.0 to 7.0 percent at a cost of $364 to $582.

Front Axle Disconnect for Four wheel-drive Systems

To provide shift-on-the-fly capabilities, many part-time four-wheel drive systems use some type of front axle disconnect. The front axle disconnect is normally part of the front differential assembly. As part of a shift-on-the-fly four-wheel drive system, the front axle disconnect serves two basic purposes. First, in two-wheel-drive mode, it disengages the front axle from the front driveline so the front wheels do not turn the front driveline at road speed, saving wear and tear. Second, when shifting from two- to four-wheel drive "on the fly" (while moving), the front axle disconnect couples the front axle to the front differential side gear only when the transfer case's synchronizing mechanism has spun the front driveshaft up to the same speed as the rear driveshaft. Four-wheel drive systems that have a front axle disconnect typically do not have either manual- or automatic-locking hubs. To isolate the front wheels from the rest of the front driveline, front axle disconnects use a sliding sleeve to connect or disconnect an axle shaft from the front differential side gear. Recent information available to the agency (not NAS) projects that front axle disconnect for 4WD vehicles reduce fuel consumption by [ ] at a cost of [ ].

Five-, Six-, Seven- and Eight-Speed Automatic Transmissions

The number of available transmission speeds influences the width of gear ratio spacing and overall coverage and, therefore, the degree of transmission ratio optimization available under different operating conditions. In general, transmissions can offer a greater available degree of engine optimization and can therefore achieve higher fuel economy when the number of gears is increased. However, potential gains may be reduced by increases in transmission weight and rotating mass. Regardless of possible changes to fuel economy standards, manufacturers are increasingly introducing 5- and 6-speed automatic transmissions on their light trucks by MY 2008. Additionally, some manufacturers are introducing 7- and 8-speed automatic transmissions within the MY 2009 – 2011 time frame, with 7-speed automatic transmissions appearing with increasing frequency. The NAS report projected that a 5-speed automatic transmission could reduce fuel consumption by 2.0 to 3.0 percent at a cost of $73 to $160 (relative to a 4-speed automatic transmission), and that a 6-speed automatic transmission could further reduce fuel consumption by 1.0 to 2.0 percent at a cost of $146 to $291. The agency has limited information available regarding the costs and fuel economy benefits of 7- and 8-speed transmissions, however, the costs and benefits of increasing a gear are expected to be similar to that exhibited by 6-speed automatic transmissions.

Continuously Variable Transmission

Unlike manual and automatic transmissions with fixed transmission ratios, continuously variable transmissions (CVTs) provide, within their operating ranges, fully variable transmission ratios with an infinite number of gears. This enables even finer optimization of the transmission ratio under different operating conditions and, therefore, some reduction of pumping and engine friction losses. CVTs use either a belt or chain on a system of two pulleys. Compared to 5-speed automatic transmissions, the NAS report projected that CVTs could reduce fuel consumption by 4.0 to 8.0 percent at a cost of $146 to $364. The NAS report also projected that torque requirements would limit the near-term applicability of CVTs to compact light trucks (less than or equal to 4,250 lbs. GVWR), but that higher-torque “advanced” CVTs could eventually further reduce fuel consumption by 0.0 to 2.0 percent at a cost of $364 to $874.

Advanced CVT

Advanced CVTs have the ability to deliver higher torques than existing CVTs and have the potential for broader market penetration. These new designs incorporate toroidal friction elements or cone-and-ring assemblies with varying diameters. We project that advanced CVT could reduce fuel consumption by up to 2.0 percent at a cost of $364 to $874. These are NHTSA estimates based on public information, not NAS estimates.

Aggressive Shift Logic

Automatic transmission energy losses are lower when torque converter lock-up (if available) is engaged. Through partial lock-up under some operating conditions and early lock-up under others—that is, aggressive shift logic—automatic transmissions can achieve some reduction in overall fuel consumption. The NAS report projected that aggressive shift logic could reduce fuel consumption by 1.0 to 3.0 percent at a cost of $0 to $73.

Automatically Shifted Clutch Transmission

Unlike current manual transmissions, which drive through a positive clutch and gears, current automatic transmissions use hydraulic torque converters in place of the clutch, which are less mechanically efficient. Adding automatic electronic controls to a clutch transmission yields an "automatic shift manual transmission," or more precisely, an automatically shifted clutch transmission without the need for a torque converter. Automatically shifted clutch transmissions that have a dual wet clutch system can provide shift quality that equals or exceeds the smoothness of current automatic transmissions. The NAS report projected that such transmissions could reduce fuel consumption by 3.0 to 5.0 percent at a cost of $73 to $291.

Forty-Two Volt Electrical System

Light trucks currently use 12 V electrical systems. At higher voltages, which appear to be under consideration to meet expected increases in on-board electrical demands, the power density of motors, solenoids, and other electrical components increases to the point that new and more efficient systems, such as electric power steering, may be feasible. A 42-volt system can also accommodate an integrated starter generator. The NAS report projected that 42 V electrical systems could reduce fuel consumption by 1.0 to 2.0 percent at a cost of $73 to $291.

Integrated Starter/Generator

In a vehicle with a 42 V electrical system, the alternator and starter could be integrated into one component that is powerful enough to quickly restart an idle engine, enabling the engine to be turned off while the vehicle is stopped (with the air conditioner off). Given sufficient battery capacity, an integrated starter/generator (ISG) could recapture some braking energy and provide some initial acceleration (i.e., launch). The NAS report projected that ISGs could reduce fuel consumption by 4.0 to 7.0 percent at a cost of $218 to $364.

Hybrid Vehicles

Hybrid vehicles (which run on two types of power, currently most run on electric power and gasoline) may be designed in several configurations. Generally, they will include electric motors, regenerative braking, integrated starter/generators, launch assist, and battery storage for regenerated energy. Honda is currently selling three hybrid passenger cars in the U.S. (the Insight, the Civic Hybrid and the Accord Hybrid) that utilize the Integrated Motor Assist System.

Toyota is selling the Prius, Camry, Highlander HEV and Lexus RX-400h which use Toyota’s Integrated Hybrid System that utilizes an electronically controlled variable transmission with a planetary gear set in addition to all the components of a hybrid such as the Insight. In the Toyota hybrids, the electric motor is used for vehicle propulsion at low speeds (under 15 mph) and to provide additional acceleration at highway speeds. Toyota recently announced plans to build the Lexus 450h hybrid in 2006.

Ford is using a technology similar to Toyota's in its Ford Escape/Mercury Mariner hybrids. Ford is expected to use this same technology for future hybrid cars and trucks.

DaimlerChrysler has announced plans for hybrid versions of the Ram 1500 pickup truck and Durango.

General Motors is currently producing a Silverado/Sierra hybrid using a flywheel alternator starter generator. General Motors has announced plans to produce a Saturn VUE using a belt alternator starter hybrid system in MY 2006 and using this same technology on a Chevrolet Malibu in MY 2007. In addition, starting with MY 2007, General Motors will be replacing the flywheel alternator starter generator used in the Silverado/Sierra hybrid with a Two Mode Full Hybrid design. This system, which will be available in General Motor's full-size pickups and SUVs, uses an electrically-variable transmission with two hybrid modes of operation designed to optimize the power and torque delivered, depending on driving conditions.

We project that manufacturers could decrease fuel consumption by anywhere from 25 to 35 percent at a cost of \$3,000 to \$5,000 for a midrange hybrid. These are NHTSA estimates, not NAS estimates [ ].

Dieselization

A diesel engine's much higher compression ratio, lean burn operation, and direct injection make it not only more fuel-efficient, but give it more torque than a spark-ignition gasoline engine of the same displacement. In addition, diesel fuel contains about 10 percent more energy by volume than gasoline. The diesel engines that will be appearing on MY 2008 – 2010 light trucks must meet Tier 2 emission standards for NOx and particulate matter. Compliance strategies are expected to include a combination of combustion improvements and aftertreatment. Combustion improvements should include those related to higher-pressure fuel injectors and improved exhaust gas recirculation. Aftertreatment technologies are projected to include lean NOx traps, particulate traps, oxidation catalysts and the use of injectable urea. The latest data shows that diesels can reduce fuel consumption by 15 to 30 percent, beyond gasoline engines with other engine technologies having been applied, at a cost of $1,000 to $5,000. These are NHTSA estimates based on public information, not NAS estimates.

Effect of Weight and Performance Reductions on Light Truck Fuel Economy

We assume that manufacturers will meet the proposed CAFE levels without any meaningful deviation from the planned performance and weight of their vehicles, as reflected in their product plans. Additionally, we do not assume any manufacturers will engage in any meaningful type of mix shifting to meet these standards, other than those already being planned. The Agency's analysis includes some CAFE gains through weight reduction of vehicles with curb weights over 5,000 pounds that are not in their product plans. According to Dr. Kahane’s revised weight and safety study,[40] if manufacturers reduced weight by 100 pounds while keeping footprint constant for all light trucks over 3,900 pounds (considered together), the net mortality effect will be near

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[40] Assuming footprint is held constant, there would be no effect on rollovers, the net fatality change per 100 pound reduction for light trucks weighing 3,870 pounds would be a loss of 15 lives (71 overall – 56 in principal rollover). “Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks”, NHTSA, October 2003, DOT HS 809 662. (See page 159)). Under the same assumption, the net fatality change per 100 pound reduction for light trucks weighing 4,000 pounds would be a gain of 15 lives (25 overall – 40 in principal rollover) (See page 162). Thus, the point estimate of the point of zero net impact is somewhere between 3,870 and 4,000 pounds curb weight.

zero. In other words, manufacturers can remove some weight from all light trucks over 3,900 pounds without any measurable effect on safety, if you hold footprint constant. There is, however, significant statistical uncertainty around the 3,900 lbs. point of zero net impact. Accordingly, we assume a confidence bound of approximately 1,000 lbs, based on additional empirical work found in Kahane's study. Kahane estimated a crossover weight[41] of 5,085 lbs. if manufacturers changed both weight and footprint, and the interval estimated ranged from 4,224 lbs. to 6,121 lbs, i.e., an interval +/-1000 lbs around the point estimate (Kahane, 2003, p. 166). Although the crossover weight differs from the point of zero net impact, they would both tend to have similar sampling errors. We applied this interval to the 3,900 lbs. point of zero net impact (which is based on the assumption that footprint is held constant); therefore, the agency felt it would be prudent to limit weight reductions to those vehicles above 5,000 lbs. curb weight.

Comments to Docket on Technology Costs

The Alliance, Sierra Research and most vehicle manufacturers argued that NHTSA has underestimated the costs of certain technologies. Specific comments are set forth below.

First, General Motors stated that the costs relied upon by the agency were derived from technologies designed for application to passenger cars, but which are being applied to light-duty trucks without consideration of the necessary adjustments for integrating such technologies while maintaining the truck's utility and function. For example, for heavier light trucks, installation of electric power steering would also require a switch to a 42-volt electrical system, and probably increased battery maintenance costs. General Motors argued that the additional costs associated with integrating technologies available on light vehicles into heavier vehicles was one of the

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[41] The "crossover weight" is the weight at which a reduction in weight would produce a zero effect on safety. Each and every light truck weighing more than the crossover weight would experience a net benefit from reduced weight. All those below the crossover weight would experience a net loss in safety.

primary reasons for the discrepancy between their internal cost estimates and NHTSA's cost estimates in the PRIA. General Motors further argued that both NAS and the estimates of Energy and Environmental Analysis (a consulting firm*)*, inadequately document sources for the costs they include.

The Alliance, Ford, Honda, Nissan, and DaimlerChrysler reiterated that technologies are not simply bolted onto the vehicle. Instead, extensive modifications are often required. These modifications involve a substantial investment. For example, the cost of a given piece of engine technology does not include the costs of redesigning the engine, testing prototypes, mapping the engine, developing new vehicle calibrations, and integrating the technology with the vehicle. For this reason, Sierra Research and at least one vehicle manufacturer disagreed with the NAS cost multiplier of 1.4, from variable cost to retail price, and argued that it should be substantially greater.

For this rulemaking, the agency has decided to use the cost and effectiveness numbers that appear in the NAS report. The NAS committee reviewed many sources of information including presentations at public meetings, and available studies and reports. It also met with automotive suppliers and industry consultants including Sierra Research. The committee then used its expertise and engineering judgment aided by the information described above to derive its own estimates of costs and effectiveness. After the prepublication copy was released in July 2001, the committee reexamined its analysis. Representatives from the industry and other stakeholders were invited to critique the findings. Several minor errors were discovered and corrected before publication of the final report.

The NAS cost and effectiveness numbers are the same for passenger cars, pickup trucks and SUVs/minivans. The technology availability differs. NAS identified two classes of pickups (small and large) and four classes of SUVs/minivans (small SUV, midsize SUV, large SUV, and minivan). Each class has a unique set of technologies available to it. While some individual technologies can be applied to any type of vehicle, the sets of technologies available to passenger cars are not the same as the sets of technologies available to light trucks. Thus, the costs assigned to passenger cars are not being used for light trucks because the technologies differ and each set of technologies has a unique cost estimate.

Second, commenters argued that the agency ignored “stranded” costs (General Motors, Sierra Research). For example, General Motors stated that the stringency of the Unreformed CAFE standard may force a manufacturer to begin purchasing 6-speed transmissions from an external supplier immediately. Consequently, in-house manufacturing efforts for which considerable resources may have already been spent would be abandoned without any return on that investment. Sierra Research also argued that NHTSA has not properly accounted for costs associated with the premature retirement of existing technology before its costs have been fully amortized. Thus, commenters argued that NHTSA incorrectly assumed costs of technologies introduced during normal product cycle turnover even when the technologies were actually attributed to vehicles mid-cycle.

The Agency has constrained its fuel economy model in consideration of manufacturers’ production plans. In determining manufacturer capabilities, significant design changes are initiated in conjunction with redesigns and vehicle introductions stipulated in production plans provided to NHTSA by vehicle manufacturers. Stranded costs are thus minimized. Despite this constraint, there may be some residual stranded costs in cases where manufacturers intended to retain a particular component into the new vehicle design. However, such costs are essentially one time write-offs that would be difficult to identify and even more difficult to quantify, especially in light of their offsetting tax savings implications. Write-offs of stranded costs are likely to occur occasionally during the routine course of business as manufacturers periodically find it necessary to curtail production plans in response to unplanned regulatory or market impacts. These write-offs will thus influence the long run cost of doing business. Although manufacturers typically attempt to price vehicles to maximize their profits, the impact of stranded costs on vehicle prices will be constrained by market conditions, and measuring their impact would be problematic. Overall, NHTSA does not believe that the revised phase-in schedule of technologies assumed in its model, which gives deference to manufacturers' production plans, would force manufacturers to incur significant stranded costs.

Changes in Technology Assumptions

The technology changes that resulted from manufacturer comments include avoiding double counting, deleting the use of some technologies for specific manufacturers, and delaying implementation of some technologies to coincide with product redesigns/model introduction. The changes instituted by the agency involve technology phase-in schedules and deleting some technologies from consideration. For the NPRM, the Volpe analysis excluded additional application of aggressive shift logic. For example, in consideration of the extremely limited planned use of automatically-shifted manual (*i.e.*, clutch) transmissions (ASMTs)—product plans submitted by manufacturers indicate [ ]—the revised Volpe analysis also excludes additional applications of ASMTs.

In submitting their updated plans, manufacturers provided the agency with data showing that they had included some technologies on their vehicles that were previously projected for use by the NPRM analyses. Manufacturers claimed that because they added these technologies after submitting product plan data to the agency in 2004, that the agency was double counting the effect of these technologies. The agency disagrees with that rationale, however it its final rule analyses it accounted for the inclusion of these technologies in manufacturers' baselines and thus didn't project the use of these technologies on those vehicles for which manufacturers stated they were present.

Manufacturers also provided information stating that certain technologies, which the agency had projected in its NPRM analysis, were incompatible with their products. In response, the agency hasn't projected the use of certain technologies on specific products for specific manufacturers that claimed technology incompatibility. In almost all cases, these technologies were classified as being available for use on other products, both for the specific manufacturers that claimed incompatibility with some products and for other manufacturers' products. The computer model used to implement the Volpe Analysis uses "engineering constraints" to apply general (*i.e.*, industry-wide) limits on the application of some technologies in consideration of technical issues (as opposed to product planning or lead time considerations, which are addressed separately).

Table V-1

Comparison of Engineering Constraints Employed in the NPRM and Final Rule

Technology	Engineering Constraint NPRM	 Final	Reason for Change
Low-Friction Lubricants	**Do not apply if engine oil is 5W30 or better**	**Do not apply if engine oil is better than 5W30 and vehicles incompatible with low friction lubricants**	**Availability of lower friction (*e.g.*, 0W) oils**
Variable Valve Timing (VVT)	**Do not apply to engines with displacement greater than 4.7 *l***	**Do not apply to OHV engines**	**OHV engines more likely to use cylinder deactivation**
Variable Valve Lift and Timing (VVLT)	**Do not apply to engines with displacement greater than 3.0 *l***	**Do not apply to engines that do not already have VVT**	**Next logical step from VVT**
Cylinder Deactivation	**Do not apply to engines with VVT, VVLT, and/or fewer than 6 cylinders.**	**As a general rule, do not apply to engines with VVT, VVLT, multivalve OHC, and/or fewer than 6 cylinders.**	**Multivalve OHC engines more likely to use VVT or VVLT**
Continuously Variable Transmission	**Do not apply to frame vehicles or 4WD SUVs.**	**Apply only to FWD unibody vehicles.**	**Less likely to mistakenly apply CVT to some RWD SUVs**
Front Axle Disconnect	**Apply only to 4WD vehicles.**	**Apply only to 4WD vehicles with cylinder count greater than six.**	**Expected to be more applicable to large vehicles**
Electric Power Steering	**No universal constraints**	**For vehicles with curb weights over 4,000 pounds, do not apply unless 42-Volt systems are already present.**	**Higher power demands for large vehicle steering**
Integrated Starter-Generator	**No universal constraints**	**Start application with the largest vehicles, which have lower fuel economy, prior to applying to smaller, more fuel efficient vehicles.**	**Mild hybridization expected to be more suitable for large vehicles due to packaging issues and fuel savings potential**
Weight Reduction	**Do not apply to vehicles with curb weights below 3,900 pounds.**	**Do not apply to vehicles with curb weights below 5,000 pounds.**	**Correction to placement of safety threshold**

In reviewing manufacturer comments, the agency noted that several manufacturers were concerned with the projected rate of implementation for technologies. The manufacturers stated that sufficient lead time is required for introduction of technologies across a manufacturer's fleet of vehicles and that some technologies would only be introduced or added to vehicles in conjunction with a major vehicle redesign or a vehicle introduction. In response, the agency has decreased the implementation rate for most technologies and has tied the introduction of two technologies (aerodynamic drag reduction and materials substitution) to coincide with a major vehicle redesign or a vehicle introduction. The computer model used to implement the Volpe analysis constrains the implementation rate for each technology by applying a "Phase-In" limit, *i.e.*, an incremental percentage of a given manufacturer's fleet to which a specific technology might be added in one year. These constraints are in addition to the "engineering constraints" discussed above. In response to the NPRM, one manufacturer questioned the agency's choices regarding these constraints, and noted that the NAS report found (*inter alia*) that "the widespread penetration of even existing technologies will probably require 4 to 8 years." ([ ], NAS, p. 5) In response to this comment, the phase-in constraints used for the Volpe analysis have been revised as summarized below:

Table V-2
Changes to "Phase-In Constraints"

Technology	NPRM	Final
Low Friction Lubricants	50%	25%
Improved Rolling Resistance	50%	25%
Low Drag Brakes	50%	17%
Engine Friction Reduction	33%	17%
Front Axle Disconnect (for 4WD)	5%	17%
Cylinder Deactivation	25%	17%
Multi-Valve, Overhead Camshaft	33%	17%
Variable Valve Timing	33%	17%
Electric Power Steering	33%	17%
Engine Accessory Improvement	33%	25%
5-Speed Automatic Transmission	33%	17%
6-Speed Automatic Transmission	25%	17%
Automatic Transmission w/ Aggressive Shift Logic	33%	17%
Continuously Variable Transmission (CVT)	33%	17%
Automatic Shift Manual Transmission (AST/AMT)	10%	17%
Aero Drag Reduction	33%	17%
Variable Valve Lift & Timing	25%	17%
Spark Ignited Direct Injection (SIDI)	3%	3%
Engine Supercharging & Downsizing	25%	17%
42 Volt Electrical Systems	33%	17%
Integrated Starter/Generator	33%	5%
Intake Valve Throttling	25%	17%
Camless Valve Actuation	25%	10%
Variable Compression Ratio	25%	10%
Advanced CVT	25%	17%
Dieselization	3%	3%
Material Substitution	20%	17%
Midrange Hybrid Vehicle	3%	3%

Additionally, the agency itself has removed technologies included in the NAS report from consideration due to indications that these technologies won’t be ready for implementation nor are any manufacturers planning to incorporate these technologies in their vehicles during the MYs 2008 – 2011 time frame. For the NPRM, the Volpe analysis excluded additional application of aggressive shift logic. For the final rule the Volpe analysis also excluded application of automatically-shifted manual (i.e., clutch) transmissions in consideration of its limit planned application. Although these technologies may eventually appear on vehicles during the MY 2011 timeframe, the agency was aware of technical and regulatory burdens for them that appeared difficult to overcome during MYs 2008 - 2011.

VI. MANUFACTURER SPECIFIC CAFE CAPABILITIES

On February 7, 2002, December 27, 2003, and August 30, 2005, NHTSA requested information—including detailed information regarding manufacturer product plans—to assist the agency in developing a proposal regarding reforms to the CAFE standards. We utilized this information, and we also made selective use of industry trade publications (e.g., Ward's Automotive Yearbook) to obtain additional information regarding the technical characteristics (e.g., gross vehicle weight rating, cylinder counts) of some light trucks.

Table VI-1a shows the MY 2008/09/10/11 CAFE product plans for each of the manufacturers, based on the manufacturer's plans without taking into account any alternative fuel attributes.

Table VI-1b shows the **ADJUSTED BASELINE**. Note that when we do cost and benefit analyses, we use the **ADJUSTED BASELINE** from Table VI-1b throughout the analysis. The adjusted baseline assumes for the analysis that each manufacturer, below the MY 2007 standard level of 22.2 mpg, (except Porsche and Volkswagen) would apply technology to achieve 22.2 mpg[42]. Those mpg levels of those manufacturers with product plans above 22.2 mpg are retained for the adjusted baseline. Our rationale for this adjustment of the baseline is that the costs and benefits of achieving 22.2 mpg have already been analyzed and estimated in previous analyses. The methodology in this analysis is to apply technologies to the manufacturers' plans and increase them to 22.2 mpg. The costs of these technologies are estimated, but they are not

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[42] Note that a manufacturer could be complying with the current standard of 22.2 mpg by using alternative fueled vehicles, but their average mpg in this analysis will not reflect that because the analysis must be done without considering alternative fueled vehicles impacts, since they are part of an incentive program.

considered part of this rule. We then estimate the costs and benefits of going from the adjusted baseline to the level of the standard.[43]

Table VI-2a shows what we believe the manufacturers' fuel economy could be for "meeting" the Unreformed CAFE standards of 22.5 for MY 2008, 23.1 for MY 2009, and 23.5 for MY 2010. Note that the agency is not using the Unreformed CAFE standards in setting requirements for MY 2011, thus no estimates were made for MY 2011 under this situation. Note that not all manufacturers would attempt to "meet" the final CAFE standards. We assume that Volkswagen and Porsche would not meet these levels because, for them, the cost of meeting these levels is more than the cost of paying penalties. These manufacturers have shown, in the past, the willingness to pay penalties rather than spend more money to improve the fuel economy of their products.

Table VI-2b shows what we believe the manufacturers' fuel economy could be under the Reform CAFE, again without taking into account fuel economy adjustments for alternative fueled vehicles.

The agency has performed two separate analyses of how manufacturers could respond to changes in the proposed CAFE levels. These are the "Technology Application Analysis" (or the "Volpe Analysis") and the "Stage Analysis." The Volpe analysis uses a technology application algorithm to systematically apply consistent cost and performance assumptions to the entire

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[43] Some manufacturer's plans are above the level of the standard already and are assumed to remain at that level. Some manufacturer's levels go slightly above the proposed mark since some technologies are applied to all models of a particular manufacturer so that the exact level for each manufacturer may be slightly higher than the level of the standard and costs and benefits are estimated to that level.

industry, as well as consistent assumptions regarding economic decision-making by manufacturers. The resultant computer model (the CAFE Compliance and Effects Model), developed by technical staff of the DOT Volpe National Transportation Systems Center in consultation with NHTSA staff, is used to help estimate the overall economic impact of the Unreformed CAFE standards. The Volpe analysis shows the economic impact of the standards in terms of increases in new vehicle prices on a manufacturer-wide, industry-wide, and average per-vehicle basis. Based on these estimates and corresponding estimates of net economic and other benefits, the agency is able to set the standards that are economically practicable and technologically feasible. The Stage Analysis and the Volpe Analysis rely on the same product plan information from manufacturers, consider many of the same technologies (the Stage Analysis considers some manufacturer-specific technologies not represented in the Volpe Analysis), and apply similar conditions regarding the applicability of those technologies.

We note that the Volpe model has been updated and refined with respect to its representation of some fuel-saving technologies, but remains fundamentally the same. The updated model has also been peer reviewed. The model documentation, including a description of the input assumptions and process, as well as peer review reports, was made available in the rulemaking docket for the August 2005 NPRM.[44]

The Unreformed CAFE levels for MYs 2008-2010 were developed using the Stage analysis. However, because the analysis conducted using the technology application algorithm covers the entire industry, it was used to estimate the overall economic impacts (benefits and costs) of the

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[44] *See* Docket Nos. NHTSA-20005-22223-3, 4, 5.

scenarios, including increases in new vehicle prices on a manufacturer-wide, industry-wide, and average per-vehicle basis.

Our analyses of the potential effects of alternative CAFE standards were founded on two major elements: (1) projections of the technical characteristics and sales volumes of future product offerings and (2) estimates of the applicability and incremental cost and fuel savings associated with different hardware changes—technologies—that might be utilized in response to alternative CAFE standards.

Tables VI-3a and VI-3b show what we believe the manufacturers' fuel economy could be under the two Step-function alternatives being considered throughout the analysis. Table VI-3a shows the projected mpg levels under the NPRM proposed Step Function (using the boundaries and targets proposed in the NPRM). Table VI-3b shows the projected mpg levels under a Revised Step Function (using the boundaries proposed in the NPRM with re-optimized targets based on the latest data available).

Table VI-1a
Manufacturers Production Plans*
Estimated mpg

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	21.29	21.29	21.29	21.31	21.31
DaimlerChrysler	21.96	22.01	22.42	22.67	22.66
Ford	21.53	21.79	22.65	23.04	23.44
Fuji – Subaru	25.87	27.15	27.05	27.05	27.05
General Motors	21.36	21.43	21.59	21.10	21.52
Honda	24.56	24.56	24.56	24.56	24.56
Hyundai	23.22	23.49	23.36	23.19	23.19
Isuzu	20.38	20.24	20.14	20.11	20.11
Mitsubishi	24.33	24.41	24.70	25.22	25.22
Nissan	21.01	20.70	21.13	21.09	21.13
Porsche	16.80	16.80	16.80	16.80	16.80
Suzuki	21.93	21.93	21.93	21.93	21.93
Toyota	22.51	22.44	22.65	23.23	23.23
Volkswagen	18.78	18.78	18.78	18.76	18.76
Harmonic Ave.	21.94	22.02	22.37	22.41	22.62

* Note: These manufacturer predicted mpg levels may not match exactly the levels provided by the manufacturers to NHTSA, because they have been normalized to match NHTSA's predictions of sales distributions.

Table VI-1b
Estimated Fuel Economy Levels
Adjusted Baseline mpg

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	21.47	21.53	21.56	21.62	21.62
DaimlerChrysler	22.15	22.16	22.56	22.76	22.76
Ford	22.15	22.15	23.05	23.32	23.74
Fuji – Subaru	25.87	27.15	27.05	27.05	27.05
General Motors	22.15	22.17	22.15	21.69	22.15
Honda	24.56	24.56	24.56	24.56	24.56
Hyundai	23.22	23.49	23.36	23.19	23.19
Isuzu	21.57	22.39	22.31	22.28	22.28
Mitsubishi	24.33	24.41	24.70	25.22	25.22
Nissan	22.15	22.18	22.46	22.42	22.46
Porsche	16.80	16.80	16.80	16.80	16.80
Suzuki	22.33	22.33	22.33	22.33	22.33
Toyota	22.51	22.44	22.65	23.23	23.23
Volkswagen	18.78	18.78	18.78	18.76	18.76
Harmonic Ave.	22.40	22.42	22.73	22.75	22.97

Table VI-2a
Estimated Fuel Economy Levels
Estimated mpg for Unreformed CAFE

	MY 2008	**MY 2009**	**MY 2010**
BMW	21.47	21.92	21.94
DaimlerChrysler	22.50	23.05	23.45
Ford	22.44	23.05	23.49
Fuji – Subaru	25.87	27.15	27.05
General Motors	22.45	23.06	23.45
Honda	24.56	24.56	24.56
Hyundai	23.22	23.49	23.46
Isuzu	21.57	22.08	23.69
Mitsubishi	24.33	24.41	24.70
Nissan	22.15	22.51	23.50
Porsche	16.80	16.80	16.80
Suzuki	23.24	23.24	23.56
Toyota	22.51	23.05	23.45
Volkswagen	18.78	18.78	18.78
Harmonic Ave.	22.62	23.14	23.54

Table VI-2b
Estimated Fuel Economy Levels
Estimated mpg for Reformed CAFE

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	21.47	21.92	21.99	22.06	22.06
DaimlerChrysler	23.18	23.65	24.08	24.25	24.35
Ford	22.65	23.03	23.74	23.91	24.38
Fuji – Subaru	25.87	27.15	27.05	27.05	27.05
General Motors	21.85	22.54	22.85	23.15	23.25
Honda	24.56	24.56	24.56	24.56	24.67
Hyundai	23.85	24.95	24.99	25.35	25.35
Isuzu	21.57	22.08	23.69	23.67	23.67
Mitsubishi	25.11	25.79	26.20	26.96	26.84
Nissan	22.15	22.51	23.65	23.86	24.02
Porsche	16.80	16.80	16.80	16.80	16.80
Suzuki	24.57	25.54	26.62	27.15	27.15
Toyota	22.60	22.95	23.17	23.76	23.76
Volkswagen	18.78	18.78	18.78	18.76	18.76
Harmonic Ave.	22.74	23.36	23.73	23.98	24.09

Table VI-3a
Estimated Fuel Economy Levels
Estimated mpg for NPRM Step Function

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	21.47	21.92	21.99	22.06	22.06
DaimlerChrysler	22.86	23.26	23.55	23.96	23.96
Ford	22.44	22.95	23.41	23.63	24.08
Fuji – Subaru	26.40	27.48	27.14	27.70	27.70
General Motors	21.85	22.34	22.66	22.56	23.06
Honda	24.56	24.56	24.56	24.56	24.56
Hyundai	23.58	24.75	24.81	25.36	25.36
Isuzu	21.57	22.08	23.69	23.67	23.67
Mitsubishi	24.56	25.47	25.94	27.27	27.27
Nissan	21.75	22.69	23.19	23.65	23.71
Porsche	16.80	16.80	16.80	16.80	16.80
Suzuki	24.57	25.54	26.66	27.26	27.26
Toyota	22.60	22.77	22.99	23.66	23.66
Volkswagen	18.78	18.78	18.78	18.76	18.76
Harmonic Ave.	22.55	23.02	23.33	23.54	23.80

Table VI-3b
Estimated Fuel Economy Levels
Estimated mpg for Revised Step Function

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	21.47	21.92	21.99	22.06	22.06
DaimlerChrysler	23.18	23.59	23.95	24.26	24.16
Ford	22.54	22.95	23.12	23.85	23.85
Fuji – Subaru	27.39	28.82	27.99	28.29	28.29
General Motors	22.05	22.55	22.97	22.76	23.15
Honda	24.56	24.56	24.56	24.56	24.56
Hyundai	23.85	24.89	24.90	25.27	25.36
Isuzu	21.57	22.08	23.69	23.67	23.67
Mitsubishi	24.87	25.57	26.36	27.24	27.24
Nissan	21.85	22.66	23.40	23.75	23.74
Porsche	16.80	16.80	16.80	16.80	16.80
Suzuki	24.57	25.54	26.66	27.26	27.26
Toyota	22.76	23.05	23.24	23.85	23.80
Volkswagen	18.78	18.78	18.78	18.76	18.76
Harmonic Ave.	22.74	23.19	23.60	23.76	23.84

Note: All of the fuel economy estimates exclude the impacts of alternative fuel credits.

Technology Assumptions

Potential cost and fuel consumption impacts of different technologies are discussed in Chapter V. Within the range of values anticipated for each technology, we selected the cost and fuel consumption impacts considered most plausible during the model years under consideration. In the Volpe model, we used the expected impacts as summarized in Table VI-4. We sometimes deviated from these impacts in the Stage Analysis, using estimates that we determined were appropriate for specific manufacturers. As discussed in chapters III and IV, we have decided to use the National Academy of Sciences[45] estimates of fuel consumption improvements and costs. The low and high estimates from the NAS report become the bases for the uncertainty ranges used in the Uncertainty Analysis (see Chapter X). The last column of Table VI-4 shows the cost per percentage point improvement in fuel consumption - gallons per mile (gpm). We use the technology with the lowest cost in this column that is available for a specific manufacturer first, and work our way down the line of available technologies on a cost per percent improvement. As shown in the annotations to that table, most technologies are available starting in MY 2008, with a few exceptions.

The agency considered whether wholesale performance reductions or mix shifts would occur and determined that they are not likely. The manufacturers have been improving the performance of their engines for years. It is not likely that they would reduce performance as a result of market forces alone. The Reformed CAFE approach takes away much of the incentive for mix shifts, since each vehicle is compared to its appropriate target mpg level. However, the manufacturers can choose to use these and/or any other approaches to achieve the level of the standard. Another option available to the manufacturer is to pay CAFE fines, rather than make the investments to improve fuel economy, which we assume will be done by Porsche and Volkswagen.

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[45] The link for the NAS report is http://www.nap.edu/books/0309076013/html/

Table VI-4
Fuel Consumption and Cost Estimates

	Fuel Consumption Benefit			**Cost in $2003**			**Cost/%Imp**
Technology	**Low**	**Expected**	**High**	**Low**	**Expected**	**High**	
Low Friction Lubricants	1.0%	1.0%	1.0%	$8	$9.50	$11	9.50
Improve Rolling Resistance	1.0	1.25	1.5	15	36.50	58	29.20
Low Drag Brakes	0.75	1.0	1.25	15	80.50	146	80.50
Engine Friction Reduction	1.0	3.0	5.0	36	91	146	30.33
Front Axle Disconnect	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Cylinder Deactivation	3.0	4.5	6.0	116	189	262	42.00
Multi-Valve, Overhead Cam	2.0	3.5	5.0	109	127.50	146	36.43
Variable Valve Timing	2.0	2.5	3.0	36	91	146	36.40
Electric power Steering	1.5	2.0	2.5	109	132.50	156	66.25
Engine Accessory Impr.	1.0	1.5	2.0	87	101.5	116	67.67
5-Speed Automatic Trans.	2.0	2.5	3.0	73	116.50	160	46.60
6-Speed Automatic Trans.	1.0	1.5	2.0	146	218.50	291	145.7
Auto Trans, w/Aggressive Shift Logic	1.0	2.0	3.0	0	36.50	73	18.25
Continuously Variable Trans.	4.0	6.0	8.0	146	255	364	42.50
Auto Shift Manual Trans.	3.0	4.0	5.0	73	182	291	45.50
Aero Drag Reduction	1.0	1.5	2.0	0	73	146	48.67
Variable Valve Lift & Timing	1.0	1.5	2.0	73	145.50	218	97.00
Spark Ignited Direct Injection	1.0	2.0	3.0	200	225	250	112.5
Engine Supercharge & Down.	5.0	6.0	7.0	364	473	582	78.83
42 Volt Electrical Systems	1.0	1.5	2.0	73	182	291	121.3
Integrated Starter/Generator	4.0	5.5	7.0	218	291	364	52.91
Intake Valve Throttling	3.0	4.5	6.0	218	327.50	437	72.78
Camless Valve Actuation	5.0	7.5	10.0	291	436.50	582	58.20
Variable Compression Ratio	2.0	4.0	6.0	218	364	510	91.00
Advanced CVTs	0.0	1.0	2.0	364	619	874	619
Dieselization	15	17.5	20	1,000	1,500	2,000	85.71
Material Substitution 1st	0.6	0.65	0.7	.75*	.75*	.75*	
Material Substitution 2nd	0.6	0.65	0.7	1.0*	1.0*	1.0*	
Material Substitution 3rd	1.75	1.93	2.10	1.25*	1.25*	1.25*	
Material Substitution 4th	-0.6	-0.65	-0.70	.75*	.75*	.75*	
Midrange Hybrid Vehicle	25	30	35	3,000	4,000	5,000	133.3

*Costs are presented in $ per pound reduced

All of the technologies are available in MY 2008 with the following exceptions:

– Applied in MY 2010 and beyond only - Hybrid Drivetrains (applies to projected use of hybrid drivetrains on vehicles that aren't currently planned to be hybrids; if hybrids were already planned, NHTSA examined whether additional quantities could be projected), Diesel Engines

Applied in MY 2011 only: Intake Valve Throttling, Camless Valve Actuation, Variable Compression Ratio

Advanced CVT and addition of ASMT beyond that planned by manufacturers were considered unavailable during MYs 2008 -2011.

Technology Application Algorithm

In order to understand how manufacturers might respond to changes in CAFE standards, we also developed an algorithm that applies technologies to different trucklines based on comparative estimated cost-effectiveness (the Volpe Analysis). Having determined the applicability of each technology to each vehicle model, engine, and/or transmission, the compliance simulation algorithm begins the process of applying technologies based on the CAFE standards applicable during the current model year. This involves repeatedly evaluating the degree of noncompliance, identifying the "best next" (in terms of cost-effectiveness) technology available on each of the parallel technology paths mentioned above, and applying the best of these. If, considering all regulatory classes, the manufacturer owes no CAFE fines, the algorithm applies no technologies beyond any carried over from the previous model year. If the manufacturer does owe CAFE fines, the algorithm first finds the best next applicable technology in each of the technology groups (e.g., engine technologies), and applies the same criterion to select the best among these. If this manufacturer is assumed to be unwilling to pay CAFE fines (or, equivalently, if the user has set the system to exclude the possibility of paying fines as long as some technology can still be applied), the algorithm applies the technology to the affected vehicles. If the manufacturer is assumed to be willing to pay CAFE fines but applying this technology would have a lower "effective cost" (discussed below) than simply paying fines, the algorithm also applies the technology. In either case, the algorithm then reevaluates the manufacturer's degree of noncompliance. If, however, the manufacturer is assumed to be willing to pay CAFE fines and doing so would be less expensive than applying the best next technology, the algorithm stops applying technology to this manufacturer's products. Whether or not the manufacturer is assumed to be willing to pay CAFE fines, the algorithm uses CAFE fines not only to determine whether compliance has been achieved, but also to determine the relative attractiveness of different potential applications of technologies. For this analysis we assumed that paying fines, rather than applying technologies to improve fuel efficiency, would not be used by the manufacturers with the exception of Porsche, and Volkswagen. Whenever the algorithm is evaluating the potential application of a technology, it considers the effective cost of applying each technology to the group of vehicles in question, and chooses the option that yields the lowest effective cost. The effective cost is used for evaluating the relative attractiveness of different technology applications, not for actual cost accounting. The "effective cost" is defined as the change in total technology costs incurred by the manufacturer plus the change in CAFE fines incurred by the manufacturer minus the value of any reduction of fuel consumed by vehicles sold by the manufacturer:

Mathematically, this is expressed as follows:

$$COST_{eff} = \frac{\Delta TECHCOST + \Delta FINE - VALUE_{FUEL}}{N_j}$$

where *ΔTECHCOST* is simply the product of the unit cost of the technology and the total sales (*Nj*) of the affected cohort of vehicles (*j*). The value of the reduction in fuel consumption achieved by applying the technology in question to all vehicles *i* in cohort *j* is calculated as follows:[46]

$$VALUE_{FUEL} = \sum_{i \in j} \left[N_i \sum_{v=0}^{v=PB} \frac{SURV_v MI_v FUELPRICE_{MY+v}}{(1-gap)\left(1+r\right)^{v+0.5}} \left(\frac{1}{FE_i} - \frac{1}{FE_i'} \right) \right]$$

where MI_v is the number of miles driven in a year at a given vintage *v*, $SURV_v$ is the probability that a vehicle of that vintage will remain in service, FE_i and FE_i' are the vehicle's fuel economy prior to and after the pending application of technology, *gap* is the relative difference between on-road and laboratory fuel economy, N_i is the sales volume for model *i* in the current model year *MY*, $FUELPRICE_{MY+v}$ is the price of fuel in year *MY*+*v*, and *PB* is the "consumer time horizon", or number of years in the future the consumer is assumed to take into account when considering fuel savings.

We assumed a consumer time horizon of 4.5 years and a discount rate of seven percent. The consumer time horizon of 4.5 years is used in this technology application algorithm; however, it

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[46] This is not necessarily the "actual" value of the fuel savings, but rather the increase in vehicle price the manufacturer is assumed to expect to be able to impose without losing sales.

is not used when setting the socially optimal Reformed CAFE levels for MY 2011. In this case, we use the fuel savings over the full 36-year lifetime of the vehicle. Our assumptions regarding fuel prices and age-specific vehicle survival and mileage accumulation rates are discussed in Chapter VIII.

The technologies in Table VI-4 were ranked primarily on the basis of cost-per-percentage-point improvement in fuel consumption (gallons per mile) and were applied where available to each manufacturer's fleet in their order of rank. However, the ranking also reflects other factors, such as the logical order in which certain technologies must be applied. Beginning with the first technology listed in Table VI-4, the model repeatedly selects the appropriate technology application for a particular make/model based on cost-effectiveness (i.e., fuel savings per dollar). Once that technology has been applied to all models for that manufacturer, the evaluation process is repeated for the next technology in the list. Each time the algorithm applies a technology, it updates the technical description, incurred cost increase, and fuel economy of the relevant vehicle, as well as the manufacturer's CAFE. The algorithm continues applying technologies until each manufacturer either complies with the assumed CAFE standard or exhausts all technologies assumed to be available in the model year under consideration. As the technology application algorithm performs/repeats, it maintains running totals of cost increases (at the truckline and corporate level). Final calculated levels are outputs of the algorithm.

In order to estimate the potential net effects of the final rule, we applied the above-mentioned technology assumptions and technology application algorithm to the baseline CAFE levels. Not all of the manufacturers' fuel economy levels reached 22.2 mpg as shown in Table VI-1a.

Therefore, for some of those manufacturers, technologies were applied to increase them up to the adjusted baseline of 22.2 mpg. The costs and benefits are included in the analysis only if those technologies were utilized to increase the manufacturer's fleet average from the adjusted baseline to the level of the final rule.

These estimates represent incremental changes if a technology is applied to a truckline to which other technologies have already been applied. We used the cost-per-percent improvement from Table VI-4 to determine the sequence that a manufacturer might follow when deciding which technologies to apply. This "application path" is not always chosen by manufacturer on a cost-per-percent improvement in mileage. First, we examined those technologies that are available in MY 2008 and ranked them. Application based strictly on a cost-per-percent improvement could not be used for every case, because some technologies are either prerequisites for other technologies or would logically precede such other technologies. For example, a five-speed automatic transmission would probably be introduced before a six-speed automatic transmission. Also, a 42 Volt Electrical System was assumed to be necessary for an integrated starter/generator, and a multi-valve, overhead camshaft was assumed to logically precede variable valve timing and, subsequently, variable valve lift and timing. Variable valve lift and timing (VVLT) is considered as a potential incremental improvement beyond (and, in this case, replacement for) variable valve timing (VVT). Weight reduction was only applied to heavier vehicles in any manufacturer's fleet.

We also applied a few explicit technical constraints on the applicability of some technologies. When considering low-friction lubricants, we assumed that all light trucks will rely on 5W-30 or, where indicated by manufacturers, 5W-20. For engines that would otherwise rely on 5W-20, we reduced the expected available reduction in fuel consumption by half. We assumed that cylinder deactivation would not be applied to engines with fewer than six cylinders. We assumed that several technologies (including multivalve OHC, VVT, VVLT, supercharging and downsizing, intake valve throttling, camless valve actuation, variable compression ratio) would only apply to gasoline engines. We assumed that transmission improvements, 42 Volt electrical systems, and integrated starter/generators would not be available as improvements to hybrid electric vehicles (HEVs). We assumed that engine friction reduction would not be applicable to large pickups and SUVs, and that low-friction lubricants would not be applicable to rear-wheel drive (and derivative) vehicles.[47]

Stage Analysis for DaimlerChrysler, General Motors, Ford, Honda, Hyundai, Nissan, Subaru and Toyota

NHTSA's Stage Analysis relies heavily on the step-by-step application of different technologies at the truckline level, emphasizing particular technologies identified by the manufacturers in their detailed submissions given in response to the Request for Product Plan Information (70 FR 51466). The technologies applied in the Stage Analysis are over and above those applied as part of the manufacturers' product plans reflected in Table VI-1a (the details of which are confidential). Some of the technologies used in the Stage Analysis have been used for over a decade (e.g., OHC, engine friction reduction, and low friction lubricants). Others have only recently been incorporated on light trucks (e.g., 5-speed and 6-speed automatic transmissions and variable valve timing). Others have been under development for a number of years but have not been produced in quantity for an extended period (e.g., cylinder deactivation, variable valve lift

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[47] For the analysis using the technology application algorithm discussed below, we approximated this last constraint by not applying low-friction lubricants to pickups and large SUVs.

and timing, continuously variable transmission (CVT), integrated starter generator, and hybrid drivetrains).

The Stage Analysis utilizes engineering judgment to project fuel economy improvement on a nameplate-by-nameplate basis. For instance, NHTSA estimates that replacing an overhead valve engine with a multi-valve overhead camshaft engine of the same displacement and replacing a 4-speed automatic transmission with a 5- or 6-speed automatic transmission offer about the same potential level of improvement. One of them may be more attractive to a particular manufacturer because of its cost, ease of manufacturing, or the model lines to which it would apply. In applying the Stage Analysis, the agency projects the use of the most cost-effective technology for a given fuel economy improvement considering its appropriateness for the specific manufacturers' capabilities and general product plans. This analysis does not include the many minor types of improvements in electronic controls and engine valving changes that could result in further fuel economy gains, because it is difficult to precisely determine which of these technologies have been included in the models that manufacturers plan to produce in MY 2008 and beyond.

This analysis also includes the possibility that manufacturers could utilize some vehicle weight reduction as a fuel economy improvement technology on light trucks with curb weights over 3,900 pounds. Based on the results of Dr. Kahane's revised weight and safety analysis, the net weight-safety effect of removing 100 pounds from a light truck - if footprint is held constant - is zero for all light trucks with curb weights above 3,900 pounds. This analysis examined opportunities for manufacturers to reduce the weight of their light trucks having curb weights over 3,900 pounds if it was determined that weight reduction was an economically logical choice for manufacturers after other more cost-effective technologies were projected. In general, weight reduction was only applied to those vehicles with curb weights in excess of 5,000 pounds, which is 1,100 pounds heavier than the 3,900 pounds threshold found in Dr. Kahane's study. Additionally, an attempt was made to apply weight reduction in conjunction with a planned vehicle redesign or freshening, sometimes in concert with a reduction in aerodynamic drag.

The analysis is divided into three stages: application of technologies which are deemed to be available for use by MY 2008, which would not require significant changes in transmission and/or engine technology (Stage I); application of transmission and/or engine technologies – classified as Production-Intent by the recent NAS study – which are added on top of those applied to the first stage (Stage II); and the application of diesel engines and hybrid powertrains to some products (Stage III).

The Stage I analysis includes technologies that manufacturers state as being available for use by MY 2008 or earlier, but that they are choosing not to use in their product plans. However, many of these technologies are currently being used elsewhere in today's light-duty truck fleet. The timing for the projected introduction of these technologies is closely related to planned model and engine changes introductions.

The Stage II analysis includes two major categories of technological improvements to the manufacturers' fleets, the timing of which is tied as nearly as possible to planned model change and engine introduction years. The first of these categories is transmission improvements, which consists of the introduction of 5-, 6-, and 7-speed automatic transmissions, and the introduction of CVTs to unibody SUVs and crossover vehicles. CVTs are restricted to these vehicles because they are not designed for rugged off-road applications and/or the need to haul heavy loads. Inherent in the design of CVTs is a reduced ability to deliver the low-end torque needed in such applications; thus, the use of this technology is restricted to unibody SUVs and crossover vehicles.

The second category was engine improvements, and it consists of gradually upgrading all light truck engines to include multi-valve overhead camshafts, introducing engines with more than 2-valves per cylinder, applying variable valve timing or variable valve lift and timing to multi-valve overhead camshaft engines, applying cylinder deactivation to 6- and 8-cylinder engines, and applying direct injection where applicable.

The Stage III analysis includes projections of the potential CAFE increase that could result from the application of diesel engines and hybrid powertrains to some products. Both diesel engines and hybrid powertrains appear in several manufacturers' plans within the MY 2008 – 2010 timeframe, and manufacturers have publicly indicated that they are looking seriously into increasing their diesel and hybrid vehicle offerings.

DaimlerChrysler

In it product plan submission, DaimlerChrysler described a variety of technologies that could be used to increase vehicle fuel economy. The description of each technology described included its estimated fuel economy benefit, the basis for that estimate, its potential applications, where it is currently employed in DaimlerChrysler's light truck fleets, where the technology could potentially be used, risks in employing the technology, and potential impacts on noise, vibration and handling (NVH), safety, emissions, and cargo and towing capacity. DaimlerChrysler also provided a projected fleet description with projected CAFE levels for MYs 2005-2012.

(a) Stage I

To determine which Stage I technologies DaimlerChrysler could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied heavily on the DaimlerChrysler-provided descriptions and on DaimlerChrysler's previous comments on the MY 2005-2007 light truck CAFE rule. Our analysis shows that DaimlerChrysler could employ [ ] by MY 2008 with an additional [ ] employed by MY 2009. The [ ] would carryover to MY 2009-2010, while the [ ] available for MY 2009 would carryover to MY 2010. For the most part, NHTSA used the NAS report's mid-range numbers for percentage increase in fuel economy in calculating the possible fuel economy increase attributable to each of these technologies. If NHTSA projected the use of a technology specific to DaimlerChrysler on additional vehicles, NHTSA used the fuel economy percentage increase described by DaimlerChrysler.

Starting with MY 2008, DaimlerChrysler could use [ ] models. These vehicles can utilize [ ] are currently in wide distribution. By MY 2006, some DaimlerChrysler models will be manufactured with [ ] The agency believes that there is more than sufficient lead time for DaimlerChrysler to equip the [ ] models with these [ ] and to make arrangements with [ ] to purchase sufficient quantities.

Starting with MY 2008, DaimlerChrysler could use [ ] models. All of these models are projected to utilize [ ] The [ ] currently uses this technology and [ ] The agency believes [ ] and [ ] are added as a package to vehicles. NHTSA believes that there is more than sufficient lead time for DaimlerChrysler to equip the [ ] models with these [ ] and to make arrangements with [ ] to purchase sufficient quantities.

Starting with MY 2008, DaimlerChrysler could include a [ ] on some models, in conjunction with product cycle and model changes. This is a technology that is used elsewhere on other DaimlerChrysler vehicles and should be able to be introduced throughout DaimlerChrysler's light truck fleet to coincide with model changes. By MY 2008, a [ ] could be included on [ ] models. By MY 2009, a [ ] could be included on [ ] models and some [ ] models. By MY 2010, a [ ] could be included on [ ] models and additional [ ] models. A [ ] must be introduced in conjunction with [.]

Starting with MY 2008, DaimlerChrysler could use [ ] In MY 2009, all [ ] The engines above all [ ] The remaining engines in DaimlerChrysler's light truck fleet use [ ] This is a technology that can be used throughout DaimlerChrysler’s light truck fleet and could be added to these engines within a relatively short lead time.

Starting with MY 2008, DaimlerChrysler could include an [ ] throughout DaimlerChrysler’s light truck fleet to coincide with model changes. By MY 2008, an [ ] could be included on [ ] models. By MY 2009, an [ ] could be included on [ ] models and some [ ] models. By MY 2010, an [ ] could be included on [ ] models and additional [ ] models. This technology [ ]

Starting with MY 2008, DaimlerChrysler could include a [.] This technology is introduced throughout DaimlerChrysler’s light truck fleet to coincide with model changes and vehicle introductions.

Starting with MY 2009, DaimlerChrysler could employ [.] In MY 2010, DaimlerChrysler could employ [ ] on [.] The agency believes that DaimlerChrysler could incorporate a [ ] of these vehicles as part of its [ ] and that is quite feasible to have this technology included on these vehicles when they are [.]

Starting with MY 2009, DaimlerChrysler could employ [.] DaimlerChrysler agrees that there is potential for [.] In response, NHTSA has projected a [.]

Starting with MY 2009, DaimlerChrysler could employ [.] The agency projected the possible use of [.]

(b) Stage II

To determine which Stage II technologies DaimlerChrysler could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied on its own engineering judgment, submissions from other manufacturers, and comments from DaimlerChrysler. Our analysis showed that DaimlerChrysler could employ [ ] by MY 2008, and [ ] by MY 2009. All the MY 2008 and MY 2009 technologies would carry over into future model years. To determine the possible fuel economy increase attributable to each of these technologies, the agency looked at the NAS study's percentage increase in fuel economy for each technology and examined DaimlerChrysler's submission and its fuel economy trends.

Starting with MY 2008, DaimlerChrysler could use [.] By MY 2009, DaimlerChrysler could use [

.] The use of this technology throughout DaimlerChrysler’s light truck fleet is timed to coincide with model changes. Many of DaimlerChrysler’s direct competitors for the small- and medium-size light truck market are introducing vehicles with [ ] during MY 2008-2010.

Starting with MY 2008, DaimlerChrysler could utilize [.] By MY 2009, the [.] These engines were chosen because of their [ ] design. The use of this technology throughout DaimlerChrysler’s light truck fleet is timed to coincide with model changes.

Starting with MY 2008, DaimlerChrysler could offer [.] By MY 2009, additional vehicles that are projected to use [.] These engines were chosen because of their [ ] design. Among DaimlerChrysler’s current [ ] engines, the [ ] engines are [ ] engines; thus it is logical to assume that other [ ] engine designs could utilize [ ] technology as well. The use of this technology throughout DaimlerChrysler’s light truck fleet is timed to coincide with model changes.

Starting with MY 2009, DaimlerChrysler could use a [.] By MY 2010, this technology could be used on the [.] This technology is currently used on [

.]

Starting with MY 2009, DaimlerChrysler could use [
.] By MY 2010, DaimlerChrysler could use [
.] These are engines that are adaptable to the technology because of they already have [
.]

Starting with MY 2009, DaimlerChrysler could apply [
.]
NHTSA projected the use of [ ] on these vehicles for many reasons, including the fact that many of DaimlerChrysler's direct competitors for the mid-size and larger light truck market are introducing vehicles with [ ] during MY 2008-2010.
DaimlerChrysler offers [
], thus [ ] are technically feasible for the above vehicles.

(c) Stage III

The Stage III analysis includes projections of the potential CAFE increase that could result from the application of diesel engines and hybrid powertrains to some products. Our projection for DaimlerChrysler indicates that the company can meet the standards contained in this final rule without the agency applying any diesel engines and hybrid powertrains to DaimlerChrysler's product plans. Thus, the agency did not identify any CAFE increases resulting from Stage III for DaimlerChrysler.

The potential improvements to the DaimlerChrysler light truck CAFE – as projected by NHTSA - are summarized in the following table. Due to rounding, the individual improvements may not equal the potential CAFE for DaimlerChrysler.

Table VI-6
Potential Daimler CAFE Improvements, mpg

Model Year	Baseline Mpg	Stage I	Stage II	Stage III	Total	Potential CAFE, mpg
2008	[ ]	[ ]	[ ]	[ ]	[ ]	22.475
2009	[ ]	[ ]	[ ]	[ ]	[ ]	23.059
2010	[ ]	[ ]	[ ]	[ ]	[ ]	23.599

Ford

In its submission, Ford described a variety of technologies that could be used to increase vehicle fuel economy. For each technology described, Ford included its estimated fuel economy benefit, the basis for that estimate, the baseline technology it is measured against, when the technology would be available for use, its potential applications, where it is currently employed in Ford's light truck fleets, where the technology could potentially be used, and potential reasons that limit the implementation rate of the technology.

(a) Stage I

To determine which Stage I technologies Ford could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied heavily on the Ford-provided descriptions. Our analysis showed that Ford could employ [ ] by

MY 2008, with an additional [ ] introduced by MY 2009. All the MY 2008/2009 technologies would carry over into future model years. For the most part, NHTSA used the NAS report's mid-range numbers for percentage increase in fuel economy in calculating the possible fuel economy increase attributable to each of these technologies. If NHTSA projected the use of a technology specific to Ford on additional vehicles, NHTSA used the fuel economy percentage increase described by Ford.

Starting with MY 2008, Ford could use [,] on all of its models that could utilize [ ]. Ford and other manufacturers have indicated that they are incorporating this cost-effective technology in other vehicle lines. By MY 2006, some [ ] models will be manufactured with [.] The agency believes that there is more than sufficient lead-time for Ford to equip the [ ] models with these [ ] and to make arrangements with [ ] to purchase sufficient quantities.

Starting with MY 2008, Ford could use [.] Additionally, in MY 2009, all [.] The engines used in the [.] The remaining engines in Ford's light truck fleet [.] This is a technology that can be used throughout Ford's light truck fleet and could be added to these engines within a relatively short lead time.

Starting with MY 2008, Ford could use a [

.] Additionally, by MY 2009, Ford could use a [ ] on all of its [.] Ford did not project the use of any [ ] on these vehicles during MY 2008 – 2010; however, the agency believes that this technology is cost-effective and can be implemented by MY 2008. Ford is currently using this technology in its truck fleet and should be able to incorporate it in its [ ] by MY 2008.

Starting with MY 2008, Ford could use [ ] on all of its [.] Additionally, by MY 2009, Ford could use [ ] on all of its [.] It does not appear that the engines projected for use in these vehicles employ [.] Ford is currently using this technology in its truck fleet and should be able to incorporate it in on the models identified by MYs 2008 -2009.

In MY 2008, Ford could use [ ] on all [.] Additionally, by MY 2009, Ford could use [.] Ford utilizes this technology on many other vehicles, especially those that are [ ], and the agency believes that this technology is applicable to a wide variety of vehicles.

Starting with MY 2008, Ford could include a [.] This technology is introduced throughout Ford’s light truck fleet to coincide with model changes and vehicle introductions.

Starting with MY 2009, Ford could employ [.] The agency projected the possible use of [.]

(b) Stage II

To determine which Stage II technologies Ford could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied on its own engineering judgment and submissions from other manufacturers. In looking at these submissions, together with what Ford provided, NHTSA has analyzed which Stage II technologies could be applied to Ford's light truck fleet for MYs 2008-2010. Our analysis showed that in MY 2008, Ford could introduce or expand its application of [ ] with an additional [ ] introduced by MY 2009.

Starting with MY 2008, Ford could update [ ]. The engine that could be updated is the [ ]. This engine would benefit by not only from being updated to [ ] but also by the addition of [ ]. In addition to other Ford engines having this technology, most other light truck manufacturers employ this technology today.

Starting with MY 2008, Ford could update [ ]. The engine that could be updated is the [ ]. Ford uses the [ ] engine widely and it is logical that instead of carrying over the [ ] when a model change occurs, that Ford could replace it with the improved [ ]. This change is projected to occur in conjunction with model changes and vehicle introductions where the [ ] is projected to be used.

Starting with MY 2008, Ford could use [ ] These engines are of [ ] design, and this technology would be a further technological advance on those engines. In addition to other Ford engines having this technology, most other light truck manufacturers employ this technology today. This technology is introduced throughout Ford's light truck fleet to coincide with model changes and vehicle introductions.

Starting with MY 2008, Ford could use .] This would be a further technological advance on engines that have [ ] today. Several other manufacturers employ this technology today. This technology is introduced throughout Ford's light truck fleet to coincide with model changes and vehicle introductions.

Starting with MY 2009, Ford could use a [.] This technology is currently used by another manufacturer and is projected to increase FE by [ ] for that company. It is expected that this technology can be used by almost all [,]; however, it is uncertain whether other manufacturers would get a [ ] FE benefit for this technology. Thus, NHTSA discounted the improvement potential to [ ] when applying this technology to other manufacturers' [.]

Starting with MY 2009, Ford could equip its [ ] with [ ]. In its submission, Ford projected the use of a [ ] on some [.] The agency believes that it is feasible and there is sufficient lead-time for these [ ] to be used on [.]

(c) Stage III

The Stage III analysis includes projections of the potential CAFE increase that could result from the application of diesel engines and hybrid powertrains to some products over and above the manufacturer's plans.

It is possible that the sales of the [ ] would steadily increase from MY 2008 to MY 2010. Ford projects the sales of these [ ] in MY 2008, 2009, and 2010 respectively. NHTSA believes that due to the increased demand for and popularity of these vehicles, the sales of these vehicles, at the very least, would tend to be constant, if not increase from year to year. Thus, NHTSA [.] Based on sales trends for [ ], NHTSA believes that the sales of the [ ] would increase during the period covered by this rulemaking.

The potential improvements to the Ford light truck CAFE are summarized in the following table. Due to rounding, the individual improvements may not equal the potential CAFE for Ford.

Table VI-5
Potential Ford CAFE Improvements, mpg

Model Year	Baseline Mpg	Stage I Improvements	Stage II Improvements	Stage III Improvements	Total Increase	Potential CAFE, mpg.
2008	[ ]	[ ]	[ ]	[ ]	[ ]	22.455
2009	[ ]	[ ]	[ ]	[ ]	[ ]	23.060
2010	[ ]	[ ]	[ ]	[ ]	[ ]	23.935

General Motors

In its product plan submission, General Motors described a variety of technologies that could be used to increase vehicle fuel economy. Each technology described included its estimated fuel economy benefit, the basis for that estimate, whether the benefit was direct or interactive, a description of how the technology works and how it increases fuel economy, when the technology would be available for use, its potential applications, where it is currently employed in General Motors' light truck fleets, where the technology could potentially be used, risks in employing the technology, and potential impacts on NVH, safety, emissions, and cargo and towing capacity. General Motors also provided a projected fleet description with projected CAFE levels for MYs 2005-2012.

(a) Stage I

To determine which Stage I technologies General Motors could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied heavily on the General Motors-provided descriptions and on General Motors' previous comments on the MY 2005-2007 light truck CAFE rule regarding the technology applications used in the Preliminary Economic Analysis in the previous rule. Our analysis shows that General Motors could employ [ ] by MY 2008 with [ ] employed by MY 2009 and [ ] employed by MY 2010. The [ ] would carryover to MY 2009-2010, while [ ] available for MY 2009 would carryover to MY 2010. NHTSA used the NAS report's mid-range numbers for percentage increase in fuel economy in calculating the possible fuel economy increase attributable for most of these technologies. For [ ], NHTSA utilized higher percentage increases that were directly derived from General Motors data.

Starting with MY 2008, General Motors could use [ ] on its [ ] models. Additionally, by MY 2010, the [ ] models could use [.] General Motors utilizes this technology on several models, and the above models are [ ] designs which can utilize [ ]. The agency believes that there is more than sufficient lead time for General Motors to equip its models with [ ] and to make arrangements with [ ] to purchase sufficient quantities.

Starting with MY 2008, General Motors could use [

.] In reviewing General Motors' submission, this technology – which was first used by General Motors in MY 2005 – is used in most of General Motors' light trucks. General Motors has indicated its desire to use this technology on all vehicles that it produces. The agency has applied this technology to the only vehicles for which General Motors does not indicate its use in the projected production plan.

Starting with MY 2008, General Motors could use a [
.] Additionally, by MY 2009 General Motors could use a [
] models. In examining General Motors' plans and the technology description provided, the agency has applied this technology to light trucks for which this technology is appropriate. General Motors' uses this technology on related models beginning with MY 2007.

Starting with MY 2008, General Motors could use a [
.] Additionally, by MY 2010 General Motors could use a [
.] In examining General Motors' plans and the technology description provided, the agency has applied this technology to light trucks for which this technology is appropriate. General Motors first introduced this technology on passenger cars in MY 2005 and light trucks by MY 2006. By MY 2008, it is employed on the vast majority of General Motors' light trucks.

Starting with MY 2008, General Motors could include an [
.] This is a technology that can be used on all but [ ] and must be introduced in conjunction with [

.]

Starting with MY 2008, General Motors could include [ ] models. By MY 2009, the [ ] models could include [.] Additionally, by MY 2010, the [ ] models could include [.] This technology, which is currently used on a variety of General Motors models [ ] and can be applied on all vehicles. This technology is introduced throughout General Motors' light truck fleet to coincide with model changes and vehicle introductions.

Starting with MY 2008, General Motors could employ [.] Additionally, by MY 2009, General Motors could employ [ ] models [.] In examining General Motors' product plan, NHTSA observed [ ] possessing the same nameplate and attributes.

Starting with MY 2009, General Motors could include an [.] Additionally, by MY 2010 General Motors could use an [.] GM's technology description states that the company hopes to utilize this technology widely. This technology is introduced throughout General Motors' light truck fleet to coincide with model changes.

Starting with MY 2009, General Motors could include a [

.]

Additionally, starting with MY 2009, General Motors could employ [ ]. Additionally, by MY 2010, General Motors could employ [ ] models. In MY 2010, the [ ]. The agency believes that General Motors could incorporate a [ ] of these vehicles as part of its [ ] and that is quite feasible to have this technology included on these vehicles [.]

Starting with MY 2010, General Motors could use [.] These models are projected to utilize [.] The agency believes [ ] and [ ] are added as a package to vehicles. NHTSA believes that there is more than sufficient lead-time for General Motors to equip the [ ] models with these [ ] and to make arrangements with [ ] to purchase sufficient quantities.

(b) Stage II

To determine which Stage II technologies General Motors could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied on its own engineering judgment, submissions from other manufacturers, and comments from General Motors about the PRIA. In looking at these submissions, together with what General Motors provided, NHTSA has analyzed which Stage II technologies could be applied to General Motors' light truck fleet for MYs 2008-2010. Our analysis showed that General Motors could employ [ ] by MY 2008 and [ ] by MY 2009. All the technologies would carry over into future model years. To determine the possible fuel economy increase attributable to each of these technologies, the agency looked at the NAS study's percentage increase in fuel economy for each technology and examined General Motors' submission and its fuel economy trends. For one technology, it appears that General Motors' application of these technologies yields greater return for the company than the NAS average [.]

Starting with MY 2008, General Motors could use a [.] This technology is currently used by another manufacturer and is projected to increase fuel economy by [ ] for that company. It is expected that this technology can be used by almost all [,]; however, it is uncertain whether other manufacturers would get a [ ] fuel economy benefit for this technology. Thus, NHTSA discounted the improvement potential to [ ] when applying this technology to other manufacturers' [.]

Starting with MY 2008, General Motors could use [.] This engine is adaptable to the technology because of its [.] General Motors currently utilizes this technology in many of its [ ].

Starting with MY 2008, General Motors could use [.] Additionally, by MY 2009, General Motors could use [

.] This would be a further technological advance on engines that have [ ] today. Several other manufacturers employ this technology today.

Starting with MY 2008, General Motors could offer [

.] These engines were chosen because of their [ ] design. General Motors currently widely uses this technology on the majority of [ ] engines and some [ ] engines. General Motors' current [ ] engines are [ ] engines; thus, it is logical to assume that other [ ] engine designs could utilize the [ ] technology as well. General Motors provided a fuel economy improvement number of [

.]

Starting with MY 2008, General Motors could use [

.] Starting with MY 2010, General Motors could use [

.] Some [ ] models are scheduled to be manufactured with [

.] Delaying the implementation of [ ] allows General Motors additional lead time to apply this technology in conjunction with model changes and vehicle redesigns. Starting with MY 2009, General Motors could use [

.] General Motors’ data show that [ ] is currently used on [.] Combining the fact that the [ ] are of similar design to four engines having [ ] with the information provided by General Motors about [ ], leads the agency to believe that [ ] could be applied to these three engines.

Starting with MY 2009, General Motors could use [.] Some [ ] models are scheduled to be manufactured with [.]

NHTSA projected the use of [ ] in the above vehicles for many reasons, including the fact that many of General Motors’ direct competitors for the mid-size and larger light truck market are introducing vehicles with [ ] during MY 2008-2010. General Motors offers [ ] on some trucks and SUVs during MY 2008-2010, thus [ ] are technically feasible for these vehicles.

(c) Stage III

The Stage III analysis includes projections of the potential CAFE increase that could result from the application of diesel engines and hybrid powertrains to some products over and above the manufacturer’s plans.

Starting with MY 2010, General Motors could [ ]. The engines that could [ ] that General Motors uses in its [.] [.]

Additionally, it is possible that the sales of the [ ] could increase by MY 2009 with additional increases possible by MY 2010. General Motors projects the sales of these vehicles [.] [ ] production of these vehicles began in [ ], and the [ ] in significantly larger quantities in [ ] in conjunction with [ ] of the [.] NHTSA believes that due to the increased demand for and popularity of these vehicles, the sales of these vehicles, at the very least, could [ ] by 2009. Based on the current sales trends for [ ], NHTSA believes that the sales of the [ ] would increase during the period covered by this rulemaking.

The potential improvements to the General Motors light truck CAFE – as projected by NHTSA - are summarized in the following table. Due to rounding, the individual improvements may not equal the potential CAFE for General Motors.

Table VI-6
Potential GM CAFE Improvements, mpg

Model Year	Baseline Mpg	Stage I	Stage II	Stage III	Total	Potential CAFE, Mpg
2008	[ ]	[ ]	[ ]	0	[ ]	22.506
2009	[ ]	[ ]	[ ]	[ ]	[ ]	23.060
2010	[ ]	[ ]	[ ]	[ ]	[ ]	23.450

NISSAN

(a) Stage I

To determine which Stage I technologies Nissan could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied heavily on the Nissan-provided descriptions. Our analysis showed that, by MY 2008, Nissan could employ [ ] to its entire light truck fleet and [ ] to part of the vehicle fleet. By MY 2009, Nissan could employ [ ] to part of its fleet. Of the [ ] that were employed to part of the vehicle fleet, [ ] have staggered introduction timed with model changes. All of these technologies were carried forward into subsequent years. NHTSA used the NAS study’s mid-range numbers for the percentage increase in fuel economy for calculating the possible fuel economy increase attributable to each of these technologies.

Starting with MY 2008, Nissan could use [ ] on all of its vehicles. This is a technology that can be used throughout Nissan’s light truck fleet and could be added to these engines within a relatively short lead time.

Starting with MY 2008, Nissan could use [

.] In MY 2008, the [

.] By MY 2009, an [ ] could be included on the [

.] By MY 2010, an [ ] could be included on the [

.] On larger vehicles, this technology would be used in conjunction with [

.] Other vehicle manufactures utilize this technology on many other vehicles, and the agency believes that this technology is applicable to the wide variety of light trucks that Nissan produces and that Nissan would have sufficient lead time to add this technology to its light trucks.

Starting with MY 2008, Nissan could use [

.] In MY 2008, the [

.] By MY 2009, an [ ] could be included on the [

.] By MY 2010, an [ ] could be included on the [.] This technology could be employed in conjunction with vehicle redesign or introduction.

Starting with MY 2008, Nissan could include a [

.] This technology is similar to one being introduced by a competitor and should be very applicable to these engines. With a relatively limited number of engines, Nissan should be able to incorporate this technology across its entire fleet without an undue burden.

Starting with MY 2008, Nissan could employ [

.] In MY 2008, the [ ]. By MY 2009, [ ] could be employed on the [ ]. By MY 2010, [ ] could be employed on the [ ]. The agency believes that Nissan could incorporate a [ ] of these vehicles as part of its [ ] and that is quite feasible to have this technology included on these vehicles [.]

Starting with MY 2009, Nissan could use [ ]. Several other manufacturers have indicated that they are incorporating this cost-effective technology on their vehicles. The agency believes that there is more than sufficient lead time for Nissan to equip its models with these [ ] and to make arrangements with [ ] to purchase sufficient quantities.

Additionally, starting with MY 2009, Nissan could employ [.] In MY 2009, the [ ]. By MY 2010, [ ] could be included on the [.] The agency believes that Nissan could incorporate a [ ] of these vehicles as part of its [ ] and that is quite feasible to have this technology included on these vehicles [.]

(b) Stage II

To determine which Stage II technologies Nissan could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied on its own engineering judgment and submissions from other manufacturers. In looking at these submissions, together with what Nissan provided, NHTSA has analyzed which Stage II technologies could be applied to Nissan's light truck fleet for MYs 2008-2010.

Our analysis showed that, by MY 2008, Nissan could employ [ ] to part of its vehicle fleet, with a staggered introduction timed with model changes. An [ ] could be introduced by MY 2009. All of these technologies were carried forward into subsequent years. NHTSA used the NAS study's mid-range numbers for the percentage increase in fuel economy attributable to each of these technologies.

Beginning with MY 2008, Nissan could change [ ]. In MY 2008, the [ ]. By MY 2009, [ ] could be included on the [ ]. NHTSA projected the use of [ ] in the above vehicles for many reasons, including the fact that many of Nissan's direct competitors for the mid-size and larger light truck market are introducing vehicles with [ ] during MY 2008-2010.

Beginning with MY 2008, Nissan could change [ ]. In MY 2008, the [ ]. By MY 2009, [ ] could be included on the [ ]. NHTSA projected the use of [ ] in the above vehicles for many reasons, including the fact that many similar vehicles already include [ ] in the product plans.

Starting with MY 2008, Nissan could use [ ] on all vehicles with [ ]. In MY 2008, the [ ]. By MY 2009, [ ] could be included on the [ ]. Several other manufacturers employ this technology today.

Starting with MY 2008, Nissan could use [ ]. In MY 2008, the [.] By MY 2009, [ ] could be included on the [ ]. By MY 2010, [ ] could be included on the [ ]. This would be a further technological advance on engines that have [ ] today. Several other manufacturers employ this technology today.

Starting with MY 2009, Nissan could use [ ]. This is a technology could be added within a relatively short lead time. This technology is currently used by another manufacturer and is projected to increase FE by [ ] for that company. It is expected that this technology can be used by almost all [ ]; however, it is uncertain whether other manufacturers would get a [ ] FE benefit from this technology. Thus, NHTSA discounted the improvement potential to [ ] when applying this technology to other manufacturers' [.]

(c) Stage III

The Stage III analysis includes projections of the potential CAFE increase that could result from the application of diesel engines and hybrid powertrains to some products.

Starting with MY 2010, Nissan could use [

.]

The potential improvements to the Nissan light truck CAFE are summarized in the following table. Due to rounding, the individual improvements may not equal the potential CAFE for Nissan.

Table VI-7
Potential Nissan CAFE Improvements, mpg

Model Year	**Baseline Mpg**	**Stage I**	**Stage II**	**Stage III**	**Total**	**Potential CAFE, Mpg**
2008	[ ]	[ ]	[ ]	[ ]	[ ]	22.452
2009	[ ]	[ ]	[ ]	[ ]	[ ]	23.091
2010	[ ]	[ ]	[ ]	[ ]	[ ]	23.470

TOYOTA

(a) Stage I

To determine which Stage I technologies Toyota could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied heavily on the Toyota provided descriptions. Our analysis showed that, by MY 2009, Toyota could employ [ ] to its light truck fleet. All of these technologies were carried forward into subsequent years. NHTSA used the NAS study's mid-range numbers for the percentage increase in fuel economy that was used calculating the possible fuel economy increase attributable to each of these technologies.

Starting with MY 2009, Toyota could use [ ]. In MY 2009, the [.] By MY 2010, [ ] could be included on the [ ]. This is a technology that can be used throughout Toyota's light truck fleet and could be added to these engines in conjunction with vehicle redesign or introduction.

Starting in MY 2009, Toyota could employ [

]. In MY 2009, the [.] By MY 2010, [ ] could be included on the [ ]. Several other manufacturers have indicated that they are incorporating this cost-effective technology on their vehicles. In conjunction with vehicle redesign or introduction, the agency believes that there is more than sufficient lead time for Toyota to equip its models with these [ ] and to make arrangements with [ ] to purchase sufficient quantities.

In MY 2009, Toyota could employ [ ]. This technology was employed because all these vehicles have or are projected to have [ ] by that date.

Starting with MY 2009, Toyota could use [ ]. In MY 2009, the [ ] could be included on the [ ]. On the [ ], this technology would be used in conjunction with [ ]. Other vehicle manufactures utilize this technology on many other vehicles, and the agency believes that this technology is applicable to the wide variety of light trucks that Toyota produces.

Starting with MY 2009, Toyota could include a [ ], in conjunction with model redesign or introduction. In MY 2009, the [.] By MY 2010, a [ ] could be included on the [

]. This technology is similar to one being introduced by a competitor and should be very applicable to these engines.

Starting with MY 2009, Toyota could add an [
]. In MY 2009, the [
.] By MY 2010, an [
] could be included on the [ ]. This is a technology that can be used throughout Toyota's light truck fleet and could be added to these engines in conjunction with vehicle redesign or introduction.

Additionally, starting with MY 2009, Toyota could employ [
.] In MY 2009, the [.] By MY 2010, [
] could be employed on the [ ]. The agency believes that Toyota could incorporate a [ ] of these vehicles as part of its [
] and that is quite feasible to have this technology included on these vehicles [
.]

(b) Stage II

To determine which Stage II technologies Toyota could employ, on which vehicles and/or engines they could be employed, and when they could be employed, NHTSA relied on its own engineering judgment and submissions from other manufacturers. In looking at these submissions, together with what Toyota provided, NHTSA has analyzed which Stage II technologies could be applied to Toyota's light truck fleet for MYs 2008-2010.

Our analysis showed that, by MY 2009, Toyota could employ [ ] to part of its vehicle fleet, with a staggered introduction timed with model changes. All of these technologies were carried forward into subsequent years. NHTSA used the NAS study's mid-range numbers for the percentage increase in fuel economy attributable to each of these technologies.

Beginning with MY 2009, Toyota could change [

]. This technology is already used in [ ].

Beginning with MY 2009, Toyota could change [

]. This technology is already planned for the [

].

Starting with MY 2009, Toyota could use [

]. In MY 2009, the [.] By MY 2010, [ ] could be included on the [.] This would be a further technological advance on engines that have [ ]. Several other manufacturers employ this technology today.

(c) Stage III

The Stage III analysis includes projections of the potential CAFE increase that could result from the application of diesel engines and hybrid powertrains to some products. Our projection for Toyota indicates that the company can meet the standards contained in this proposed rule without the agency applying any diesel engines and hybrid powertrains to Toyota's product plans. Thus, the agency did not identify any CAFE increases resulting from Stage III for Toyota.

Table VI-8
Potential Toyota CAFE Improvements, mpg

Model Year	**Baseline Mpg**	**Stage I**	**Stage II**	**Stage III**	**Total**	**Potential CAFE, Mpg**
2008	[ ]	[ ]	[ ]	[ ]	[ ]	22.506
2009	[ ]	[ ]	[ ]	[ ]	[ ]	23.054
2010	[ ]	[ ]	[ ]	[ ]	[ ]	24.044

VII. COST IMPACTS

Technology Costs

The technology application algorithm implemented with the Volpe model was used as the basis for estimating costs for the fleet. The Stage Analysis will predict different technological responses to CAFE standards and different estimates of costs. In the previous Final Economic Assessment for the CAFE standards for MY 2005-2007[48], the agency compared the costs for Ford and GM using both the stage analysis and the technology application algorithm and showed that the Stage Analysis had costs that were, on average, 6 to 16 percent higher than the technology application algorithm. From a practical perspective, the Stage Analysis provides a basis for judging the general reasonableness of the technology application algorithm. However, because a myriad of responses are, in fact, plausible, NHTSA believes that the cost methodology utilized in the technology application algorithm will provide similar estimates and reasonable estimates of the costs of the alternative CAFE standards analyzed.

Table VI-4 presented potential retail price impacts and fuel consumption impacts of different technologies. We applied the technology application algorithm described in Chapter VI. Some manufacturers might achieve more benefit than others using similar technologies or on specific vehicles. However, because NHTSA believes that technology characteristics are subject to greater uncertainty on a manufacturer-specific basis, this analysis assumes an equal impact from specific technologies for all manufacturers and vehicles. The technologies were ranked based primarily on the cost-per-percentage point improvement in fuel economy and applied (where available) to each manufacturer’s fleet in their order of rank.

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[48] “Final Economic Assessment, Corporate Average Fuel Economy Standards for MY 2005-2007 Light Trucks”, April 2003, Docket No. 11419-18358, Page VII-7.

The first row of Table VII-1 shows the average baseline mpg for the industry resulting from product plans submitted by the vehicle manufacturers. The second row shows the industry average fuel economy level obtained by adjusting upward the baseline mpg levels of those manufacturers whose product plans resulted in mpg levels below the MY 2007 standard of 22.2 mpg, called the "Adjusted Baseline" mpg level. The remaining rows of Table VII-1 report the estimated mpg level for the industry under the various scenarios. (Note that no level is shown for MY 2011 in the Unreformed CAFE system, since the agency is requiring Reformed CAFE must be used in MY 2011.) The estimated fleet average under the Adjusted Baseline exceeds the current CAFE standard because the fuel economy levels resulting from some manufacturers' product plans exceed 22.2 mpg.

The Alliance and Ford argued that in establishing manufacturer baselines for our analysis, the agency erroneously assumed that each manufacturer's fleet average would be at 22.2 mpg for Model Year 2007. These commenters stated that this assumption is incorrect, because some manufacturers did not submit product plan information to support this assumption and other manufacturers achieve compliance with the CAFE requirements through the use of credits and payment of fines. The Alliance and Ford also stated that some manufacturers (in anticipation of future CAFE increases) might have taken steps in support of higher fleet averages and might have already incorporated costly fuel-saving technologies.

In response, we note that the agency did not assume that each manufacturer's fleet average would be 22.2 mpg for MY 2007. We used the manufacturers' plans to determine the fleet average for MY 2007. When a manufacturer's plans were below 22.2 mpg, we estimated the technologies and costs necessary to bring its fleet average up to a 22.2 mpg baseline. These costs were assigned to the MY 2007 standards, and such costs were not included in the costs for MY 2008. Technologies used in MY 2007 to bring manufacturer's fleets up to 22.2 mpg were not available for use in future years.

The agency must have a consistent methodology to determine a CAFE baseline across manufacturers. That methodology includes using the manufacturer's plans as supplied to us. We cannot determine with certainty why their plans were made, including whether or not they were set in contemplation of future fuel economy standards.

Table VII-1
Baseline and Estimated mpg Levels
Harmonic Averages

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Manufacturers' Production Plans Average	21.94	22.02	22.37	22.41	22.62
Adjusted Baseline With a 22.2 mpg Minimum	22.40	22.42	22.73	22.75	22.97
Unreformed CAFE	22.62	23.14	23.54	N.A.	N.A.
Reformed CAFE	22.74	23.36	23.73	23.98	24.09
NPRM Step Function	22.55	23.02	23.33	N.A.	23.80
Revised Step Function	22.74	23.19	23.60	23.76	23.84
Unreformed CAFE Standard	22.5	23.1	23.5	N.A.	N.A.

Table VII-2 presents the estimated costs to bring those manufacturers that are not planning on meeting the current level of 22.2 mpg for MY 2008-2011, without using fuel economy adjustments for alternative fueled vehicles, up to 22.2 mpg. These are the most cost- effective technologies available to the manufacturers. These costs have been estimated, but they are not considered to be part of the costs of meeting the proposed requirements. Those costs, and commensurate benefits, are considered part of the costs and benefits of complying with previously issued rules. These are average industry cost estimates over all vehicles sold, not just for those manufacturers with a baseline below 22.2 mpg. The reason for decreases in the latter model years are that some manufacturers are planning to make improvements in fuel economy in the later model years, resulting in bringing them closer to 22.2 mpg or above 22.2 mpg. These estimates represent the costs to bring the manufacturer's plans that are below 22.2 mpg back up to 22.2 mpg, for each model year individually.

Tables VII-3 and VII-4 show the costs (on an average cost-per-vehicle basis) of applying technology necessary to move each manufacturer's planned fuel economy levels up to the level of the final rule. Thus, if a manufacturer's product plans resulted in a fuel economy level of 22.2 mpg during each model year, the cost represents the cumulative cost of technologies necessary to bring that manufacturer's fleet average up to the levels of the final rule. The costs for Porsche and Volkswagen are the fines that these manufacturers would have to pay on an average vehicle basis. We assume that the costs of fines will be passed on to consumers.

The second part of each of these tables shows the estimated total manufacturer costs in millions of dollars. Since the manufacturers' plans for MYs 2008, 2009, 2010, and 2011 are different, the baseline changes in each year (as shown in Table V-1). Each individual year is analyzed compared to the manufacturer's plans for that year (adjusted by bringing those manufacturers with an average mpg below 22.2 mpg, up to 22.2 mpg). Fines are not included in the second part of these tables, since these are transfer payments and not technology costs.

The agency has set the Reformed CAFE levels such that they result in costs that approximate the costs of Unreformed CAFE during the transition period. A comparison of Tables VII-3 and VII-4 indicates that total costs are fairly close under each approach for MYs 2008, 2009, and 2010.

Tables VII-5 and VII-6 show the costs of the alternative Step Functions. The costs of the Revised Step Function are relatively close to the Reformed standard costs. The costs of the NPRM Step Function levels are much lower.

Table VII-2

Estimated Incremental Costs or Fines* over Manufacturer's Plans
To get to Adjusted Baseline - Average Cost per Vehicle

	MY 2008	**MY 2009**	**MY 2010**	**MY2011**
BMW	49	55	55	63
Daimler Chrysler	34	25	25	17
Ford	128	71	74	56
Fuji – Subaru				
General Motors	183	132	98	101
Honda				
Hyundai				
Isuzu	413	555	657	659
Mitsubishi				
Nissan	305	328	301	301
Porsche	297	297	297	297
Suzuki	64	64	64	64
Toyota				
Volkswagen	188	188	188	189
Fleet Ave.	101	76	67	62

* Porsche and Volkswagen are assumed to pay fines.

Total Incremental Costs in Millions

	MY 2008	**MY 2009**	**MY 2010**	**MY2011**
BMW	1	1	1	2
Daimler Chrysler	67	51	53	35
Ford	214	122	129	99
Fuji – Subaru				
General Motors	406	300	227	236
Honda				
Hyundai				
Isuzu	13	20	24	24
Nissan				
Porsche				
Suzuki	2	2	2	2
Toyota				
Volkswagen				
Total Fleet	851	661	590	552

Table VII-3
Estimated Incremental Costs or Fines over Manufacturer's Plans
Unreformed - Average Cost per Vehicle

	MY 2008	**MY 2009**	**MY 2010**
BMW	17	92	113
Daimler Chrysler	58	161	148
Ford	95	275	132
Fuji – Subaru			
General Motors	116	281	385
Honda			
Hyundai			4
Isuzu	17	50	480
Mitsubishi			
Nissan	17	179	321
Porsche	17	50	72
Suzuki	176	176	221
Toyota		91	121
Volkswagen	17	50	71
Fleet Ave.	64	185	195

Total Incremental Costs in Millions

	MY 2008	**MY 2009**	**MY 2010**
BMW			
Daimler Chrysler	115	332	311
Ford	158	472	230
Fuji – Subaru			
General Motors	258	640	893
Honda			
Hyundai			1
Isuzu			18
Mitsubishi			
Nissan		74	163
Porsche			
Suzuki	5	5	6
Toyota		93	126
Volkswagen			
Total Fleet	536	1,621	1,752

Table VII-4
Estimated Incremental Costs or Fines over Manufacturer's Plans
Reformed - Average Cost per Vehicle

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	127	202	229	246	246
Daimler Chrysler	192	339	312	296	322
Ford	169	304	223	178	188
Fuji – Subaru					
General Motors	See note after cost tables	87	168	397	297
Honda					21
Hyundai	114	319	337	478	478
Isuzu		38	480	482	482
Mitsubishi	205	334	426	522	466
Nissan	6	190	363	416	461
Porsche	44	83	99	110	110
Suzuki	601	947	1,179	1,316	1,316
Toyota	18	77	69	72	72
Volkswagen	50	83	105	110	110
Fleet Ave.	66	201	213	271	255

Total Incremental Costs in Millions

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW		5	5	5	5
Daimler Chrysler	380	700	657	628	681
Ford	281	505	387	336	333
Fuji – Subaru					
General Motors	See note after cost tables	198	389	1,001	694
Honda					12
Hyundai	35	102	109	156	156
Isuzu			18	18	18
Mitsubishi	23	38	49	61	54
Nissan		74	184	216	236
Porsche					
Suzuki	14	24	32	36	36
Toyota	18	78	72	75	75
Volkswagen					
Total Fleet	553	1,724	1,903	2,531	2,301

Table VII-5
Estimated Incremental Costs or Fines over Manufacturer's Plans
NPRM Step Function - Average Cost per Vehicle

	MY 2008	**MY 2009**	**MY 2010**	**W/o MDPVs MY 2011**
BMW	88	186	207	240
Daimler Chrysler	115	219	179	212
Ford	95	232	91	82
Fuji – Subaru	73	43	3	67
General Motors	See note after cost tables	32	113	227
Honda				
Hyundai	45	240	287	480
Isuzu	6	38	480	482
Mitsubishi	38	213	332	640
Nissan	See note after cost tables	192	224	373
Porsche	6	72	99	127
Suzuki	628	969	1,203	1,379
Toyota	18	42	44	48
Volkswagen	28	93	116	143
Fleet Ave.	21	137	129	185

Total Incremental Costs in Millions

	MY 2008	**MY 2009**	**MY 2010**	**W/o MDPVs MY 2011**
BMW		5	5	5
Daimler Chrysler	227	453	376	450
Ford	158	398	159	145
Fuji – Subaru	7	4		7
General Motors	See note after cost tables	73	262	531
Honda				
Hyundai	14	76	93	157
Isuzu			18	18
Mitsubishi	4	24	38	75
Nissan	See note after cost tables	94	114	191
Porsche				
Suzuki	14	24	32	37
Toyota	18	43	46	51
Volkswagen				
Total Fleet	171	1,194	1,144	1,665

Table VII-6
Estimated Incremental Costs or Fines over Manufacturer's Plans
Revised Step Function - Average Cost per Vehicle

	MY 2008	**MY 2009**	**MY 2010**	**MDPVs MY 2011**	**W/o MDPVs MY 2011**
BMW	110	186	213	235	235
Daimler Chrysler	192	321	270	267	291
Ford	125	254	179	154	162
Fuji – Subaru	366	350	211	232	232
General Motors	See note after cost tables	86	206	397	325
Honda					
Hyundai	114	300	329	480	452
Isuzu	17	50	480	482	482
Mitsubishi	112	242	483	633	633
Nissan	See note after cost tables	185	304	405	414
Porsche	28	61	88	110	110
Suzuki	667	1,013	1,258	1,412	1,412
Toyota	35	86	79	76	82
Volkswagen	50	83	110	132	127
Fleet Ave.	68	189	205	264	251

Total Incremental Costs in Millions

	MY 2008	**MY 2009**	**MY 2010**	**MDPVs MY 2011**	**W/o MDPVs MY 2011**
BMW		5	5	5	5
Daimler Chrysler	380	662	568	566	616
Ford	209	437	311	291	287
Fuji – Subaru	33	33	21	23	23
General Motors	See note after cost tables	196	478	1,001	759
Honda					
Hyundai	35	96	107	157	148
Isuzu			18	18	18
Mitsubishi	12	28	56	74	74
Nissan	See note after cost tables	89	154	210	212
Porsche					
Suzuki	14	24	32	37	37
Toyota	35	88	82	79	86
Volkswagen					
Total Fleet	575	1,658	1,832	2,461	2,265

Note: Numbers are not reported in these cases. The resulting standard for General Motors and Nissan in these years for the Reformed and Step Function are below the MY 2007 standard of 22.2 mpg. In theory, these manufacturers could take technologies out of some of their vehicles and reduce price. We do not believe this would occur. It is more likely that the manufacturers will generate credits in MY 2008, rather than take technologies out of some vehicles. The negative numbers were included in the average vehicle estimates and total costs in millions.

The Impact of Higher Prices on Sales

The fuel economy standards are expected to increase the price of light trucks. The potential impact of higher vehicle prices on sales was examined on a manufacturer-specific basis, since the estimated cost of improving fuel economy and the mpg improvement is different for each manufacturer. There is a broad consensus in the economic literature that the price elasticity for demand for automobiles is approximately –1.0.[49,50,51] Thus, every one percent increase in the

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[49] Kleit, A.N. (1990). "The Effect of Annual Changes in Automobile Fuel Economy Standards." *Journal of Regulatory Economics*, vol. 2, pp 151-172.

[50] Bordley, R. (1994). "An Overlapping Choice Set Model of Automotive Price Elasticities," *Transportation Research B*, vol 28B, no 6, pp 401-408.

price of the vehicle would reduce sales by one percent. Elasticity estimates assume no perceived change in the quality of the product. However, in this case, vehicle price increases result from adding technologies that improve fuel economy. If consumers do not value improved fuel economy at all, then the estimated impact on sales from price elasticity could be applied directly. However, we believe that consumers do value improved fuel economy, because they reduce the operating cost of the vehicles.

To estimate the average value consumers place on fuel savings at the time of purchase, we assume that the average purchaser considers the fuel savings they would receive over a 4.5 year timeframe. We chose 4.5 years because this is the average length of time of a financing agreement. The present values of these savings were calculated using both a 3 percent and 7 percent discount rate. We used a fuel price forecast (see Table VIII-3) that included taxes, because this is what consumers pay and respond to. Based on Table VIII-2, the average truck would travel 66,975 miles in 4.5 years out of the lifetime weighted travel of 179,954 miles. Fuel savings were recalculated over the first 4.5 years under the assumptions discussed above.

Using our projections of sales by manufacturer and the Ward's 2003 Market Data Book, light truck sales volumes were matched with base vehicle average prices for MY 2004 to determine an average light truck price per manufacturer. The average base price for all light trucks using this method was $24,400. While this method does not give an exact price, the results are reasonable and specific to individual manufacturers[52]. For example, the average price for BMW was

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[51] McCarthy , P.S. (1996). "Market Price and Income Elasticities of New Vehicle Demands," *The Review of Economics and Statistics*, vol. LXXVII, no. 3, pp. 543-547.

[52] The base price does not include the more expensive lines of a model or purchased optional equipment; nor does it count discounts given. Thus, it is not an average light truck purchase transaction price, but a price that we can track.

$38,500, the average price for Ford was $23,860, and the average price for Suzuki was $18,920. These prices are in 2003 dollars. Average prices and estimated sales volumes are needed because price elasticity is an estimate of how a percent increase in price affects the percent decrease in sales.

A sample calculation for Ford under the Unreformed CAFE alternative in MY 2008 is an estimated retail price increase of $95 and a fuel savings over the 4.5 years of $81 at a 7 percent discount rate. The net cost is $14 at a 7 percent discount rate. Comparing that to the $23,860 average price is 0.0587 percent price increase. Ford sales were estimated to be 1,665,146 for MY 2008. With a price elasticity of –1.0, a 0.0587 percent decrease in sales could result in an estimated loss of sales of 977 light trucks at a 7 percent discount rate.

Sales increases occur when the value of improved fuel economy exceeds the consumer cost of added technology. Overall, across all manufacturers combined, there would be a slight loss in sales for all of the alternatives examined. Some manufacturers would gain sales slightly and others would lose some sales. Tables VII-7a, 7b, 8a, and 8b show the estimated total impact on sales for Unreformed and Reformed CAFE at a 3 percent and 7 percent interest rate, if we assumed that consumers value an improvement in fuel economy for 4.5 years. A negative number means a decrease in sales and a positive number means an increase in sales. The largest estimated impact on sales, which is relatively small, is a loss of 17,490 light truck sales or about 0.2 percent of the estimated light truck sales for that year (17,490/9,015,521 = 0.00194).

The California State Energy Commission commented that the agency mentioned the potential for the CAFE proposal to result in job losses, but it failed to discuss the issue of employment in detail. The Commission stated that increasing CAFE stringency may actually increase employment among automobile manufacturers and related sectors, although union employment and employment in the petroleum manufacturing industry might decline. Without going into detail, the commenter stated that several previous studies have concluded that increasing CAFE standards could increase U.S. employment and economic output. The Commission also suggested that by requiring U.S. automakers to produce more fuel-efficient vehicles, stricter CAFE standards could enhance the competitive positions of those manufacturers in international markets where fuel prices are typically higher, thereby increasing total sales, production volumes, and domestic employment. The Commission asked the agency to address the issue of the employment impacts of its CAFE standards more explicitly in the final rule.

The Marine Retailers Association of America (MRAA) expressed concern that increases in CAFE levels could lead to vehicle downsizing, which in turn could have a negative impact upon the boating industry, According to the MRAA, there are approximately 17 million recreational boats in the U.S., about 80 percent of which are pulled by a light truck or SUV. MRAA stated that to the extent vehicle downsizing occurs, manufacturers may find it more difficult to produce a vehicle with adequate horsepower and torque to tow a boat, and without an adequate vehicle to tow a boat, many consumers may simply decide not to purchase a boat. Accordingly, the MRAA asked NHTSA to carefully consider the employment, sales, and other impacts of its CAFE proposal upon the boating industry.

The agency believes that the CAFE impact on jobs is fairly minor and that there are counterbalancing impacts. The agency estimates that higher prices will result in a small loss of sales, which negatively impacts employment. On the other hand, in a few limited cases, the requirements could result in the use of additional new technology, which would increase employment. For example, hybrid engines are more complex than gasoline engines and would result in increased employment at the engine factory and for suppliers of engine parts. Both of these impacts (a potential decrease in sales and a potential increase in assembly line and supplier labor) on jobs are anticipated to be very minor, and the counterbalancing impacts will be near zero.

Very few light trucks are exported for sale and we believe that the increases in fuel economy are unlikely to change these sales volumes appreciably. Thus, we expect that there is little chance of improving the competitive position of the manufacturers in international markets as a result of revised light truck CAFE standards.

The agency has not included changes in vehicle performance as part of its strategy for the manufacturers to improve fuel economy, and changes in weight were not accompanied by changes in horsepower. Thus, our assumptions include no changes that would affect the boating industry. However, our assumptions do not require a manufacturer to follow our predicted course of action.

Table VII-7a
Potential Impact on Sales by Manufacturer
Unreformed CAFE at 3 percent discount rate

	MY 2008	**MY 2009**	**MY 2010**
BMW	32	-62	-16
Daimler Chrysler	-4095	-9356	-9623
Ford	488	791	729
Fuji – Subaru	0	0	0
General Motors	2179	1719	876
Honda	0	0	0
Hyundai	0	0	-5360
Isuzu	26	79	166
Mitsubishi	0	0	0
Nissan	388	1876	591
Porsche	5	14	20
Suzuki	-119	-122	-185
Toyota	0	-3816	-4741
Volkswagen	12	36	52
Total Fleet	-1082	-8841	-17490

Table VII-7b
Potential Impact on Sales by Manufacturer
Unreformed CAFE at a 7 percent discount rate

	MY 2008	**MY 2009**	**MY 2010**
BMW	32	-44	4
Daimler Chrysler	-3398	-7630	-7865
Ford	977	2158	1386
Fuji – Subaru	0	0	0
General Motors	2682	3351	3328
Honda	0	0	0
Hyundai	0	0	-4946
Isuzu	26	79	218
Mitsubishi	0	0	0
Nissan	388	2040	1136
Porsche	5	14	20
Suzuki	-91	-94	-147
Toyota	0	-3239	-3973
Volkswagen	12	36	52
Total Fleet	633	-3330	-10788

Table VII-8a
Potential Impact on Sales by Manufacturer
Reformed CAFE at 3 percent discount rate

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	239	151	183	214	214
Daimler Chrysler	-9496	-8266	-9993	-10179	-10067
Ford	1396	3237	2480	1480	1634
Fuji – Subaru	0	0	0	0	0
General Motors	0	-2062	-3415	-3653	-2028
Honda	0	0	0	0	-148
Hyundai	-941	-932	-1413	-1267	-1267
Isuzu	0	60	166	180	180
Mitsubishi	64	25	399	711	551
Nissan	137	2134	639	288	643
Porsche	12	23	28	31	31
Suzuki	-15	144	137	176	176
Toyota	-389	-3195	-3702	-3274	-3274
Volkswagen	35	60	77	82	82
Total Fleet	-9022	-8646	-14815	-15922	-13824

Table VII-8b
Potential Impact on Sales by Manufacturer
Reformed CAFE at a 7 percent discount rate

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	239	168	202	234	234
Daimler Chrysler	-7492	-5269	-7032	-7378	-7084
Ford	2163	4676	3501	2416	2600
Fuji – Subaru	0	0	0	0	0
General Motors	0	-1375	-2102	-562	88
Honda	0	0	0	0	-99
Hyundai	-726	-457	-862	-556	-556
Isuzu	0	60	218	226	229
Mitsubishi	137	151	532	860	690
Nissan	137	2298	1230	1033	1430
Porsche	12	23	28	31	31
Suzuki	48	232	254	449	449
Toyota	-303	-2662	-3160	-2774	-2774
Volkswagen	35	60	77	82	82
Total Fleet	-5587	-2246	-7646	-6799	-5370

Testing Costs for MDPVs

The EPA estimates that regulating MDPVs under the fuel economy standards would require approximately 50-100 city/highway paired tests at a cost of $2,000 per pair, plus an additional $50,000 – 100,000 per test vehicle for test preparation (i.e., a coast-down analysis[53] and appropriate mileage accumulation). Based on these estimates, the industry wide compliance test costs for MDPVs range from $2.1 million to $8.2 million. The EPA noted that this cost could potentially be further reduced due to the fact that a manufacturer is permitted to certify up to 20 percent of its fleet through an analytical process that does not require vehicle testing.

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[53] A coast-down analysis is used to determine a vehicle’s horsepower for running the chassis dynamometer tests.

VIII. BENEFITS

Economic Impacts from Higher CAFE Standards

Economic impacts from adopting a more stringent CAFE standard for light trucks were estimated separately for each model year over the lifespan of those vehicles in the U.S. vehicle fleet, extending from the initial year when a model is offered for sale through the year when nearly all vehicles from that model year have been retired or scrapped (assumed to be 36 years in this analysis). The underlying source of the economic and environmental impacts considered in this analysis is the reduction in gasoline use resulting from the improvement in fuel economy of new light-duty trucks produced. Each of these impacts is measured by comparing their value under each alternative approach to their value under the adjusted baseline. Future impacts are estimated after discounting to the year the vehicle is sold to determine their present value, using a 3 and 7 percent discount rate.[54]

The Discount Rate

OMB Circular A-4 provides guidance to agencies on discounting costs and benefits in the context of regulatory analysis. Circular A-4 states that agencies should provide estimates of net benefits using both 3 percent and 7 percent discount rates and recommends using other discount rates to show the sensitivity of the estimates to the discount rate assumption. Circular A-4 also points out that in some instances there is reason to expect that the regulation may cause resources to be reallocated away from private investment in the corporate sector which may have an opportunity cost that lies outside the range of 3 to 7 percent. Where there is uncertainty about

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[54] Discounting to the year when each model year was produced allows future economic benefits from improving each model year's fuel economy to be compared to added production costs for making those vehicles more fuel-efficient, which are assumed to be incurred at the time those vehicles are manufactured.

the nature of the opportunity cost, Circular A-4 directs agencies to conduct regulatory analysis using a higher discount rate as a further sensitivity analysis in addition to using the 3 and 7 percent rates.

The rationale for using a particular range of discount rates in the context of a particular rulemaking should reflect the opportunity cost over time of the cost and benefit effects of that rule. It is well known that this opportunity cost can differ widely depending on who bears the costs and benefits, and there is often uncertainty about that incidence. The 7 percent rate is an estimate of the average before-tax rate of return to private capital in the U.S. economy, reflecting the returns to real estate, small business, and corporate capital. It approximates the opportunity cost of capital, and it is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector.

As Circular A-4 points out however, the effects of regulation do not always fall exclusively or primarily on the allocation of capital. When regulation primarily and directly affects private consumption (e.g., through higher consumer prices for goods and services), a lower discount rate may be appropriate. The alternative most often used is sometimes called the “social rate of time preference.” This simply means the rate at which society discounts future consumption flows to their present value. If we take the rate that the average saver uses to discount future consumption as our measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a fair approximation. Over the last thirty years, this rate has averaged around 3 percent in real terms on a pre-tax basis.

In the context of CAFE standards, an argument can thus be made for using a range of discount rates depending on one’s view of the likely incidence of the costs and benefits of fuel economy improvements. In addition to the 3 and 7 percent rates, the interest rate likely to be paid by consumers to finance vehicle purchases is relevant because the majority of new vehicle purchases are financed and the majority of net benefits of this rulemaking accrue to vehicle purchasers. The interest rate on vehicle loans in this case directly reflects the opportunity cost that vehicle purchasers face when buying vehicles with greater fuel economy and a higher purchase price. Based on historical interest rates for new and used car loans, and relevant interest rate and inflation rate forecasts for the period of this rulemaking, an appropriate real discount rate from this point of view is 5 to 10 percent. Evidence of implicit discount rates even higher than 10 percent has been found by studies, examining the tradeoffs between energy efficiency and purchase price that consumers implicitly make in the context of purchasing decisions for energy-using durables, including passenger vehicles.

For the NPRM, we used a rate of 7 percent in the process of determining the standards and computed the net benefits of the resultant standards at a rate of both 7 percent and 3 percent, as described in the Preliminary Regulatory Impact Analysis. We asked for comment on what discount rates are appropriate for this rulemaking, including the use of 3, 7, and 10 percent.

The Alliance, General Motors, the Mercatus Center, and Criterion Economics all argued that in assessing costs associated with the CAFE standards, the agency should rely on a discount rate greater than 7 percent (the value currently recommended by OMB). (The “discount rate” reflects consumers’ rate of time preferences for current versus future consumption.) The Alliance stated that the Congressional Budget Office discounts consumers’ fuel savings at a rate of 12 percent per year and that other recent studies of CAFE standards have also used that rate. According to the Alliance, that rate is slightly higher than the interest rate that consumers reported for used car purchases in the most recent Consumer Expenditure Survey (a survey performed by the Census Bureau for the U.S. Department of Labor's Bureau of Labor Statistics), and consumers can be expected to discount the value of future fuel savings at a rate at least as high as their cost of borrowing funds (i.e., the point at which annual interest on a dollar would exceed the incremental fuel economy savings). General Motors suggested a discount rate of 9 percent, based on its assertions that new vehicles are financed at 8 percent and used vehicles at 10 percent. General Motors argued that fuel economy is not the only thing which consumers value and that the agency should take efforts to separate private benefits from public externalities. Criterion Economics also recommended use of a 9 percent discount rate in its comments, which it suggested is a conservative rate between the average real rates for new and used cars that adequately accounts for volatility in future energy prices. The Mercatus Center stated that the 7 percent discount rate selected by the agency is arbitrary and too low, and as a result, it results in the setting of standards that are inequitable to low-income households. According to published academic research referenced by the Mercatus Center, most households have discount rates higher than 7 percent, with low-income households having particularly high discount rates. Therefore, the Mercatus Center urged NHTSA to rely on discount rates of 12 percent for all households and as high as 20 percent for low-income households in evaluating proposed standards.

Opposing viewpoints were provided by Environmental Defense, NRDC, and the Union of Concerned Scientists. These organizations expressed their belief that a 7-percent discount rate is too high, proposing instead a rate of 3 percent. Environmental Defense and NRDC stated that OMB Circular A-4 (2003) recommends a discount rate of 3 percent when the regulation directly affects private consumption. These commenters asserted that the CAFE regulation primarily and directly affects private consumption (i.e., by affecting the sales price of new vehicles and reducing the per-mile cost of driving). NRDC also argued that OMB Circular A-4 further indicates that lower rates may be appropriate for rules that produce benefits over multiple generations (as asserted by the commenter may be the case here with reductions in greenhouse gas emissions resulting from stricter CAFE standards). Thus, these commenters recommended that a discount rate reflecting the social rate of time preference (i.e., a 3 percent real rate) should be used.

The Union of Concerned Scientists also commented that NHTSA’s methodology for calculating the discounted present value of certain external costs and benefits appears to be inconsistent. Specifically, the commenter stated that the benefits of petroleum market effects (monopsony and disruption cost reductions) and reduced emissions of particulate matter (PM) and SOx and the external costs of increased congestion, noise, and crashes, appear to be discounted differently from the fuel cost savings, driving time, and refueling time savings. The Union of Concerned Scientists urged NHTSA to utilize the same methodology for calculating the discounted present value of all such CAFE-related elements.

The Alliance advocated the use of a 12 percent discount rate because this value was used in the NAS report and approximates the used car loan rate published in the Consumer Expenditure Survey. However, the NAS report did not use a single discount rate. Instead, the NAS used a range of 12 percent (based on 14 years of fuel savings) and 0 percent (based on 3 years of fuel savings) due to the assumption of the proper discount rate being “subjective.” Therefore, NAS did not advocate a particular discount rate.

As explained below, the vehicle loan rate faced by consumers is an appropriate measure of the discount rate. However, the loan rate for both new and used cars should be considered, since vehicles affected by this regulation will likely be sold in both the new and used car markets. In contrast, loan estimates provided by both General Motors and Criterion Economics are considerably higher than data from the Federal Reserve, which estimates new loan rates (as of October 2005) of 6 percent for new cars and 9 percent for used cars. In addition, the Mercatus Center cited studies that examined the implied discount rate of energy-conserving devices such as furnaces and air conditioners (not vehicles), concluding that consumers have a high discount rate. However, these studies were conducted in the late 1970’s and early 1980’s and are not representative of current economic conditions.

In response to the comments of Environmental Defense, the Union of Concerned Scientists, and NRDC, the guidelines in OMB Circular A-4 state that the agency should analyze the costs and benefits of a regulation at a 3 percent and 7 percent discount rate. The Circular does not state what discount rate should be used to determine the actual standards. In accordance with these guidelines, the agency analyzes the impacts of costs and benefits using both discount rates.

As explained below, the car loan rate is used as the appropriate discount rate to determine the standards, because the agency believes it is the opportunity cost faced by consumers when buying vehicles with greater fuel economy and a higher purchase price. Since the majority of both new and used vehicles are financed (70 percent, according to recent data from CNW Marketing/Research), and since the vast majority of the benefits of higher fuel economy standards accrue to vehicle purchasers in the form of fuel savings, the appropriate discount rate is the car loan interest rate paid by consumers.

According to the Federal Reserve[55], the interest rate on new car loans made through commercial banks has closely tracked the rate on 10-year Treasury notes, but exceeded it by about 3 percent (Federal Reserve Board). The official Administration forecast is that real interest rates on 10-year Treasury notes will average about 3 percent through 2016, implying that 6 percent is a reasonable forecast for the real interest rate on new car loans. During the last five years, the interest rate on used car loans made through commercial banks has closely tracked the rate on new car loans made through auto financing companies, but exceeded it by about 3 percent (Federal Reserve Board). Thus, given the 6 percent estimate for new car loans, a reasonable forecast for used car loans is 9 percent. Since the benefits of fuel economy accrue to both new and used car owners, a discount rate between 6 percent and 9 percent is appropriate. Both new car loans and used car loans are approximately 60 months in duration (Federal Reserve Board). This suggests that 7 percent is very close to the average opportunity cost for CAFE investment faced by buyers and is used by the agency to represent equivalent present value fuel savings.

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[55] http://www.federalreserve.gov/Releases/G20/hist/fc_hist_tc.txt

Sales Projections

A critical variable affecting the total economic benefits from improving light truck fuel economy is the number of vehicles likely to be produced under stricter CAFE standards. Forecasts of total light truck sales for future years (see Table VIII-1) were obtained from the Energy Information Administration's (EIA) *Annual Energy Outlook 2005* (*AEO 2005*), a standard government reference for forecasts of energy production and consumption in different sectors of the U.S. economy.[56] NHTSA estimated the sales by manufacturer, based to some degree by information provided by the manufacturers. These values will be used as multipliers to estimate the overall impacts (both costs and benefits) of changes in CAFE standards.

Table VIII-1
Sales Projections

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
BMW	72,435	74,354	75,653	76,202	76,202
Daimler Chrysler	1,980,958	2,065,464	2,103,952	2,123,432	2,119,566
Ford	1,665,146	1,716,454	1,740,194	1,859,273	1,772,750
Fuji – Subaru	93,405	95,883	97,556	98,266	98,266
General Motors	2,221,561	2,277,294	2,320,694	2,482,394	2,336,848
Honda	560,177	575,025	585,058	589,308	589,308
Hyundai	309,995	318,209	323,761	326,113	326,113
Isuzu	35,266	36,202	36,828	37,098	37,098
Mitsubishi	110,889	113,830	115,816	116,656	116,656
Nissan	490,032	503,020	507,606	515,513	511,292
Porsche	15,118	15,519	15,789	15,904	15,904
Suzuki	25,797	26,481	26,944	27,138	27,138
Toyota	996,232	1,022,646	1,040,487	1,048,039	1,048,039
Volkswagen	24,112	24,749	25,183	25,364	25,364
Fleet Total	8,601,123	8,865,130	9,015,521	9,340,700	9,100,544

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[56] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2005*, Table 45,. http://www.eia.doe.gov/oiaf/aeo/index.html.

Benefits from Fuel Savings

The main source of economic benefits from the final rule for light truck CAFE standards is the value of the resulting fuel savings over the lifetimes of vehicles that are required to comply with the stricter standards. These fuel savings for each scenario are measured by the difference between total lifetime fuel use by light trucks of each model year at 22.2 mpg (or the values supplied for each model in manufacturers' product plans if those are higher), and the fuel economy levels corresponding to that scenario in effect. The sum of these annual fuel savings over each calendar year that light trucks from a model year remain in service represents the cumulative fuel savings resulting from applying the final rule to vehicles produced during that model year.

Actual fuel economy levels for each future model year's light trucks under the current CAFE standard and with alternative scenarios in effect were estimated using the model of fuel economy technology application described in Chapter VI. Under current standards, the average actual fuel economy for all new light trucks manufactured during each model year is expected to slightly exceed the prevailing standards on an industry –wide basis. However, the actual fuel economy levels achieved by light trucks in on-road driving falls significantly short of the level measured under test conditions, and the actual fuel economy performance of each future model year is adjusted to reflect the expected size of the fuel economy "gap" of 15 percent.

The agency assumes that there is a 15 percent difference between the EPA fuel economy rating and the actual fuel economy achieved by vehicles on the road. For example, if the overall EPA fuel economy rating of a light truck is 20 mpg, the actual on-road fuel economy achieved by the average driver of that vehicle is expected to be 17 mpg (20*.85). NRDC and the Union of Concerned Scientists commented that the 15-percent reduction the agency applied to reported fuel economies to adjust for in-use fuel economy performance is too low, and both commenters recommended using an on-road gap of 20 percent. The Union of Concerned Scientists stated that the EPA is in the process of revising its estimates of real-world fuel economy in response to widespread consumer dissatisfaction with the reliability of its present adjustment. In support of its recommendation to use a 20-percent reduction, NRDC cited the range of 20 to 23 percent relied upon by EIA's National Energy Modeling System (NEMS) over the expected lifetimes of MY 2008-2011 vehicles (see AEO2005 Table 47).

General Motors stated that it agrees with a 15 percent on-road fuel economy gap.
On February 1, 2006, the Environmental Protection Agency proposed changes to their fuel economy labeling to more closely match on-road fuel economy. In its proposal, EPA estimated that the actual highway driving fuel economy estimate would be 5 to 15 percent lower than the EPA fuel economy rating and that the actual city driving fuel economy estimate would be 10 to 20 percent lower than the EPA fuel economy rating for most vehicles. The EPA has not issued a final rule on this issue. However, the agency will reassess its estimate for the next CAFE rulemaking in light of any final changes in the EPA assessment.

The number of light trucks manufactured during each model year that remains in service during each subsequent calendar year is estimated by applying estimates of the proportion of vehicles surviving to each age up to 36 years (Table VIII-2). These "survival rates," which are estimated from experience with recent model-year light trucks, are slightly different than the survival rates used in past NHTSA analyses since they reflect recent increases in durability and usage of more recent light truck models.[57] Updated estimates of average annual miles driven by vehicle age were developed from the Federal Highway Administration's 2001 National Household Transportation Survey, and also differ from those employed in past NHTSA analyses (Table VIII-2).[58] The total number of miles driven by light trucks of a single model year during each year of its life span in the fleet with the base CAFE standard of 22.2 mpg in effect is estimated by multiplying these age-specific estimates of annual miles driven per vehicle by the number of vehicles projected to remain in service at each age (Table VIII-2).

Table VIII-2 provides new schedules of vehicle miles traveled and survivability based on updated analyses performed by NHTSA. Vehicle survivability and vehicle miles traveled (VMT) schedules for light trucks were developed from 1977 to 2003 registrations and 2001 mileage survey data. In this analysis, vehicle age was cut off when approximately two percent of the fleet remained (at 25 years for passenger cars and 36 years for light trucks). Thus, the lifetime of a light truck was extended to 36 years to arrive at 179,954 miles, and benefits are

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[57] The survival rates were calculated from R.L. Polk, National Vehicle Population Profile, 1977-2002; see NHTSA, "Vehicle Survivability and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, NCSA, January 2006, pp. 9-11, Docket No. 22223-2218.

[58] See also NHTSA, "Vehicle Survivability and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, January 2006, pp. 15-17.

calculated over this 36-year lifetime. The previous lifetime VMT estimate was 153,698 (25 years) for light trucks. It should be noted, however, that survivability weighted VMT after year 25 is extremely low (less than 1,000 miles per year) and has little impact on benefits after discounting.

General Motors questioned whether NHTSA's estimate of the average vehicle's lifetime mileage (152,032 miles) was overstated. NADA also cautioned that the agency's fuel conservation predictions should reflect an appropriate range of fuel price and vehicle-miles-traveled assumptions. As noted above, the agency has published a recent analysis of vehicle miles traveled supporting these estimates.

The primary source of data for determining vehicles in operation is the National Vehicle Population Profile (NVPP) compiled by R.L. Polk and Company. The NVPP is an annual census, as of July 1 of each year, of passenger cars and light trucks registered for on-road operation in the United States. NVPP registration data was utilized from vehicle model years 1977 to 2003. Survival rates were averaged for the five most recent model years for vehicles up to 20 years old.

The 2001 National Household Travel Survey (NHTS)—previously called the Nationwide Personal Transportation Survey (NPTS)—sponsored by the Federal Highway Administration, Bureau of Transportation Statistics, and the National Highway Traffic Safety Administration attempted to develop up-to-date VMT behavior. The NHTS is the integration of two national travel surveys: the Federal Highway Administration-sponsored Nationwide Personal

Transportation Survey (NPTS) and the Bureau of Transportation Statistics-sponsored American Travel Survey (ATS). The 2001 NHTS was the source of updated VMT information.

Finally, it should be noted that these estimates, while new for NHTSA, are based on historical data (based on 2001 vehicle miles traveled) with the applicable historical price of gasoline (the price at the pump in 2001). As such, they are changed in this analysis based on the projected price of gasoline and the rebound effect, to be discussed later in this chapter. Two factors affect the cost of gasoline per mile driven - fuel prices and miles-per-gallon. Because the intensity of vehicle use depends partly on the cost per mile of driving, the estimates of light truck use developed from NHTS data reflect the fuel prices and light truck fuel economy levels that prevailed during 2000 and 2001, when the survey was conducted. In analyzing the final rule, the agency adjusted the annual usage estimates derived from the NHTS data to reflect the effect of the higher EIA fuel prices that are forecast over the covered vehicles' expected lifetimes, which exceed those that existed during 2000-2001.

Specifically, the adjustment accounted for the difference between the average price per gallon of fuel forecast over the expected lifetimes of model year 2008-2011 light trucks and the average price that prevailed during 2000 and 2001 was first calculated. When expressed in percentage terms, this difference was assumed to represent the percent increase in fuel cost per mile driven between the time the survey was conducted and the time period when model year 2008-2011 light trucks would be in service. The same elasticity of annual light truck use with respect to fuel cost per mile that was used to estimate the increase in light truck use resulting from improved fuel economy (the "rebound effect"), assumed to be –0.20, was applied to this percent difference to adjust the estimates of light truck use derived from the survey to reflect the effect of higher future fuel prices. In contrast, this adjustment reduces model year 2008-2011 light trucks' average annual usage at each age to account for the fact that fuel cost per mile driven is expected to be higher throughout their expected lifetimes than at the time the NHTS was conducted. The primary result of this adjustment is that fuel-saving technologies produce lowers benefits in terms of fuel savings, than they would under the VMT schedule relied on for the NPRM.

Table VIII-2
Vehicle Miles Traveled and Survival Rates
By Age for Light Trucks
(Based on 2001 data)

Vehicle Age	Estimated Survivability	Estimated VMT	Weighted Yearly Travel Miles
1	0.9741	16,085	15,668
2	0.9603	15,782	15,155
3	0.9420	15,442	14,547
4	0.9190	15,069	13,849
5	0.8913	14,667	13,072
6	0.8590	14,239	12,230
7	0.8226	13,790	11,343
8	0.7827	13,323	10,428
9	0.7401	12,844	9,506
10	0.6956	12,356	8,595
11	0.6501	11,863	7,712
12	0.6040	11,369	6,867
13	0.5517	10,879	6,002
14	0.5009	10,396	5,207
15	0.4522	9,924	4,488
16	0.4062	9,468	3,846
17	0.3633	9,032	3,281
18	0.3236	8,619	2,790
19	0.2873	8,234	2,366
20	0.2542	7,881	2,004
21	0.2244	7,565	1,697
22	0.1975	7,288	1,440
23	0.1735	7,055	1,224
24	0.1522	6,871	1,046
25	0.1332	6,739	898
26	0.1165	6,663	776
27	0.1017	6,648	676
28	0.0887	6,648	590
29	0.0773	6,648	514
30	0.0673	6,648	448
31	0.0586	6,648	389
32	0.0509	6,648	339
33	0.0443	6,648	294
34	0.0385	6,648	256
35	0.0334	6,648	222
36	0.0290	6,648	193
Estimated Lifetime Light Truck VMT			179,954

Table VIII-2a
Average Annual Miles Driven by Age for Light Trucks

Age	All Light Trucks	Pickups	SUVs	Vans
1	16,085	16,869	16,270	16,321
2	15,782	16,270	15,786	15,951
3	15,442	15,681	15,316	15,555
4	15,069	15,105	14,859	15,135
5	14,667	14,541	14,417	14,693
6	14,239	13,990	13,988	14,234
7	13,790	13,453	13,571	13,759
8	13,323	12,931	13,167	13,271
9	12,844	12,424	12,775	12,774
10	12,356	11,932	12,395	12,270
11	11,863	11,457	12,025	11,763
12	11,369	10,999	11,667	11,255
13	10,879	10,559	11,320	10,750
14	10,396	10,138	10,983	10,249
15	9,924	9,736	10,656	9,757
16	9,468	9,353	10,338	9,275
17	9,032	8,991	10,031	8,808
18	8,619	8,650	9,732	8,358
19	8,234	8,331	9,442	7,927
20	7,881	8,034	9,161	7,519
21	7,565	7,761	8,888	7,137
22	7,288	7,511	8,623	6,783
23	7,055	7,285	8,367	6,461
24	6,871	7,085	8,118	6,174
25	6,739	6,911	7,876	5,923
26	6,663	6,762	7,641	5,714
27	6,648	6,641	7,414	5,547
28	6,648	6,548	7,193	5,427
29	6,648	6,483	6,979	5,355
30	6,648	6,448	6,771	5,336
31	6,648	6,448	6,771	5,336
32	6,648	6,448	6,771	5,336
33	6,648	6,448	6,771	5,336
34	6,648	6,448	6,771	5,336
35	6,648	6,448	6,771	5,336
36	6,648	6,448	6,771	5,336

Table VIII-2b
Projected Vehicle Miles Traveled and Survival Rates
By Age for Light Trucks
(Based on Projected Fuel Price and Rebound Effect)

Vehicle Age	**Estimated Survivability**	**Estimated VMT**	**Weighted Yearly Travel Miles**
1	0.9741	14,941	14,554
2	0.9603	14,660	14,078
3	0.9420	14,345	13,513
4	0.9190	13,998	12,864
5	0.8913	13,624	12,143
6	0.8590	13,226	11,361
7	0.8226	12,809	10,537
8	0.7827	12,376	9,687
9	0.7401	11,931	8,830
10	0.6956	11,478	7,984
11	0.6501	11,020	7,164
12	0.6040	10,561	6,379
13	0.5517	10,105	5,575
14	0.5009	9,657	4,837
15	0.4522	9,219	4,169
16	0.4062	8,795	3,573
17	0.3633	8,390	3,048
18	0.3236	8,006	2,591
19	0.2873	7,649	2,198
20	0.2542	7,321	1,861
21	0.2244	7,027	1,577
22	0.1975	6,770	1,337
23	0.1735	6,554	1,137
24	0.1522	6,382	971
25	0.1332	6,259	834
26	0.1165	6,189	721
27	0.1017	6,175	628
28	0.0887	6,175	548
29	0.0773	6,175	477
30	0.0673	6,175	362
31	0.0586	6,175	314
32	0.0509	6,175	274
33	0.0443	6,175	238
34	0.0385	6,175	206
35	0.0334	6,175	179
36	0.0290	6,175	179
Estimated Lifetime Light Truck VMT			166,927

The results are shown for all LTVs in Table VIII-2b.

To determine the impact of improved CAFE standards, fuel consumption is calculated using both current and revised CAFE levels. The difference between these estimates represents the net savings from increased CAFE standards. With the current CAFE standard assumed to remain in effect, total fuel consumption by each model year's light trucks during each calendar year they remain in service is calculated by dividing the total number of miles they are driven during that year by the average on-road fuel economy level they would achieve under the 22.2 mpg standard. With the final rule in effect, total fuel consumption by each model year's light trucks during each future calendar year is calculated by dividing the total number of miles they are driven by the higher on-road fuel economy level associated with that stricter CAFE standard. The total number of miles that light trucks are driven each year is different under the final rule than with the current 22.2 mpg standard remaining in effect as a result of the fuel economy "rebound effect," which is discussed in detail later in this chapter.

The economic benefits to vehicle owners that result from future fuel savings are valued in this analysis over the complete expected lifetimes of the vehicles affected by the final rule. This reflects the assumption that while the purchaser and first owner of a new vehicle might not realize the full lifetime benefits of improved fuel economy, subsequent owners of that same vehicle will continue to experience the resulting fuel savings until the vehicle is retired from service. It is important to note, however, that not all vehicles produced during a model year remain in service for the complete 36-year lifetime of each model year assumed in this analysis.

Due to the pattern of vehicle retirement over this period, the expected or average lifetime of a representative vehicle is approximately half of that figure.

Commenters differed in terms of their recommended approach for properly assessing consumer valuation of fuel economy and the payback period for fuel-saving technologies. As discussed below, some commenters favored focusing on the preferences of individual consumers using a short-term perspective, while others recommended focusing on the societal benefits to all consumers over the long term.

General Motors requested that the agency compare consumer preference for fuel economy versus vehicle utility, in order to determine consumer valuation of improved fuel economy. General Motors also asked NHTSA to consider how many vehicle sales would be deferred due to CAFE-related price increases. According to General Motors, history has shown that consumers value fuel economy increases of up to 1.2 percent per year, so any higher standard forces consumers to accept a lower level of performance utility than they would otherwise choose. However, General Motors did state that consumers are well informed and extremely rational, arguing that car buyers are less concerned with fuel economy improvements when gasoline costs $1.50 per gallon, as compared to marginal improvements when gasoline costs $2.50 per gallon.

According to the NADA, recent new light truck sales data suggest that, despite higher fuel prices, consumers continue to rank fuel economy below other purchase considerations, such as capacity, convenience, utility, performance, and durability. Thus, NADA suggested that NHTSA’s fuel economy standards should not be permitted to result in undue constraints on light truck product availability or in significant price increases, which could in turn result in reduced sales, profits, and workforces, and the retention of older vehicles with poorer fuel efficiency. The California State Energy Commission commented that stringency levels of fuel economy targets should be established by considering the value of fuel savings from vehicle owners' perspective over the first few years of each model year's lifetime, rather than from a society-wide perspective. For example, the California State Energy Commission argued that consumers appear to attach some value to owning hybrid vehicles beyond the fuel savings they produce, sometimes paying large price premiums (up to $3,500 compared to equivalent gasoline-powered models) and waiting extended periods of time for such vehicles to become available. The commenter stated that the size of the hybrid vehicle market is expected to grow significantly by MY 2010. According to the California State Energy Commission, such consumer valuation considerations should be taken into account as part of the CAFE standards.

Conversely, Environmental Defense argued that technology application should be based on societal costs, not private costs, and that the agency needs to consider benefits over the lifetime of the vehicle, as opposed to the consumer time horizon of 4.5 years.

CAFE's most immediate impacts are on individual consumers, but regulating fuel economy also has a broader societal impact that must be considered. The agency believes that CAFE standards should reflect the true economic value of resources that are saved when less fuel is produced and consumed, higher vehicle prices, and, to the extent possible, any externalities that impact the broader society. Consumers' perceptions of these values may differ from their actual impacts, but they will nonetheless experience the full value of actual fuel savings just as they will pay the full increased cost when the vehicle is purchased. Moreover, owners will realize these savings throughout the entire on-road life of each vehicle. Initial purchasers may only experience fuel savings for the limited time they typically own a new vehicle (4.5 years), but subsequent (used vehicle) purchasers will continue to experience savings throughout the vehicle's useful life. The agency does restrict its analysis of sales impacts to a 4.5 year period under the assumption that initial buyer's purchase behavior will be influenced only by their perception of benefits they will receive while owning the vehicle, as opposed to benefits flowing to subsequent owners. However, the agency believes that the lifetime value of impacts from CAFE improvements should be fully reflected in its analysis of societal impacts that will determine CAFE standards.

The economic value of fuel savings resulting from the final rule is estimated by applying the forecast of future fuel prices from the Energy Information Administration's *Annual Energy Outlook 2006 (Early Forecast)* to each future year's estimated fuel savings.[59] These future fuel prices, which are reported in Table VIII-3, represent the retail price of fuel per gallon including Federal and State taxes. While the retail price of fuel is the proper measure for valuing fuel savings from the perspective of vehicle owners, two adjustments to the retail price are necessary in order to reflect the economic value of fuel savings to society as a whole. First, Federal and State taxes are excluded from the social value of fuel savings because these do not reflect costs of resources used in fuel production, and thus do not reflect resource savings that would result from reducing fuel consumption. Taxes are transfer payments from one segment of the population to another. Any reduction in State and Federal fuel tax payments by consumers will

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[59] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006*, Table 12, http://www.eia.doe.gov/oiaf/aeo/index.html.

reduce government revenues, and thus services, by the same amount. The benefit derived from lower taxes to individuals is thus offset by a reduction in services provided to society.

Second, the economic cost of externalities generated by imports and consumption of petroleum products will be reduced in proportion to gasoline savings resulting from the final rule. The estimated economic value of these externalities is converted into its per-gallon equivalent and added to the pre-tax price of gasoline in order to measure this additional benefit to society for each gallon of fuel saved. This also allows the magnitude of these externalities to be easily compared to the value of the resources saved from reduced fuel production and use, which represent the most important component of the social benefits from saving gasoline. Table VIII-3 illustrates the adjustment of forecast retail fuel prices to remove the value of fuel taxes and add the value of economic externalities from petroleum imports and use. The derivation of the estimated value of reduced economic externalities from petroleum use shown in the table is explained in detail in the following section.

The agency realizes that there has been a recent surge in the price of gasoline. The fuel prices used in this analysis reflect the most recent projections by the Department of Energy. These projections were published in early 2006 and were made after the fourth quarter 2005 surge in gasoline prices. They thus reflect the Department of Energy’s best estimate in light of recent domestic and international events which drove up fuel prices over the past year. The uncertainty analysis uses two other fuel price scenarios from DOE to examine a range of possible fuel price scenarios (see Chapter X).

Many commenters stated that the fuel price estimates used in the agency's analysis and modeling were too low and should be revised to reflect the best current projections of market prices (SUVOA, NADA, Mercatus Center, Union of Concerned Scientists, California State Energy Commission). Environmental organizations, citing the record prices for fuel at the pump, went further, arguing that more stringent standards are justified (Environmental Defense, NRDC, ACEEE).

In contrast, vehicle manufacturers requested that the agency not rely solely on higher fuel price forecasts to automatically increase the stringency of the CAFE standards (the Alliance, General Motors, Mitsubishi). Such commenters urged the agency to not allow CAFE standards to rise precipitously based upon a spike in oil commodity prices, thereby disregarding technology costs and other limitations. Specific comments related to fuel prices follow below.

Environmental Defense argued that NHTSA's fuel price estimates in its CAFE proposal, based upon AEO2005, are too low. While Environmental Defense acknowledged NHTSA's stated intention to revise its fuel prices estimates in light of AEO2006 projections, it argued that even this forecast may be too low, particularly in light of private oil price estimates of $42 to $100 per barrel over the analysis period. Accordingly, Environmental Defense urged NHTSA to utilize the best available fuel price forecasts in revising the level of the standards in the final rule.

NRDC made a similar argument regarding the proposal's fuel prices estimates, which it perceives to be too low. To remedy this problem, NRDC recommended that the agency use fuel price forecasts consistent with the world oil price forecasts reported in EIA's "High B Oil Price

Scenario" or the International Energy Agency's World Energy Outlook 2005 "Deferred Investment Scenario," forecasts which NRDC suggested are more consistent with recent world oil prices and current petroleum futures market prices.

As another suggestion for revising the NPRM's fuel prices estimates, the California State Energy Commission stated that future fuel prices are likely to be at least as high as the "Base Case" scenario adopted in the 2005 Integrated Energy Policy Report for California, which forecasts retail fuel prices (including Federal and California State taxes). The Commission recommended using this forecast, which it argued is more consistent with current fuel prices. According to the commenter, recent EIA forecasts (at least since 1996) have significantly underestimated actual future fuel prices.

The Alliance stated that while higher gasoline price forecasts may appear to justify further increases in fuel economy levels, "NHTSA must proceed carefully and consider all of the ramifications of moving to higher levels than those proposed." Along the same lines, General Motors commented that increased fuel prices could lead to significantly higher CAFE standards under NHTSA's model; according to General Motors, a recent study by Resources for the Future (RFF) found that increasing the price per barrel of oil by $20 would lead to a CAFE target 4 mpg higher.

In its comments, General Motors also compared the American light truck fleet with the European light truck fleet, stating that Europeans pay approximately $5 per gallon for gasoline, yet their vehicles do not use technologies beyond those present in the U.S. fleet. An appendix to General

Motors' comments further analyzed the differences in fuel economy between American and European vehicles, suggesting that the fuel economy of vehicles on both sides of the Atlantic is roughly comparable, once other relevant factors are taken into account (*e.g.*, vehicle weight, transmission type, engine power, engine type, and premium gas usage). General Motors asked the agency to explain this apparent discrepancy between real world experience in Europe and NHTSA's analysis.

General Motors also stated that NHTSA's analysis did not use the proper value for the tax on gasoline, which the American Petroleum Institute (API) currently reports to be $0.46 per gallon.

Mitsubishi stated that fuel prices are currently in a state of flux and recommended using AEO2006 in the final rule. However, Mitsubishi cautioned that raising the fuel economy target levels, based upon higher fuel prices, might not be economically practicable and could force manufacturers to completely reanalyze their business strategies.

The Mercatus Center commented that as part of the final rule, the agency should increase its fuel price forecasts and take steps to adequately address likely future volatility of fuel prices. Specifically, the Mercatus Center recommended adjusting the baseline sales mix and fuel economy levels from manufacturer product plans for future model years to reflect shifts in sales patterns toward more fuel-efficient models resulting from current high fuel prices and buyer concerns about continued fuel price volatility. It also urged NHTSA to include a separate estimate of the economic value of reduced fuel price volatility expected to result from lower fuel use.

Several commenters also noted that the State gasoline taxes in some States were changing as of January 1, 2006 and that the agency should update their gasoline tax estimates accordingly.

The agency will continue to rely on the most recent fuel price projections from the Energy Information Administration (EIA) from the Department of Energy. We consider the EIA projections to be the most reliable long-range projections. No one can predict the impact of hurricanes and other external factors that could affect the price of gasoline at particular points in time or in the short term. However, the agency's analyses require long range projections from 2008 through 2047. Accordingly, we have decided to utilize the EIA's Annual Energy Outlook 2006, which is the most recent projection available, and considers the most recent events.

Specifically, the latest fuel price projections are taken from the EIA's *Annual Energy Outlook 2006* (*AEO2006*) reference case, translated into 2003 economics to match other cost estimates in the analysis, and are extrapolated until 2047 to match the 36-year lifetime for light trucks produced for MY 2011. AS Table VIII-3 shows, the estimated gasoline price per gallon in 2003 economics varies over the time period, starting at $2.16 in 2008, reducing to $1.96 in 2014, and then increasing to $2.39 by 2047.

The agency will consider additional fuel price projections (higher and lower than the reference case) from EIA in its uncertainty analysis; however, there is no way to adequately predict or analyze the volatility of fuel prices.

Since gasoline taxes are a transfer payment and not a societal cost, the value of gasoline taxes is subtracted from the estimated gasoline price to estimate the value of saving gasoline to society. The agency has updated its estimates of gasoline taxes, using the January 1, 2006 update in State gasoline taxes. In 2003 economics, in 2006, Federal taxes are $0.176 and State and local taxes average $0.262 for a total of $0.438. Following the assumptions used by EIA in its National Energy Modeling System (NEMS), state and local gasoline taxes are assumed to keep pace with inflation in nominal terms, and thus to remain constant when expressed in constant 2003 dollars. In contrast, federal gasoline taxes are assumed to remain unchanged in nominal terms, and thus to decline throughout the forecast period when expressed in constant 2003 dollars. These differing assumptions about the likely future behavior of federal and state/local fuel taxes are consistent with recent historical experience, and reflect the fact that Federal motor fuel taxes and most State taxes are specified on a cents-per-gallon basis (some are a percentage of the price), and typically require legislation to change.

As discussed elsewhere in this document, the agency has carefully considered the broad ramifications of the final rule and alternative stringency levels, and has not increased the fuel economy levels solely on the basis of a projection of higher gasoline prices.

The agency does not believe it is necessary to try to explain the difference in fuel prices and technology between Europe and the United States, as requested by General Motors. As General Motors points out in its comments, there are a variety of factors which differentiate the U.S. and Europe. These jurisdictions have different legal/regulatory frameworks, and their driving publics have different expectations, all of which vehicle manufacturers endeavor to accommodate. Thus, the fuel economy situations in Europe and the U.S. are not directly comparable, and any such effort would entail an extensive analysis, which is likely to generate inconclusive results and which is well beyond the scope of this rulemaking.

Table VIII-3
Adjustment of Forecast Retail Gasoline Price
to Reflect Social Value of Fuel Savings
(all figures in year 2003 dollars)

Year	**AE0 2006 Fuel Price Forecast (2003$/gallon)**	**Total Federal and State Taxes (2003$/gallon)**	**Fuel Price Excluding Taxes (2003$/gallon)**
2008	$2.161	$0.430	$1.731
2009	$2.086	$0.427	$1.659
2010	$1.999	$0.423	$1.576
2011	$2.000	$0.420	$1.580
2012	$1.985	$0.416	$1.569
2013	$1.975	$0.412	$1.563
2014	$1.960	$0.409	$1.551
2015	$1.969	$0.405	$1.564
2016	$1.983	$0.402	$1.581
2017	$1.993	$0.399	$1.594
2018	$2.007	$0.395	$1.612
2019	$2.023	$0.392	$1.631
2020	$2.048	$0.388	$1.660
2021	$2.062	$0.385	$1.677
2022	$2.075	$0.381	$1.694
2023	$2.086	$0.378	$1.708
2024	$2.095	$0.374	$1.721
2025	$2.105	$0.371	$1.734
2026	$2.116	$0.371	$1.745
2027	$2.123	$0.371	$1.752
2028	$2.135	$0.371	$1.764
2029	$2.145	$0.371	$1.774
2030	$2.157	$0.371	$1.786
2031	$2.169	$0.371	$1.798
2032	$2.182	$0.371	$1.811
2033	$2.195	$0.371	$1.824
2034	$2.208	$0.371	$1.837
2035	$2.221	$0.371	$1.850
2036	$2.235	$0.371	$1.864
2037	$2.248	$0.371	$1.877
2038	$2.261	$0.371	$1.890
2039	$2.275	$0.371	$1.904
2040	$2.288	$0.371	$1.917
2041	$2.302	$0.371	$1.931
2042	$2.315	$0.371	$1.944
2043	2.329	$0.371	$1.958
2044	2.343	$0.371	$1.972
2045	2.357	$0.371	$1.986
2046	2.371	$0.371	$2.000
2047	2.385	$0.371	$2.014

Other Economic Benefits from Reducing Petroleum Use

U.S. consumption and imports of petroleum products may impose costs on households and businesses that are not reflected in the market price for imported oil or by consumers of petroleum products. Increasing imports of crude oil or refined petroleum products into the U.S. may increase the magnitude of these external economic costs, thus increasing the true cost of importing additional oil supplies by an amount that exceeds the market price of increased oil purchases themselves. More broadly, increasing U.S. consumption of petroleum products may increase these costs regardless of whether they are imported or refined domestically. In either case, gasoline savings resulting from the final rule may produce additional benefits in the form of reductions in these external costs from petroleum use that are not reflected in the market price of gasoline, and thus must be accounted for separately from the savings in resources for producing gasoline itself.

The full economic cost of importing petroleum into the U.S. is often defined to include three components in addition to the purchase price of petroleum itself. These are: (1) higher costs for oil imports resulting from the combined effect of U.S. import demand and OPEC market power on the world oil price; (2) the risk of reductions in U.S. economic output and disruption of the domestic economy caused by sudden reductions in the supply of imported oil to the U.S.; and (3) costs for maintaining a U.S. military presence to secure imported oil supplies from unstable regions, and for maintaining the strategic petroleum reserve (SPR) to cushion against resulting price increases. The following discussion reviews the nature of each of these costs, assesses the degree to which they are likely to vary in response to changes in the level of oil imports, and provides empirical estimates of each component drawn from recent research.

Demand Costs

Demand or "monopsony" costs of U.S. oil consumption arise because the U.S. is a sufficiently large purchaser of foreign oil supplies that its purchases can affect the world oil price. U.S. "monopsony" power means that increases in domestic petroleum demand can cause the world price of oil to rise, and conversely that declining U.S. oil purchases can reduce the world price of oil. Thus one consequence of increasing U.S. oil purchases is an increase in the price paid for *all* oil purchased by the U.S., including both imported and domestically-produced petroleum, since changes in the world oil price also affect the price of domestically-produced oil.

This demand or monopsony effect can be readily illustrated with an example. If the U.S. purchases 10 million barrels per day at a world oil price of $20 per barrel, its total daily bill for oil purchases is $200 million. If an increase in U.S. demand to 11 million barrels per day causes the world oil price to rise to $21 per barrel, the daily U.S. oil bill rises to $231 million (11 million barrels times $21 per barrel). The resulting increase in oil purchase payments of $31 million per day is attributable to increasing daily imports by only 1 million barrels, which means that the incremental cost of importing each additional barrel is $31, or $10 more than the newly-increased world price of $21 per barrel. This additional $10 per barrel represents the cost imposed on all U.S. oil purchasers by those responsible for the increase in U.S. oil demand, which is a cost in excess of the $21 per barrel price they pay for their increased oil purchases. This additional cost arises only because the increase in U.S. oil imports affects the world oil price.

The key determinants of the magnitude of this demand or price effect are the degree of monopoly power over foreign oil supplies that is exercised by the OPEC cartel, and the degree of monopsony power over world oil prices exerted by the U.S. If OPEC has no monopoly power, thenchanges in U.S. petroleum purchases will influence the world price of oil, thus creating the demand or monopsony cost of additional U.S. oil purchases. Under these same conditions, reductions in U.S. demand for petroleum would reduce the world oil price, thus creating additional benefits for all domestic oil purchasers beyond the savings they experience simply from purchasing less oil. In contrast, if OPEC has complete monopoly power over the world oil market, then it will adjust world oil supply in response to fluctuations in U.S. demand so that price changes will be zero.

The degree of current OPEC monopoly power is subject to considerable debate, but appears to have declined somewhat since the 1970s. Nevertheless, the consensus appears to be that OPEC remains able to exercise some degree of control over the response of world oil supplies to variation in world oil prices, so that the world oil market does not behave competitively. The extent of U.S. monopsony power is determined by a complex set of factors including the relative importance of U.S. imports in the world oil market, and the sensitivity of petroleum supply and demand to its world price among other participants in the international oil market. Most evidence appears to suggest that variation in U.S. demand for imported petroleum continues to exert some influence on world oil prices, although this influence appears to be limited.

Empirical estimates have been made of the demand component of the economic cost of additional petroleum purchases by the U.S. A particularly detailed and careful analysis by Leiby *et al*. (1997) estimated a range of values for this cost corresponding to approximately $1.50-3.50

per barrel expressed in year 2003 dollars.[60] In other words, the Leiby study estimated that reducing U.S. demand by one barrel saved a total of about $2.50 (using the midpoint of this range) by reducing the price of all other U.S. oil purchases when oil prices were at mid-1990s levels.

However, the savings in monopsony costs that results from reducing gasoline use (and thus U.S. oil demand) depends directly on the initial world oil price. The value of the monopsony effect used in this analysis reflects the Energy Information Administration's recent Annual Energy Outlook 2006 forecast of future world oil prices, which is significantly higher than previously projected by EIA. At the average world oil price of $46 per barrel (in 2003 dollars) projected in AEO 2006, reducing the level of U.S. oil imports would result in "social" cost savings to the U.S. economy of $2.56-4.00 per barrel beyond the direct savings in gasoline costs, using the range of values for the elasticity of oil imports suggested in the study by Leiby *et al*.. The midpoint of this range is equivalent to $0.078 per gallon of gasoline saved by a more stringent light truck CAFE standard.[61]

However, the agency also notes that part of the monopsony cost of increased U.S. oil consumption represents additional revenue received by domestic producers of petroleum, while the remainder of the added payments by U.S. oil purchasers resulting from higher world oil prices is received by foreign suppliers (including suppliers of both crude petroleum and refined

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[60] Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997.

[61] Depending on the extent to which OPEC were to respond to a decline in U.S. demand by reducing its output, the effect of CAFE on the world oil price would be lower, and could be zero.

products). As a result, that same fraction of any *reduction* in monopsony costs resulting from lower U.S. oil purchases is exactly offset by revenue losses to domestic petroleum producers, and does not represent a net savings to the U.S. economy. In contrast, the reduction in monopsony payments to foreign oil suppliers represents a net benefit to U.S. oil purchasers.

In order to include only the fraction of savings in monopsony payments that represents a net savings to the U.S. economy, , the reduction in monopsony costs from reduced fuel use must be adjusted downward to reflect the fraction of reduced fuel consumption that will be reflected in reduced U.S. purchases of imported petroleum. This includes both the fraction of fuel savings that results in reduced domestic refining of imported crude oil, and the fraction that results in lower imports of refined gasoline, which is produced from foreign-supplier crude petroleum. . This adjustment results in a net benefit from reduced monopsony payments by U.S. oil purchasers amounting to $0.044 per gallon.

Disruption and Adjustment Costs

The second component of the external economic costs resulting from U.S. oil consumption arises partly because the increase in oil prices triggered by a disruption in world oil supplies reduces the level of output that the U.S. economy can produce using its available resources. The resulting reduction in potential economic output depends on the extent and duration of any disruption in the world supply of oil to the U.S., since these determine the magnitude of the resulting increase in prices for petroleum products, as well as whether and how rapidly these prices return to their pre-disruption levels. Even if the world oil price returns to its original level, however, the nation's economic output will be at least temporarily reduced compared to the level that would have been possible without the disruption in oil supplies and consequent increase in energy prices.

Because supply disruptions and resulting price increases occur suddenly rather than gradually, they also impose additional costs on businesses and households for adjusting their use of petroleum products and other sources of energy more rapidly than if the same price increase had occurred gradually over time. These adjustments temporarily reduce the level of economic output that can be achieved even below the level that would ultimately be reached once the economy's adaptation of output levels and energy use to higher petroleum prices was complete. The additional costs imposed on businesses and households for making these adjustments reflect their inability to adjust prices, output levels, and their use of energy and other resources quickly and smoothly in response to rapid changes in prices for petroleum products.

Since future disruptions in foreign oil supplies are an uncertain prospect, each of these two components of the disruption cost must be weighted or adjusted for the probability that the supply of petroleum to the U.S. will actually be disrupted. Thus, the "expected value" of these costs – the product of the probability that an oil import disruption will occur and the sum of costs from reduced economic output and the economy's abrupt adjustment to sharply higher petroleum prices -- is the relevant measure of their magnitude. Further, only the *change* in their expected value that results from lowering the normal (pre-disruption) level of domestic petroleum use through a policy such as tightening CAFE standards is relevant when assessing its effect on the "true" cost of U.S. petroleum consumption.

While the vulnerability of the U.S. economy to oil price shocks depends on total petroleum consumption rather than on the level of oil imports, variation in imports may still have some effect on the magnitude of the price increase resulting from any disruption of import supply. In addition, changing the quantity of petroleum imported into the U.S. may also affect the probability that such a disruption will occur. If either the size of the resulting price increase or the probability that U.S. oil imports will be disrupted is affected by the pre-disruption level of oil imports, the expected value of the costs stemming from supply disruptions will also vary in response to the level of oil imports.

A variety of market mechanisms - including oil futures markets, energy conservation measures, and technologies that permit rapid fuel switching – are now available within the U.S. economy for businesses and households to anticipate and “insure” themselves against the effects of petroleum price increases. By employing these mechanisms – for example, by investing in energy conservation measures or installing technologies that can operate using multiple fuel sources – businesses and households can reduce their costs for adjusting to sudden increases in oil prices. While their availability has undoubtedly reduced the potential costs that could be imposed by disruptions in the world supply of oil, the remaining value of these costs is probably not reflected in the market price of petroleum.. This is because consumers of petroleum products are unlikely to take account of the potential costs that a disruption in oil supplies imposes on other sectors of the U.S. economy. Thus, changes in petroleum consumption continue to affect the expected cost to the U.S. economy from potential oil supply disruptions, although the current value of this component of oil consumption externalities is likely to be significantly smaller than those estimated by studies conducted in the wake of the oil supply disruptions that occurred during the 1970s.

Leiby *et al.* (1997) estimate that under reasonable assumptions about the probability that world supplies will be disrupted to varying degrees in the future, this component of the social cost of U.S oil consumption ranges from less than $1.00 to approximately $2.50 per additional barrel of oil consumed by the U.S., with adjustment costs accounting for the largest share of this total. Less recent studies of expected costs from prospective oil supply disruptions generally reported somewhat higher estimates, ranging from $2.00-3.00 per additional barrel at current import levels, but as indicated previously, these costs are likely to have declined over time.

Most other recent research focuses on the historical costs to the U.S. economy from actual supply disruptions, which seems unlikely to provide relevant evidence on the disruption costs associated with future variation in oil supplies. While some recent studies estimate costs to the U.S. economy from hypothetical future oil supply disruptions that imply higher values, these studies generally do not estimate the *changes* in these costs that would result from higher or lower levels of U.S. oil consumption.

Expressed in year 2003 dollars, this analysis uses an estimate of $2.00 per barrel for the incremental disruption cost component of the economic externalities resulting from U.S. petroleum consumption. Specifically, this implies that reductions in the level of U.S. gasoline consumption that result from tighter CAFE standards for light-duty trucks would produce additional benefits of $2.00 per barrel of petroleum saved, in addition to the value of savings in gasoline use itself. This figure is equivalent to about $0.045 per gallon ($2.00 per barrel/42 gallons per barrel) of gasoline saved.

Military Security and Strategic Petroleum Reserve Costs

The third component of the external economic costs of importing oil into the U.S. is usually identified as the costs to the U.S. taxpayers for maintaining a military presence to secure the supply of oil imports from potentially unstable regions of the world and to protect the nation against their interruption. Some analysts also include the costs to taxpayers for maintaining the U.S. Strategic Petroleum Reserve (SPR), which is intended to cushion the U.S. economy against the consequences of disruption in the supply of imported oil, as additional costs of protecting the U.S. economy from such oil supply disruptions. Thus, many analyses include part or all of the annual cost for U.S. military operations in the Persian Gulf (and occasionally other regions of the world), together with the full costs of stocking and maintaining the SPR, as additional economic costs associated with importing oil into the U.S.

The overall costs for U.S. military security and for maintaining the SPR may vary over time in response to long-term changes in the actual level of oil imports into the U.S., but these costs seem unlikely to decline from their current threshold level to a lower level in response to the reduction in the level of U.S. oil imports that would result from this particular rulemaking. In addition, military activities even in world regions that represent vital sources of oil imports undoubtedly serve a range of security and foreign policy objectives that is considerably broader than simply protecting oil supplies. Further, the scope and duration of any specific U.S. military activities that were undertaken for the purpose of protecting imported oil supplies seem unlikely to be tailored to the actual volume of petroleum imports from the regions where they take place. As a consequence, annual expenses to support U.S. military activities do not seem likely to vary closely in response to changes in the level of oil imports prompted by conservation efforts or other policies. More specifically, reductions in gasoline use resulting from stricter CAFE standards seem unlikely to result in savings in the military budget that could be included as additional benefits.

Similarly, while the optimal size of the SPR from the standpoint of its potential influence on domestic oil prices during a supply disruption may be related to the level of U.S. oil consumption and imports, its actual size has not appeared to vary in response to recent changes in the volume of oil imports. Thus while the budgetary costs for maintaining the Reserve are similar to other external costs in that they are not likely to be reflected in the market price for imported oil, these costs have not varied in response to changes in oil import levels (although in theory they might ideally do so). As a result, this analysis does not include any cost savings from maintaining a smaller SPR among the external benefits of reducing gasoline consumption and petroleum imports by means of a tighter CAFE standard for light-duty trucks.

General Motors commented extensively on the issue of externalities associated with the agency's CAFE proposal. As a general observation, General Motors stated that the CAFE proposal would result in a net externality cost on consumer welfare, because the externality costs (*e.g.*, congestion, noise, highway fatalities/injuries) exceed the externality benefits (*e.g.*, reduction in oil import dependence, reduction in pollution). General Motors stated that the agency's proposal did not identify any specific market failures that would justify its fuel economy regulation. The commenter asked the agency to present empirical estimates of reduced economic and environmental externalities resulting from the proposed CAFE standards, along with supporting analyses demonstrating how these benefits were estimated.

In its comments, General Motors also challenged certain specific figures related to externalities incorporated by the agency as part of the CAFE proposal. For example, General Motors expressed disagreement with the proposal's externality estimate of $0.106 per gallon, as well as the estimate of costs related to pollution. The commenter stated that the National Research Council estimates the total cost of economic and environmental externalities from fuel production and use to be $0.26 per gallon, and if this estimate is correct, consumers are already paying fuel taxes (which it estimated at $0.46 per gallon) that exceed the cost of these externalities. General Motors also asked the agency to address the research finding by Dr. Kleit purporting to show net negative costs for the MY 2004-2007 CAFE standards.

In addition, General Motors argued that higher steady-state oil prices reduce any demand costs or monopsony power, and energy demand from China and other emerging economies will only strengthen this trend. The company disagreed with the monopsony estimate of $0.061 per gallon relied upon by the agency. General Motors further argued that the agency relied upon the monopsony value reported in a 1997 study by Lieby *et al.*, but stated that this study assumes no cartel of producers such as OPEC. According to General Motors, in light of the potential for OPEC to respond to U.S. efforts to decrease demand, the monopsony value of $0.061 is too high. General Motors stated that like Resources for the Future, it believes that using U.S. monopsony power has marginal benefits at best, and that at worst, attempting to use it could actually provoke retaliatory pricing or supply responses by OPEC that would harm the U.S. economy.

General Motors also challenged the oil disruption cost of $0.045 per gallon included in the proposal. According to General Motors, the agency has not addressed Congressional Research Service and the Bohi and Toman studies which reported that the only reason for oil disruption is an increase in price (*i.e.*, an oil price "shock"), so because the CAFE standards do not affect the price of gasoline, there should be no disruption effect.

Criterion Economics commented that NHTSA's CAFE proposal "argued the wrong case," in that externalities alone should be the determinant of socially optimal CAFE levels (*i.e.*, allowing the marketplace to determine privately optimized CAFE targets). According to Criterion Economics, mandatory increases in fuel economy above market-determined levels would generate marginal private costs that exceed marginal private benefits. In support of its position that only externalities should be considered in setting CAFE standards, Criterion Economics provided a Figure illustrating the interaction of marginal social benefits, marginal social costs, marginal private benefits, and marginal private costs to argue that the market automatically determines the optimal level for private benefits. Criterion Economics recommended that the agency revise the CAFE standards to reflect socially optimal levels based on externality costs and benefits.

In contrast, NRDC and Environmental Defense argued that monopsony costs are underestimated in the proposal. Environmental Defense stated that monopsony costs should range from $0.083

(under the EIA reference scenario) to \$0.198 per gallon (under a \$65 per barrel oil price scenario). Environmental Defense also commented that there is an arithmetic error in NHTSA's application of disruption and adjustment costs (which are otherwise conceptually correct), and it argued that in setting final CAFE standards, the agency should address non-quantified externalities such as strategic petroleum reserve and national security costs, at least qualitatively if not quantitatively.

The California State Energy Commission argued that the agency's estimate of \$0.106 for oil import externalities is too low and should be increased to \$0.33 per gallon of gasoline. The California State Energy Commission broke down this estimate as follows: \$0.12 per gallon for oil import externalities; \$0.01 to reflect costs of gasoline spill remediation; \$0.02 to reflect damage from criteria pollutant emissions resulting from fuel delivery volumes, and \$0.18 to reflect damage costs of greenhouse gas emissions. The Commission based its recommendation upon values reported in a 2003 report titled "Benefits of Reducing Demand for Gasoline and Diesel."

The agency believes that assessing the economic case for increasing the stringency of the light truck CAFE standard requires a comprehensive analysis of the resulting benefits and costs to the U.S economy, rather than simply comparing the external costs associated with petroleum use and fuel production to current fuel taxes. The benefits of more stringent CAFE standards include the market value of the savings in resources from producing less fuel, together with the resulting reductions in the costs of economic externalities associated with petroleum consumption, and of environmental externalities caused by fuel production. The costs imposed on the U.S. economy by more stringent CAFE regulation include those costs for manufacturing more fuel-efficient vehicles, as well as the increased external costs of congestion, crashes and noise from added driving caused by the rebound effect.

Vehicle buyers value improved fuel economy using retail fuel prices and miles per gallon, but may consider fuel savings only over the time they expect to own a vehicle, while the value to the U.S. economy of saving fuel is measured by its pre-tax price, and includes fuel savings over the entire lifetime of vehicles. Thus, it cannot simply be assumed that the interaction of manufacturers' costs and vehicle buyers' demands in the private marketplace will determine optimal fuel economy levels, and that these levels should only be adjusted by Federal regulation if the external costs of fuel production and use exceed current fuel taxes.

The Agency's analysis estimates the value of each category of benefits and costs separately, and it compares the total benefits resulting from each alternative CAFE level to its total costs in order to assess its desirability. This more complete accounting of benefits and costs to the U.S. economy from reducing fuel use is necessary to assess the case for CAFE regulation generally, and for increasing the stringency of the current light truck CAFE standard in particular.

In response to comments on the specific values of certain externalities employed in the NPRM analysis, the agency agrees that higher world oil prices increase the monopsony or demand costs imposed by U.S. petroleum purchases, while greater sensitivity of the supply of oil imported by the U.S. to variation in its price (a higher elasticity of petroleum supply) reduces the monopsony costs associated with variation in U.S. oil demand.[62] Thus, the value of the monopsony effect used in the FRIA analysis reflects the Energy Information Administration's recent Annual Energy Outlook 2006 forecast of future world oil prices, which is significantly higher than previously projected by EIA. The FRIA continues to use the midpoint of the range of values for the elasticity of oil imports suggested in the study by Leiby *et al*. to estimate the monopsony cost of increased U.S. petroleum use.

However, the agency also notes that only a fraction of the monopsony cost of increased U.S. oil consumption is imposed on domestic purchasers of petroleum and refined products, since part of the burden of higher world oil prices is borne by foreign purchasers. As a result, that same fraction of any *reduction* in monopsony costs resulting from lower U.S. oil purchases is exactly offset by revenue losses to domestic petroleum producers, so it does not represent a net savings to the U.S. economy. Thus, in order to include only the fraction that represents a net savings to U.S. purchasers, the savings in monopsony costs from reduced fuel use must be adjusted by the percent of fuel savings that will be result in lower U.S. petroleum imports, including both imported crude oil refined in the U.S. and imports of gasoline refined overseas from foreign-produced crude petroleum. This results in a monopsony value of $0.044 per gallon.

In contrast, the entire reduction in total U.S. petroleum demand that results from more stringent CAFE standards reduces potential costs to the U.S. economy from rapid increases in world oil prices, because (as the studies cited by reviewers of the NPRM point out) these costs depend on *total* U.S. petroleum consumption rather than on the fraction that is imported. The agency agrees

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[62] For the exact relationship among monopsony costs, oil prices, and the elasticity of supply of imported oil, see Leiby *et al*., p. 68.

that petroleum buyers’ use of hedging strategies and private oil inventories can reduce these costs, but the significant costs of adopting these strategies will also be reduced as declines in U.S. petroleum demand moderate the potential effect of rapid fluctuations in world oil prices. Thus, the analysis presented in the FRIA continues to employ the agency’s previous estimate of the reduction in the price shock component of U.S. oil consumption externalities that is likely to result from more stringent CAFE regulation.

Finally, the agency believes that while costs for U.S. military security in oil-producing regions and for maintaining the Strategic Petroleum Reserve will vary in response to long-term changes in U.S. oil imports, these costs are unlikely to decline significantly in response to the modest reduction in the level of U.S. oil imports that would result from the more stringent CAFE standards for MY 2008 - 2011 light trucks. The U.S. military presence in world regions that represent vital sources of oil imports also serves a range of security and foreign policy objectives that is considerably broader than simply protecting oil supplies. As a consequence, no savings in government outlays for maintaining the Strategic Petroleum Reserve or a U.S. military presence are included among the benefits of the light truck CAFE standard adopted for MY 2008 - 2011.

The “Rebound Effect”

The “rebound effect” refers to the tendency for vehicle owners to change their driving behavior in response to changes in the cost of driving. This could occur in response to changes in the price of motor fuel or changes in vehicle efficiency. In response to higher CAFE standards, consumers would perceive a lower cost/mile of driving, which is the typically the largest component of the cost of operating a vehicle. In response, consumers would increase the number of miles they drive. These added miles result in additional fuel consumption, which will partially offset the fuel savings that result from higher CAFE standards.

At the same time, this added driving due to the rebound effect provides benefits to vehicle owners that are at least equal to costs of the additional fuel it consumes (as evidenced by the fact that the additional driving is voluntary). Thus while the rebound effect reduces *fuel savings* resulting from stricter CAFE standards, this reduction in fuel savings does not necessarily reduce the *economic benefits* resulting from stricter standards. As discussed subsequently, however, the increased driving caused by the rebound effect imposes additional costs for congestion, noise, and accidents, and these added costs do offset part of the benefits resulting from tighter CAFE standards.

In this analysis, the impact of the rebound effect is estimated by applying a representative estimate of the elasticity of vehicle use with respect to fuel cost per mile driven to the reduction in that cost that would result from the more stringent CAFE standard. With both the current or baseline standard and the higher CAFE standard in effect, the average fuel cost per mile for operating light trucks of any model year during each future calendar year is calculated by the forecast retail price of gasoline during that future calendar year, divided by the average actual on-road fuel economy level achieved by light trucks of that model year.[63] The reduction in fuel cost per mile driven resulting from adopting the higher CAFE standard is equal to the difference between this calculated fuel cost per mile under the base standard and with the more stringent

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[63] Gasoline price forecasts are also obtained from U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2006*, Table 12, http://www.eia.doe.gov/oiaf/aeo/supplement/index.html.

standard in effect. The increase in the number of miles that vehicles are driven in response to this reduction in fuel costs represents the rebound effect.

The rebound effect is usually expressed as the percentage by which this additional vehicle use would reduce the fuel savings that would have resulted if no additional driving occurred. The magnitude of the rebound effect from higher fuel economy standards for light-duty vehicles is equal to the negative of the elasticity of vehicle use (which is itself a negative value) with respect to either fuel cost per mile driven or fuel efficiency measured in miles per gallon, expressed as a percent. Most recent estimates of the magnitude of the rebound effect for light-duty vehicles fall in the range of 10% to 30%,[64] which imply that increasing vehicle use will offset 10-30% of the fuel savings resulting directly from an improvement in fuel economy.[65] In the analysis of benefits from higher CAFE standards for light-duty trucks, a rebound effect of 20% is employed.

Commenters expressed a variety of views regarding the rate used by the agency to estimate the rebound effect anticipated in response to the new CAFE standards, with some suggesting that the

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[64] "Energy Efficiency and Consumption – the Rebound Effect – A Survey" Lorna A. Greening, David L. Greene, Carmen Difiglio. Energy Policy (28) 2000, pp. 389-401

[65] Recent estimates of the rebound effect resulting from higher fuel economy standards for light-duty vehicles indicate that a 10% reduction in fuel costs per mile results in a 1-2% increase in the number of miles driven. These estimates are derived from statistical estimates of the elasticity of miles driven per vehicle with respect to fuel cost per mile that range from approximately –0.10 to –0.20; see for example David L. Greene, "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" *The Energy Journal*, 13:1 (1992), 117-143; David L. Greene, James R. Kahn, and Robert C. Gibson, "Fuel Economy Rebound Effect for Household Vehicles", *The Energy Journal*, 20:3 (1999), 1-21; Jonathan Haughton and Soumodip Sarkar, "Gasoline Tax as a Corrective Tax: Estimates for the United States," *The Energy Journal*, 17:2, pp. 103-126; and S.L. Puller and L.A. Greening, "Household Adjustment to Gasoline Price Changes: An Analysis Using Nine Years of U.S. Survey Data," *Energy Economics*, 21:1, pp. 37-52. This study employs an elasticity of miles driven per vehicle with respect to fuel cost per mile of –0.20, approximately the upper end of the range suggested by recent research, to estimate the rebound effect from tightening CAFE standards for light-duty trucks. Small, K.A. and VanDender, K. (2005) "A Study to Evaluate the Effect of Reduced Greenhouse Gas Emissions on Vehicle Miles Traveled, State of California Air Resources Board, California Environmental Protection Agency, and the California Energy Commission.

rate is too low (Alliance, General Motors) and others suggesting that it is too high (Environmental Defense, NRDC, ACEEE, Union of Concerned Scientists, California State Energy Commission). Specific comments related to the rebound effect are set forth below.

In general, manufacturers and their associations deemed the 20-percent rebound rate relied upon by the agency to be conservative. For example, the Alliance argued that a 20-percent rebound effect is overly conservative, based upon recent studies. Specifically, the Alliance stated that a study by Small and Van Dender estimated a long-term rebound effect of 24 percent (which means that a 10-percent increase in fuel economy, which translates into a 10-percent decrease in fuel cost-per-mile, would ultimately stimulate a 2.4-percent increase in total miles traveled).[66] According to the Alliance, an independent analysis by Crawford of the Small and Van Dender data found a similar rebound effect of 24.6 percent.[67] The Alliance opined that the rebound effect is probably on the order of 35 percent, although it did not supply any data to substantiate this estimate.

According to General Motors, studies have shown that the rebound effect lowers fuel savings by 20-50 percent. (As an aside, General Motors also agreed with the agency that the increased driving resulting from the rebound effect is also associated with societal or externality costs, including increased collisions and traffic congestion.) General Motors stated that it commissioned four studies of the rebound effect, each of which concluded that the rebound effect would be approximately 25 percent. (General Motors did not provide copies of the

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[66] Kenneth A. Small and Kurt Van Dender, “The Effect of Improved Fuel Economy on Vehicle Miles Traveled: Estimating the Rebound Effect Using U.S. State Data, 1996-2001, Paper EPE-014, University of California Energy Institute, 2005; item #1702 in NHTSA Docket 22223. An earlier version of the study is item 15 in the same docket.

[67] Crawford, *et al*, “Review and Assessment of VMT Rebound Effect in California,” Sept. 2004.

referenced studies). However, General Motors stated that 20 percent is adequate for calculations related to rebound effect. No other vehicle manufacturers commented on this issue. The National Automobile Dealers' Association commented that fuel savings should clearly be discounted to reflect the rebound effect, but did not recommend a specific value for it.

In contrast to the above commenters, Environmental Defense argued that the agency has overestimated the rebound effect, presumably due to the PRIA's reliance upon earlier studies in the literature which tended to miss significant effects and which did not have sufficiently large datasets to observe long-term trends. While the Alliance relied upon the 2005 study by Small and Van Dender, using a 36-year panel dataset (U.S. State data from 1966-2001), to estimate the rebound effect at 24 percent, Environmental Defense used the same study to show that the rebound effect dropped to 12.1 percent in the years 1997-2001, consistent with higher income levels during those years as opposed to the full range of years for the study. Environmental Defense argued that if one presumes continued income growth during the 25-year period analyzed under the CAFE proposal, the rebound effect would continue to decline, so the analyses presented in its comments used a primary estimate of 5 percent for rebound effect. The commenter urged NHTSA to similarly adopt a lower rebound rate which is in keeping with the most recent research in this area.

Other commenters also urged NHTSA to adopt a lower rate for the rebound effect, based on the study published by Small and Van Dender. For example, NRDC suggested using a 6-percent rate for the rebound effect over the lifetime of MY 2008-2011 vehicles, which it argued would correctly recognize the effect of income. ACEEE urged the agency to use a 10-percent rate, a change which it suggested would increase monetized social benefits (undiscounted) of Reformed CAFE for MY 2011 vehicles by about $1.3 billion (approximately 30 percent).

Again, relying on results from the Small and Van Dender study, the Union of Concerned Scientists recommended that NHTSA reduce the rebound effect rate to no more than 10 percent. The commenter stated that NHTSA offered no justification or rationale for choosing the upper end of its discussed range (10-20 percent) and that updated results by the study authors supported a long-run rebound effect rate of 6.8 percent or lower. Accordingly, the Union of Concerned Scientists stated that NHTSA should adopt 10 percent as a reasonable and conservative estimate of rebound and that the average fuel economy target for 2011 should increase by 1.4-1.9 mpg.

The California State Energy Commission called for a rebound effect of 12 percent, which it believes is reflective of the long-term rebound effect of 12.1 percent for California estimated by Small and Van Dender.

All reviewers who recommended a lower value for the rebound effect than the 20 percent estimate used in the PRIA analysis relied upon a recent study conducted by Small and Van Dender for the California Air Resources Board as evidence in support of a smaller rebound effect.[68] While the agency regards this study as an important new contribution to the extensive literature on the magnitude of the rebound effect, it does not regard the very low values for the

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[68] Kenneth A. Small and Kurt Van Dender, “The Effect of Improved Fuel Economy on Vehicle Miles Traveled: Estimating the Rebound Effect Using U.S. State Data, 1996-2001, Paper EPE-014, University of California Energy Institute, 2005; item #1702 in NHTSA Docket 22223. An earlier version of the study is item 15 in the same docket.

rebound effect recommended by various reviewers who relied on the study as persuasive for several reasons.

First, unlike the studies relied upon by the agency in developing its estimate of the rebound effect, the Small and Van Dender analysis remains an unpublished working paper that has not been subjected to formal peer review. Thus, the agency does not yet consider the estimates it provides to have the same credibility as the published and widely-cited estimates it relied upon.

Second, the estimates of the rebound effect suggested by some reviewers and attributed to the Small and Van Dender actually appear to be forecasts of its future value derived by those commenters from the model used in the study, rather than estimates reported in the study itself. In fact, the study's preferred estimate of the nationwide long-run rebound effect over the entire period it analyzed (1966-2001) is 22%, slightly above the 20% estimate used in the NPRM analysis.[69]

While the authors argue that growth in household incomes and changes in urban development patterns have reduced the long-term rebound effect significantly over this period, they estimate a value of 12 percent for the period from 1997-2001. The lower values recommended by Environmental Defense, NRDC, ACEEE, and Union of Concerned Scientists appear to project the decline in the rebound effect estimated by Small and Van Dender well into the future under

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[69] Small and Van Dender, Table 6, p. 23. The long run refers to the period after which vehicle owners have had adequate time to adjust their vehicle ownership levels and driving patterns to an increase in fuel economy, which the agency believes is the appropriate measure of the rebound effect to use in analyzing the lifetime fuel savings from improving the fuel economy of new vehicles.

the assumptions of constant real fuel prices and continuing robust growth in income, which produces values that the agency regards as unrealistically low. [70]

Finally, some of the very low estimates of the rebound effect attributed to the Small and Van Dender study by commenters on the NPRM appear to have been intended to apply to the State of California, rather than to the U.S. as a whole.[71] Because the values of some variables that influence the rebound effect in Small and Van Dender's model differ between California and the entire U.S., these particularly small estimates of its magnitude are not appropriate for use in analyzing fuel savings from Federal fuel economy standards.

After reviewing the various comments on the NPRM, the agency has elected to continue using a value of 20 percent for the rebound effect in its analysis of potential fuel savings from stricter CAFE standards for model year 2008-2011 light trucks. The agency will continue to monitor new published research on the rebound effect (as well as on other critical parameters affecting fuel savings from CAFE regulation), and will revise the estimates of the rebound effect it employs in future analyses of fuel savings if it concludes that new evidence points conclusively toward a different value.

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[70] Over the period from 1997 to 2001, U.S. retail gasoline prices averaged $1.30 per gallon (in 2003 dollars), while they are forecast to average $2.13 (again in 2003 dollars) over the expected lifetimes of model year 2008-11 light trucks, see Energy Information Administration, Weekly Retail Gasoline and Diesel Prices, http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm., and Annual Energy Outlook 2006 (Early Release), http://www.eia.doe.gov/oiaf/aeo/index.html. By themselves, rising fuel prices would increase the magnitude of the rebound effect from the value that may have been appropriate for the 1990-2001 period.

[71] Small and Van Dender's analysis was originally conducted for the State of California Air Resources Board, and was primarily intended to identify the likely magnitude of the rebound effect for California itself.

Because the increase in light truck fuel economy differs among the alternatives, the resulting increase in total light truck usage from the rebound effect differs as well. Under the Unreformed Alternative, the expected additional number of miles each vehicle is driven over its lifetime as a result of the rebound effect is 281 miles for light trucks produced during MY 2008, 901 miles for MY 2009 vehicles, and 1,001 miles for MY 2010 light trucks. Multiplying these figures by forecast light truck sales for each of those model years' results in a total of 2.4 billion additional miles for all MY 2008 light trucks over their expected lifetimes, with corresponding figures of 8.0 and 9.0 billion additional miles for MY 2009 and 2010 vehicles.

Under the Reformed Alternative, the expected additional number of miles each vehicle is driven over its lifetime as a result of the rebound effect is 372 miles for light trucks produced during MY 2008, 967 miles for MY 2009 vehicles, 1,100 for MY 2010, 1,336 miles for MY 2011 light trucks including MDPVs, and 1,281 without MDPVs. Multiplying these figures by forecast light truck sales for each of those model years results in a total of 3.2 billion additional miles for all MY 2008 light trucks over their expected lifetimes, with corresponding figures of 8.6, 9.9, 12.5, and 11.7 billion additional miles for MY 2009, 2010, 2011 vehicles including MDPVs, and 2011 vehicles excluding MDPVs. These estimates increase over the four model years because the increase in the required CAFE levels from the adjusted baseline is progressively larger; in turn, this causes the decline in fuel cost per mile driven and resulting increase in average miles driven per vehicle to be larger.

Other Impacts of the Rebound Effect

The rebound effect also produces additional benefits to vehicle owners in the form of consumer surplus from the increase in vehicle-miles driven, but may also increase the costs associated with traffic congestion, motor vehicle crashes, and noise. These effects are likely to be relatively small by comparison to the value of fuel saved as a result of raising CAFE standards, but they are nevertheless important to include, and the following discussions analyze each of these effects in detail.

Consumer Benefits from Additional Driving

The increase in travel associated with the rebound effect produces additional benefits to vehicle owners, which reflect the value to drivers and other vehicle occupants of the added (or more desirable) social and economic opportunities that become accessible with additional travel. As evidenced by the fact that they elect to make more frequent or longer trips when the cost of driving declines, the benefits from this added travel are at least as large as drivers' added costs for the fuel it consumes (measured at the improved level of fuel economy resulting from stricter CAFE standards).[72] The benefits from additional rebound effect travel also include the consumer surplus received by vehicle buyers who value the opportunities that increased travel makes available to them at more than the fuel cost of the additional driving. Because it depends on the improvement in fuel economy, the value of benefits from increased vehicle use changes by model year and alternative CAFE standard, and is shown in Tables VIII-5 through VIII-12.

Added Costs from Congestion, Crashes, and Noise

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[72] These benefits are included in the value of fuel savings reported in Tables VIII-5 through VIII-12.

While it provides some benefits to drivers, increased vehicle use associated with the fuel economy rebound effect can also contribute to increased traffic congestion, motor vehicle crashes, and highway noise. Additional vehicle use can contribute to traffic congestion and delays by increasing recurring congestion on heavily-traveled roadways during peak travel periods, depending on how the additional travel is distributed over the day and on where it occurs. By increasing the number of crashes and disabled vehicles, added driving can also increase the delays that often result from these incidents, although the extent to which it actually does so again depends on when and where the added travel occurs. In either case, any added delays impose higher costs on drivers and other vehicle occupants in the form of increased travel time and operating expenses, and these should be considered as an additional economic cost associated with the rebound effect. Because drivers do not take these added costs into account in deciding when to make trips or where they travel, they must be accounted for separately as a cost of the added driving associated with the rebound effect.

Increased light truck use due to the rebound effect may also increase the costs associated with traffic crashes. Drivers presumably take account of the potential costs they (and the other occupants of their vehicles) face from the possibility of being involved in a crash when they decide to make additional trips. However, they probably do not consider all of the potential costs they impose on occupants of other vehicles and on pedestrians when crashes occur, so any increase in these “external” crash costs must be considered as another cost of additional rebound-effect driving. Like increased delay costs, any increase in these external crash costs caused by added driving is likely to depend on the traffic conditions under which it takes place, since crashes are more frequent in heavier traffic, but their severity may be reduced by the slower speeds at which heavier traffic typically moves. Thus estimates of the increase in external crash costs from the rebound effect also need to account for when and where the added driving occurs.

Finally, added light truck use from the rebound effect may also increase traffic noise. Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property. Because none of these effects are likely to be taken into account by the drivers whose vehicles contribute to traffic noise, they represent additional externalities associated with motor vehicle use. Although there is considerable uncertainty in estimating its value, the added inconvenience and irritation caused by increased traffic noise imposes economic costs on those it affects, and these added costs are unlikely to be taken into account by drivers of the vehicles that cause it. Thus any increase in noise costs resulting from added light truck use must be included together with other increased external costs from the rebound effect.

Our analysis uses estimates of the congestion costs, crash costs, and noise costs for pickup trucks and vans developed by the Federal Highway Administration to estimate the increased external costs caused by added light truck use from the rebound effect.[73] These estimates are intended to measure the increases in external costs – that is, the marginal external costs – from added congestion, property damages and injuries in traffic crashes, and noise levels caused by additional usage of light trucks that are borne by persons other than their drivers. FHWA's "Middle" estimates for congestion, crash, and noise costs imposed by pickup trucks and vans are

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[73] These estimates were developed by FHWA for use in its 1997 *Federal Highway Cost Allocation Study*.

4.0 cents, 2.15 cents, and 0.06 cents per vehicle-mile, respectively, at year-2000 prices.[74] Updated to 2003 dollars, these values are 4.27 cents for congestion, 2.30 cents for crashes, and 0.06 cents for noise. These costs are multiplied by the estimated increases in light truck use from the rebound effect during each year of the affected model years' lifetimes in the fleet to yield the estimated increases in congestion, crash, and noise externality costs during that year. The resulting estimates are discounted to their present values as of the date each model year is sold and summed to obtain their total values.

The Federal Highway Administration's estimates of these costs agree closely with some other recent estimates. For example, recent published research conducted by Resources for the Future (RFF) estimates marginal congestion and external crash costs for increased light-duty vehicle use in the U.S. to be 3.5 and 3.0 cents per vehicle-mile in year-2002 dollars.[75] These estimates incorporate careful adjustments of congestion and crash costs that are intended to reflect the traffic conditions under which additional driving is likely to take place, as well as its likely effects on both the frequency and severity of motor vehicle crashes. While both the FHWA and RFF estimates of congestion crash costs are considerably lower than those cited by some commenters on the proposed rule, we regard them as more credible estimates of the likely magnitude of these costs.

General Motors agreed with the agency's cost estimates related to traffic congestion, crashes, and noise. However, the commenter again stated its belief that the proposed CAFE standards

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[74] Federal Highway Administration, 1997 *Federal Highway Cost Allocation Study*, Tables V-22, V-23, and V-24.

[75] Ian W.H. Parry and Kenneth A. Small, "Does Britain or the U.S. Have the Right Gasoline Tax?" Discussion Paper 02-12, Resources for the Future, March 2002, pp. 19 and Table 1, http://www.rff.org/rff/Documents/RFF-DP-02-12.pdf.

would result in a net externality cost -- not benefit -- in terms of consumer welfare. Specifically, General Motors stated that the costs associated with increased congestion, noise, and highway fatalities and injury costs resulting from increases in driving outweigh the benefits associated with decreased oil import dependence and pollution reduction.

NHTSA agrees that this is a correct observation made by General Motors on the agency's analysis, although we believe the commenter overstates its significance. We say this because the savings in lifetime fuel expenditures significantly outweigh the combined net externalities costs and the costs of added technology, making this a cost-beneficial rule.

Costs from Increased Air Pollutant Emissions

Finally, additional light truck use associated with the rebound effect will increase emissions of air pollutants that occur as motor vehicles are driven (air pollutant emissions from gasoline production are discussed in a later section). Air pollutants emitted in significant quantities by light-duty motor vehicles, such as the light trucks affected by the CAFE rule, include hydrocarbon compounds (usually referred to as "volatile organic compounds," or VOC), nitrogen oxides (NOx), fine particulate matter (PM), and sulfur dioxide (SO_2). The increased use of light trucks that occurs through the rebound effect causes higher emissions of these "criteria" pollutants, since Federal standards limit their permissible emissions by motor vehicles on a per-mile basis. The increase in emissions of these pollutants from additional light truck use is estimated by multiplying the increase in total miles driven by light trucks of each model year and age during a calendar year by age-specific emission rates per vehicle-mile developed using the U.S. Environmental Protection Agency's MOBILE6.2 motor vehicle emissions factor model[76]. The resulting increases in emissions are converted to economic values using estimates of the economic costs (primarily from damages to human health) reported by the Federal Office of Management and Budget.[77]

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[76] U.S. Environmental Protection Agency, MOBILE6 Vehicle Emission Modeling Software, http://www.epa.gov/otaq/m6.htm#m60

[77] White House Office of Management and Budget, Office of Information and Regulatory Affairs, "Progress in Regulatory Reform: 2004 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded

Emissions Reductions Resulting from Fuel Savings

While added driving caused by the rebound effect can increase air pollutant emissions, the fuel savings resulting from the proposed rule will reduce emissions of these same pollutants that are generated during the production and distribution of gasoline. Since these emissions occur during crude oil extraction and transportation, gasoline refining, and gasoline storage and distribution, the reduction in emissions from each of these sources depends on whether fuel savings result in lower imports of refined gasoline or in reduced domestic gasoline refining.[78] Based on a detailed examination of historical and forecast changes in U.S. gasoline imports in relation to changes in domestic gasoline consumption, this analysis assumes that 50 percent of fuel savings resulting from the CAFE rule will be reflected in reduced gasoline imports, and that the remaining 50 percent will reduce domestic refining.[79] The resulting reduction in domestic refining is assumed to leave the mix of imported and domestic crude petroleum feedstocks currently utilized in domestic refining unchanged.

This analysis estimates reductions in criteria pollutant emissions from gasoline refining and distribution using emission rates obtained from Argonne National Laboratories' Greenhouse

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Mandates on State, Local, and Tribal Entities," December 2004, p. 134, http://www.whitehouse.gov/omb/inforeg/regpol-reports_congress.html The values used for VOC, NOx, and SO2 are the midpoints of the ranges used by OMB, adjusted to 2003 dollars. However, OMB does not provide a damage cost estimate for carbon monoxide (CO); the value used here was derived from Donald R. McCubbin and Mark A. Delucchi, "The Health Costs of Motor-Vehicle-Related Air Pollution," Journal of Transport Economics and Policy, September 1999, Volume 33, part 3, pp. 253-86.

[78] To a lesser extent, they also depend on whether any reduction in domestic gasoline refining is translated into reduced imports of crude oil or reduced domestic extraction of petroleum.

[79] Estimates of the response of gasoline imports and domestic refining to fuel savings from stricter CAFE standards are variable and highly uncertain, but our analysis indicates that under any reasonable assumption about these responses, the magnitude of the net change in criteria pollutant emissions (accounting for both the rebound effect and changes in refining emissions) is extremely low relative to their current total.

Gases and Regulated Emissions in Transportation (GREET) model.[80] The GREET model provides separate estimates of air pollutant emissions that occur in four separate activities entailed in gasoline production and distribution: crude oil extraction, crude oil transportation and storage, gasoline refining, and gasoline distribution and storage.[81] Our calculations assume that reductions in imports of gasoline in response to fuel savings from the CAFE rule would reduce air pollutant emissions during gasoline storage and distribution only. Reductions in domestic refining of gasoline using imported crude oil as a feedstock are assumed to reduce emissions that occur during crude oil transportation and storage, and during gasoline refining, distribution, and storage. Finally, lower domestic refining using domestically-produced crude oil as a feedstock is assumed to reduce emissions during all four phases of gasoline production and distribution.[82] The resulting reductions in air pollutant emissions from gasoline production and distribution are converted to economic values using the same economic damage costs used to value emissions increases resulting from additional driving.

Fuel savings from more stringent light truck CAFE standards also result in lower emissions of carbon dioxide, the main greenhouse gas emitted as a result of refining, distribution, and use of

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[80] Argonne National Laboratories, *The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model*, Version 1.6, April 2005, http://www.transportation.anl.gov/software/GREET/index.html

[81] Emissions that occur during vehicle refueling at retail gasoline stations (primarily evaporative emissions of volatile organic compounds, or VOCs) are already accounted for in the "tailpipe" emission factors used to estimate the emissions generated by increased light truck use. GREET estimates emissions in each phase of gasoline production and distribution in mass per unit of gasoline energy content; we convert these factors to mass per gallon of gasoline using the average energy content of gasoline. We assume that the current mix of approximately 60% conventional gasoline, 30% federal "reformulated" gasoline (FRFG2), and 10% California reformulated gasoline will continue to be refined over the period covered by our analysis.

[82] In effect, this assumes that the distances crude oil travels to U.S. refineries are approximately the same regardless of whether it travels from domestic oilfields or import terminals, and that the distances that gasoline travels from refineries to retail stations are approximately the same as those from import terminals to gasoline stations.

transportation fuels.[83] Lowering fuel consumption reduces carbon dioxide emissions directly, because the primary source of transportation-related greenhouse gas emissions is fuel combustion in internal combustion engines. Reductions in carbon dioxide emissions from vehicle operation are estimated by assuming that the entire carbon content of gasoline is converted to carbon dioxide in the combustion process.[84] Reduced gasoline consumption also reduces carbon dioxide emissions that result from fuel combustion, as well as from other energy use that occurs during the production and distribution of gasoline. Reductions in emissions from petroleum extraction and transportation, refining, and distribution are calculated using estimates of carbon dioxide emission rates in those activities obtained from Argonne National Laboratories' GREET model.

In its comments, General Motors maintained that increases in emissions of criteria pollutant resulting from the rebound effect are not likely to be offset by reduced refinery emissions, as assumed in the agency's analysis. General Motors argued that domestic refineries are subject to strict emission caps, and they must buy permits (credits) in order to support current production. It concluded that a small reduction in overall "demand for fuel would allow domestic refineries to simply buy fewer pollution permits without changing the emissions at the refineries."

General Motors also asserted that domestic refineries produce at over 95 percent of capacity, and that all increases in demand for refined products must be met by imports. Therefore, General

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[83] Carbon dioxide emissions account for more than 97% of total greenhouse gas emissions from the refining and use of transportation fuels; U.S. Environmental Protection Agency, *Draft Inventory of GHG Emissions and Sinks (1990-1999*), Tables ES-1 and ES-4, http://www.epa.gov/globalwarming/publications/emissions/us2001/energy.pdf.

[84] This assumption results is an overestimation of carbon dioxide emissions, since a small fraction of the carbon content of gasoline is emitted in the forms of carbon monoxide and unburned hydrocarbons. However, the magnitude of this overestimate is likely to be extremely small.

Motors concluded that a reduction in demand for fuel would not reduce domestic refinery output and corresponding pollutants, but instead would cause a reduction in imports of refined products such as gasoline.

Environmental organizations stated that the agency must attach some value to reducing greenhouse gas emissions, and adjust the benefits of more stringent CAFE standards accordingly. Both NRDC and Environmental Defense argued that the agency should monetize the benefits associated with reduced greenhouse gas (GHG) emissions. NRDC recommended using a value of $10-$25 per ton of GHG emissions reduced by fuel savings resulting from stricter CAFE standards, based on values assigned by the California Public Utilities Commission, Idaho Power Co., and the European Union emissions program. NRDC added that U.S., State, and European regulatory agencies currently estimate benefits from reducing GHG emissions costs at $3-$27 per ton. Environmental Defense stated that the agency should use a value of $50 per ton of reduced carbon dioxide emissions. The Union of Concerned Scientists similarly objected to the zero value assigned to reduced emissions of greenhouse gases in the CAFE proposal, and instead recommended using a value of $50 per ton of carbon (corresponding to approximately $0.15 per gallon of gasoline) as a needed start to resolving the problem of global warming.

In response to General Motors' comments, the agency notes that there are currently two cap-and-trade programs governing emissions of criteria pollutants and by large stationary sources. The Acid Rain Program seeks to limit NOx and SO_2 emissions, but applies only to electric generating facilities.[85] The NOx Budget Trading Program is also primarily intended to reduce electric utility emissions, but does include some other large industrial sources such as refineries;

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[85] See http://www.epa.gov/airmarkets/arp/index.html

however, as of 2003, refineries participating in the program accounted for less than 5% of total NOx emissions by U.S. refineries.[86] In addition, some refineries could be included among the sources of NOx emissions that will be controlled under the recently-adopted Clean Air Interstate Rule, which is scheduled to take effect beginning in 2009.[87] However, refinery NOx emissions could only be affected in states that specifically elect to include sources other than electric generating facilities in their plans to comply with the rule, and EPA has indicated that it expects states to achieve the emissions reductions required by the Clean Air Interstate Rule primarily from the electric power industry.[88] Thus the agency continues to believe that the reduction in domestic gasoline refining estimated to result from the adopted CAFE standard will be reflected in reduced refinery emissions of criteria pollutants.

The estimated reductions in emissions of criteria pollutants from gasoline refining and distribution used in the PRIA analysis were adjusted to reflect only the fraction of fuel savings that is expected to reduce domestic refining, rather than imports of refined gasoline. They were also adjusted to include only reductions in emissions that occur during domestic extraction and transportation of crude petroleum feedstocks. The estimates of these reduced emissions from crude oil extraction and gasoline refining used in the FRIA continue to reflect these adjustments.

The agency continues to view the value of reducing emissions of carbon dioxide and other greenhouse gases as too uncertain to support their explicit valuation and inclusion among the

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[86] Estimated from EPA, *NOx Budget Trading Program (SIP Call) 2003 Progress Report, Appendix A*, http://www.epa.gov/airmarkets/cmprpt/nox03/NBP2003AppendixA.xls, and *National Air Quality and Emissions Trends Report 2003*, Table A-4, http://www.epa.gov/air/airtrends/aqtrnd03/pdfs/a4.pdf

[87] The Clean Air Interstate Rule also requires reductions in SO_2 emissions and establishes an emissions trading program to achieve them, but only electric generating facilities are included in the rule's SO_2 emissions trading program; see EPA, Clean Air Interstate Rule: Basic Information, http://www.epa.gov/cair/basic.html#timeline

[88] See EPA, Clean Air Interstate Rule: Basic Information, http://www.epa.gov/cair/basic.html#timeline, and "Fact Sheet: Clean Air Interstate Rule," http://www.epa.gov/cair/pdfs/cair_final_fact.pdf

savings in environmental externalities from reducing gasoline production and use. There is extremely wide variation in published estimates of damage costs from greenhouse gas emissions, costs for controlling or avoiding their emissions, and costs of sequestering emissions that do occur, the three major sources for developing estimates of economic benefits from reducing emissions of greenhouse gases. Similarly, costs for remediating gasoline spills are highly variable depending on the volume of fuel released, the environmental sensitivity of the immediate environment, and the presence of specific fuel additives. As a consequence, the agency has elected to include no economic value for reducing greenhouse gas emissions or remediating fuel spills among the benefits of reducing gasoline use via more stringent fuel economy regulation.

The Value of Increased Driving Range

Improving the fuel economy of light-duty trucks will also increase their driving range between refueling. By reducing the frequency with which drivers typically refuel their vehicles, and by extending the upper limit of the range they can travel before requiring refueling, improving fuel economy thus provides some additional benefits to their owners. (Alternatively, if manufacturers respond to improved fuel economy by reducing the size of fuel tanks to maintain a constant driving range, the resulting savings in costs will presumably be reflected in lower vehicle sales prices.) No direct estimates of the value of extended vehicle range were readily available, so our analysis calculates the reduction in the annual number of required refueling cycles that results from improved fuel economy, and applies DOT-recommended values of travel time savings to convert the resulting time savings to their economic value.[89] The estimated change in required refueling frequency reflects the increased light truck use associated with the rebound effect, as well as the increased driving range stemming from higher fuel economy.

The following example illustrates how the economic value of extended refueling range is estimated in this analysis. Smaller light trucks have an average fuel tank size of approximately 20 gallons, and increasing the CAFE standard for model year 2008 from 22.2 to 22.5 mpg for the Unreformed alternative is estimated to increase the average CAFE rating for these models from the adjusted baseline of 22.35 to 22.61 mpg, which raises their actual on-road fuel economy from 19.00 to 19.22 mpg. Assuming that drivers typically refuel when their tanks are 20 percent full (i.e., 4 gallons in reserve), this increase in fuel economy raises the driving range for these vehicles from 19.00 x 16 = 304 to 19.22 x 16 = 307.5 miles. For a light truck driven 12,000

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[89] See http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf and http://ostpxweb.dot.gov/policy/Data/VOTevision1 2-11-03.pdf

miles/year, this reduces the number of required refuelings from 12,000/304 = 39.5 to 12,000/307.5 = 39.0, or by one half of a refueling per year.

Weighted by the actual mix of urban (about 2/3) and rural (about 1/3) travel and average vehicle occupancy (1.6 persons), the DOT-recommended value of travel time per vehicle-hour is $21.90 (in year 2003 dollars).[90] Assuming that locating a station and filling up takes five minutes, the value of time savings resulting from less frequent refueling amounts to $0.91 (calculated as 5/60 x 0.5 x $21.90) per vehicle per year for MY 2008 light trucks. This calculation is repeated for each calendar year that light trucks of each model year affected by the proposed rule would remain in the fleet, although its results differ for each year because different numbers of these vehicles remain in service during each year and their average use (and thus the number of fill ups saved) varies with their age as well. As with the other future benefits (and costs) of improved fuel economy, these annual values are discounted to their present values as of the date each model year is produced and sold, and the results are summed for each model year. This is considered an upper bound of savings, since not all drivers would wait until they have as little as a quarter tank of gas before they fill up again.

General Motors argued that the value of time spent refueling should be zero. General Motors stated that during the fuel economy test, EPA requires fuel tanks to contain a fixed percentage of

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[90] "Departmental Guidance for Valuation of Travel Time in Economic Analysis", memorandum from Frank E. Kruesi, Assistant Secretary for Transportation Policy, U.S. Department of Transportation, to Secretarial Officers and Modal Administrators, April 9, 1997. The hourly wage rate during 2003 is estimated to be $21.90. Personal travel (94.4% of urban travel) is valued at 50 percent of the hourly wage rate. Business travel (5.6% of urban travel) is valued at 100 percent of the hourly wage rate. For intercity travel, personal travel (87%) is valued at 70 percent of the wage rate, while business travel (13%) is valued at 100 percent of the wage rate. The resulting values of travel time are $11.57 for urban travel and $16.12 for intercity travel, and must be multiplied by vehicle occupancy (1.6) to obtain the estimate value of time per vehicle hour.

gasoline compared to tank capacity and that manufacturers have reduced gasoline tank volume on average in response to higher fuel efficiency.

Sierra Research added that range is a design criterion and that there is no basis for assuming that this criterion will change in response to an increase in CAFE standards. Sierra Research provided illustrations purported to show the relationship between fuel capacity and fuel economy standards, and fuel economy and range for 2004 light trucks, in order to demonstrate that increased fuel economy standards might not result in increased vehicle range.

The following reflects our understanding of vehicle driving range and tank size. Typically, the tank size for a model is determined when the model is designed, and the tank size does not change for small incremental improvements in fuel economy (as would occur by virtue of these standards) until the vehicle is redesigned. Thus, until redesign, we assume increased fuel economy would result in increased driving range, and the value of time for reduced refueling is real.

If tank downsizing is considered, manufacturers must trade off changes in production costs (added tooling costs and a cost saving from having a smaller tank) for varying fuel tank size against the value buyers attach to increased driving range in deciding how large to make fuel tanks and thus what range their vehicles will have. For current tank sizes, MPG levels, and resulting driving ranges, the marginal cost to manufacturers of changing any vehicle's tank size should be approximately equal to the marginal value to buyers of the resulting change in its driving range. As long as an exogenous increase in MPG (from CAFE, for example) only increases driving range incrementally, it should not disturb this equality too much, and insofar as it does, it should move it in a direction (increased range) that reduces the marginal value of range (assuming the usual diminishing marginal utility) relative to the cost of providing increased range (assuming increasing marginal costs for expanding tank size). So, whether manufacturers leave tank sizes unchanged and buyers get the benefit of extended range, or they reduce tank sizes and save manufacturing costs, there is some benefit, and these two ways of measuring it should give about the same answer for small changes in MPG. Thus, the agency is retaining its benefit estimates for increased driving range.

Summary of Benefits

The societal impacts from the CAFE rule are summarized for each model year and compliance option (Reformed and Unreformed) in Tables VII-5 through VII-12. These tables include undiscounted values as well as present value calculations at 3 percent and 7 percent. They also show changes in the physical units of measure that produced these values. Negative values in these tables reflect net reductions in fuel consumption or emissions and their resulting economic impacts, which represent benefits from the proposal, while positive values represent increasing emissions, congestion, noise or crash severity and their added costs. The net social benefit from these societal impacts is shown on the Total line in each table.

Highlights from Tables VIII-5 through VIII-12 are shown in Tables VIII-13 and VIII-14. Table V-13 summarizes the total savings in gallons of fuel over the lifetime of the light trucks manufactured during each model year and scenario. There is a steady increase in fuel savings with each model year. The savings for MY 2011 are roughly 4 times those in MY 2008.

Savings from both the Unreformed and Reformed scenarios are of similar magnitude during the three-year transition period. Table VII-13 also summarizes the total benefits for the other alternatives considered which were based on the NPRM's step function and the revised step function using more recent data.

Table VIII-14 summarizes the total social benefits for each scenario, discounted at 3 and 7 percent. The value of these impacts also increases steadily to a level that is roughly 3 times as high by 2011. The values for both Unreformed and Reformed CAFE also exhibit similar magnitudes during the transition period. Table VII-14 also summarizes the total benefits for the other alternatives based on the NPRM's step function and the revised step function using more recent data.

The Alliance commented that in proposing its fuel economy standards, NHTSA ignored the opportunity costs to consumers who may be forced to forego incremental improvements in vehicle performance, safety, capacity, comfort, and aesthetics (citing a 2003 study by the Congressional Budget Office (CBO) titled, "The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax," Chapter 2, pages 1-5). The Alliance also cited a recent study which found that a CAFE increase of 3 mpg results in a hidden tax of $0.78 per gallon of fuel conserved. General Motors added that to the extent the CAFE standards force trade-offs between fuel economy and other vehicle attributes which consumers value, consumer welfare will be reduced and "stranded costs" will be imposed on vehicle manufacturers.

Furthermore, General Motors argued that NHTSA's engineering and economic analyses are incomplete because they do not account for the potential economic harm to automobile companies (which are already facing difficult financial challenges) and their employees, and the analyses do not include producer and consumer welfare losses. General Motors stated the Congressional Budget Office estimated a consumer welfare loss of $230 per vehicle.

In response, the agency notes that the CBO report cited by General Motors and the Alliance is based on estimates of consumers' preferences over a period from roughly 1980 through 2001. The CBO report states that "Consumers' preferences over the past 15 or 20 years have led automakers to increase vehicles' size and horsepower, while holding gasoline mileage more or less constant." The CBO report also acknowledges that if consumers' tastes change significantly, the report's conclusions would be affected. The period examined by CBO corresponds to the period when automakers created and successfully marketed SUVs as an alternative to passenger cars for routine driving. For most of this period, gasoline prices were stable and low by historical standards. Near the end of the period, prices began to rise, but since that time they have reached levels that are more than double the typical price during the period. In response, consumers have shown a dramatic shift in their purchase preferences. Sales of small passenger cars and fuel-efficient hybrids have increased, while sales of large SUVs have plunged. Circumstances have, thus, already overtaken the assumptions regarding consumer preferences used in the CBO analysis. Moreover, the CBO analysis is based on a CAFE regulation that achieves an assumed 10 percent reduction in gasoline consumption, a greater reduction than that which would be accomplished by this regulation. Thus, the agency does not believe that the $230 loss in consumer welfare estimated in the CBO report is an appropriate measure of the impact of CAFE reform.

NHTSA acknowledges that there are potential shifts in consumer welfare which are not reflected in its model (e.g., if a manufacturer reduced horsepower as a strategy to improve fuel economy, some consumers would value that horsepower loss more than the fuel economy gain). However, it believes that measuring these impacts is problematic, especially in light of the recent dramatic shift in gasoline prices and geopolitical events surrounding the world oil supply. Moreover, the agency is using its model, not as an absolute standard, but rather as an initial measure to consider in setting standards. The agency is cognizant of the financial difficulty facing automobile manufacturers and is striving to minimize costs by scheduling improvements in such a way that they would coincide with normal design cycles. Further, the agency believes that incrementally improving fuel economy across the vehicle fleet will not deprive consumers of their choice of vehicles. A wide variety of vehicle types will continue to be available, and consumers' selection of vehicles should still reflect their judgments of the relative value of fuel economy versus horsepower at the margin.

Table VIII-5
Lifetime Monetized Societal Impacts, Unreformed CAFE, 2008 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-555,178 (k gal)	-906,967	-734,502	-586,528
Consumer Surplus from Additional Driving	2,418,857 (kmiles)	-4,779	-3,880	-3,104
Refueling Time Value	-1,929,954 – hours	-42,266	-34,364	-27,516
Petroleum Market Externalities	-555,178 (k gal)	-41,270	-26,493	-15,637
Congestion Costs	2,418,857 (kmiles)	103,285	66,304	39,136
Noise Costs	2,418,857 (kmiles)	1,451	932	550
Crash Costs	2,418,857 (kmiles)	55,634	35,714	21,080
VOC	368 (tons)	626	215	15
NOX	-16 (tons)	-85	-631	-727
PM	-81 (tons)	-4,637	-2,977	-1,757
SOX	-712 (tons)	-5,980	-3,839	-2,266
Total		-844,988	-703,521	-576,754

Table VIII-6
Lifetime Monetized Societal Impacts,
Unreformed CAFE 2009 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-1,812,857 (k gal)	-2,949,713	-2,382,266	-1,896,220
Consumer Surplus from Additional Driving	7,989,936 (kmiles)	-20,866	-16,777	-13,487
Refueling Time Value	-6,452,740 hours	-141,315	-114,678	-91,965
Petroleum Market Externalities	-1,828,857 (k gal)	-134,760	-83,964	-47,698
Congestion Costs	7,989,936 (kmiles)	341,170	212,407	120,774
Noise Costs	7,989,936 (kmiles)	4,794	2,985	1,697
Crash Costs	7,989,936 (kmiles)	183,769	114,411	65,054
VOC	939 (tons)	1,597	457	-54
NOX	-116 (tons)	-615	-2,125	-2,261
PM	-264 (tons)	-15,076	-9,396	-5,336
SOX	-2,324 (tons)	-19,518	-12,160	-6,908
Total		-2,750,533	-2,291,107	-1,876,404

* Because there are two streams of benefits, some values are positive and some values negative, and discounting affects the first few years in the stream less than the last years, the discounted values can actually change signs after discounting, as with the volatile organic compounds (VOC) values, or get larger after discounting as with the nitrogen oxides (NOx).

Table VIII-7
Lifetime Monetized Societal Impacts, Unreformed CAFE, 2010 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-2,023,142 (k gal)	-3,307,552	-2,677,941	-2,118,721
Consumer Surplus from Additional Driving	9,025,510 (kmiles)	-23,815	-18,917	-15,343
Refueling Time Value	-7,281,050 hours	-159,455	-130,386	-103,775
Petroleum Market Externalities	-2,023,142 (k gal)	-150,392	-91,463	-49,752
Congestion Costs	9,025,510 (kmiles)	385,389	235,233	127,501
Noise Costs	9,025,510 (kmiles)	5,415	3,305	1,792
Crash Costs	9,025,510 (kmiles)	207,587	126,706	68,678
VOC	-1,720 (tons)	-2,925	-1,430	-1,214
NOX	-2,790 (tons)	-14,786	-7,600	-5,589
PM	-275 (tons)	-15,702	-10,969	-5,188
SOX	-2,616 (tons)	-21,970	-13,369	-7,250
Total		-3,098,206	-2,586,830	-2,108,861

Table VIII-8
Lifetime Monetized Societal Impacts, Reformed CAFE, 2008 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-746,277 (k gal)	-1,219,311	-1,1001,601	-787,534
Consumer Surplus from Additional Driving	3,201,705 (k miles)	-11,414	-8,424	-7,407
Refueling Time Value	2,809,817 hours	-61,535	-50,943	-40,016
Petroleum Market Externalities	-746,277 (k gal)	-55,475	-36,124	-20,995
Congestion Costs	3,201,705 (k miles)	136,713	90,008	51,739
Noise Costs	3,201,705 (k miles)	1,921	1,265	727
Crash Costs	3,201,705 (k miles)	73,639	48,482	27,869
VOC	438(tons)	745	247	-11
NOX	-114 (tons)	-606	-1,129	-1,129
PM	-110 (tons)	-6,268	-4,065	-2,372
SOX	-2,489 (tons)	-8,054	-5,244	-3,048
Total		-1,149,645	-967,528	-782,177

Table VIII-9
Lifetime Monetized Societal Impacts, Reformed CAFE, 2009 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-1,940,475 (k gal)	-3,157,530	-2,582,764	-2,029,162
Consumer Surplus from Additional Driving	8,568,947 (k miles)	-26,834	-21,855	-17,334
Refueling Time Value	-7,185,479 hours	-157,362	-129,355	-102,371
Petroleum Market Externalities	-1,940,475 (k gal)	-144,247	-91,025	-51,038
Congestion Costs	8,568,947 (k miles)	365,894	230,849	129,481
Noise Costs	8,568,947 (k miles)	5,141	3,244	1,819
Crash Costs	8,568,947 (k miles)	197,086	124,345	69,744
VOC	960 (tons)	1,632	450	-82
NOX	-247 (tons)	-1,309	-2,685	-2,614
PM	-282 (tons)	-16,126	-10,177	-5,706
SOX	-2,489 (tons)	-20,910	-13,195	-7,399
Total		-2,954,565	-2,492,166	-2,014,662

Table VIII-10
Lifetime Monetized Societal Impacts, Reformed CAFE, 2010 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-2,229,615 (k gal)	-3,650,847	-2,945,363	-2,339,534
Consumer Surplus from Additional Driving	9,921,218 (kmiles)	-30,682	-24,428	-19,784
Refueling Time Value	8,208,767 hours	-179,772	-147,039	-117,034
Petroleum Market Externalities	-2,229,615 (k gal)	-165,740	-100,411	-54,846
Congestion Costs	9,921,218 (kmiles)	423,636	257,267	140,195
Noise Costs	9,921,218 (kmiles)	5,953	3,615	1,970
Crash Costs	9,921,218 (kmiles)	228,188	138,575	75,515
VOC	2,990 (tons)	-5,083	-2,530	-1,804
NOX	-4,201 (tons)	-22,263	-11,706	-7,546
PM	-289 (tons)	-16,477	-10,289	-5,444
SOX	-2,891 (tons)	-24,284	-14,668	-8,007
Total		-3,437,371	-2,856,977	-2,336,319

Table VIII-11
Lifetime Monetized Societal Impacts, Reformed CAFE With MDPVs, 2011 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-2,834,173 (k gal)	-4,663,847	-3,774,775	-2,981,413
Consumer Surplus from Additional Driving	12,481,447 (k miles)	-44,589	-35,838	-28,685
Refueling Time Value	10,239,639 hours	224,248	-183,526	-145,871
Petroleum Market Externalities	-2,834,173 (k gal)	-210,608	-124,388	-65,107
Congestion Costs	12,481,447 (k miles)	532,958	315,046	164,711
Noise Costs	12,481,447 (k miles)	7,489	4,427	2,314
Crash Costs	12,481,447 (k miles)	287,073	169,697	88,720
VOC	3,578 (tons)	-6,083	-3,022	-2,054
NOX	-4,652 (tons)	-24,657	-12,825	-8,090
PM	-371 (tons)	-21,192	-12,871	-6,546
SOX	-3,704 (tons)	-31,116	-18,316	-9,616
Total		-3,950,324	-3,676,391	-2,991,637

Table VIII-12
Lifetime Monetized Societal Impacts, Reformed CAFE, Without MDPVs,2011 MY

Societal Effect	**Physical Units**	**Undiscounted Value (2003$ k)**	**Present Discounted Value @ 3%**	**Present Discounted Value @ 7%**
Lifetime Fuel Expenditures	-2,583,390 (k gal)	-4,252,132	-3,450,433	-2,718,384
Consumer Surplus from Additional Driving	11,661,462 (kmiles)	-38,579	-31,051	-24,821
Refueling Time Value	-9,587,443 hours	-209,965	-172,251	-136,578
Petroleum Market Externalities	-2,583,390 (k gal)	-192,038	-113,682	-59,347
Congestion Costs	11,661,462 (kmiles)	497,944	294,952	153,885
Noise Costs	11,661,462 (kmiles)	6,997	4,145	2,162
Crash Costs	11,661,462 (kmiles)	268,214	158,873	82,889
VOC	-3,958 (tons)	-6,728	-3,316	-2,160
NOX	-5,236 (tons)	-27,751	-14,278	-8,642
PM	-357 (tons)	-20,400	-12,435	-6,300
SOX	-3,381 (tons)	-28,398	-16,754	-8,776
Total		-4,002,836	-3,356,230	-2,726,072

Table VIII-13
Savings in Millions of Gallons of Fuel
Undiscounted over the Lifetime of the Model Year Fleet

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	555	1,813	2,023	NA	NA
Reformed CAFE	746	1,940	2,230	2,834	2,583
NPRM Step Function	390	1,505	1,511	NA	2,043
Revised Step Function	848	1,944	2,190	2,786	2,572

Table VIII-14
Present Value of Lifetime Social Benefits by Alternative
(Millions of $2003)
(Discounted **3%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	704	2,291	2,587	N.A.	N.A.
Reformed CAFE	968	2,492	2,857	3,676	3,356
NPRM Step Function	530	1,906	1,934	N.A.	2,613
Revised Step Function	1,066	2,460	2,815	3,581	3,315

(Discounted **7%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	577	1,876	2,109	N.A.	N.A.
Reformed CAFE	782	2,015	2,336	2,992	2,726
NPRM Step Function	411	1,561	1,576	N.A.	2,146
Revised Step Function	887	2,018	2,288	2,934	2,703

References

Argonne National Laboratories, The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model, Version 1.6, February 2002.

Greene, David L., "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" ***The Energy Journal***, 13:1 (1992), 117-143.

Greene, David L., Donald W. Jones, and Paul N. Leiby, ***The Outlook for U.S. Oil Depend***ence, ORNL-6873, Oak Ridge National Laboratory, May 11, 1995.

Greene, David L., James R. Kahn, and Robert C. Gibson, "Fuel Economy Rebound Effect for Household Vehicles," The Energy Journal, 20:3 (1999), 1-31.

Greene, David L., and Nataliya I. Tishchishyna***, Costs of Oil Dependence: A 2000 Update***, ORNL/TM-2000/152, Oak Ridge National Laboratory, May 2000.

Haughton, Jonathan, and Soumodip Sarkar, "Gasoline Tax as a Corrective Tax: Estimates for the United States," ***The Energy Journal***, 17:2, 103-126.

Jones, Clifton T., "Another Look at U.S. Passenger Vehicle Use and the 'Rebound' Effect from Improved Fuel Efficiency, ***The Energy Journal***, 14:4 (1993), 99-110.

Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, ***Oil Imports: An Assessment of Benefits and Costs***, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997.

Pickrell, Don H., "Description of VMT Forecasting Procedure for 'Car Talk' Base line Forecasts," manuscript, Volpe National Transportation Systems Center, U.S. Department of Transportation, 1994.

Puller, S.L., and L.A. Greening, "Household Adjustment to Gasoline Price Changes: An Analysis Using Nine Years of U.S. Survey Data," ***Energy Economics***, 21:1, pp. 37-52.

Small, K.A. and VanDender, K. (2005) "A Study to Evaluate the Effect of Reduced Greenhouse Gas Emissions on Vehicle Miles Traveled", State of California Air Resources Board, California Environmental Protection Agency, and the California Energy Commission.

U.S. Department of Energy, Program Analysis Methodology Office of Transportation Technology: Quality Metrics 2002, Final Report, Office of Transportation Technologies, May 9, 2001.

U.S. Environmental Protection Agency, MOBILE Motor Vehicle Emission Factor Model, version 6.2, November 2002.

IX. NET BENEFITS

This chapter compares the costs of technologies needed to make improvements in fuel economy to meet the final rule and the alternatives with the potential benefits, expressed on a per-vehicle basis and in total (millions of dollars) per year. The following tables combine the estimated costs and benefits from Chapters VII and VIII. These are incremental costs and benefits compared to an adjusted baseline of manufacturers' production plans. Tables utilizing a 3 percent discount rate and 7 percent discount rate are presented.

Table IX-1 provides the costs on a per-vehicle basis. Table IX-2 provides the average net benefits per vehicle at a 3 and 7 percent discount rate from a societal perspective for all light trucks produced during each model year to which the standard is applicable.

Table IX-1
Incremental Cost Analysis
Per Vehicle
(In Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	64	185	195	N.A.	N.A.
Reformed CAFE	66	201	213	271	255
NPRM Step Function	21	137	129	N.A.	185
Revised Step Function	68	189	205	264	251

* By policy design, the mpg levels under Reformed CAFE are set so that the industry-wide costs of Reformed CAFE are roughly equal to the industry-wide costs of Unreformed CAFE for MY 2008-2010.

Table IX-2
Incremental Societal Benefits per Vehicle
Over the Vehicle's Lifetime – Present Value

(Discounted **3%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	82	258	287	N.A.	N.A.
Reformed CAFE	112	281	317	394	363
NPRM Step Function	62	215	215	N.A.	287
Revised Step Function	124	277	312	383	364

(Discounted **7%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	67	212	234	N.A.	N.A.
Reformed CAFE	91	227	259	320	300
NPRM Step Function	48	176	175	N.A.	236
Revised Step Function	103	228	254	314	297

Table IX-3 provides the net benefits per vehicle at a 3 percent and 7 percent discount rate.

Table IX-3
Net Benefits per Vehicle
Over the Vehicle's Lifetime – Present Value

(Discounted **3%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	18	73	92	N.A.	N.A.
Reformed CAFE	46	80	104	123	114
NPRM Step Function	41	78	86	N.A.	102
Revised Step Function	56	88	107	119	113

(Discounted **7%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	3	27	39	N.A.	N.A.
Reformed CAFE	25	26	46	49	45
NPRM Step Function	27	39	46	N.A.	51
Revised Step Function	35	39	49	50	46

Table IX-4 shows the total costs; Table IX-5 shows the total benefits, and Table IX-6 shows the total net benefits in millions of dollars at a 3 and 7 percent discount rate for the projected fleet of sales for each model year.

Table IX-4
Incremental Total Cost
(In Millions of Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	536	1,621	1,752	N.A.	N.A.
Reformed CAFE	553	1,724	1,903	2,531	2,301
NPRM Step Function	171	1,194	1,144	N.A.	1,665
Revised Step Function	575	1,658	1,832	2,461	2,265

* By policy design, the mpg levels under Reformed CAFE are set so that the industry-wide costs of Reformed CAFE are roughly equal to the industry-wide costs of Unreformed CAFE for MY 2008-2010.

Table IX-5
Present Value of Lifetime Societal Benefits by Alternative
(Millions of $2003)
(Discounted **3%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	704	2,291	2,587	N.A.	N.A.
Reformed CAFE	968	2,492	2,857	3,676	3,356
NPRM Step Function	530	1,906	1,934	N.A.	2,613
Revised Step Function	1,066	2,460	2,815	3,581	3,315

(Discounted **7%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	577	1,876	2,109	N.A.	N.A.
Reformed CAFE	782	2,015	2,336	2,992	2,726
NPRM Step Function	411	1,561	1,576	N.A.	2,146
Revised Step Function	887	2,018	2,288	2,934	2,703

Table IX-6
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of $2003)

(Discounted **3%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	168	670	835	N.A.	N.A.
Reformed CAFE	415	768	954	1,145	1,055
NPRM Step Function	359	712	790	N.A.	948
Revised Step Function	491	802	983	1,120	1,050

(Discounted **7%** in Year 2003 Dollars)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	41	255	357	N.A.	N.A.
Reformed CAFE	229	291	433	461	425
NPRM Step Function	240	367	432	N.A.	481
Revised Step Function	312	360	456	473	438

All of the alternatives examined provide net benefits for society. For MY 2008-2010, the Reformed CAFE scenarios provide more net benefits than the Unreformed Scenarios. The Revised Step Function alternative provides more net benefits than the Reformed CAFE alternative for MYs 2008-2010, but then they have about the same net benefits for MY 2011. In MY 2011, the alternatives with MDPVs provide more net benefit than those alternatives without MDPVs.

Payback Period

The "payback period" represents the length of time required for a vehicle buyer to recoup, through savings in fuel use, the higher cost of purchasing a more fuel-efficient vehicle. When a higher CAFE standard requires a manufacturer to improve the fuel economy of some of its vehicle models, the manufacturer's added costs for doing so are reflected in higher prices for these models. While buyers of these models pay higher prices to purchase these vehicles, their improved fuel economy lowers the consumer's costs for purchasing fuel to operate them. Over time, buyers will recoup the higher purchase prices they pay for these vehicles in the form of savings in outlays for fuel. The length of time required to repay the higher cost of buying a more fuel-efficient vehicle is referred to as the buyer's payback period.

The length of this payback period depends on the initial increase in a vehicle's purchase price, the improvement in its fuel economy, the number of miles it is driven each year, and the retail price of fuel. We calculated payback periods using the fuel economy improvement and average price increase for each manufacturer's vehicles estimated to result from the standard, the future retail gasoline prices, and estimates of the number of miles light trucks are driven each year as they age. These calculations are taken from a consumer's perspective, not a societal perspective. Thus, only gasoline savings are included on the benefits side of the equation. The price of gasoline includes fuel taxes and future savings are not discounted to present value, since consumers generally only consider and respond to what they pay at the pump. The payback periods for all manufacturers over all alternatives ranged from 2.0 to 5.5 years. The payback periods for the final rule alternatives (i.e., Unreformed and Reformed CAFE) range from 2.9 to 4.9 years. In other words, the average consumer can expect to save enough fuel in 2.9 to 4.9 years to equal their incremental price increase for the more fuel-efficient vehicle.

Table IX-7
Payback Periods for the Consumer
(In years)

	MY 2008	**MY 2009**	**MY 2010**	**MY 2011 With MDPVs**	**MY 2011 Without MDPVs**
Unreformed CAFE	4.9	4.3	4.1	N.A.	N.A.
Reformed CAFE	2.9	3.4	3.5	4.4	4.0
NPRM Step Function	2.0	3.7	3.5	N.A.	4.4
Revised Step Function	3.0	4.0	4.0	4.6	5.5

X. PROBABILISTIC UNCERTAINTY ANALYSIS

This chapter identifies and quantifies the major uncertainties in the final regulatory impact analysis and estimates the probability distribution of how those uncertainties affect the benefits, costs, and net benefits of the compliance options selected for the final rule (either Reformed or Unreformed standards for MY 2008-2010, and Reformed standards for 2011.) Throughout the course of the analysis, many assumptions were made, and diverse data sources were used. The uncertainty of these assumptions and data sources potentially could impact the net benefits of the standards. These assumptions and data sources all can be considered as uncertainty factors for the regulatory analysis. Some of these uncertainty factors contributed less to the overall variations of the outcomes, and, thus, are less significant. Some uncertainty factors depend on others or are closely related (e.g. oil import externalities), and thus can be combined. With the vast number of uncertainties imbedded in this regulatory analysis, this uncertainty analysis identifies only the major independent uncertainty factors having appreciable variability and impact on the end results and quantifies them by their probability distributions. These newly defined values are then randomly selected and fed back into the model to determine the net benefits using the Monte Carlo statistical simulation technique.[91] The simulation technique induces the probabilistic outcomes accompanied with degrees of probability or plausibility. This facilitates a more informed decision-making process.

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[91] See, for example, Morgan, MG, Henrion, M, and Small M, “Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis”, Cambridge University Press, 1990.

The analysis is based on the actual processes used to derive net benefits as described in the previous chapters. Each variable (e.g., cost of technology) in the mathematical model represents an uncertainty factor that would potentially alter the modeling outcomes if its value was changed. We assume that these variables are independent of each other. The confidence intervals around the costs and benefits of technologies reflect independent levels of uncertainty regarding costs and benefits, rather than linked probabilities dependent on higher or lower quality versions of a specific technology. By contrast, there is reason to believe that monopsony costs may be dependent on fuel prices. However, monopsony costs are only one of several oil import externalities, and the range of monopsony costs is quite narrow. The potential for significant error due to an assumption of independence for monopsony costs is thus quite low. Given this, the agency has elected to treat monopsony costs as an independent variable.

The uncertainties of these variables are described by appropriate probability distribution functions based on available data. If data are not sufficient or not available, professional judgments are used to estimate the probability distributions of these uncertainty factors. A complete description of the formulas and methods used in the CAFE model is available in the public docket.[92]

After defining and quantifying the major uncertainty factors, the next step is to simulate the model to obtain probabilistic results rather than single-value estimates. In the uncertainty analysis, CAFE levels were kept constant; in other words, we did not change the Reformed CAFE standards for each run based on net benefits. The simulation process was run repeatedly

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[92] CAFE Compliance and Effects Modeling System Documentation, Volpe Center, U.S. Dept. of Transportation, July 2005, pp. 27-46 and C-22 to C-35. Docket No. NHTSA 21974-2.

for 5,600 trials under each discount rate scenario. Each complete run is a trial. For each trial, the simulation first randomly selects a value for each of the uncertainty factors based on their probability distributions. The selected values are then fit into the models to forecast results. In addition to the simulation results, the program also estimates the degree of certainty (or confidence, credibility). The degree of certainty provides the decision-maker with an additional piece of important information with which to evaluate the forecast results.

The California State Energy Commission stated that NHTSA’s proposal does not adequately deal with the primary source of uncertainty in setting standards -- the extent to which the application of additional technology could be justified by higher future fuel prices. This commenter stated that the agency’s uncertainty analysis should first examine the sensitivity of optimum standards to variation in retail fuel prices only, and then analyze the effect of alternative stringency levels on social benefits.

In response, we note that the purpose of the uncertainty analysis is to examine uncertainty surrounding the impact of the final rule. OMB Circular A-4 requires formal probabilistic uncertainty analysis of complex rules where there are large, multiple uncertainties whose analysis raises technical challenges or where effects cascade and where the impacts of the rule exceed $1 billion. CAFE meets these criteria on all counts. However, the commenter appears to be concerned primarily with uncertainty surrounding the CAFE standard selection process, rather than that surrounding the impacts of the selected standards. The agency believes that its selection of CAFE levels should be based on its best estimates of all input variables used to estimate optimized social benefits. An examination of the uncertainty of outcomes in this process would produce information of academic interest but would not alter the agency's reliance on the most probable outcome for setting standards. It is also not clear that uncertainty surrounding the price of gasoline is greater than that surrounding other variables used in the NHTSA model. In fact, the range of uncertainty for both the effectiveness and cost of most technologies includes more potential variation than the three fuel price scenarios examined in the uncertainty analysis. Since each of these factors influences the calculation of optimized social benefits, the agency does not believe it would be useful to isolate only the uncertainty in fuel prices.

Simulation Models and Uncertainty Factors

A Monte Carlo simulation was conducted using the CAFE modeling system that was developed to estimate the impacts of higher CAFE requirements described in previous chapters. The focus of the simulation model was variation around the chosen uncertainty parameters and their resulting impact on the key output parameters, fuel savings, and net benefits. Net benefits measure the difference between (1) the total dollar value that would be saved in fuel and other benefits and (2) the total costs of the rule.

The agency reviewed the inputs and relationships that drive the CAFE model to determine the factors that are the major sources of uncertainty. Five factors were identified as contributing the most uncertainty to the estimated impacts of higher CAFE standards:

(1) Technology costs;

(2) Technology effectiveness;

(3) Fuel prices;

(4) The value of oil consumption externalities; and

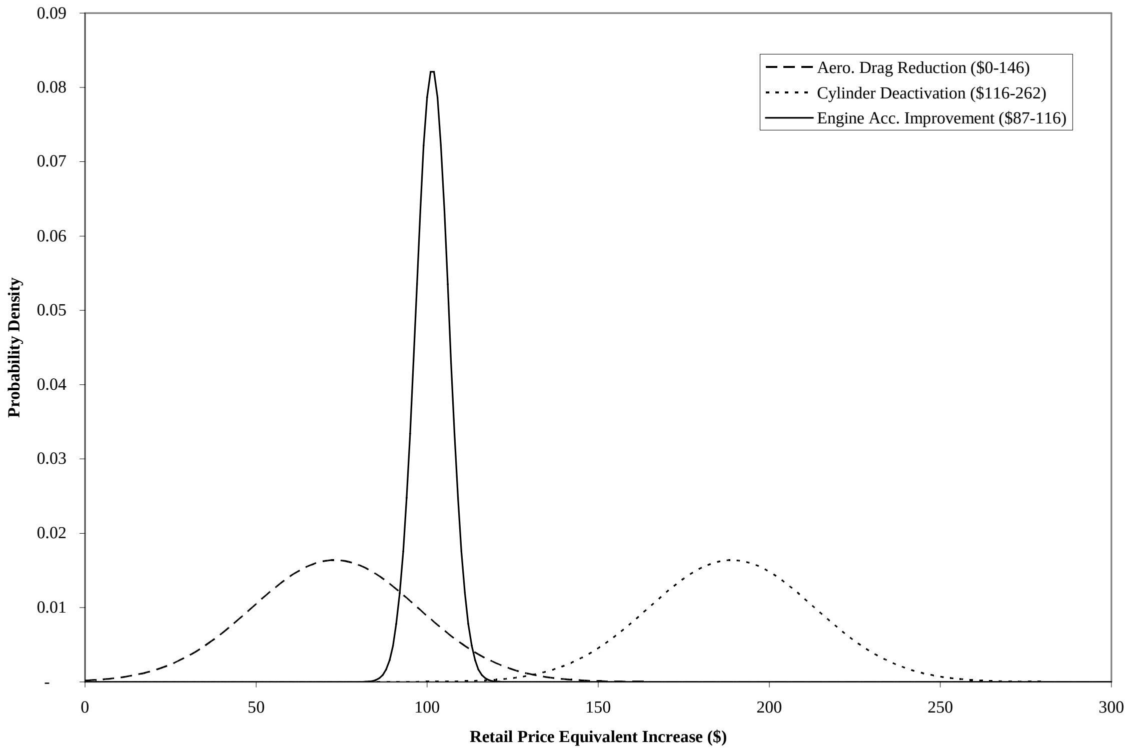
(5) The rebound effect.

Technology Costs

The costs incurred by manufacturers to modify their vehicles to meet new CAFE levels are assumed to be passed on to consumers in the form of higher new car prices. These technology costs are the primary determinant of the overall cost of improving fuel economy.

Thirty-one different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were summarized in Table VI-4 earlier in this analysis. Table VI-4 also summarizes the estimated range of costs for these technologies as provided by the National Academy of Sciences (NAS) in their report on CAFE. The expected values (mid-range values) from this table were used in the main analysis. For the uncertainties analysis, the full range of NAS cost estimates is used. The uncertainty model assumes a normal distribution for these costs, with each end of the range being three standard deviations from the mean (or expected) value. Figure X-1 graphically demonstrates the distributions of a sample of three of the technologies.

Figure X-1
Normal Distributions for 3 Different Technologies



Technology Effectiveness

The modifications adopted by manufacturers to enable their vehicles to meet new CAFE levels will improve fuel efficiency and reduce the cost of operating the more efficient vehicles. The effectiveness of each technology determines how large an impact it will have towards enabling manufacturers to meet the higher CAFE standards, and will thus determine how much additional improvement is needed and which additional technologies will be required to achieve full compliance. In selecting the likely path that manufacturers will choose to meet CAFE, the CAFE model tests the interaction of technology costs and effectiveness to achieve an optimal (cost-minimizing) technological solution. Technology effectiveness is thus a primary determinant of the overall cost and benefit of improving fuel economy.

Thirty-one different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were summarized in Table VI-4 earlier in this analysis. Table VI-4 also summarizes the estimated range of effectiveness for these technologies as provided by the National Academy of Sciences in their report on CAFE. The expected values (mid-range values) from this table were used in the main analysis. For the uncertainty analysis, the full range of effectiveness estimates is used. The uncertainties model assumes a normal distribution for these values, with each end of the range being three standard deviations from the mean (or expected) value.

Fuel Prices

Higher CAFE standards will result in reduced gasoline consumption, which will translate into lower vehicle operating costs for consumers. The value of this reduced fuel consumption is a direct function of fuel prices. Fuel prices are thus a primary determinant of the overall social benefit that will result from improving fuel economy.

The analysis attempts to measure impacts that occur as much as 40 years in the future and estimating gasoline prices this far in advance is an uncertain process. In the main analysis, the agency utilized predicted fuel prices from the Energy Information Administration’s (EIA) publication Annual Energy Outlook 2006 (AEO) Early Release. The main analysis is based on the AEO Reference Case scenario, which represents EIA’s best estimate of future fuel prices.

For the uncertainty analysis, the Agency examined two other AEO scenarios, the Low Oil Price scenario (LOP) and the High Oil Price scenario (HOP). The LOP scenario was chosen to allow for the possibility that the EIA's Reference Case predictions could overestimate the price of gasoline in the future. However, recent escalation in the price of gasoline has resulted in prices that have at times exceeded those estimated by EIA for their reference case. It is unclear whether this just reflects a temporary spike in price levels or whether it is an indication of permanently higher price levels. To reflect the possibility of significantly higher prices, the Agency selected the HOP case, which among the AEO 2006 scenarios comes closest to matching the highest prices seen during the recent gasoline price surge, and which gives the highest gasoline price forecasts among all AEO 2006 scenarios.

Each of these scenarios was applied as a discrete input (i.e., draws were not made from among the three scenarios separately for each future year). Rather, for each draw, one of the three scenarios was chosen and applied across the full vehicle life for each model year. The probability of selection for each of the three scenarios was modeled using discrete weights of 50 percent for the Reference Case, and 25 percent for both the LOP and HOP cases. Table X-2 lists the AEO gasoline price forecasts under each scenario. These same prices are demonstrated graphically (in 2003 economics) in Figure X-2. Note that these prices include Federal, State, and local fuel taxes. For the uncertainty analysis, taxes were removed because they are viewed as transfer payments (see discussion in Chapter VIII). Estimated retail prices are shown here because they are a better reference point for most readers.

Table X-2

AEO 2006 Gasoline Price Scenarios (all figures in year 2003 dollars) [93]

Year	AE0 2006 Fuel Price Forecast (2003$/gallon)	High Case (2003$/gallon)	Low Case (2003$/gallon)
2008	$2.161	$2.362	$2.106
2009	$2.086	$2.369	$1.967
2010	$1.999	$2.334	$1.833
2011	$2.000	$2.409	$1.793
2012	$1.985	$2.473	$1.746
2013	$1.975	$2.490	$1.698
2014	$1.960	$2.557	$1.682
2015	$1.969	$2.669	$1.666
2016	$1.983	$2.675	$1.651
2017	$1.993	$2.670	$1.652
2018	$2.007	$2.726	$1.648
2019	$2.023	$2.782	$1.641
2020	$2.048	$2.814	$1.664
2021	$2.062	$2.856	$1.653
2022	$2.075	$2.849	$1.647
2023	$2.086	$2.873	$1.648
2024	$2.095	$2.821	$1.640
2025	$2.105	$2.872	$1.632
2026	$2.116	$2.897	$1.638
2027	$2.123	$2.904	$1.640
2028	$2.135	$2.937	$1.642
2029	$2.145	$2.974	$1.652
2030	$2.157	$2.998	$1.650
2031	$2.169	$3.031	$1.654
2032	$2.182	$3.061	$1.658
2033	$2.195	$3.092	$1.661
2034	$2.208	$3.122	$1.665
2035	$2.221	$3.153	$1.669
2036	$2.235	$3.185	$1.673
2037	$2.248	$3.216	$1.676
2038	$2.261	$3.248	$1.680
2039	$2.275	$3.281	$1.684
2040	$2.288	$3.313	$1.688
2041	$2.302	$3.346	$1.692
2042	$2.315	$3.380	$1.695
2043	$2.329	$3.413	$1.699
2044	$2.343	$3.447	$1.703
2045	$2.357	$3.482	$1.707
2046	$2.371	$3.516	$1.711
2047	$2.385	$3.551	$1.715

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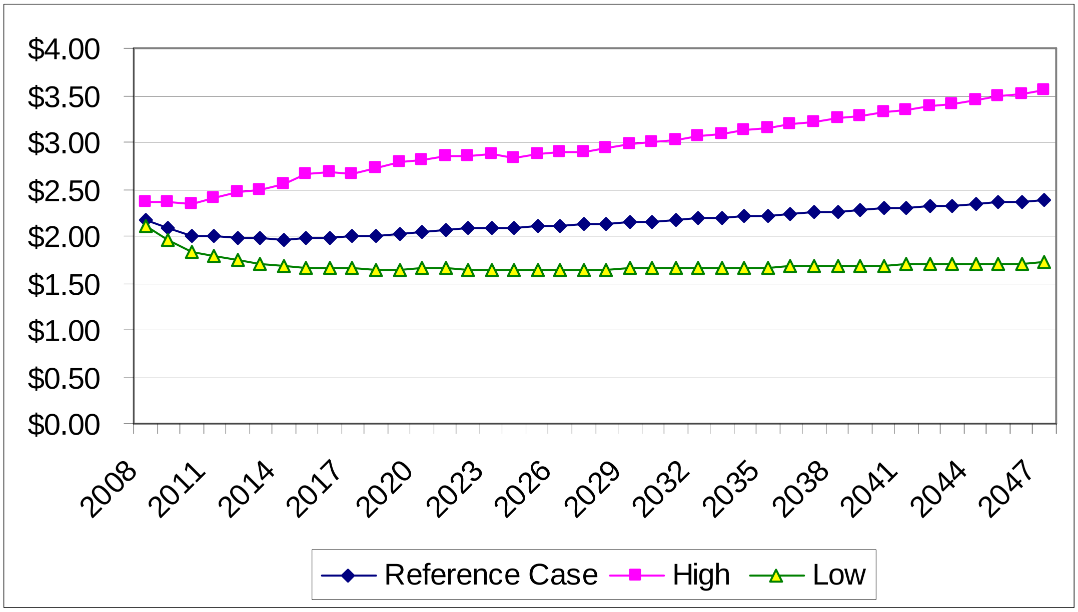
[93] The EIA gasoline prices are provided in 2003 dollars. In terms of 2006 dollars (based on the 2003 GDP deflator) the forecasted low and high range of fuel prices during this period would be $2.04 to 2.49.

Figure X-2

AEO Fuel Price Scenarios



Oil Consumption Externalities

Reduced fuel consumption can benefit society by lowering the world market price for oil, reducing the threat of petroleum supply disruptions, and reducing the cost of maintaining military security in oil producing regions and operating the strategic petroleum reserve. These benefits are called "externalities" because they are not reflected directly in the market price of fuel. A full description of these externalities is included in Chapter VIII under "Other Economic Benefits from Reducing Petroleum Use." These factors increase the net social benefits from reduced fuel consumption. Although they represent a relatively small portion of overall social benefits, there is a significant level of uncertainty as to their values. For this reason, they were examined in the uncertainty analysis.

Table X-3 lists the range of values that were examined for oil consumption externalities. The expected values were used in the main analysis. Both the value of reducing U.S. demand on the world market price for oil and the value of reduced threat of supply disruptions were derived from a study by Leiby et al (see Chapter VIII). For reasons noted in Chapter VIII, military security is not specifically valued in this analysis. A normal distribution was assumed for the range of values for oil consumption externalities with the low and high values assumed to be two standard deviations from the mean, based on the Leiby estimates.

Table X-3
Uncertainty Ranges for Oil Consumption Externalities ($/gallon)

	Low	**Expected**	**High**
For reducing U.S. demand on world market price	$0.0340	$0.0436	$0.0532
For reducing the threat of supply disruptions	$0.0153	$0.0445	$0.0737

The Rebound Effect

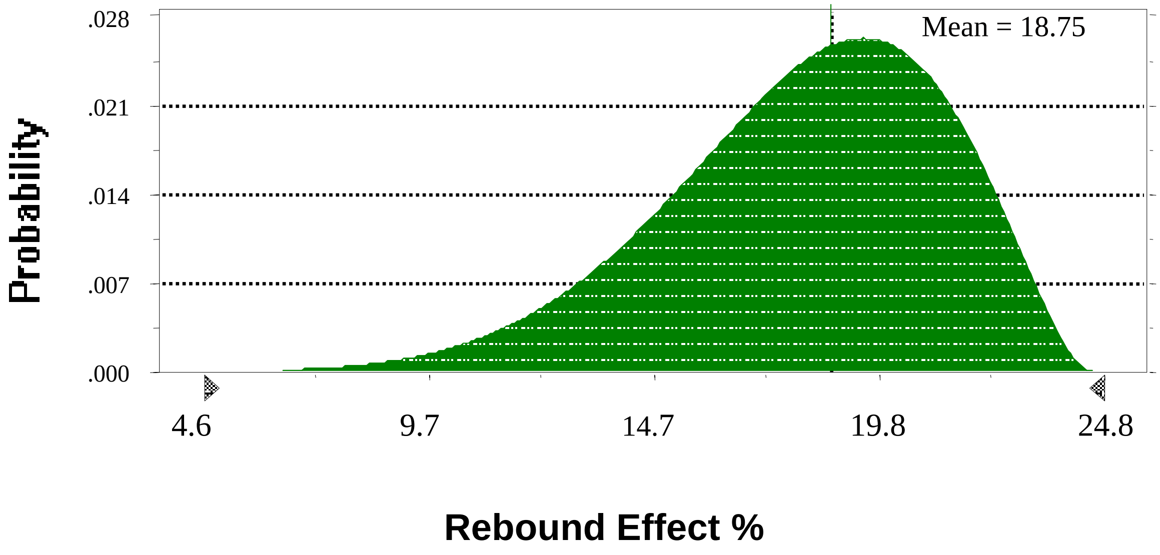
By reducing the amount of gasoline used and, thus, the cost of operating a vehicle, higher CAFE standards are expected to result in a slight increase in annual miles driven per vehicle. This "rebound effect" impacts net societal benefits because the increase in miles driven offsets a portion of the gasoline savings that results from more fuel-efficient vehicles. Although consumers derive some value from this extra driving, it also leads to increases in crash, congestion, noise, and pollution costs associated with driving. Most recent estimates of the magnitude of the rebound effect for light duty vehicles fall in the range of 10-20 percent (i.e., increasing vehicle use will offset 10-20 percent of the fuel savings resulting from an improvement in fuel economy). A more complete discussion of the rebound effect is included in

Chapter VIII. The agency employed a rebound effect of 20 percent in the main analysis. For the uncertainty analysis, a range of 5 to 25 percent is used and employed in a skewed Beta distribution with a mean of approximately 20 percent. The skewed distribution reflects the agency's belief that the 20 percent value chosen for the main analysis is likely conservative and the probability that the correct value is less than 20 percent exceeds the probability that it is greater than 20 percent.

Figure X-3 demonstrates the modeled distribution used for the rebound effect.

FIGURE X-3
Uncertainty Distribution for the Rebound Effect

Beta Distribution
Alpha = 9
Beta = 3
Scale = 25
Mode = 20.07
Range: about 5 to 25%



Modeling Results – Trial Draws

Because of the complexity of the CAFE model, the computer time required to perform the uncertainty analysis was significant. The uncertainty analysis conducted a total of 11,200 trials (5,600 for each discount rate) over a 40 hour period using four workstations, each of which had two dual-core (AMD Opteron) processors. Because of parallel processing, the workstations were able to process each trial in 50-60 seconds. The process was stopped when the accumulated draws were judged to adequately reflect the modeled distributions for the uncertainty factors (see for example Figures X-4 through X-12). This produced distributions that were imperfect, but which did reflect the general shapes expected for the uncertainty factor distributions. The agency believes that the number of trials that were run adequately describes the level of uncertainty that exists within the analysis. Figures X- 4 through X-12 illustrate the draw results for a sample of the 65 variables (31 technology effectiveness rates, 31 technology costs, the fuel price scenario, oil import externalities, and the rebound effect) that were examined.

Figure X-4

Monte Carlo Draw Profile
Cost of Low Rolling Resistance Tires

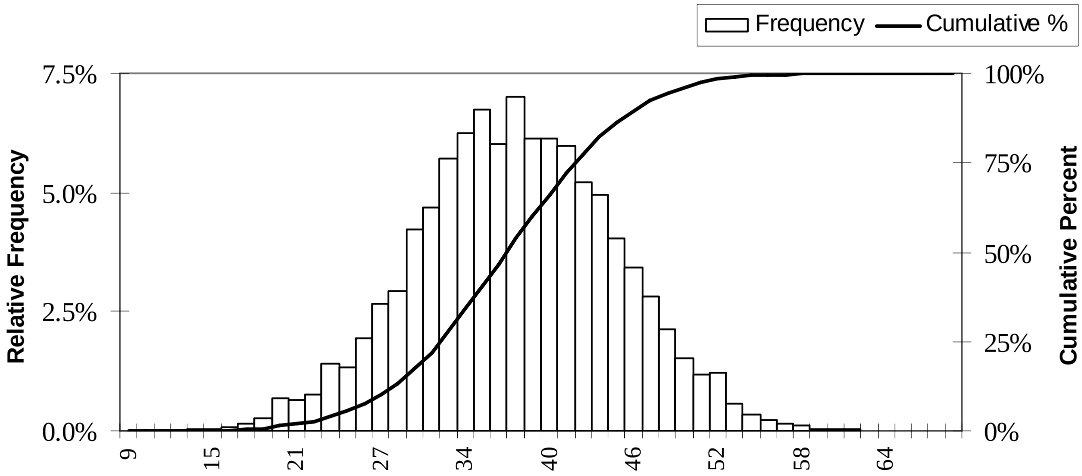


Figure X-5

Monte Carlo Draw Profile
Cost of Variable Valve Timing

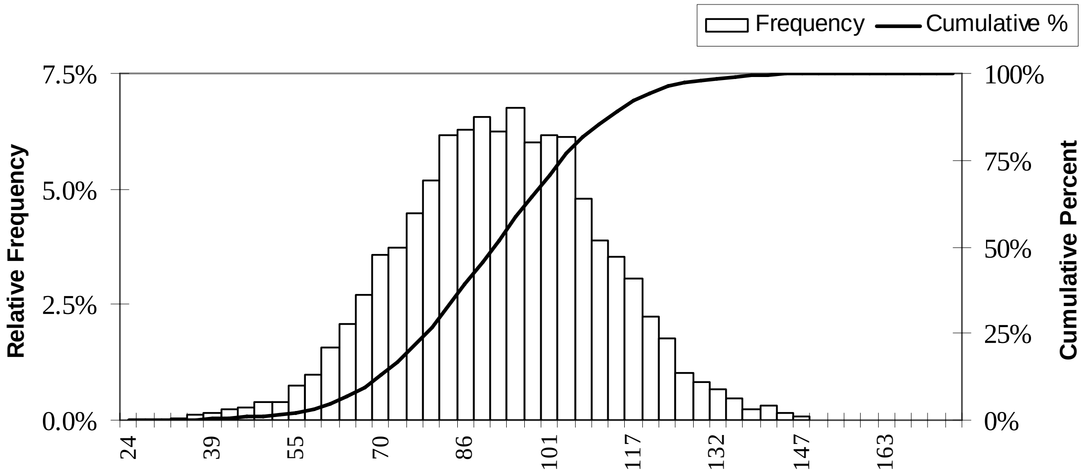


Figure X-6

Monte Carlo Draw Profile
Cost of Six Speed Automatic Transmission

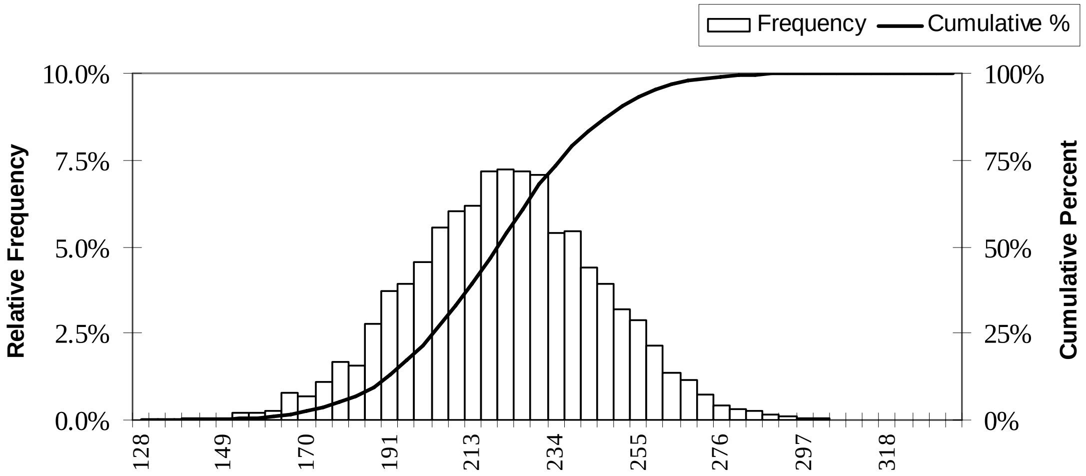


Figure X-7

Monte Carlo Draw Profile
Effectiveness of Improved Rolling Resistance

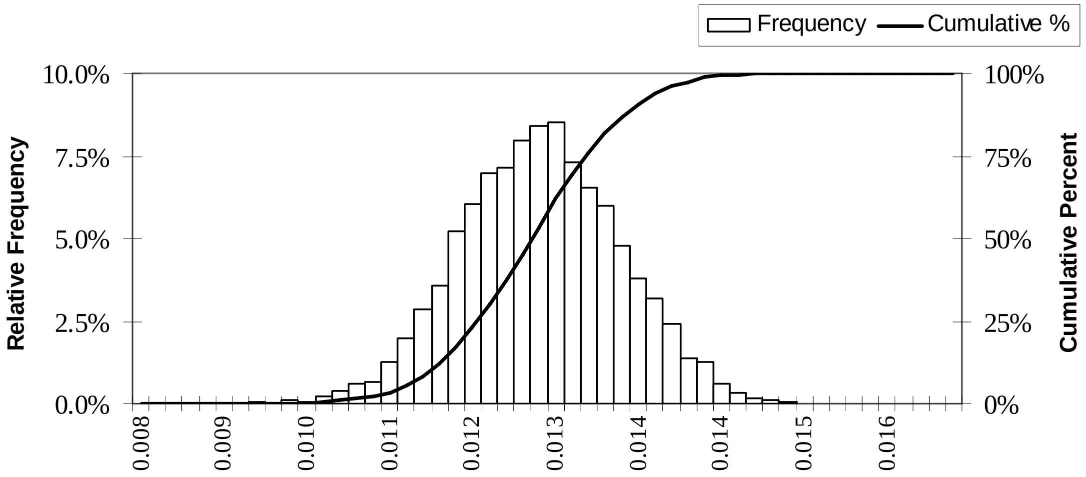


Figure X-8

Monte Carlo Draw Profile
Effectiveness of Continuously Variable Transmission

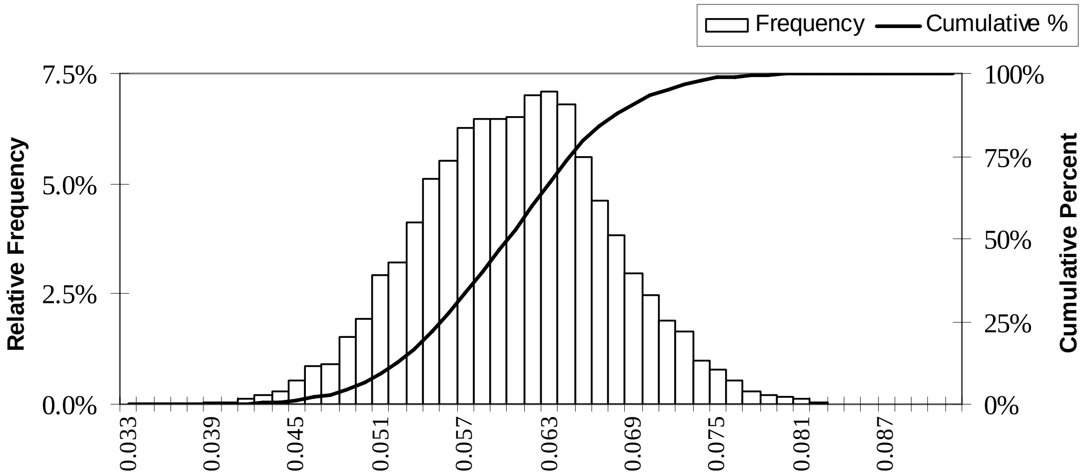


Figure X-9

Monte Carlo Draw Profile
Effectiveness of Engine Supercharge and Downsizing

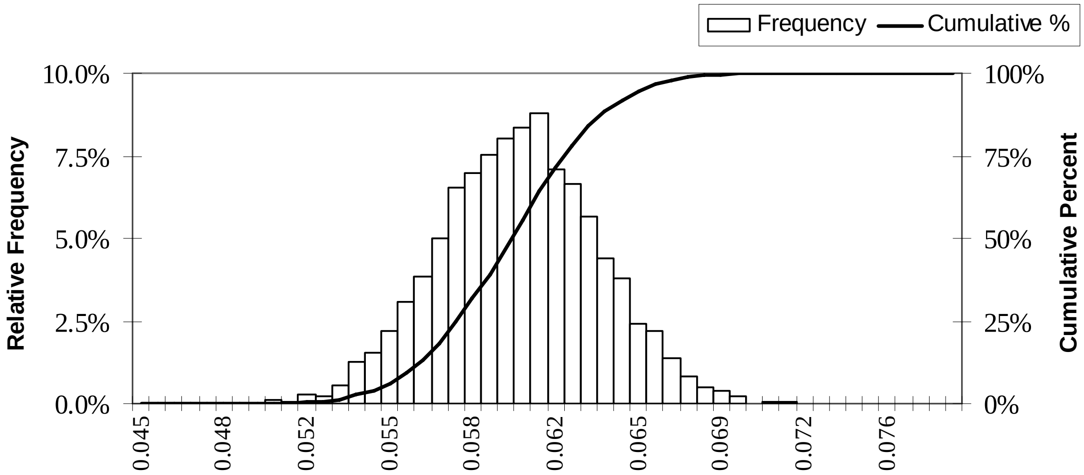


Figure X-10

Monte Carlo Draw Profile

Pretax Fuel Price Path

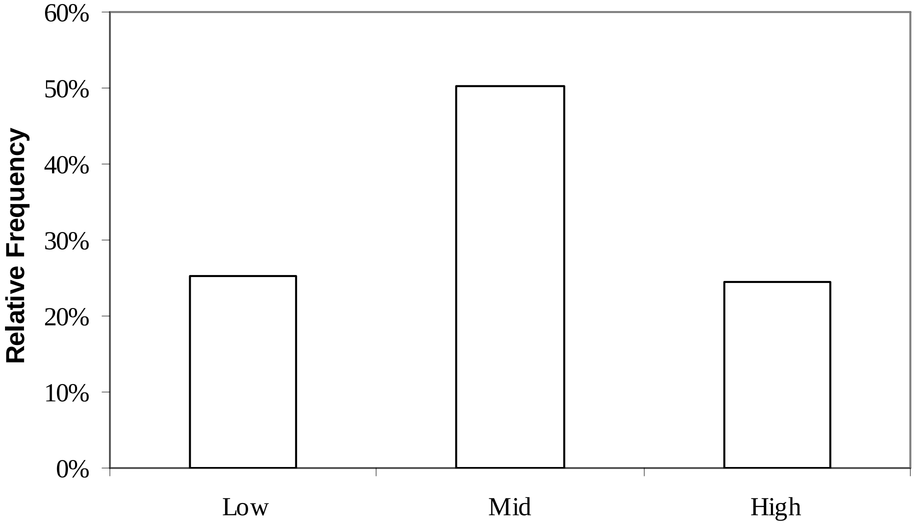


Figure X-11

Monte Carlo Draw Profile
Monopsony Cost

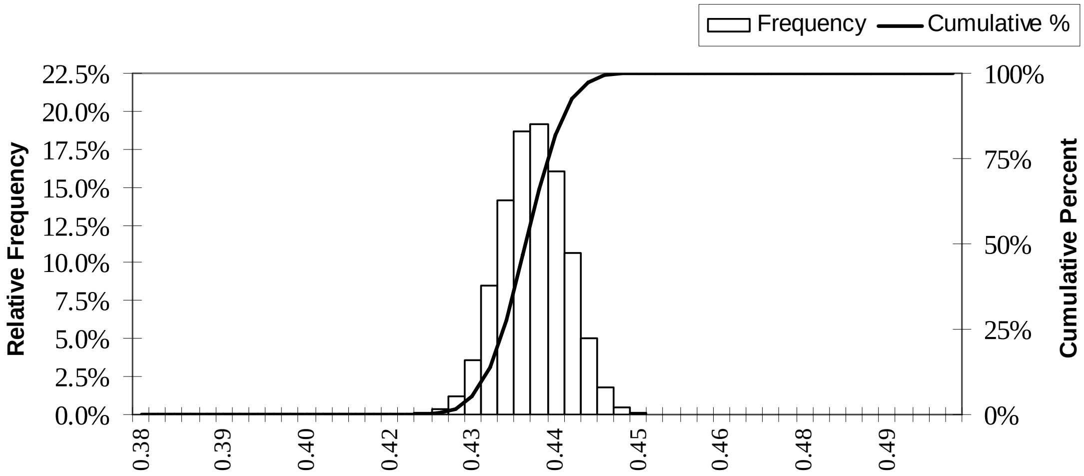
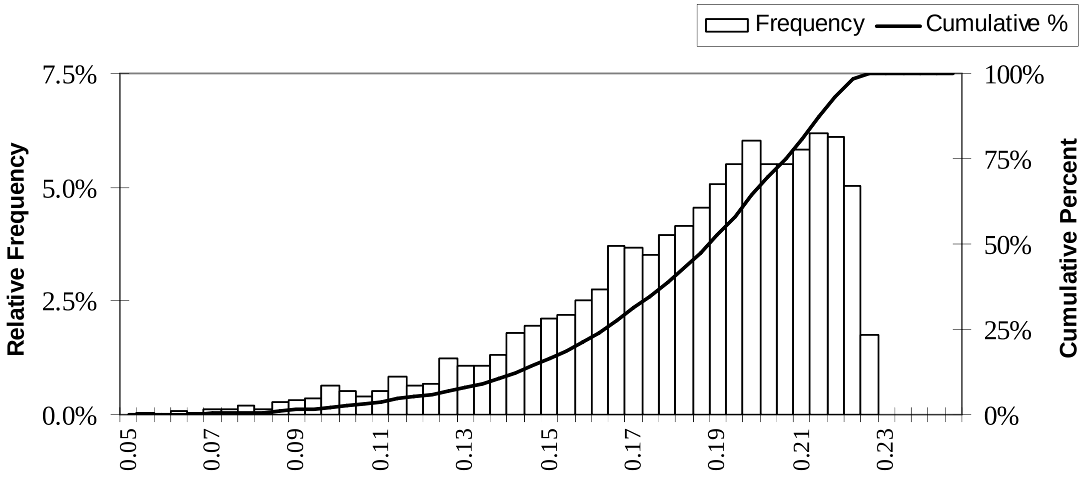


Figure X-12

Monte Carlo Draw Profile
Rebound Effect



Modeling Results – Output

Tables X-4 and X-5 summarize the modeling results for fuel saved, total costs, societal benefits, and net benefits. They also indicate the probability that net benefits exceed zero. These results are also illustrated in Figures X-13 through X-16 under Reformed CAFE at 7 percent for MY 2011. Although not shown, the general shape of the resulting output distributions are similar for Unreformed CAFE, for the 3 percent discount rate, and for other years as well. The triple-humped shape that occurs for both social benefits and net benefits reflects the three different gasoline price scenarios. About half of all draws were selected from the AEO Reference Case, while about one quarter were drawn from the Low Oil Price scenario and one quarter were drawn from the High Oil Price scenario. The three separate humps reflect the increasing impact on benefits from the three progressively higher oil price scenarios. The following discussions summarize the range of results presented in these tables across both the 7 percent (lower range) and 3 percent (upper range) discount rates.

<u>Fuel Savings</u>: The analysis indicates that MY 2008 vehicles will experience between 373 million and 937 million gallons of fuel savings over their useful lifespan. MY 2009 vehicles will experience between 1,650 million and 2,323 million gallons of fuel savings over their useful lifespan. MY 2010 vehicles will experience between 1,907 million and 2,812 million gallons of fuel savings over their useful lifespan. MY 2011 vehicles will experience between 2,682 and 3,429 million gallons of fuel savings over their useful lifespan. Over the combined lifespan of the four model years, between 6.6 billion and 9.5 billion gallons of fuel will be saved.

Total Costs: The analysis indicates that owners of MY 2008 vehicles will pay between $300 million and $823 million in higher vehicle prices to purchase vehicles with improved fuel efficiency. MY 2009 owners will pay between $1,338 million and $2,170 million more. MY 2010 owners will pay between $1,367 million and $2,490 million more. MY 2011 owners will pay between $1,981 million and $3,126 million more. Owners of all four model year vehicles combined will pay between $5.0 billion and $8.6 billion in higher vehicle prices to purchase vehicles with improved fuel efficiency.

Societal Benefits: The analysis indicates that changes to MY 2008 vehicles will produce overall societal benefits valued between $359 million and $1,801 million. MY 2009 vehicles will produce benefits valued between $1,319 million and $4,576 million. MY 2010 vehicles will produce benefits valued between $1,533 million and $5,622 million. MY 2011 vehicles will produce benefits valued between $2,165 million and $6,726 million. Over the combined lifespan of the four model years, societal benefits valued between $5.4 billion and $18.7 billion will be produced.

Net Benefits: The analysis shows that Reformed CAFE generally provides more net benefits than Unreformed CAFE for every model year. Reformed CAFE provides more benefits at roughly the same costs as Unreformed CAFE. This uncertainty analysis indicates that the net impact of the higher CAFE requirements for MY 2008 will be between a net cost of $273 million and a net benefit of $1,236 million. There is at least a 68 percent certainty that changes made to MY 2008 vehicles to achieve the higher CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2009 will be between a net cost of $523 million and a net benefit of $2,902 million. There is at least a 79 percent certainty that changes made to MY 2009 vehicles to achieve the CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2010 will be between a net cost of $500 million and a net benefit of $3,431 million. There is at least an 82 percent certainty that changes made to MY 2010 vehicles to achieve the higher CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2011 will be between a net cost of $730 million and a net benefit of $4,329 million. There is at least an 83 percent certainty that changes made to MY 2011 vehicles to achieve the CAFE standards will produce a net benefit. Over all four model years, the higher CAFE standards will produce net impacts ranging from a net cost of $2.0 billion to a net benefit of $11.9 billion. There is <u>at least</u> a 68 percent certainty that higher CAFE standards will produce a net societal benefit in <u>each</u> of the model years covered by this final rule. In most years, this probability is significantly higher, especially under the 3 percent discount rate and for Reformed scenarios.

Table X-4

Uncertainty Analysis Results

(3% Discount Rate)

	Unreformed			**Reformed**		
MY 2008	Mean	Low	High	Mean	Low	High
Fuel Saved (mill. gall.)	547	373	787	739	569	937
Total Cost ($mill.)	516	300	823	541	312	762
Societal Benefits ($mill.)	734	434	1,327	1,003	636	1,801
Net Benefits ($mill.)	218	-165	805	462	-6	1,236
% Certainty Net Ben. > 0	87.9%			100%		
MY 2009						
Fuel Saved (mill. gall.)	1,846	1,650	2,207	1,974	1,775	2,323
Total Cost ($mill.)	1,656	1,338	2,061	1,720	1,394	2,170
Societal Benefits ($mill.)	2,502	1,574	4,232	2,682	1,680	4,576
Net Benefits ($mill.)	846	-212	2,745	962	-210	2,902
% Certainty Net Ben. > 0	98.2%			99.1%		
MY 2010						
Fuel Saved (mill. gall.)	2,169	1,907	2,666	2,299	2,062	2,812
Total Cost ($mill.)	1,902	1,367	2,505	1,954	1,467	2,490
Societal Benefits ($mill.)	3,005	1,830	5,326	3,185	2,002	5,622
Net Benefits ($mill.)	1,102	-162	3,297	1,230	-106	3,431
% Certainty Net Ben. > 0	99.1%			99.8%		
MY 2011	**Not Applicable**					
Fuel Saved (mill. gall.)				2,909	2,682	3,429
Total Cost ($mill.)				2,526	1,981	3,126
Societal Benefits ($mill.)				4,075	2,585	6,726
Net Benefits ($mill.)				1,549	-291	4,329
% Certainty Net Ben. > 0				99.1%		

Table X-5
Uncertainty Analysis Results
(7% Discount Rate)

	Unreformed			**Reformed**		
MY 2008	Mean	Low	High	Mean	Low	High
Fuel Saved (mill. gall.)	547	373	787	739	569	937
Total Cost ($mill.)	516	300	823	541	312	762
Societal Benefits ($mill.)	596	359	1,045	813	526	1,414
Net Benefits ($mill.)	80	-273	527	272	-115	859
% Certainty Net Ben. > 0	68.1%			96.5%		
MY 2009						
Fuel Saved (mill. gall.)	1,846	1,650	2,207	1,974	1,775	2,323
Total Cost ($mill.)	1,655	1,338	2,061	1,720	1,394	2,170
Societal Benefits ($mill.)	2,029	1,319	3,329	2,175	1,417	3,587
Net Benefits ($mill.)	373	-523	1,842	455	-491	1,936
% Certainty Net Ben. > 0	79.0%			81.1%		
MY 2010						
Fuel Saved (mill. gall.)	2,169	1,907	2,666	2,299	2,062	2,812
Total Cost ($mill.)	1,901	1,367	2,505	1,954	1,467	2,490
Societal Benefits ($mill.)	2,431	1,533	4,168	2,577	1,674	4,395
Net Benefits ($mill.)	529	-500	2,248	623	-455	2,333
% Certainty Net Ben. > 0	81.7%			85.9%		
MY 2011	**Not Applicable**					
Fuel Saved (mill. gall.)				2,909	2,682	3,429
Total Cost ($mill.)				2,526	1,981	3,126
Societal Benefits ($mill.)				3,292	2,165	5,257
Net Benefits ($mill.)				765	-730	2,940
% Certainty Net Ben. > 0				83.1%		

Figure X-13
Model Output Profile
Reformed CAFE Fuel Savings, MY 2011

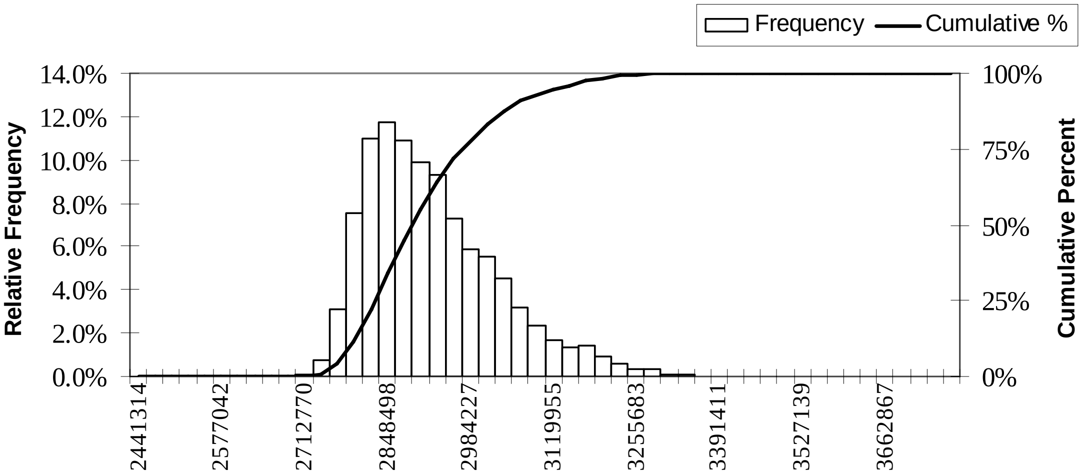


Figure X-14
Model Output Profile
Reformed CAFE Total Social Benefits, MY 2011

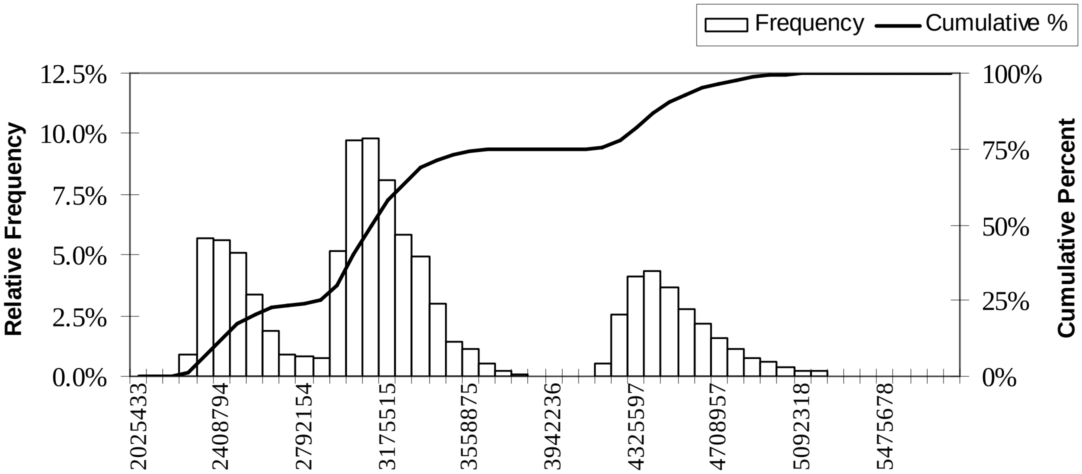


Figure X-15

Model Output Profile

Reformed CAFE Technology Costs, MY 2011

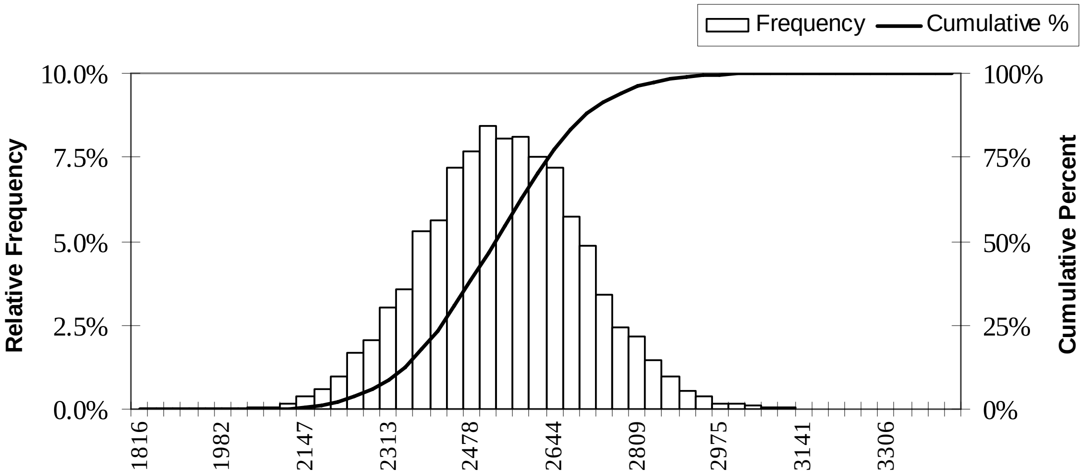
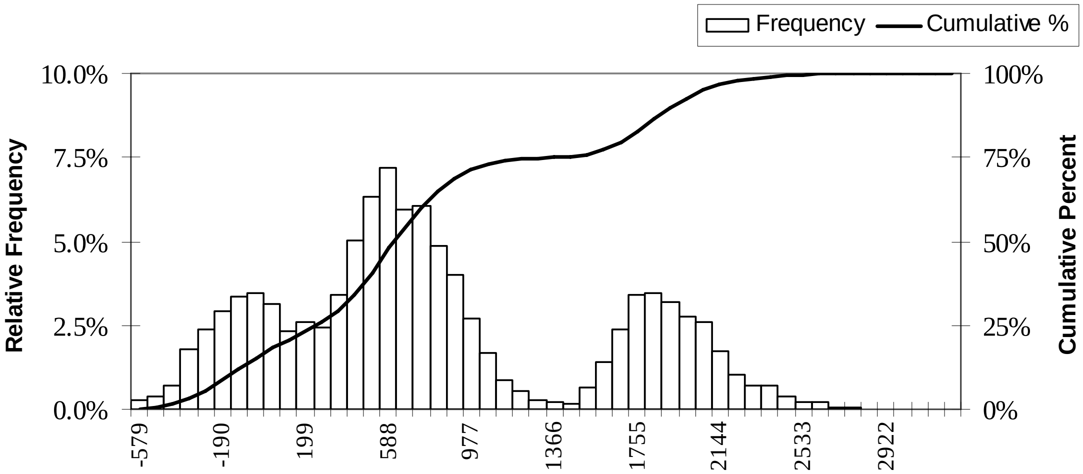


Figure X-16

Model Output Profile

Reformed CAFE Net Benefits, MY 2011



XI. SMALL BUSINESS IMPACT

Regulatory Flexibility Act

The Regulatory Flexibility Act of 1980 (5 U.S.C. §601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small businesses, small organizations and small governmental jurisdictions. According to the Small Business Administration's small business size standards (see CFR 121.201), an automobile manufacturer (NAICS code 336111) must have less than 1,000 employees to qualify as a small business.

The agency knows of no small businesses that produce light trucks. All of the manufacturers of light trucks have thousands of employees.

Unfunded Mandate Reform Act Analysis

The Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure of State, local, or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (annually adjusted for inflation with a base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for the year 2003 (base year 2000 = 100) results in $115 million (105.998/92.106 = 1.15).

The assessment can be included in conjunction with other assessments, as it is here. These effects have been discussed in detail in previous sections of this Final Regulatory Impact Analysis. This proposal is not likely to result in expenditures by State, local, or tribal governments of more than $115 million annually. However, it is estimated to result in expenditures by light truck manufacturers of more than $115 million annually.

Appendix A: A Comparison of Fuel Savings Results in the NPRM and Final Rule

This appendix compares the fuel savings estimated for the reformed CAFE standards in the NPRM and final rule, and discusses the revisions incorporated into the final rule analysis that produced these changes.

Table A -1 compares the industry-wide CAFE levels required by the Reformed standard proposed in the NPRM to those established in the final rule. As this comparison shows, the standards established in the final rule are more stringent than those proposed in the NPRM. Moreover, the final rule incorporates an additional class of vehicles - MDPVs - into the standard in MY 2011 that were not included in the NPRM proposal. The final rule thus requires higher levels of fuel efficiency for more vehicles than was proposed in the NPRM. However, while the NPRM estimated fuel savings of 10.2 billion gallons over the lifetimes of the 4 model years affected by the rule, the final rule estimates that 7.8 billion gallons will be saved. This difference, which occurred despite the increased stringency of the final rule, can be explained by a number of factors that affected the agency’s analysis. These include:

- Changes in the Volpe CAFE model
- Higher fuel price forecasts
- Revisions to the Reformed CAFE standard
- Changes to manufacturers’ product plans

Each of these factors and their impact on NHTSA's estimates of fuel savings will be discussed separately and then summarized to account for the difference between the NPRM and final rule fuel savings estimates.

Table A-1
Industry-Wide Fuel Economy Levels Required
by Proposed and Final Reformed CAFE Standards

MY	Proposed	Final	Increase
2008	22.6	22.7	+0.1
2009	23.1	23.4	+0.3
2010	23.4	23.7	+0.3
2011	23.9	24.0	+0.1

Changes in the NHTSA CAFE Model

There were two changes made to the Volpe CAFE model between the analysis reported in the NPRM and the analysis conducted for the final rule. First, the maximum lifetime of light trucks was extended from 25 to 36 years, and the fraction of vehicles originally produced during a model year that remain in service at each age was increased to reflect this longer lifetime. These changes were made in response to NHTSA's detailed analysis of R.L. Polk registration data for recent model year light trucks. These changes increase fuel savings resulting from any increase in CAFE standards because they increase the number of miles driven (and the amount of fuel consumed under the Baseline standard) during a vehicle's expected lifetime. This change increased the total fuel savings estimated to result from the Reformed CAFE standard by 0.2 billion gallons.

The second change to the Volpe CAFE model was a revision to the way it applied technology to achieve increased fuel economy. In the NPRM, the agency applied technologies at a more aggressive rate than suggested in the NAS report. In some cases this forced technologies to be applied earlier and to be used on a larger proportion of a manufacturer's fleet than in the final rule. Manufacturers commented that this would result in stranded costs as they were forced to prematurely curtail normal production cycles and write off capital investments over reduced production levels. The NPRM also considered one technology, automatic shift manual transmission, which was judged to be unavailable in the stage analysis.

In the final rule, model technology availability was altered to be consistent with the stage analysis. Consistent with NAS recommendations, this reflects more realistic assumptions about the timing of significant technological changes in individual vehicle models, so that they correspond to manufacturers' normal product planning and production cycles. These changes reduced the estimate of fuel savings for the Reformed CAFE standard by 1.5 billion gallons. Thus, the net effect of changes in the NHTSA CAFE model was to reduce estimated fuel savings for the Reformed standard by 1.3 billion gallons (1.5 minus 0.2 billion gallons).

Higher Fuel Price Forecasts

Recent instability in global oil exporting regions combined with disruption in oil refining capabilities caused by Hurricane Katrina have caused dramatic increases in the price of oil. In response to these and other factors, the Energy Information Administration (EIA) has increased its forecasts of fuel prices over the 2006-2025 period by approximately $0.50 per gallon. The agency adopted these higher prices in its analysis of the final rule. These higher fuel prices had the effect of raising the optimized fuel economy targets for MY 2011 under the Reformed CAFE standard.[94] This, in turn, raised the estimate of fuel savings resulting from the Reformed standard by 0.7 billion gallons.

However, as discussed in Chapter VIII, higher fuel prices increase the per-mile cost of driving and therefore are expected to reduce the average number of miles driven each year by light trucks (an impact of the "rebound effect" discussed in detail in Chapter VIII). The effect of the resulting reduction in lifetime use of MY 2008-11 light trucks is to reduce fuel savings resulting from the Reformed standard by 0.7 billion gallons, offsetting the gain that occurred due to higher fuel prices. This 0.7 billion gallon reduction results from the effect of higher fuel prices on usage of all four model years of light trucks affected by the Reformed CAFE standard (2008-11), while the 0.7 billion increase in fuel savings resulting from higher fuel prices resulted from higher fuel economy targets for only MY 2011 light trucks. The impact of higher standards for MY 2011 was thus offset by the combined impact of less driving over the 4 model years combined.

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[94] Because the fuel economy targets for MY 2008-10 are set by equating industry-wide compliance costs for the Reformed CAFE standard to those under the Unreformed standard (rather than by the optimization process used in MY 2011), higher fuel prices do not affect the targets for those years.

Revisions to the Reformed CAFE Standard

The fuel savings estimates for the Reformed CAFE standard reported in the NPRM and final rule also differ because the Reformed standard adopted by the final rule differs in certain details from the Reformed standard described in the NPRM. First, the Reformed CAFE standard adopted in the final rule replaces the step function for setting fuel economy targets for different footprint values that was used in the NPRM Reformed standard with a continuous function. While the continuous function closely follows the shape of the step function, this change slightly reduced the fuel savings estimate for the Reformed CAFE standard by less than 0.1 billion gallons.

Second, the Reformed CAFE standard adopted in the final rule set fuel economy targets for MY 2008-10 that are more stringent than those proposed in the NPRM. This occurred because the targets for those model years are set by equalizing total industry-wide compliance costs with the Unreformed CAFE standard. Estimated compliance costs for the Unreformed standard are higher in the final rule than in the NPRM because of the more restrictive assumptions regarding technology availability and phase-in rates. Setting fuel economy targets under the Reformed standard to equal these higher compliance costs therefore results in more stringent targets. This change increased the estimated fuel savings resulting from the Reformed standard by 1.6 billion gallons.

Finally, the Reformed CAFE standard adopted in the final rule includes MDPVs effective in MY 2011, while the NPRM excluded MDPVs in all model years. The basis for the agency's decision to include these vehicles is discussed in the preamble to the final rule. Including MDPVs under the Reformed standard in MY 2011 increased the estimate of fuel savings by 0.3 billion gallons.

The net effect of these three revisions to the Reformed CAFE standard was to increase estimated fuel savings from the Reformed standard by 1.8 billion gallons (1.6 plus 0.3 minus 0.1 billion gallons).

Changes to Manufacturers' Product Plans

Changing market conditions and anticipated changes in CAFE regulations have induced manufacturers to revise their production plans. After publication of the NPRM, manufacturers submitted revised plans which indicate that they intend to produce fewer large trucks and more small trucks, and to voluntarily improve the fuel efficiency of many of the light truck models they plan to produce in the model years affected by the rule.

Many of the technology improvements that the agency included in setting standards for the NPRM are thus no longer available to increase fuel economy because they are already being utilized to achieve the higher baseline fuel economy levels reflected in manufacturers' revised product plans. These changes increased the industry average baseline fuel economy used in the analysis of the final rule well beyond the level employed in the NPRM analysis. Table A-2 summarizes these changes for the largest manufacturers.

Table A-2
Baseline Fuel Economies Relied Upon in the NPRM and Final Rule

Manufacturer	**MY 2008 (mpg)**		**MY 2009 (mpg)**		**MY 2010 (mpg)**	
	NPRM	**Final**	**NPRM**	**Final**	**NPRM**	**Final**
General Motors	21.2	21.3	21.3	21.4	21.3	21.5
Ford	21.6	21.7	22.0	21.9	22.3	22.9
DaimlerChrysler	21.9	22.0	22.3	22.0	22.3	22.4
Toyota	22.9	22.5	22.9	22.4	22.9	22.9
Honda	24.4	24.5	24.4	24.5	24.4	24.5
Nissan	20.7	21.0	20.8	21.0	21.2	21.2

This increase in baseline fuel economy reduced the estimated fuel savings resulting from the Reformed standards by 5.3 billion gallons. This reduced fuel consumption by MY 2008-11 light trucks now appears to be attributable to voluntary actions taken by manufacturers, rather than to the final rule.

A second impact of the manufacturers’ revised product plans occurs because a larger portion of their planned fleets now consists of smaller light trucks, which face more stringent fuel economy targets under the Reformed CAFE standard. This shift in the mix of vehicle sizes results in a higher overall average CAFE requirement for the entire vehicle fleet, which increases estimated lifetime fuel savings for MY 2008-2011 light trucks by 2.4 billion gallons. The net effect of revised manufacturer product plans is to reduce the fuel savings attributed to the Reformed CAFE standard in the NPRM by 2.9 billion gallons (5.3 minus 2.4 billion gallons).

Summary

Table A-3 summarizes the various changes that have affected the agency's original estimate of fuel economy savings reported previously in the NPRM. By far the largest impact was from the shift in manufacturer product plans to voluntarily adopt many of the technologies previously used in setting the proposed standards (-5.3 billion gallons) and to shift their production plans towards smaller vehicles with higher CAFE targets (+2.4 billion gallons). Significant shifts also were associated with the agency's decision to adopt technology application rates consistent with the NAS report (-1.5 billion gallons), and from setting more stringent fuel economy targets for MY 2008-10 (+1.6 billion gallons).

Higher fuel prices caused adoption of more stringent optimum standards in MY 2011 (+ 0.7 billion gallons), but this impact was offset by the adjustment in light truck use and lifetime fuel consumption assumed to result from higher fuel prices. Including MDPVs in MY 2011 increased fuel savings by 0.3 billion gallons, while minor impacts were caused by adopting an updated estimate of maximum vehicle lifetime (+ 0.2 billion gallons) and the shift to a continuous function (less than -0.1 billion gallons).

Overall, the net impact of these changes was to decrease the agency's estimate of fuel savings that will result from the Reformed CAFE standard from the 10.2 billion gallons reported in the NPRM to 7.8 billion gallons. Because of the variety of factors that contributed to this revised estimate, any direct comparison to the NPRM forecast is likely to be misleading. A more meaningful comparison can be made by recalculating the impacts of NPRM Reformed CAFE standard using modeling assumptions and product plans that are consistent with the final rule.

In order to allow this more meaningful comparison, NHTSA re-estimated the fuel savings for the NPRM Reformed standard using the final rule modeling assumptions and product plans and found that the Reformed standard presented in the NPRM would save 5.5 billion gallons under these revised assumptions.[95] Thus increasing the stringency of the final rule and including MDPVs in MY 2011 together increased lifetime fuel savings projected to result from the rule by 2.3 billion gallons, or more than 40%.

In a broader sense, the fuel efficiency of the light truck fleets that will be produced in MYs 2008-2011 will improve significantly over that of the fleets that were originally planned when manufacturers first submitted their initial product plans to NHTSA in 2004. Since that time, gasoline prices have risen dramatically and consumer preferences have shifted away from the largest vehicles and towards more modestly sized and fuel efficient light trucks. In addition, the Reformed CAFE proposal announced in the NPRM put manufacturers on notice that standards for light truck fuel efficiency would be increasing, and that future standards would challenge manufacturers to improve fuel efficiency for all vehicles, regardless of their size.

The revised product plans that manufacturers submitted following publication of the NPRM responded to these changed conditions, and together with the more stringent standards required by the final rule, the more fuel efficient vehicles that will be produced in MY 2008-2011 will

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[95] The 5.5 billion gallon figure differs from the estimate of fuel savings for the Proposed Reformed standard that would be obtained by beginning with the estimate of fuel savings for the Final Reformed standard (7.8 billion gallons) and subtracting the effect of revisions to the Reformed standard (1.8 billion gallons). This is because the 7.8 billion gallon figure was obtained using the revised model parameters and manufacturer product plan data used in the analysis supporting the Final Rule, while the 1.8 billion gallon figure reflects the earlier model parameters and product plan data used to analyze the Reformed standard proposed in the NPRM. Thus these figures are based on different model parameters and product plan data, and are not directly comparable. Using the revised model parameters and product plan data, fuel savings estimated for the Final Reformed standard are 2.3 billion gallons (= 7.8 – 5.5 billion gallons) higher than fuel savings for the Proposed Reformed standard.

consume 11 billion gallons less fuel over their lifetimes than they would have based on the manufacturers' initial product plans.[96]

Changing market conditions, a revised regulatory landscape, and the more stringent fuel efficiency levels required under Reform CAFE will result in the production of MY 2008-2011 light truck fleets that will consume 11 billion gallons less fuel than the fleets that were originally planned.

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[96] A total of 10.7 billion gallons is obtained from Table A-2 by adding the fuel savings for the Final Reformed standard (7.8 billion gallons) to the effects of changes in product plan data (2.9 billion gallons).

Table A-3

Reconciliation of Fuel Savings Estimates for Reformed Standards
NPRM vs. Final Rule

Source of Difference	Effect of Change on Fuel Savings (billion gallons)
NPRM Reformed CAFE Standard	**10.2**
Changes in NHTSA/Volpe CAFE Model	
Longer Vehicle Lifetimes	**0.2**
Revised Technology Availability	**-1.5**
Subtotal	**-1.3**
Higher Fuel Price Forecast	
Adjustment of VMT Schedules	**-0.7**
Reoptimization of Fuel Economy Targets	**0.7**
Subtotal	**0.0**
Revisions to Reformed CAFE Standard	
Change from Step to Continuous Function	**-0.1**
Higher Fuel Economy Targets in MY 2008-10	**1.6**
Including MDPVs in MY 2011	**0.3**
Subtotal	**1.8**
Changes in Product Plan Data	
Effect on Baseline Fuel Use	**-5.3**
Effect of Change in Size Mix	**2.4**
Subtotal	**-2.9**
Sum of All Changes	**-2.4**
Adopted Reformed CAFE Standard	**7.8**