

BLUE RIBBON COMMISSION ON AMERICA'S
NUCLEAR FUTURE

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REACTOR AND FUEL CYCLE TECHNOLOGY
SUBCOMMITTEE

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MEETING

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TUESDAY,
OCTOBER 12, 2010

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The Subcommittee convened at 8:15 a.m.
in Salon A of the Marriott Metro Center at 775
Twelfth Street, Northwest, Washington, DC,
Pete Domenici and Per Peterson, Co-Chairs,
presiding.

MEMBERS PRESENT:

PETE V. DOMENICI, Chair
PER PETERSON, Chair
ALBERT CARNESALE ALLISON MacFARLANE
RICHARD A. MESERVE

ALSO PRESENT:

TIM FRAZIER, Designated Federal Official
KATHRYN McCARTHY, Idaho National
Laboratory
CATHRYN CARSON, University of California
Berkeley
MARK ABKOWITZ, Nuclear Waste Technical

Review Board

ALSO PRESENT(Cont'd):

ARJUN MAKHIJANI, Institute for Energy
and Environmental Research

HUSSEIN KHALIL, Argonne National
Laboratory

ERICH SCHNEIDER, University of Texas

EVERETT REDMOND, Nuclear Energy
Institute

ANDREW SOWDER, Electric Power Research
Institute

CHRISTOPHER PAINE, Natural Resources

Defense Council

MUJID KAZIMI, Massachusetts Institute of
Technology

JAMES ACTON, Carnegie Endowment for
International Peace

ROBERT BARI, Brookhaven National
Laboratory

RICHARD GARWIN

EDWIN LYMAN, Union of Concerned
Scientists

ROBERT GALLUCCI, John D. and Catherine
T. MacArthur Foundation

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2 8:17 a.m.

3 MR. FRAZIER: All right, if I
4 could, in the interest of staying with some
5 semblance of time -- on time. Welcome to the
6 Reactor and Fuel Cycle Technology
7 Subcommittee meeting, and with that, Dr.
8 Peterson or Senator Domenici, which,
9 Senator? Whenever you're ready, sir.

10 CHAIR DOMENICI: Let me first --
11 thank you, Tim, good morning. I hope you can
12 hear me, my voice has been a bit of a
13 problem lately but it will get better, I
14 think.

15 Thanks to the commissioners who
16 were able to be here today, and on behalf of
17 the Commission, I'd like to welcome all the
18 panelists that are here today, and I'd like
19 to thank the members of the public that are
20 in attendance as well, and those who will be
21 with us, who have already agreed to be with
22 us but aren't here at this moment.

1 Today marks the start of the
2 third Reactor and Fuel Cycle Technology
3 Subcommittee public hearing. Following up on
4 two successful meetings and an informative
5 tour of the Idaho National Laboratory, our
6 Subcommittee is moving successfully ahead
7 with our work.

8 The meeting today was designed to
9 discuss the waste-management implications of
10 the nuclear fuel cycle alternatives. The
11 advantages and disadvantages of new fuel
12 cycles and the issues of nuclear
13 proliferation and security risks associated
14 with these technologies.

15 I believe these issues are
16 important and essential in helping us make
17 our recommendations. Given my history in
18 these areas, I believe we must make real
19 recommendations that our government and
20 policymakers can use to benefit our nation.

21 Our Commission was appointed to
22 do this, and I remain confident that we will

1 find a way to do it. Our nation has time to
2 get this done and get it done right.

3 As we know, our existing fuel
4 cycle is not perfect. We can do better and
5 we must, whatever the final fuel cycle and
6 waste streams look like.

7 We need to think ahead and we
8 certainly must make decisions now and
9 preserve, multiply the technology --
10 multiple technology options for the future,
11 including reprocessing, interim storage, and
12 deep geological disposal.

13 We look forward to hearing from
14 our panelists, and I know my fellow
15 Commissioners and I have plenty of
16 questions. With that, I'd like to turn it
17 over to our co-Chairman, Dr. Per Peterson.

18 CHAIR PETERSON: Thank you,
19 Senator Domenici. I, too, look forward to
20 hearing from our speakers today. We are
21 fortunate to have such a well-respected
22 group of experts, and we look forward to

1 hearing your testimony.

2 When looking at this meeting's
3 agenda, it's important to note that our
4 Reactor and Fuel Cycle Technology
5 Subcommittee was formed to address the
6 question, quote, "do technical alternatives
7 to today's once-through fuel cycle offer
8 sufficient promise to warrant serious
9 consideration and R&D investment, and do
10 these technologies hold significant
11 potential to influence the way in which used
12 fuel is stored and disposed?"

13 Well, our first Subcommittee in
14 Idaho specifically focused on understanding
15 major U.S. R&D programs, specifically R&D
16 conducted by the Department of Energy's
17 Office of Nuclear Energy and the industry's
18 Electric Power Research Institute.

19 And our second meeting focused on
20 major issues associated with bringing new
21 technologies to commercial deployment. This
22 meeting takes a deeper look at our key

1 question, particularly how technologies can
2 influence the way in which used fuel is
3 stored and disposed.

4 Our first panel will examine the
5 waste management implications of fuel cycle
6 alternatives, particularly waste
7 projections, the effects of various waste
8 characteristics on repository design and
9 capacity, disposal costs and licensing.

10 Our second panel will be looking
11 at the evaluation of advantages and
12 disadvantages of new fuel cycles, including
13 the performance criteria by which nuclear
14 fuel cycle options should be compared and
15 life cycle assessments of costs and benefits
16 of these options.

17 Our final panel today will
18 address the issues of nuclear proliferation
19 and security risks. Panelists will discuss
20 the policy and technical tools to reduce
21 proliferation risks, methods for
22 proliferation risk assessment, the resources

1 needed to reduce proliferation risk, and the
2 resolution of potential conflicts between
3 security and safety requirements for our
4 infrastructure.

5 In closing, I would again like to
6 thank all of our panelists. We look forward
7 to a productive meeting today. Now, I'd like
8 to open the floor to any of our other
9 Commissioners who would like to make a brief
10 statement.

11 (No response.)

12 CHAIR PETERSON: Very good. Thank
13 you. Senator?

14 CHAIR DOMENICI: Thank you very
15 much -- thank you very much, Mr. Chairman.
16 I'm going to address the, introduce the
17 panel number one. Before we begin, for the
18 sake of keeping to our schedule, let me
19 remind our panelists to keep their
20 presentations to ten minutes.

21 Also, in order to help keep us on
22 schedule today, we are introducing our

1 panelists with abbreviated bios. This is
2 difficult given the quality of our
3 panelists.

4 We are grateful to have the
5 participation of such an accomplished group
6 of experts, but you will have to bear with
7 us and accept that skinnied-down bios. We
8 put formal ones in the record so everyone
9 will know of your great accomplishments.

10 Our first panel is entitled
11 "Waste Management Implications of Fuel Cycle
12 Alternatives", and our first speaker is Dr.
13 Kathryn McCarthy. Dr. McCarthy is a Deputy
14 Associate Laboratory Director of Nuclear
15 Science and Technology at the Idaho National
16 Laboratory. Thank you very much, Doctor, for
17 being here.

18 Our second speaker is Dr. Cathryn
19 Carson. Dr. Carson is the Associate Dean of
20 the Division of Social Sciences at the
21 University of California, Berkeley. Thank
22 you very much, Dr. Carson.

1 Our second speaker is Dr. Mark --
2 say it for me?

3 DR. ABKOWITZ: Abkowitz.

4 CHAIR DOMENICI: Abkowitz. Thank
5 you very much. He is currently a Board
6 member of the U.S. Nuclear Waste Technical
7 Review Board, appointed by President Bush in
8 2002. Thank you very much, Doctor, for being
9 here.

10 Our next speaker is Dr. Arjun
11 Makhijani. Close? Thank you. Doctor is
12 currently the President of the Institute for
13 Energy and Environmental Research. Thank you
14 very much, Doctor.

15 Our next speaker is Dr. Hussain
16 Khalil. Doctor is the Division Director of
17 the Nuclear Engineering Division at Argonne
18 National Laboratory.

19 Thank you to you, very much,
20 Doctor, and we'll note that attached to my
21 remarks are detailed biogs and they're in
22 the record. Let us proceed. Proceed in the

1 order that I introduced you.

2 DR. MCCARTHY: Is -- should I do
3 it from here, or should I do it from there?
4 What's the process here?

5 MR. FRAZIER: It's up to you,
6 Kathy.

7 DR. MCCARTHY: In the five to ten
8 minutes that I have, I'm going to give you a
9 brief overview of some of the systems
10 analysis activities that are, have been done
11 and are underway under the fuel cycle R&D
12 program, the Department of Energy Office of
13 Nuclear Energy Program. Next slide, please.

14 Just briefly, and I know that you
15 have already heard from Dr. Miller, who has
16 given you an overview of the program, but I
17 wanted to just take a minute to put into
18 perspective what the program is looking at
19 now.

20 Under the Advance Fuel Cycle
21 Initiative, the GNEP program, the Global
22 Nuclear Energy Partnership, there were, the

1 focus was on incremental improvement of
2 existing technologies, and one of the
3 drivers was better or more efficient
4 utilization of a Yucca Mountain type
5 repository.

6 And, really, it was focused on
7 near-term technology deployment. Now, what I
8 want to emphasize is that the program has
9 changed, and now the fuel cycle R&D program
10 is looking for transformational
11 breakthroughs.

12 Now, whether they exist or not is
13 still under question, but it's something
14 that we're looking for, what can we do that
15 can make very large differences.

16 Unconstrained range of storage
17 and disposal options. We're no longer tied
18 to a Yucca Mountain-type repository, so the
19 potential geological repository could be any
20 type.

21 The focus is really on long term,
22 goal oriented, science based approach,

1 really trying to take what we know, what we
2 can do in terms of science, and improve the
3 technologies that could potentially be
4 deployed in the future. Next slide, please.

5 I wanted to first go over a brief
6 summary of the characteristics of
7 radioactive waste that are important when
8 considering ultimate disposal. Both decay
9 heat and radiotoxicity are important factors
10 in radioactive waste handling, storage, and
11 disposal.

12 Decay heat can damage or impair
13 the ability of the waste form to protect the
14 source term. Radiotoxicity is really the
15 source term of the waste.

16 And, the decay heat can also
17 affect the ability of the storage and
18 disposal site to effectively isolate the
19 waste form from the environment, so it's an
20 important consideration in looking at the
21 long-term behavior of waste.

22 Now, I want to emphasize that

1 radiotoxicity represents the hazard
2 contained in the waste form that must be
3 isolated. It is the source term. What you
4 really need to look at in the end is the
5 dose.

6 But in order to calculate the
7 dose, we need to have the specific
8 information on the waste form, the
9 packaging, and the disposal site, because
10 it's the job of the waste form and the site
11 to isolate that hazard from the environment.

12 Radiation requires shielding
13 during radioactive waste handling and
14 storage, and it can also damage and impair
15 the ability of the waste form and packaging
16 to contain the waste, so radiation is also
17 an important consideration in looking at the
18 long-term behavior of the waste.

19 Radioactive contaminated waste
20 that result from operating and maintaining
21 nuclear facilities are generated in all
22 phases of a nuclear cycle. Now, I'm going to

1 focus on the waste that needs to be
2 contained for long periods of time.

3 But it's important to keep in
4 mind that there is, for example, low-level
5 waste and greater than class-C waste that
6 can be generated in other parts of the fuel
7 cycle and all of those things need to be
8 looked at ultimately when considering waste
9 disposal.

10 The importance of each of these
11 factors depends on the choice of repository,
12 so I can't tell you which one is more
13 important. It depends ultimately on the type
14 of the repository and, of course, the waste
15 packaging that is associated with the waste.

16 Volume can also be an important
17 indicator, but it needs to be considered
18 together with radiotoxicity and decay heat.
19 Next slide, please. What I wanted to do
20 first is just put into perspective what
21 we're talking about in terms of
22 constituents.

1 For example, a typical Light
2 Water Reactor fuel assembly after
3 irradiation. This is a typical burnup, so
4 this is where the current Light Water
5 Reactor's fifty-one gigawatt-days per ton is
6 the current burnup in our existing Light
7 Water Reactors.

8 So, when you look at a fuel
9 assembly, what you can see is the hulls and
10 the hardware are about 141 kilograms, so a
11 significant portion of the overall assembly.
12 Uranium is the largest piece, at about 430
13 kilograms.

14 And what you see down at the
15 bottom are the smaller constituents, smaller
16 but very important -- fission products,
17 iodine, technetium, other gases, cesium,
18 strontium, and other fission products, and
19 then the actinides, which is about 5.94
20 kilograms.

21 So, what's important in this is
22 that although, for example, the actinides

1 and the fission products are a relatively
2 small percentage in terms of mass, that's
3 where you get the majority of your
4 radioactivity --radiotoxicity and decay
5 heat. Next slide, please.

6 So, this slide shows the
7 radiotoxicity of waste as a function of time
8 after reactor discharge. And again I want to
9 emphasize that this is the source term, this
10 information is important in calculating the
11 dose, but it's not equivalent to the dose.

12 Now, what you can see here are
13 several different potential fuel cycles and
14 what is the ingestion radiotoxicity of that
15 material as a function of time after the
16 fuel is removed from the reactor. In the
17 grouping where you can see circled once-
18 through and single recycle.

19 That includes once-through fuel
20 cycles such as our traditional uranium
21 oxide, current Light Water Reactors, gas
22 reactors, and also single recycle concepts

1 such as deep burn, for example, where the
2 actinides are put into a gas reactor for one
3 pass with the purpose of burning as many of
4 the actinides as possible.

5 And also, a single recycle burner
6 fast reactor but what's important in all
7 these is once-through or single recycle. And
8 so what you see is, they're not -- there's
9 not a significant difference amongst them,
10 and as a -- in terms of long-term
11 radiotoxicity, they're approximately equal.

12 Now, we look at the family of
13 full recycle options, and this is where the
14 only material that's going into a repository
15 are fission projects and process losses.

16 Process losses are an important
17 part of this, and in this particular
18 analysis we've assumed they're .1% per
19 recycle. So, changing that will have an
20 impact on where that bottom line lies.

21 So, what you can see, that, with
22 the full recycle, we do start to burn down

1 the transuranics. The transuranics are
2 what's dominating the radiotoxicity and
3 decay heat in the long term.

4 Fission products in the short
5 term. And then, when you move out to the
6 right, the difference between the lines, the
7 grouping of the three, the two, out of the
8 three, is the burner reactors. The bottom is
9 the breeder reactors.

10 The difference between them is
11 the breeder reactors are utilizing all of
12 the recovered uranium, and so the
13 contribution from the uranium isotopes is
14 decreasing, that's the difference between
15 the burners and the breeders. Next slide,
16 please.

17 Now, you can see on this slide a
18 similar behavior in terms of the long-term
19 decay heat, and again, I've highlighted what
20 the groupings are. Fission products dominate
21 the decay heat for the first couple of
22 hundred of years.

1 And then the middle section is
2 where the transuranics dominate. Lower right
3 hand is where the, especially for the fast
4 reactor cases, the continuous recycle cases,
5 the uranium isotopes will dominate.

6 And so what you can see is, in
7 order to make a significant impact in the
8 long-term on the decay heat similar to the
9 radiotoxicity you need to destroy the
10 transuranics. And so the fuel cycles where
11 you can do that again are the continuous
12 recycle fuel cycles. Next slide, please.

13 Now, one of the questions that
14 the panel had asked is what projections
15 exist for waste. There are lots and lots of
16 them out there.

17 And so what I've done is I've
18 chosen one scenario to go through, this is
19 an example scenario, it doesn't represent,
20 necessarily, a real case. Well, if it were a
21 real case and my projections were that good,
22 then I wouldn't be working, I'd be playing

1 the stock market.

2 But, what I want to show with
3 this is that there are ways to have an
4 impact on the waste. Now, one of the things
5 that's really important in looking at any of
6 these scenarios is that the assumptions need
7 to be considered, because we can drive lots
8 of different results, depending on the
9 assumptions that we use.

10 Now, I have a relatively short
11 list of assumptions but behind us there are
12 actually several more pages of assumptions.
13 And if you're interested in those, I can
14 talk about those further.

15 But these are the major
16 assumptions. In this particular analysis,
17 first new Light Water Reactor is built in
18 2020. Nuclear grows, about doubles, in terms
19 of installed capacity, by the middle of the
20 century, and then from 2050 to 2100 the
21 nuclear share of total electricity is kept
22 constant from that point.

1 The first separations plant is
2 operational in 2050, the size is 800 metric
3 tons of LWR fuel per year. Then, every ten
4 years, an additional 1,600 metric tons is
5 added, through 2090.

6 And, basically, at 2090, you've
7 almost matched the discharge from the Light
8 Water Reactors with the capacity of the
9 separations plants. It's not quite, but
10 close.

11 In this particular scenario,
12 we're looking at continuous recycle, so fast
13 reactors are built when separated material
14 is available for startup. The remainder of
15 nuclear energy demand is met by the Light
16 Water Reactors.

17 Now, I could have chosen
18 different technologies, I could have chosen
19 different dates, and all of that would have
20 an impact in the next slide that I'm going
21 to show you. But for this particular
22 example, this is what it would look like.

1 The fast reactors are what we
2 would call a burner reactor. The discharged
3 fuel has half as many transuranics as the
4 charge fuel, okay, so we're actually burning
5 down the transuranics in this particular
6 analysis.

7 After removal from the reactor,
8 and this is from the Light Water Reactor,
9 the used Light Water Reactor fuel is kept in
10 wet storage for ten years and then it's
11 moved to dry storage until it's recycled.
12 Next slide, please.

13 Okay. In this particular example
14 scenario, the used fuel in storage is
15 decreased by almost 50% by 2100. That's
16 driven entirely by the buildup of the
17 separations plant.

18 If I had said they would be built
19 slower, you would see less of a decrease. If
20 we built them more quickly, then you would
21 see a larger impact, earlier.

22 So what you see on the left is

1 for a once-through fuel cycle. By the end of
2 the century, about 450,000 tons of used fuel
3 have been discharged from Light Water
4 Reactors and in that scenario there's no
5 recycling.

6 In the scenario where we have a
7 continuous recycle in fast reactors,
8 starting after the middle of the century,
9 what you see in green is the reduction
10 versus once-through.

11 And so, the blue in both of them
12 is the fuel that's in wet storage. The
13 yellow is the fuel that's been moved into
14 dry storage. It's cool enough in this
15 particular scenario to recycle.

16 And so what you see in the right
17 hand graph is that we've started to turn
18 that line around so that we have -- we're
19 using more of the fuel in the dry storage
20 than we are putting into it.

21 And if we continue that beyond
22 the century, you would eventually see the

1 two lines meet if we built our capacity
2 appropriately. Next slide, please.

3 So, in summary, the choice of
4 fuel cycle affects the waste
5 characteristics, reducing the long-term
6 radiation and decay heat can reduce the
7 uncertainty associated with disposing of the
8 waste.

9 Humans -- there are examples of
10 human engineering that have lasted for on
11 the order of a few thousand years, not tens
12 of thousands or millions.

13 We can reduce the challenges
14 associated with waste form development.
15 Reducing volume can be important but we need
16 to consider it together with radiotoxicity
17 and decay heat.

18 And the fuel cycle R&D program is
19 examining a broad range of technology
20 options, I've only shown you a scenario from
21 one. Thank you.

22 CHAIR DOMENICI: Our next witness,

1 please? Dr. Carson.

2 DR. CARSON: Thank you, Senator.

3 I'm --

4 CHAIR DOMENICI: Would you like to
5 stay there?

6 DR. CARSON: I would.

7 CHAIR DOMENICI: All right.

8 DR. CARSON: I'm glad to be here
9 this morning. I am a historian of science.
10 Before I switched over to history, my
11 background was in physics. And recently,
12 I've been working on the history of nuclear
13 waste R&D. And it seems to me that there are
14 insights that that history can offer you as
15 you think about designing for the future.

16 I'll be centering what I say
17 around fuel cycle alternatives, but I think
18 the challenges there are a lot like those
19 facing the Commission at large. I might
20 begin my presentation by saying how things
21 look to a historian who's followed the waste
22 story and who's been following your

1 discussions, since this Commission is
2 creating the history I work on.

3 What's going on in this
4 Commission's meetings is like nothing I've
5 seen in the historical record. It's, I
6 think, unique. It's been stated openly that
7 Yucca Mountain has taught us a lesson, that
8 the system around nuclear waste policy is
9 broken, that lots of excellent work and good
10 intentions and thoughtful consideration has
11 still left us entirely stuck.

12 Now, historians are interested in
13 these kinds of moments, moments when old
14 ways of doing business get rethought and
15 revisited. The present moment has that kind
16 of potential.

17 The closest thing I as a
18 historian can find to it in the record is
19 the remarkable openness of the mid 1950s.
20 I'll come back to the fifties.

21 For the moment, let me say that I
22 am watching to see what you'll do with this

1 historical moment that you've been handed.
2 Now, from a historian's perspective, there
3 are two distinct sets of questions you're
4 facing now, coming out of two different time
5 periods.

6 I can lay them out this way. The
7 first comes out of the late 1970s and
8 eighties. It's a challenge, essentially, of
9 legislative and organizational design.

10 In short form, fix the Nuclear
11 Waste Policy Act, seemed like a good idea at
12 the time, and devise a new institutional
13 structure to house waste management, because
14 the one put in place among the DOE, EPA and
15 NRC -- all of these really finding their
16 footing in the late seventies and eighties -
17 - has had problems.

18 That's one set of challenges,
19 around legislative and organizational
20 design. The other set of challenges has its
21 origins farther back. They're challenges
22 around designing policies and an R&D program

1 in support of them that respond to public
2 input and public concerns.

3 Whatever else you think about
4 Yucca Mountain, it's a good example of a
5 project that suffered on this score. This
6 challenge of public responsiveness is not
7 one that's historically gotten much
8 attention in the R&D phase of nuclear
9 projects in this country.

10 That pattern really goes back to
11 the DOE's predecessor, the Atomic Energy
12 Commission, the AEC. The basic strategy was
13 put in place not too long after the Second
14 World War. I think the formative decade was
15 really the 1950s, when the AEC began to take
16 on the job of projecting a civil nuclear
17 industry alongside the weapons program it
18 was created to run.

19 So, today is not actually the
20 first time that the United States has asked
21 how alternative fuel cycles, waste
22 characteristics and disposal options go

1 together. Back at the very beginning of R&D
2 on disposal, back in the 1950s, this was
3 actually an active and quite troublesome
4 issue.

5 This was at a time when massive
6 expansion was being forecast for nuclear
7 power, when the options on the table went
8 well beyond Light Water Reactors, when even
9 PUREX reprocessing was just a half-decade
10 old.

11 Scientists in the National Labs
12 were asking about alternative fuel cycles
13 and waste characteristics, trying to figure
14 out what choices to lead with.

15 This was the 1950s, so much was
16 open, open in part because scientists and
17 engineers at Oak Ridge and Hanford and
18 elsewhere had very little experience with
19 waste and with fuel cycles beyond what was
20 sitting in their backyards. They were facing
21 a future of almost unlimited alternatives.

22 Few of them were hemmed in by

1 technical or societal constraints or gauged
2 by what other countries were doing. So they
3 were essentially doing at this point a kind
4 of blank slate analysis.

5 What kinds of wastes would
6 different fuel cycles produce? How would the
7 consequences play out for storage, for
8 transportation, for disposal?

9 And central to all of this, how
10 much would it cost? Now their estimates in
11 those days were pretty rough. These were
12 very hard problems to tackle.

13 And interestingly, most of the
14 research moved on to other, more tractable
15 questions, largely technical problems that
16 seemed decoupled from societal outcomes,
17 political or market outcomes beyond sheer
18 order of magnitude estimates of the scale of
19 the problem.

20 So, beginning in the 1950s, in
21 the face of this openness, this became how
22 the AEC did research. Questions about the

1 fuel cycle were defined as technical
2 questions.

3 The deference that the AEC got
4 meant that it had to deal very little with
5 societal acceptance, much less do research
6 on it, until ten or twenty years later on.

7 When change there did come, it
8 was due to developments around the AEC's
9 handing of potential controversies, such as
10 its ways of dealing with the leaking waste
11 tanks at Hanford and to conflicts between
12 the AEC and the states that were
13 preliminarily being considered for new waste
14 disposal plants.

15 On a larger scale, the new
16 challenges on the scene went back to bigger
17 societal conflicts arising around nuclear
18 power, and I would stress this just as
19 importantly, to a kind of society-wide
20 displacement away from trust in existing
21 institutions in government, industry, and
22 science.

1 So, I should say that this loss
2 of trust is partly about nuclear, but it's
3 not solely about nuclear. It shows up in
4 many other domains.

5 It has a great deal to do with
6 skepticism about inherited organizational
7 and institutional arrangements and about the
8 disinterestedness or truthfulness of experts
9 working for some government agencies or for
10 large corporations.

11 This is not about anti-nuclear
12 activism alone, dealing with what is
13 sometimes characterized as a kind of stirred
14 up fearful public that mainly needs
15 education on technical facts. A lot changed
16 over the AEC's life cycle, and into DOE's
17 era.

18 We are now residing on the other
19 side of a kind of historical divide.
20 Historians should not go predicting the
21 future, but I will wager one thing, that
22 there probably will be social and political

1 complications around fuel cycle
2 alternatives, as there have been around
3 waste.

4 So, whether its disputes over the
5 relative credibility of scenarios for
6 proliferation, or public confidence in
7 assurances that the new technologies are
8 safe, or arguments over the claim that new
9 fuel cycles are needed to help with the
10 waste problem, or substantial government
11 investment in R&D that will help private
12 firms, or facility siting or trust or
13 transparency, or whatever.

14 The things we've seen before are
15 probably will not go away, and new things
16 will be added, and that's leaving aside the
17 complications if something goes wrong. Now,
18 in the context of waste, DOE as well as the
19 National Academy did start engaging some of
20 these problems.

21 Social scientists got brought in.
22 Often, they went away feeling unheard.

1 Still, the challenges exactly around Yucca
2 Mountain and more positively, WIPP, have
3 opened up some new activity around public
4 acceptance. There is a base to build on.

5 There's been much comparative
6 experience, internationally comparative
7 experience gained by other countries that
8 are also dealing with waste management.

9 Here is the kind of back door
10 benefit to not being out alone in front, as
11 the U.S. was in the 1950s, even the
12 seventies and eighties.

13 And comparative experience in
14 other controversial technical domains that
15 have come along in the mean time, such as,
16 for instance, the National Nanotechnology
17 Initiative in this last decade, which has
18 taken on questions of public acceptance in
19 interesting and provocative ways.

20 So, to wrap up, this Commission
21 has a chance to consolidate that experience.
22 The challenges that are around from the

1 1970s and eighties around legislative and
2 organizational design, probably do need to
3 be addressed in the short term.

4 The challenges that are still
5 around from the fifties, though, to design
6 R&D programs that fit better with
7 contemporary social reality, are adaptive,
8 evolving challenges with a time constant of
9 decades.

10 They can be addressed in the
11 waste disposal program if the present moment
12 is recognized for what it is, and they can
13 be addressed in fuel cycles as well.

14 They can be addressed if we
15 broaden a lesson from our experience with
16 repositories, which is one thing that, as a
17 historian, I am curious to see if the
18 Commission will do. Thank you.

19 CHAIR DOMENICI: Give us a second,
20 we were talking. We'll be right with you.
21 Would you please proceed, Doctor?

22 DR. ABKOWITZ: Thank you, Senator

1 and members of the Subcommittee. Speaking
2 today on behalf of the Nuclear Waste
3 Technical Review Board, and we are very
4 appreciative of the opportunity to spend
5 some time with you today and we hope to be
6 able to share other information that
7 involves our activities as the deliberations
8 of the Subcommittees and the full Committee
9 continue.

10 In my brief comments today, I'm
11 going to talk predominantly about our
12 systems analysis capabilities and some of
13 the applications that we're running that
14 relate to understanding various waste
15 streams under various scenarios.

16 We do intend to submit a more
17 detailed testimony to the BRC Subcommittee
18 and it just requires, as you probably know,
19 some clearances from the full board and we
20 will be meeting in a couple of weeks to
21 cover that ground. Next slide, please.

22 Most of you are familiar with the

1 Nuclear Waste Technical Review Board but
2 just as a very quick review, our duty is to
3 conduct an independent and ongoing
4 evaluation of the technical activities that
5 are undertaken by the Secretary.

6 And that purview includes both
7 high level radioactive waste and various
8 forms of spent nuclear fuel, commercial
9 included.

10 I think the bullet number three
11 on this slide is perhaps the most important,
12 which is that, although the Yucca Mountain
13 Repository Program has undergone an
14 evolution, it has not changed the
15 responsibilities of our Board.

16 We were never considered, I don't
17 believe, the Yucca Mountain Waste Review
18 Board, we are the Nuclear Waste Technical
19 Review Board. And therefore, we've had to
20 shift our focus, much as this Commission has
21 been focusing on some of the new questions.
22 Next slide, please.

1 As Senator Domenici mentioned
2 before, we are appointed by the President of
3 the United States. We serve fixed terms. But
4 we are supported by a full time staff that's
5 located here in Arlington, Virginia. In
6 fact, Nigel Mote, who is our executive
7 Director, is with us today in the audience.

8 And it is also important, I
9 think, to recognize that the Board is an
10 independent agency, not part of the
11 Department of Energy, and for that reason,
12 we believe that the objectivity and
13 credibility that we bring to these
14 challenges remain intact. Next slide,
15 please.

16 There's a number of major
17 initiatives that we have underway. They are
18 listed here. You will be hearing from, and
19 have heard from, various members of the
20 Board and its staff on these subjects.

21 The one I'm actually going to
22 focus on today is the first bullet, which is

1 our capabilities to look at various spent
2 nuclear fuel and high level waste options.

3 And we have referred to this by
4 the acronym of NUWASTE. As is typical, that
5 acronym kind of came about late at night and
6 on the back of a napkin. The objectives --
7 next slide, please -- the objectives of
8 NUWASTE, I think, are particular important
9 for this Subcommittee and for the full
10 Committee.

11 We believe it takes a lot of
12 systems analysis capability to recognize all
13 the different fuel cycle initiatives and
14 what kinds of implications that has on spent
15 nuclear fuel, high level waste, and other
16 wastes.

17 I think Kathryn pointed out that
18 there's just a number of scenarios that one
19 can concoct and be interested in looking at
20 what the tradeoffs are.

21 And, consequently, the Board felt
22 that they needed the ability to look at all

1 these different scenarios and understand
2 from a waste-centric standpoint, what's
3 going on.

4 And I think one of the most
5 important messages for me today is the last
6 bullet on this slide, and that's that we
7 need to recognize there are a lot of
8 different waste management criteria.

9 And so the eye of the beholder
10 really governs whether one strategy looks
11 more attractive than another. And I think
12 that from the Commission's standpoint, there
13 needs to be the acknowledgment that there
14 are various criteria out there and that one
15 needs to be able to come to terms with how
16 important these criteria are and whether
17 there are certain scenarios that can achieve
18 most of what you want out of the various
19 criteria such as a hybrid or compromise type
20 of approach. Next slide, please.

21 I'm not going to bore you with
22 details of what's in our tool, but I think

1 that some of the features that you see
2 listed on this slide really bring out how
3 we're organizing ourselves.

4 First of all, we're looking at
5 the entire U.S. program and for now we're
6 focused on the Light Water Reactor world.
7 And we're doing that initially because
8 that's the world we're dealing with right
9 now, it's the world that we'll be dealing
10 with for at least the next fifty to sixty
11 years by most everyone's account.

12 There are other features to what
13 we're building into this tool that I'll
14 mention at the end of my presentation, where
15 we'll go and extend beyond this vision.

16 But for the early stages of the
17 work we're doing, we really believe you've
18 got to start with the here and now and then
19 move forward based on your understanding of
20 what that is.

21 There's a variety of different
22 spent nuclear fuel management options. The

1 three most popular ones are the ones you
2 hear discussed quite a bit, which are dry
3 surface storage, perhaps for long periods of
4 time, the use of reprocessing and recycling,
5 or just direct repository disposal.

6 There's a variety of different
7 ways in which nuclear energy generation
8 capacity is being viewed that range from the
9 present nuclear power plants and their
10 extensions, all the way to creating the
11 capability to maintain the current
12 generating capacity that we have into the
13 foreseeable future.

14 And there's a variety of fuel
15 fabrication options as well. Next slide,
16 please. To add to the mix, we have the
17 facilities that are capable of doing these
18 things that can come on board at any
19 particular time in the future, can operate
20 for any particular time and may have varying
21 capacities.

22 There's also the issue of burnup

1 that was introduced by one of the previous
2 speakers, and there's also issues with
3 regard to what fuel is aged at what level
4 and how we pick it out for disposal and
5 reprocessing. And there's the ability to put
6 certain criteria at the forefront of what's
7 important to consider. Next slide, please.

8 I am not going to try to explain
9 the graph you see on the right, other than
10 to say that this is a full representation of
11 the Light Water Reactor world that we live
12 in today, with the possibilities of
13 recycling and various fuel fabrication
14 options listed as well.

15 The point of this slide is that
16 it's a very complex process and from a
17 systems perspective, you have to look at all
18 the different combinations of scenarios that
19 represent ways that you can work through
20 this particular graph.

21 Every arrow is a potential
22 transportation movement. Every trash can --

1 that's not meant to say that it's
2 necessarily unusable waste, but every trash
3 can and green drums you see are waste
4 streams.

5 And so you can, you can
6 appreciate, I hope, just how important it is
7 to recognize the pushes and the pulls that
8 go on when you look at these scenarios.

9 The first bullet on this slide --
10 I want to bring to your attention primarily
11 because there's a lot of different waste
12 streams that can be generated through this
13 process.

14 And we need to be mindful of the
15 fact that while we're trying to solve the
16 management of spent nuclear fuel there's the
17 possibility of generating more high level
18 waste and generating a lot of other
19 different waste types as well. Next slide,
20 please.

21 I'm going to share with you three
22 scenarios today that we consider to be

1 somewhat reasonable in terms of ideas or
2 options that have been discussed by people
3 in, in the industry. And each of them is
4 kind of representative of a different
5 direction that we might go in terms of
6 implementation.

7 Scenario one is just looking at
8 long-term storage only. That's the idea that
9 between now and 2100, we would have no
10 repository or reprocessing.

11 Scenario two introduces direct
12 disposal into a repository, starting in
13 2040, with a capacity of 3,000 metric tons
14 per year, but no reprocessing.

15 And scenario three involves
16 bringing both a repository and reprocessing
17 on board with the capacities that you see.
18 We're in the process of looking at a variety
19 of one-offs, if you will, relative to these,
20 but I think these are very important points
21 to anchor our discussion around.

22 I might also point out that the

1 results I'm going to share with you now are
2 preliminary in nature, but we do believe
3 they're indicative of trends that, that are
4 emerging and that the Board will be speaking
5 more about in short order. Next slide,
6 please.

7 If you remember the criteria that
8 I showed you before, I'm going to now walk
9 you through four or five of those with
10 respect to these three scenarios. This first
11 one has to do with the number of dry storage
12 casks that would be required over time.

13 And as you can see from the red
14 and the blue lines, that if we do introduce
15 a repository and even more so if we
16 introduce reprocessing, we will be able to
17 reduce the capacity of dry storage
18 facilities required for spent nuclear fuel.

19 However, the number of dry
20 storage casks do not drop down to zero, and
21 in fact, if you were to introduce the
22 repository and or reprocessing at a later

1 date or perhaps with lower capacity,
2 everything is going to shift up on this
3 curve, meaning that we'll have that much
4 more dry storage casks that we need to deal
5 with as time goes on. Next slide, please.

6 Under the criteria for number of
7 waste packaged required, what's kind of
8 interesting when you look at this
9 relationship is even though we are able to
10 cut down, perhaps in the neighborhood of 25%
11 on the number of waste packages that we
12 would need to eventually deal with, the,
13 even under the reprocessing with repository
14 option, we're still going to have a
15 substantial amount of waste that's going to
16 require a permanent home. Next slide,
17 please.

18 There's been a lot of discussion
19 about how much savings in natural uranium
20 that we might have from reprocessing. And
21 this particular scenario, as you can see
22 that there is a measurable amount of

1 savings, but in the big picture, it only
2 amounts to about 10-to-15% of natural
3 uranium usage.

4 So, consequently, under a
5 scenario like this, we would still be
6 substantially dependent on using raw uranium
7 for most of our generation. Next slide,
8 please.

9 I've been concerned a little bit
10 about people who refer to recycling and
11 reprocessing as a closed fuel cycle.
12 Depending upon your interpretation, that may
13 be true.

14 But one of the byproducts of
15 going through reprocessing is the generation
16 of other waste streams and particularly with
17 regard to the low-level waste.

18 You can see that there's a fairly
19 large quantity that's generated in that
20 regard, and therefore we need to be
21 cognizant that there are ramifications with
22 trying to solve one problem which may

1 introduce another type of bottleneck or
2 challenge. Next slide, please.

3 My final slide, just looking at
4 some of these scenarios and comparing and
5 contrasting, is under the proliferation
6 concern about the quality of plutonium
7 separated. Now, the red bars show the amount
8 of plutonium that's generated from recycling
9 and reprocessing in a given year.

10 The blue line represents the
11 accumulation over time. And the point of
12 this particular slide is that unless we have
13 the ability to use the MOX fuel that we
14 intended to fabricate from the plutonium,
15 we're going to accumulate a stockpile of
16 plutonium that I don't believe anyone is
17 interested in trying to have occur.

18 And I think the French are a good
19 indication of the types of issues that they
20 have to deal with when you have supply of
21 plutonium around and nowhere to go with it.
22 Let me wrap up with my last two slides, next

1 one, please.

2 Just some overarching
3 observations. We believe that NUWASTE can
4 help understand the impacts of potential
5 fuel cycle initiatives on the generation and
6 management of spent nuclear fuel, high level
7 waste, and other wastes.

8 And we believe it's important
9 that when you use these types of tools that
10 you understand the criteria that are driving
11 whether you believe one approach or another
12 is more sensible.

13 But I think the takeaway points,
14 just based on a preliminary analysis alone,
15 and I think you've heard from others about
16 this, but it's pretty clear that we need a
17 geologic repository one way or another.

18 It's pretty clear that the longer
19 that we delay in at least opening a
20 repository, the more accumulation of dry
21 storage casks that we'll have.

22 And in our preliminary

1 assessment, those casks, absent moving them
2 to a centralized facility, would have them
3 residing in at least thirty-three states.
4 And based on our analyses up to this point
5 in time, and they are ongoing, we don't see
6 a major advantage from reprocessing.

7 Let me complete my presentation
8 by just mentioning where we are in our
9 process and where we're going. Clearly,
10 being in forums such as this one gives us an
11 opportunity to share the information that
12 we're accumulating on the subject and we
13 intend to continue to do that.

14 We are right now adding the
15 capability to look at relative costs,
16 because the economic aspects associated with
17 these things are also very important, as are
18 the risks in terms of relative dose to the
19 public. So those capabilities are in the
20 process of getting put into place and once
21 we do that, we'll pretty much have all those
22 criteria represented.

1 We continue to be interested in
2 looking at additional scenarios and would
3 certainly invite the Blue Ribbon Commission
4 to identify some things that they might be
5 interested in having us try to evaluate and
6 we would certainly take those under
7 consideration.

8 And then, finally, there's a
9 number of different capabilities that we're
10 adding to the tool, in addition to the ones
11 I just mentioned about functionality with
12 criteria. We don't want to forget about the
13 stranded DOE spent nuclear fuel and high
14 level waste.

15 We want to look at transportation
16 logistics more carefully, interim storage
17 facilities away from the reactor, and some
18 of the more advanced reactor designs.

19 I tried to do a quick job of
20 that, I apologize for going over my time.

21 Thank you.

22 CHAIR DOMENICI: Thank you very

1 much.

2 DR. MAKHIJANI: I mixed up my
3 schedule, so my slides are still in drop
4 form, I'll submit them for the record later
5 on.

6 CHAIR DOMENICI: That's fine.

7 DR. MAKHIJANI: Just to give you
8 an overview, you know, last time I suggested
9 when I made a presentation to the full
10 Commission, that the problem of existing
11 spent fuel from the current fleet should be
12 separated from new reactor initiatives.

13 If you're going to develop
14 breeders, what happens with the fuel that
15 goes into it. The uranium that you use --
16 and I suggest, you know, although I don't
17 think breeder reactors are a very good shot
18 for, for putting public money into their
19 development, that even if you went there,
20 the uranium and existing spent fuel is, is
21 not the right uranium to be using there.

22 Depleted uranium, we have plenty,

1 it's a waste, it's free, be reducing the
2 waste burden if you targeted that uranium
3 for breeder reactor development. So I do
4 think that you're hearing, at least the
5 sessions I've attended, a pretty consistent
6 message that reprocessing of existing
7 reactor spent fuel doesn't make sense.

8 And to remind you of the numbers
9 that I gave you last time, to use up the
10 uranium in existing reactor spent fuel would
11 take 100,000 reactor years in breeder
12 reactors, which we haven't developed yet.
13 That's 500 reactors operating for 200 years,
14 some, whatever combination you want.

15 And at a penny a kilowatt-hour
16 extra, that amounts to about eight trillion
17 dollars. That makes, you know, current
18 deficit ideas, I don't think industry would
19 be willing to pay for that. It's a more than
20 the worth of the electricity that's being
21 produced from the existing reactors.

22 So I really think an early

1 indication that -- you've heard this, that
2 we ought to think about managing the spent
3 fuel from existing LWRS as settled once-
4 through to a repository would be very
5 useful. You know, the waste volume issues,
6 the MOX fuel cycle issues, so on.

7 So, the short of it is, the new
8 reactors will produce new issues and so I
9 want to go over some of the transmutation
10 issues that are involved, so. You have
11 breeder reactors, you have repeated recycle.
12 The first thing to know is that you're going
13 to have to have repeated reprocessing and
14 repeated separations in order to be able to
15 deal with the troublesome radionuclides that
16 are not plutonium.

17 Plutonium in principle, you could
18 say, well, you're going to use it in breeder
19 reactors, and you're going to improve the
20 isotopic composition, and if you do repeated
21 recycle and produce very high purity
22 plutonium in the blanket, then somehow you

1 can deal with the plutonium.

2 But the other -- the minor
3 actinides, the neptuniums, the americiums,
4 and so on, as well as the technitium-99, the
5 iodine-129, you're going to have to have
6 repeated recycles to deal with it. Let me
7 just go over the list of problem
8 radionuclides, and there are quite a few.

9 Tin-126, about 100,000 years.
10 Long lived fission product. Very, very
11 difficult to conceive of transportation.
12 Selenium-79, the same. Cesium-135, very
13 difficult. You've got to separate from
14 cesium-137, doesn't look like a sensible
15 idea. So cesium-135, 2.3 million year half
16 life. You've go to live with that, and the
17 more fission you have, the more cesium-135
18 you're going to have, guaranteed.

19 Zirconium-93, no transportation
20 option available at present. And I have to
21 say, we looked at this a few years ago, so
22 there's not completely fresh research.

1 Carbon-14, also no potential. Chlorine-36,
2 none. Technitium-99, repeated recycle, you
3 could make a dent into it. Iodine-129, also.

4 Uranium, I've already told you,
5 it's a real problem. If you pay a penny a
6 kilowatt-hour extra in any type of reactor,
7 you're already into trillions. So the idea
8 that you can use breeder reactors to create
9 a closed fuel cycle, probably from the
10 Nuclear Waste Technical Review Board, is
11 that the idea of a closed fuel cycle is a
12 physicist's idea.

13 This is the magical thing of
14 Alvin Weinberg, the magical energy source.
15 But when you translate physics into
16 engineering and cost, this becomes an
17 essentially impossible thing. To leave aside
18 all the proliferation implications.

19 So, unless breeder reactors are
20 somehow magically reduced in cost and
21 physicists somehow don't seem -- I guess,
22 you know, you could, you can get as much

1 money to study the universe as you like, and
2 so you don't have to worry about cost or
3 results or -- you know, with all due respect
4 to physics. I love physics. It's my first
5 discipline, love.

6 But it's not very efficient in
7 terms of practical, everyday considerations
8 and this has got to be taken out of the
9 magical idea of physics giving us some great
10 energy source. You got strontium-90 and
11 cesium-137, they are your major, medium term
12 heat sources.

13 And I can't imagine storing these
14 things for hundreds of years on surface. I
15 think its not a very good idea, so. So your
16 main heat load is going to be there in the
17 repository anyway.

18 I want to make some comments on
19 small modular reactors, because there's been
20 a lot of talk of those and we're hurtling
21 into this public funding of small modular
22 reactors as if they're going to solve the

1 nuclear reactor renaissance problem.

2 Now, so far as waste is
3 concerned, the Light Water Reactor
4 evolutionary small modular reactors are not
5 going to change the waste picture. They have
6 the same type of fuel, so it's going to be a
7 quantity problem not a quality problem.

8 But we haven't begun to talk, at
9 least I'm not aware that there's been any
10 serious considerations of the new waste
11 problems you're going to have from some of
12 these graphite moderated reactors, pebble
13 bed reactors.

14 You're going to have massive
15 amounts of carbon-14. Can you put unoxidized
16 carbon-14 in a repository and how is it
17 going to complicate? Now you remember before
18 the new rules for Yucca Mountain, Yucca
19 Mountain had standards problems because it
20 could not meet the carbon-14 standard of the
21 EPA.

22 I was on that EPA Subcommittee

1 that looked at that problem, so all graphite
2 moderated reactors are going to give you
3 severe headaches for thinking about
4 repositories, in my opinion. The idea that
5 you can bury a sodium cooled reactor for
6 thirty years is, in itself, kind of far
7 fetched, you know, in some Alaskan village
8 out there and it would work perfectly for
9 thirty years.

10 But once you take it out and take
11 it away from the Alaskan village, it's
12 completely unthinkable to me, technically,
13 that you're going to bury a reactor with
14 liquid sodium in it. And we haven't even
15 begun to discuss what you do with a sealed
16 reactor that has liquid sodium in it, as a
17 waste management problem.

18 If we have difficult technical
19 problems with repositories now, I think
20 we're going to have headaches that we
21 haven't even begun to imagine. Because in
22 principle, a ceramic fuel form, waste form,

1 is a pretty good waste form. It's hard to
2 do, make a fuel that will in itself have
3 some resistance to leeching out into the
4 groundwater and so on. Then, the existing
5 ceramic waste form, it does have that
6 virtue.

7 Reprocessing involves waste that
8 you really need to consider. Repeated
9 reprocessing is going to create repeatedly
10 increased volumes of aqueous wastes, even if
11 you have an initial electrolytic cycle,
12 you're going to have large volumes of side
13 wastes.

14 While I agree with some of Dr.
15 McCarthy's presentations, I cannot agree
16 that a 0.1 residual from repeated
17 reprocessing and a completely closed fuel
18 cycle is realistic based on past experience.
19 The main past experience we have with
20 repeated reuse of transuranic materials is
21 in the weapons program.

22 And in the weapons program --

1 first of all, we haven't been able to keep
2 track of it. Los Alamos has two sets of
3 books on plutonium, one in the waste streams
4 and one in the security stream, and they
5 have a 300 kilogram discrepancy in the waste
6 statistics.

7 If you look at the official
8 memorandum with the fifty year plutonium
9 report and look at the waste totals
10 estimated by the waste management people in
11 the U.S. nuclear weapons complex, it's more
12 than five tons. That's about 5%.

13 So, that's fifty times the
14 estimate that you've just received for the
15 radionuclides we're most familiar with and
16 can control best and whose chemistry we
17 understand best, among the transuranics, let
18 alone the americiums and the neptuniums and
19 the more headachy kind of things that are
20 difficult to transmute.

21 I think .1% from repeated reuse
22 is, you know, hope against technical

1 reality. Maybe we'll improve the technology
2 by nearly two orders of magnitude, I don't
3 know. But I know that the Japanese had a 200
4 kilogram tussle for many years with the IAEA
5 just from the simple reprocessing.

6 To summarize, I think we really
7 should put an end to the notion that
8 existing spent fuel reprocessing can solve
9 anything, and it will complicate every
10 single problem and introduce new problems.
11 You should separate the new reactor
12 development.

13 In the new reactor development, I
14 think you've got two streams. You've got
15 these small, modular reactors that are going
16 to create new waste headaches that, I don't
17 know that you've begun to consider, but I've
18 seen almost no public debate.

19 The third thing, is industry
20 going to pay for this wonderful new system
21 that we're talking about, the reprocessing
22 and repeated recycle? I think the cost

1 issues are very big public policy issues. My
2 suggestion for repositories, fairly
3 independently of what you see for the future
4 of nuclear power, is we're going to need a
5 high level waste repository that's pretty
6 big.

7 Most everything's going to be
8 occupied by existing spent fuel. I also
9 think that you ought to recommend a separate
10 repository possibly, or at least a
11 repository for all the other waste that
12 we're going to have. We have a lot of
13 depleted uranium, we have a lot of
14 transuranic waste.

15 There's a lot of defense wastes
16 that really need to go to a repository that
17 isn't a high heat load, and we ought not to
18 be burdening the high heat load repository
19 with large volumes of long lived materials
20 that don't need to meet the standards.

21 So we've got a successful example
22 before us in this country of WIPP. I think a

1 WIPP-like repository is really, needs to be
2 put on the table of public debate separately
3 from the issue that the utilities are
4 concerned with, which is spent fuel.

5 I think if we have these three
6 streams of thinking, we'll at least have the
7 right technical bins in which to consider
8 the problem of nuclear waste. Thank you.

9 CHAIR DOMENICI: Thank you. Our
10 last speaker for this panel is Dr. Hussein
11 Khalil. Thank you, Hussein.

12 DR. KHALIL: Well, thanks for the
13 opportunity to contribute a very different
14 perspective from the one that you just
15 heard, and I hope there will be an
16 opportunity to have some discussion of some
17 of the sweeping assertions that were made.

18 I will provide some perspectives
19 on reactor and fuel cycle technology options
20 that can impact waste management. Next
21 slide, please. Regarding the question of
22 used fuel and waste generation and the

1 interest in estimating these, as you've
2 already heard, there have been many scenario
3 studies that have been done by DOE and other
4 institutions that have looked at different
5 scenarios and have made estimates of used
6 fuel and waste discharge rates.

7 The situation with used fuel is
8 very simple. The annual discharge of used
9 fuel is simply equal to the average thermal
10 power generated by the reactors, divided by
11 the burnup of the fuel. So, the quantity of
12 discharged fuel is inversely proportional to
13 burnup and one way of reducing used fuel is
14 do increase the burnup from reactors.

15 The benefit from that is limited,
16 however, because with increasing burnup,
17 there is generation of plutonium and higher
18 actinides of course in the used fuel which
19 have to be disposed of.

20 So, the burnup of used fuel of
21 course determines its composition and its
22 emission characteristics, its radiotoxicity,

1 its decay heat emission. And of course,
2 other than extending burnup, there's the
3 possibility of recycling the spent fuel.

4 And the main, the main goal with
5 recycling is to make use of the actinides
6 that are discharged from the used fuel. And
7 there are many different possibilities in
8 terms of what fraction or what types of fuel
9 that reprocessing and recycle are applied
10 to, as well as which elements are targeted
11 for recycle and reuse in the reactors.

12 So, the recycle can be partial
13 recycle or it can be full recycle. The
14 reference to repeated recycle simply means
15 that you recycle the fuel that's discharged,
16 simply recycle all the discharged fuel. That
17 is the basically what is done when you are
18 doing repeated recycle.

19 There's been recently a very
20 extensive compilation of used fuel
21 generation and waste quantities that DOE has
22 developed. It provides used fuel quantity

1 and composition as a function of burnup and
2 cooling time, looking at different
3 alternatives, different energy use
4 scenarios, different recycle processes.

5 And also looking, of course, at
6 generation of low-level waste. It's very
7 likely that recycle will increase the
8 generation of low-level waste, though we
9 think this problem will be much easier to
10 manage than the very long isolation that's
11 required for high-level waste.

12 The main point in this chart
13 though is that in all the scenarios that
14 we've looked at, we will need both temporary
15 storage of used fuel and long term isolation
16 of the hazardous constituents of used
17 nuclear fuel. Next slide, please.

18 The design and licensing of waste
19 isolation sites is a very challenging
20 undertaking that requires consideration and
21 accommodation of many different physical
22 phenomenon. And among the characteristics of

1 the waste, there are many of them that Dr.
2 McCarthy mentioned in her presentation.

3 The quantity of waste, the
4 radiotoxicity, the heat emission. Among
5 these, I'd like to focus on the heat
6 emission from the waste as a particularly
7 important factor that affects the capacity
8 of a disposal system and also its operation.

9 This is to meet thermal limits
10 that are defined to preclude the degradation
11 of the, of the waste forms and the
12 perturbation of the engineered or natural
13 barriers in the disposal site. Heat
14 generation effects the capacity, the waste
15 emplacement capacity in that configuration.

16 And also, operationally, cooler
17 wastes are much easier to handle. They could
18 be placed in a repository sooner, and would
19 require less active cooling. Additionally,
20 to the design and operation and construction
21 challenges for waste isolation sites that
22 come from heat generation, heat generation

1 also greatly increases the complexity of
2 modeling the performance of disposal sites.

3 And in particular, the ability of
4 a disposal system to mitigate the dose
5 release. The dose release is the criterion
6 typically by which a disposal site is
7 evaluated. Radiotoxicity is the source of
8 the dose, but the criterion for licensing a
9 repository is typically the dose released to
10 the biosphere.

11 And heat generation perturbs the
12 disposal environment, it effects the
13 geochemistry in the near field, the
14 degradation rate of engineered materials,
15 the hydrologic flow and mechanical processes
16 in the disposal system, in ways that aren't
17 necessarily easy to represent.

18 So we expect reduction of heat
19 generation to provide a benefit not only for
20 design of a repository but also for the
21 licensing phase. Next, please.

22 So, in considering how to deal

1 with heat generation, we first look at its
2 sources. This chart shows the total heat
3 generation from used fuels starting at ten
4 years post discharge of standard Light Water
5 Reactor fuel through 10,000 years. The total
6 heat decays by a couple of orders of
7 magnitude in this period.

8 Initially, it's dominated by
9 fission products, and almost strictly by the
10 cesium and strontium and their decay
11 daughters. Their heat emission decays to
12 where it's comparable to that from the
13 actinides, the heavy elements that are
14 fissioned and produce energy, in about sixty
15 years. So at sixty years, the heat source
16 comes from the actinides, to a greater
17 extent than the fission products.

18 And in less than 300 years, the
19 heat emission from the fission products is
20 essentially negligible. Now, the thing
21 that's very important to keep in mind is
22 that the dose released from a repository is

1 typically governed by the long lived fission
2 products: technitium 99, iodine 129,
3 isotopes of cesium and chlorine.

4 So they are the dominant source
5 of dose release. However, it's the short
6 lived fission products that contribute the
7 heating to the repository. This decays away
8 quickly and much more slowly decaying is the
9 heat source from the actinides.

10 And the integrated heat source
11 from the actinides is much greater than that
12 from the fission products. So the heating
13 from the fission products can be handled
14 through interim storage, through active
15 cooling in the initial waste isolation
16 period. But the long term heating from the
17 actinides is much more difficult to manage,
18 and it contributes the vast majority of the
19 long term heating. Next, please.

20 So, I already mentioned then that
21 for the storage period, the fission
22 products, the short-lived fission products

1 dominate the heat emission. For long term
2 disposal, the actinides dominate heat
3 emission.

4 And so it's very natural to look
5 at fuel cycle options that don't discharge
6 these long-lived and slowly decaying
7 actinides to the repository. It turns out
8 that these are precisely the same
9 constituents of spent fuel that are reusable
10 for making energy, they're the actinides.

11 And in particular, americium and
12 plutonium are, govern the long-term heat
13 emission. So, fuel cycle options that
14 fission and recycle these elements, keep
15 them out of the high-level waste repository
16 and this is a very compelling argument for
17 recycle is that it's exactly the problematic
18 constituents that are reusable for energy
19 generation.

20 Fuel recycle converts the
21 actinides to fission products. That's true,
22 however, fission product generation is only

1 dependent on the amount of nuclear power
2 generation. So their production is
3 completely unaffected by recycle. It's
4 strictly proportional to the amount of
5 nuclear power generation.

6 So, by keeping the actinides out
7 of the waste stream, we greatly reduce the
8 long term decay heating. Also, we avoid the
9 discharge of very long-lived radiotoxic
10 elements. This is the radiotoxicity aspect
11 of the problem, as Dr. McCarthy pointed out.

12 And keeping the actinides and
13 especially their heat emission out of the
14 waste stream should greatly facilitate the
15 design, licensing, and operation of a
16 disposal site.

17 And one of the most effective
18 approaches to keep the actinides out of the
19 waste stream is to enhance their fission
20 probability in a reactor, to employ
21 efficient recycle of actinides that are
22 discharged, minimize the losses of the

1 elements that are being recycled and, of
2 course, durable waste forms are also
3 important as part of the isolation strategy,
4 additionally to engineer barriers and the
5 natural isolation that's provided by the
6 repository environment.

7 The first bullet is why we're
8 interested in fast neutron reactors.

9 Fundamentally, fast neutron reactors, as
10 this chart shows, are much more efficient in
11 fissioning the even isotopes of plutonium
12 and the minor actinides.

13 Both fast and thermal reactors
14 fission the fissile isotopes like uranium
15 235, plutonium 239, but only fast spectrum
16 reactors efficiently fission plutonium 240,
17 plutonium 242, and this is of very
18 fundamental importance because it avoids the
19 capture to heavier elements, which are
20 problematic in, during the reactor
21 irradiation. Next slide, please.

22 So, then to summarize, fast

1 reactors and recycle have tremendous
2 potential to reduce the cost and improve the
3 performance of waste disposal systems. This
4 is true whether they are implemented to help
5 manage the back end of the Light Water
6 Reactor fuel cycles or they're implemented
7 for energy generation in a break even or
8 even a breeding fuel cycle.

9 But they can also contribute to
10 the management of the back end of the Light
11 Water Reactor fuel cycle. And, again,
12 primarily through the reduction of heat
13 generation from the waste.

14 Now, people may argue about
15 whether this waste management benefit is the
16 primary incentive for pursuing fast reactors
17 that recycle, but at least it's a benefit.

18 Other benefits are vastly improved
19 utilization of uranium resources, and
20 ability to use up vast quantities of
21 depleted uranium that have, have been
22 produced as a result of enrichment

1 operations, as well as used uranium that's
2 discharged from reactors.

3 There's also a benefit of
4 reducing enrichment by recycle. It's true,
5 you are separating plutonium and minor
6 actinides, and this has to be, has to be
7 safeguarded in the fuel cycle, but it has a
8 compensating benefit of reducing the fuel
9 enrichment, which is probably one of the
10 most proliferation-sensitive aspects of the
11 fuel cycle.

12 I don't mean to imply that there
13 aren't significant challenges for fast
14 reactor recycle. There are and I've listed
15 them here.

16 They are: chief competitive cost
17 and they're to assure safety and reliability
18 of operation, and to assure efficient
19 implementation of safeguards and physical
20 protection, and these are exactly the goals
21 of the DOE R&D program on fast reactor and
22 recycle technologies.

1 And then, most fundamentally
2 though, is that irrespective of the fuel
3 management option that is pursued, a full
4 used fuel management infrastructure will be
5 required even where we are today.

6 This includes storage of used
7 fuel, transport of fuel to either processing
8 or disposal locations, and of course, final
9 disposal of high-level waste in a
10 repository.

11 That concludes my presentation.

12 CHAIR DOMENICI: Thank you very
13 much. I think we have finished the
14 witnesses. Mr. Co-Chairman and in the rest
15 of our time, I think we'll follow the
16 agenda, is that correct? Do you have
17 questions? Let's start with anyone. Al, do
18 you want to proceed?

19 MEMBER CARNESALE: Before I get to
20 specific questions, most of what we've heard
21 when it comes to reprocessing and whether
22 its fast reactors or other form, whatever

1 benefits arise, arise in the long-term.

2 Those are the benefits.

3 And yet we've also heard not just
4 today but elsewhere that the principle,
5 among the principle things we need to
6 address is the societal implications and the
7 political obstacles and the like. The U.S.
8 Government, to a first approximation, and
9 the people, have a very high discount rate.

10 The idea that the benefits are
11 going to come more than 100 years from now
12 is inconsistent with the way we think about
13 climate change, Medicare, social security,
14 the debt, everything else, where the
15 discount rate is roughly one, or perhaps
16 eight years at the outside.

17 So, can you help me out. It
18 appears that among these, whether you
19 reprocess or not, there aren't many
20 differences for 100 years except if you
21 reprocess, you have to build reprocessing
22 plants, you need more transportation, you

1 need more low-level waste, or I should say,
2 lower-level waste. Because it really isn't,
3 it's not the same as what comes out of the
4 hospital.

5 So, it sounds like the
6 disadvantages come up front, and the
7 advantages come after not only when nobody's
8 any longer in elected Office, but they're
9 all dead. So, help me to understand how I
10 put these two things together. I have a
11 nuclear waste technical, but I don't have a
12 political Board.

13 And yet, we all realize that
14 that's a big part of the problem. So could
15 you tell me a little bit about, what are the
16 disadvantages in the near term, by which I
17 mean fifty years, of moving away from once-
18 through? What are the advantages, what are
19 the disadvantages, moving away from once-
20 through fuel cycle and saying goodbye to
21 that spent fuel and putting it in a
22 repository someplace?

1 CHAIR DOMENICI: Who do you want
2 the question of, Al? Who do you direct the
3 question to?

4 MEMBER CARNESALE: Well, they've
5 all sort of --

6 CHAIR DOMENICI: They were all put
7 up to manage answers --

8 MEMBER CARNESALE: I'd like it
9 from the technical people, perhaps, first, I
10 think the, but whoever --

11 CHAIR DOMENICI: Why don't you put
12 up your hand if you'd like to answer the
13 question? Anybody like to volunteer?

14 MEMBER CARNESALE: Well, why don't
15 we have Mr. Abkowitz?

16 DR. ABKOWITZ: Okay, I guess we'll
17 go by alphabetical order here. I don't -- I
18 can't answer. I agree with what you just
19 said, that it's not clear that there are any
20 advantages in the next fifty to sixty years,
21 for sure.

22 So I'm not here to argue the

1 tradeoffs. We've not yet found a compelling
2 argument for reprocessing and recycling in
3 the world as we know it today and in the
4 foreseeable future.

5 DR. KHALIL: I think we need to
6 distinguish between implementation of these
7 technologies in the near term to address
8 existing spent fuel stocks and the like,
9 which is probably not going to happen and
10 may not make that much sense. On the other
11 hand, there's a tremendous incentive for the
12 future to develop an emission-free energy
13 source that produces less waste, that uses
14 uranium more efficiently. And that's the
15 benefit from recycle.

16 When those technologies for fast
17 neutron reactors and recycle become
18 available, they can help manage the
19 accumulation of spent fuel from other types
20 of reactors, as well as just generate energy
21 independently from Light Water Reactors and
22 perhaps supercede Light Water Reactors and

1 provide you an energy, a sustainable energy
2 form.

3 So, I see a lot of incentive to
4 develop these technologies. I don't think
5 there's an urgency to their commercial
6 implementation. I strongly suspect we
7 wouldn't see a commercial implementation
8 until, say, decades from now.

9 But the technology is very
10 compelling and, I think, worth developing
11 and worth commercializing in the future.

12 DR. MCCARTHY: I think what you
13 have pointed out is one of the biggest
14 challenges that we have, and I spend a lot
15 of time going out to talk to various
16 stakeholders to try to explain what it would
17 mean to implement some of these other fuel
18 cycles, and what are the advantages and the
19 urgency argument is the one that's difficult
20 to argue.

21 And that's because our political
22 system sort of works in four year bites, and

1 if something is further than four years out,
2 it tends to be infinity. But I don't think
3 that that means that we ought to not pursue
4 this, and the sooner that we begin to
5 implement this, the sooner we'll see the
6 advantages.

7 Albeit, it will take a while. It
8 is possible to start earlier than, for
9 example, the analysis that I've shown and
10 it's to a large extent a matter of political
11 will to do it, the technical risk that one
12 wants to take on and the political risk
13 associated with it.

14 DR. CARSON: It's a fascinating
15 design challenge and I think one of the sets
16 of people to pose that to is the political
17 scientists, who may be able to bring in,
18 personally, as a historian I can't think of
19 any, but are there any success stories of
20 designing for a long term payoff with short
21 term benefits that are hard to define?

22 I would also suggest that if

1 there are lessons to be learned from other
2 nations that have taken on the interest in
3 either reprocessing or other kinds of
4 advanced reactors, that analysis be done of
5 that, of both the reasons for their success
6 and the limitations that they have run up
7 against.

8 DR. MAKHIJANI: I would just add
9 one thing. There is no short term pay off.
10 That's very clear. And by short term we mean
11 thirty, forty, fifty, sixty years. I, I
12 would question the framework that there is a
13 long-term payoff, because it assumes that
14 nuclear energy will be the non-carbon energy
15 of choice fifty years from now.

16 Anybody who's got a crystal ball
17 for technology that looks out fifty years,
18 is better than me, certainly. The crystal
19 ball we do have, that at least I look into,
20 and not as a Hindu, the technical crystal
21 ball I look into is pretty murky. But from
22 what we can tell is solar energy costs are

1 coming down very rapidly.

2 The technology is not where wind
3 energy was twenty-five years ago. If you
4 look at the evolution of wind energy in the
5 last twenty-five years, it's quite
6 remarkable and it's still developing
7 extremely rapidly. The issues of
8 indeterminacy and so on, I've looked at all
9 of that. I've sent you copies of some of
10 that.

11 But I would say that betting a
12 huge amount of public money on payoff fifty
13 years from now from a technology that has
14 failed after 100 billion dollars of public
15 expenditures globally over the last, is a
16 poor choice, of public policy, especially as
17 we can see other benefits in the much short
18 -term.

19 And if it doesn't, if the crystal
20 balls about solar energy are wrong, you
21 don't lose very much. You don't risk very
22 much. You will have a lot of choices open to

1 you, including existing LWR technology,
2 right, I don't think the nuclear renaissance
3 is coming about anyway.

4 But you don't lose anything by
5 investing large public dollars in a fifty-
6 year technology payoff, I don't think. Look
7 at fusion, my chosen discipline for my
8 doctorate, it's always thirty years away.
9 And if we don't have a good crystal ball on
10 fusion after untold billions of dollars of
11 public expenditures and some of the best
12 scientists in the world, I think the idea
13 that you're going to have benefits fifty
14 years from now is really far fetched.

15 DR. KHALIL: And nuclear energy,
16 I'm not sure I understand the reference to a
17 failed development. I mean, it's 20% of
18 electricity generation in this country, it's
19 70% of emission-free electricity generation.
20 It has a non-negligible fraction of energy
21 and electricity generation worldwide.

22 Its development is being

1 accelerated in other countries that are
2 looking at population growth and economic
3 development, including fast neutron systems
4 and more sustainable versions of nuclear
5 energy. And, by the way, as a component of
6 the energy mix of the future, not as the
7 only option.

8 So, I think we are not-- when I
9 mentioned sustainable nuclear energy, I mean
10 it as part of the portfolio of energy supply
11 options for the future.

12 DR. MAKHIJANI: Just for the
13 record, you know, when I say failed
14 development, I'm referring to sodium cooled
15 reactors, and you've heard my presentation
16 before. Frank has talked about this. I mean,
17 it's very clear that the public estimate of
18 around 100 billion dollars expenditures
19 worldwide in the development of sodium
20 cooled fast breeders, and we still don't
21 have a commercial system.

22 It's quite simple, we do have a

1 commercial LWR system. Now, how it became
2 commercial and whether it is still
3 commercial is a separate argument, but I'm
4 not talking about LWRS. Just for the record.

5 CHAIR PETERSON: Next? Allison?

6 MEMBER MACFARLANE: Okay. If
7 you'll indulge me, I have questions for
8 three of you. Okay, so let's start with
9 Kathryn McCarthy. Would you characterize the
10 difference between the burner breeder and
11 the other cycles that you showed us as
12 significant in terms of long term
13 radiotoxicity and decay heat and in regards
14 to their repository impacts?

15 DR. MCCARTHY: So, the two
16 groupings were basically continuous recycle
17 --

18 MEMBER MACFARLANE: Yes.

19 DR. MCCARTHY: -- versus once-
20 through and single recycle. Okay. And there
21 was on the order of one to two orders of
22 magnitude depending on where you look.

1 MEMBER MACFARLANE: Okay, and do
2 you characterize that as significant?

3 DR. MCCARTHY: Depends on the
4 repository. It depends on what's important
5 to the particular repository. It depends on
6 the mobility of the particular --

7 MEMBER MACFARLANE: So, basically
8 --

9 DR. MCCARTHY: -- elements.

10 MEMBER MACFARLANE: -- is it a
11 reducing or oxidizing repository.

12 DR. MCCARTHY: Right.

13 MEMBER MACFARLANE: And then, have
14 you looked at MIT's report? Because they say
15 the opposite of what you're saying, that
16 these aren't significant differences.

17 DR. MCCARTHY: You know, it is
18 subjective and in the end, you have to look
19 at the whole system, including the
20 repository. One thing we're doing here is
21 focusing specifically on the repository,
22 understand that. But in the end, you have to

1 take into consideration waste package,
2 environment, the entire thing.

3 MEMBER MACFARLANE: Okay. Question
4 for Cathryn Carson. So, in your writeup, you
5 say that our, my, us, the BRC's design
6 challenge is to build in societal concerns
7 from the beginning. I just want to push you
8 here, take off your historian hat, just
9 leave the social scientist hat on and, you
10 know, how would you do that?

11 DR. CARSON: So, if we were
12 thinking about how to bring in societal
13 considerations, which you can include social
14 science, largely reaching over into public
15 outreach, my suggestion would be first to
16 look at other countries that have given a
17 shot at this. I believe the full Commission
18 has heard from representatives of the
19 Canadian program.

20 MEMBER MACFARLANE: Yes.

21 DR. CARSON: And my understanding,
22 though I don't have direct contact with

1 them, is that social scientists have been
2 brought into the framing, at least, of their
3 process definition. And, as I understand it,
4 they have made a commitment to continue
5 funding, particular relevant kinds of social
6 science research for that process.

7 MEMBER MACFARLANE: Yes.

8 DR. CARSON: Believe there's
9 something similar that's done with Sweden,
10 though I know that case even less well. So,
11 there are models for this that have been,
12 begun to be tried out in other countries,
13 again, specifically around the waste
14 problem.

15 But I think that can be the basis
16 for generalization for the questions facing
17 this Subcommittee as well as the Commission
18 at large. The other place to look for models
19 is in programs like the Human Genome Project
20 or the National Nanotechnology Initiative,
21 which I mentioned. Which, in their case,
22 designated a certain proportion of funding

1 to go to outreach, education and what, in
2 the jargon of the domain, is called ELSI,
3 Ethical Legal and Social Implications
4 research.

5 Now, I'm not sure the percentage
6 model for funding social science research
7 gets you where you want to go. But, given
8 the fact that it's a model that has been
9 tried out and can be queried to the people
10 who have been involved in it, overseen it,
11 managed it, and in some cases, seen what the
12 payoff is, I suggest that there's a scoping
13 out process that can be done that will give
14 guidance about what could be useful in this
15 particular case.

16 MEMBER MACFARLANE: Great. Thanks.

17 And then, finally, for Mark Abkowitz, a
18 couple questions. Let's see. So, one thing
19 it seemed like that was missing from your,
20 what did you call it, NUWASTE? Whatever it
21 is. Analysis, is whether you really quantify
22 the gases, the liquid effluents, the

1 decommissioning wastes, that you have in
2 these different processes.

3 And then, secondly, you know, I
4 noticed that -- and this isn't just limited
5 to you, but a number of you have spoken
6 about the repository, singular. Is that
7 what, really what you believe? Or are we
8 looking at repositories, plural?

9 DR. ABKOWITZ: Okay, let me take
10 on the two of those questions separately.
11 First of all, we've taken great pains in
12 taking that schematic that you saw in one of
13 the slides, with the little icons and
14 everything, to make sure that we have
15 complete enough balance between --

16 MEMBER MACFARLANE: Right, you
17 didn't have any, you didn't have any liquid
18 effluence or decommissioning wastes, I don't
19 think, I saw in that.

20 DR. ABKOWITZ: Okay.

21 MEMBER MACFARLANE: You had the
22 gases.

1 DR. ABKOWITZ: Okay. To my --

2 MEMBER MACFARLANE: -- a cloud.

3 DR. ABKOWITZ: I'm not the
4 programmer, but to my knowledge, we are
5 taking into consideration everything, and if
6 it hasn't, if it hasn't been discretely
7 shown in the manner that you would like to
8 see it, we can certainly produce that
9 information in that form. But we've been
10 very careful to make sure that we account
11 for everything that comes in to each of
12 those boxes and how it comes out, and we
13 have benchmarked that against quite a bit of
14 literature and in communication with a
15 number of industry professionals.

16 MEMBER MACFARLANE: Right, right.
17 I mean, I think that that's really important
18 to emphasize because that is what gets lost.
19 All we end up discussing about is the high-
20 level waste and the low-level waste and
21 intermediate-level wastes, especially for
22 the cycle that you looked at --

1 DR. ABKOWITZ: Yes.

2 MEMBER MACFARLANE: -- are huge.

3 DR. ABKOWITZ: Absolutely.

4 MEMBER MACFARLANE: And they, and
5 the intermediate level wastes, greater than
6 class C, call them whatever you want, they
7 require a repository.

8 DR. ABKOWITZ: Yes. When we get --

9 MEMBER MACFARLANE: There we are,
10 into repositories, plural.

11 DR. ABKOWITZ: Right. Let me
12 answer that part of the question. When I
13 made reference to the term repository in the
14 singular sense, it was really focused
15 predominantly on what to do with spent
16 nuclear fuel and high level waste. The
17 argument I was making is that we're not
18 going to avoid the need for that.

19 Clearly, the extent to which
20 we're generating large volumes of other
21 wastes implies that we would need to have
22 other repositories as well. Or expand on

1 whatever repositories people were thinking
2 about for those other situations.

3 MEMBER MACFARLANE: Yes.

4 DR. KHALIL: Some of the
5 quantities of wastes are not fundamentals of
6 nature, and improvements are clearly,
7 they're targeted, they're desired, they're
8 being pursued in R&D programs around the
9 world. So there, there is, clearly there's
10 room for improvement, but I don't think we
11 should, just, be, adopt the attitude that
12 the current state is the way, the way that
13 it has to be.

14 MEMBER MACFARLANE: No, but I am
15 chastened by the fact that we cannot dispose
16 even of our low-level waste in this country.
17 So, we have a problem across the Board, and
18 if we are going to be producing more than
19 just high level waste, you know, if we're
20 going to be producing low-level waste in
21 addition and we don't have a solution for
22 that, we have to keep that in mind as we

1 look forward.

2 CHAIR DOMENICI: Let's see who is
3 next. Dick?

4 MEMBER MESERVE: Just a quick
5 followup on that. I did notice, Dr.
6 Abkowitz, that you had lumped together the
7 low-level waste with greater than class-C
8 waste, and it really would be important,
9 acknowledging that, may not necessarily be a
10 technologically defined mind, but separating
11 those I think would be very important given
12 the current lack of any pathway for greater
13 than class-C wastes, a problem certainly
14 with low-level waste but aggregating them
15 is, I think, would be very helpful--
16 disaggregating them would be very helpful.

17 DR. ABKOWITZ: Point well taken.
18 This was the manifestation of five to ten
19 minutes and trying to point out that there
20 are other wastes that are generated, but you
21 are absolutely correct, they are different
22 animals and, and we can produce that

1 information for you.

2 MEMBER MESERVE: To follow up on
3 that, it does seem to me, although we have
4 not agreed on this among the group, that the
5 kind of modeling that at least three of you
6 have discussed about what the waste forms
7 are, where the flows are, and so forth, are,
8 under various scenarios, are going to have
9 to be something that we include on our
10 report at some way.

11 You've described I think at
12 least, maybe I think, at least three
13 different models. That there's the Idaho
14 model, apparently there's an Argonne set of
15 models that may be different from those at--
16 and then, Mark, I'm not sure whether your
17 models include the fast reactors yet.

18 But it does seem to me that if we
19 have a, a, some scenarios that we need to
20 examine as a Commission and models that we
21 need to evaluate and I'm wondering the
22 extent to which you have communicated with

1 each other already and have some consensus,
2 at least consistent models, whether you've
3 done the evaluation that gives us some
4 confidence that there's a foundation on
5 which we can build.

6 DR. ABKOWITZ: Let me, let me
7 respond to that. This question actually came
8 up about three weeks ago at the DOE used
9 fuel workshop that was actually held here in
10 DC in which I was participating, I was with
11 some folks from Idaho who used the, what's
12 referred to as the VISION model.

13 And there are, there are other
14 models out there as well. Argonne referred
15 to one. There's actually some
16 internationally. And it's actually spawned a
17 discussion that, that our Board is now
18 taking up and, at our business meeting a
19 couple weeks, about the idea of having some
20 type of modeling workshop, most likely in
21 the early, late winter, early spring, where
22 we bring together all these different

1 parties and somehow go through the gyrations
2 of trying to understand how we're each
3 designing our approaches and what types of
4 results we get when we're all given the same
5 set of inputs, so, so that we can try to get
6 at this very question.

7 DR. MCCARTHY: Let me quickly
8 address what has been done with respect to
9 VISION that Dr. Abkowitz referred to. VISION
10 is actually the fuel cycles R&D code, it's
11 not an Idaho code. It's developed by multi-
12 laboratories. It was Idaho folks who
13 presented it.

14 We had gone through several
15 benchmark activities, both nationally and
16 internationally. We participated in a
17 benchmark via MIT, their study. We
18 participated in two international
19 benchmarks, one through the OECD nuclear
20 energy agency and the other through the INPO
21 activity, another international activity.

22 What you find with systems codes,

1 first of all, to specify a set of
2 assumptions does not mean--or, input--does
3 not mean you're going to get the same
4 answers. What you tend to find is systems
5 codes have certain things built into them,
6 and that will come out in these benchmarks.

7 But, there are two, one already
8 published report, and I think two that are
9 coming out soon, that speak to the bench
10 marking of systems codes if you're
11 interested.

12 MEMBER MESERVE: Well, I think
13 that I for one would find it very valuable
14 to get some sense of what the community
15 thinks our least consistent, believable
16 codes, and would be useful I think to have a
17 wide range of people involved in that
18 exercise so that their buried assumptions
19 are revealed.

20 DR. MCCARTHY: One thing I want to
21 add really quickly is what you get from
22 these types of codes, systems codes,

1 typically, is trends and sensitivities. If
2 what you want is a fuel tracking code,
3 that's a different animal and its important
4 to keep those two separate.

5 DR. ABKOWITZ: But I think that,
6 if I understand your point, it's really more
7 to be able to evaluate a consistent set of
8 scenarios and see whether we come up with
9 similar results. And if we don't, then we
10 need to go in and find out whether its
11 because of some assumption that was made, or
12 a very different way in which we're viewing
13 the fuel cycle world.

14 But, one way or another, we need
15 to be able to understand the differences so
16 we're in a position to be able to respond to
17 the types of questions that you people are
18 asking us.

19 MEMBER MACFARLANE: Let me suggest
20 that you have a science studies person
21 there. Really, that, that might help.

22 DR. KHALIL: I just wanted to

1 clarify one point--

2 CHAIR DOMENICI: If I could make a
3 comment--has your question been answered?

4 MEMBER MESERVE: I think the one--

5 CHAIR DOMENICI: --if he's talking
6 about when he talked about a model, you all
7 got, understand what he's asking for? You
8 understand it, can we get it, I mean, is
9 that what you're asking, Dick? Are you--

10 MEMBER MESERVE: Yes, yes.

11 CHAIR DOMENICI: --and what time,
12 how long, time frame to get it?

13 DR. KHALIL: I wanted to clarify
14 that, that none of the points that I made or
15 the results that I showed were produced
16 using an Argonne model. It's true we have a
17 system modeling capability. I was referring
18 to studies that were done by DOE in their
19 systems analysis area and their used fuel
20 disposition area. So these were DOE studies,
21 they weren't produced using an Argonne
22 model.

1 MEMBER MESERVE: Well, let me
2 suggest to our co-Chairs that we probably
3 ought to assign some staff to get work with
4 these people, because I think we are going
5 to want to have some of these scenarios,
6 that we understand them and employ them in
7 our final report.

8 CHAIR DOMENICI: I, I agree--

9 CHAIR PETERSON: I concur.

10 CHAIR DOMENICI: We're going to
11 get that done by our staff if they don't
12 have the expertise we ask them to get it, so
13 that can be done.

14 DR. MAKHIJANI: Could I make a
15 suggestion about these models, if I might?
16 You know, I don't know if their outputs are
17 geared to the existing low-level waste
18 classifications. You know, we've got waste
19 mass and then we've got a classification
20 mess. And currently, the Chairman of the NRC
21 has written the staff that they've got
22 inefficient and ineffective way of trying to

1 update the low-level waste group.

2 And I think when these models are
3 being considered, it might be sensible to
4 have two different types of bins in which
5 you get the output. One set of bins would be
6 geared to existing low-level, the 10 CFR
7 part 61, so you know which is greater than
8 class-C waste, and which wastes can be
9 disposed of under existing rules and shallow
10 land burial.

11 And the other might look to this
12 Revision of part 61 that the NRC is
13 considering and perhaps you might usefully
14 communicate with a Chairman of the NRC on
15 this question, because they, they clearly
16 are embarked on this, and the industry is
17 requesting it. They've got depleted uranium,
18 unique risk forms.

19 There's, there's a huge problem
20 and you might come out with your
21 recommendations in regard to how to handle
22 all these other things, and the

1 repositories, and so on, and at the same
2 time, there's a different part 61 coming
3 out, which might throw your recommendations
4 into some turmoil, depending on what kind of
5 models and outputs you're relying on.

6 So, I really think the model bins
7 should be geared to some forward thinking
8 way of managing long lived radionuclides
9 that's more sensible than what we've got.

10 MEMBER MESERVE: I have just one
11 quick question--

12 CHAIR DOMENICI: Go ahead, before
13 Mr. Abkowitz--

14 MEMBER MESERVE: You mentioned in
15 your NUWASTE model that proliferation risk
16 was one of the elements. You showed a chart
17 about separated plutonium. Is that the
18 extent to which that is included or is it
19 broader?

20 DR. ABKOWITZ: Right now, that's
21 kind of our proxy measure at the screening
22 level. And, and I think what our general

1 approach that, by running through some of
2 these scenarios of what our, I guess,
3 reasonably foreseeable options, we, we hope
4 to identify issues that require a deeper
5 dive, if you will, and that's our initial
6 proxy measure for looking at proliferation
7 and then we'll, we'll start to investigate
8 the question in more detail.

9 CHAIR DOMENICI: I would like to
10 proceed for a few more minutes. WE have how
11 much time before we're supposed to go on
12 recess?

13 CHAIR PETERSON: Fifteen.

14 CHAIR DOMENICI: Fifteen minutes.
15 Let me just engage Al and Dick in, in,
16 perhaps, Doctor. I don't believe that you're
17 convincing me, Al, that because it might
18 take 100 years to develop a reprocessing
19 system, that that's not going to be accepted
20 by the American public, because, let me
21 suggest, everything we're about is going to
22 be in terms of forty, fifty, sixty, and even

1 100 years, without reprocessing.

2 We're talking about dry casks as
3 an interim storage, and acknowledging that
4 they are already thirty and forty year
5 licenses. That might extend beyond that once
6 this, the engineering excellence of both dry
7 cask is all in, it may be that the nuclear
8 Regulatory Guide, if given authority, will
9 extend those for 100 years.

10 It also may be, since this
11 Commission is talking about interim storage
12 and saying the nation needs one or two
13 interim storage facilities, what are interim
14 storage facilities? They are 100 year
15 storage places. And if you write that in,
16 you're kind of saying, if you buy the Al
17 theory, you're saying that the public must
18 accept the 100 years.

19 They're going to accept the 100
20 years, they already know that interim waste
21 is 100 year, a 100 year problem. So it seems
22 to me, whether you do reprocessing is not an

1 issue of 100 years or being too long span
2 for the American people. It's an issue of
3 whether it fits economically in the, in the,
4 action during the next forty or fifty years
5 in the evolution of the use of nuclear
6 power.

7 And, remember, just because we're
8 not building one and have no renaissance,
9 there are fifty four under construction in
10 the world, now, all exceeding 1000
11 megawatts. And I don't know where they go
12 next, but just because we're not going,
13 they, the world is going, and we might come
14 along with the small ones taking the place
15 of the big ones, who knows, in America, in
16 the next fifteen or twenty years.

17 But the point I'm making, we
18 should not confuse how long it takes for
19 some of these things to evolve if we have
20 the knowledge about the necessity or the--
21 not necessity--the certainty that it will
22 happen. And I don't believe that the

1 longevity is an issue of whether the
2 American people will accept it or not.

3 This Commission is going to lay
4 down the criteria, Guidelines and the like,
5 for 100 year decisions. On interim--we can
6 just as well lay down 100 year evolution
7 criteria for the, for the, recycling that
8 may occur. And it would appear to me that
9 we're getting very close, everybody speaks,
10 want to have a great deal, great quantity of
11 our extra--

12 Excuse me, I'm very sorry about
13 my voice, it's, it's really a part of what I
14 have going wrong with me, I lose words and
15 I'm very, it upsets me very much and I'm
16 sorry. Let me try to go back for a minute
17 and do this. And again, can't do it.

18 We have a great quantity, now, of
19 energy locked up in the high level nuclear
20 waste that has come from our 103 nuclear
21 power plants, and it's accumulating rather
22 significantly every year. And it has fallen

1 upon us quite accidentally that the only way
2 to store it is to store it on site.

3 And, and, we didn't have that in
4 mind fifteen years ago, everybody was
5 telling the public that was the wrong way to
6 do it. There's very little opportunity, I
7 see, as I see it, for the Commission to do
8 anything but recommend that that's a good
9 way for interim storage to happen.

10 It just happened upon us, much
11 like we're now compliant with something else
12 to be on us, which is the price of natural
13 gas, which we didn't even have a idea that
14 it would be \$3.50, it was \$15 and \$16 three
15 years ago. Now, it's entered in the American
16 market, but not in the world market.

17 And it's effecting where we build
18 nuclear power plants and how fast, because
19 they found shale in others that they could
20 produce in large quantities, looks like we
21 have 100 to 125 years, okay? So that's in,
22 the economics for America, but does it throw

1 out the window that we can still plan and
2 participate in 100 year decisions with the
3 fuel, the spent fuel that we've got?

4 We know we're already leaning in
5 the direction of first time through, huge
6 quantity of it, and it'll probably be
7 buried, from what I can read, it'll probably
8 be buried in salt or something comparable.

9 It's not big, people have in mind that it
10 looks as big as the outside of these plants.

11 If you want to go see it, go see
12 the spent fuel rods over in Europe, they're
13 in a gymnasium. You walk on water and all
14 the spent fuel rods are in one building, and
15 you look down in there, there they are. But
16 they're going to last fifty years. If we do
17 it right, they're going to last 100 years.

18 Is the public going to say no
19 because it's a 100 year decision? You don't
20 know what's going to happen to it after 100
21 years? I don't think so. If we recommend it
22 right, the time it takes is not going to be

1 relevant. It's whether or not we should be
2 doing it as a nation, the research and
3 development, because we need it. And because
4 it's an evolution in something we already
5 invented.

6 I mean, we can't help it that we
7 invented this stuff called spent fuel which
8 has more energy in it, and energy we use to
9 get, to make it energy loaded, it's a
10 strange thing that that happened. And now
11 we, making kind, we did that.

12 We put it into play, and here it
13 is, and got more energy left in it and we
14 don't even know in America what to do with
15 the energy in it, so we're saying throw it
16 away.

17 And I'm not, I came here thinking
18 I'd fight that, but I'm beginning to think
19 we've got to put a bunch of it in deep
20 repositories that are not recoverable, gone,
21 and I leave with one last thought. If we do
22 that, it would seem to me that we ought to

1 get some experts an idea of how much of that
2 one time through waste is leaving for
3 America's future, and we ought to create a
4 reserve, at least saying we will never go
5 below that in terms of preserving the option
6 to use it for its energy.

7 And I'm sorry that I didn't
8 engage the witnesses, but I engaged the
9 fellow Commissioners, but it, if I said
10 something that doesn't make sense, then one
11 of you up there can comment as experts. But
12 it does seem to me that I, that what I've
13 said is not totally without some kind of
14 common sense.

15 Let me make one last observation.
16 I believe whatever has, has captivated the
17 public mind in America whereby twenty years
18 ago they were against nuclear power, I
19 believe the Americans are no longer against
20 nuclear power.

21 And pray to God we don't have
22 another one of those things that happened in

1 Pennsylvania, accidents that killed nobody,
2 hurt nobody, it'll change the American mind
3 again.

4 But if we already have it written
5 up, the American mind will change back again
6 too, and it can, we have to proceed even
7 though they may be against it for a while.
8 They are for it now.

9 I'm talking too long but I guess
10 a co-Chairman gets to, especially at the
11 end, when there's plenty of time left. But I
12 yield what's left to Al or anybody else.
13 Thank you very much.

14 CHAIR PETERSON: I'll quickly, and
15 then I'll--

16 MEMBER CARNESALE: I'd just like
17 to--this is not the opportunity for us to
18 debate the point, but--I do, I do, I think,
19 an important part for this Commission and
20 for the future of nuclear power is that the
21 U.S. appear to have a strategy, what it is
22 we're going to do, about the waste.

1 Not to solve the problem, but to
2 appear to have a strategy. I think if you
3 said to the average American, interim
4 storage is 100 years, they would say
5 "interim is 100 years? You've got to be
6 kidding." So that may be a technical notion
7 of, of what we believe.

8 But we need some sort of strategy
9 that goes beyond that. If the strategy is,
10 oh, we discovered there's no problem, you
11 can just store it for 100 years above
12 ground, we'll figure out what to do about
13 the decommissioned reactors later, I think
14 that probably goes nowhere and serves no
15 interest whether you're for or against
16 nuclear power. It's almost irrelevant.

17 We need more than that. We're not
18 a site selection Committee, but we need
19 something that says, "and what do you do
20 after that", other than "we'll figure it out
21 later".

22 CHAIR DOMENICI: And, I'm, let me

1 say, I don't disagree with you, okay. I just
2 think that, that--agreeing with you does not
3 mean that we should not have R&D directed at
4 a concept that might not be in place for 100
5 years.

6 MEMBER CARNESALE: Okay.

7 CHAIR PETERSON: I'd like to try
8 to shoo-in--shoehorn in two more questions
9 before we need to close. The first is for
10 Dr. Carson. And, this, this, this question
11 relates to research and social science. And
12 you mentioned that you may not, there may
13 not be a way to define a proper percentage
14 of funding and such that should go towards
15 that purpose, in the waste area.

16 But, of course, zero is also a
17 bad answer, so, and as a percentage, even
18 though that tends to be about where it, it
19 tends to sit. And as an engineer, you have
20 to be hit over the head with a two by four
21 to understand sometimes that this is
22 relevant.

1 But, you sent me an article on
2 nanotechnology by Cyrus Moody, and reading
3 it, I found it striking, the fact that some
4 of the research, for example, by Christopher
5 Kelly, who's an anthropologist, working with
6 people who are developing these technologies
7 in the nanotechnology area, actually
8 resulted in substantive change in the
9 technology.

10 In other words, the path that
11 these researchers were taking on the
12 technical side. And, I think that's, that
13 that actually provides an important insight
14 and I wonder if this can be generalized,
15 that when you bring social science in early
16 on in a process that might appear to be a
17 purely technical one, that it actually
18 changes the physical outcome in addition to
19 perhaps the social outcome, or it has the
20 potential to do that.

21 DR. CARSON: That's clearly going
22 to depend on a case by case basis, I think.

1 One of the differences between nano and
2 nuclear technologies is that, at least as, a
3 sort of well defined field of new funding,
4 nano is an emergent phenomena of the last
5 ten years.

6 Certainly, there was nano going
7 on before, but there's a sort of moment of
8 origin with nano funding and with nano
9 consolidation that I think made an opening
10 for anthropologists or other kind of open
11 ended social scientists to become involved
12 in the design process.

13 With nuclear, that's harder to
14 see, and I think one of the challenges would
15 be to figure out where the moments are for,
16 where the spaces are for engagement that
17 would lead to potential alternative
18 outcomes.

19 As a kind of thought experiment,
20 think through where your thinking would be
21 on fuel cycle questions if there had not
22 already been a group of people engaged with

1 questions around proliferation. Sort of,
2 imagine removing that from the scene, and
3 then bringing them into the picture at this
4 point.

5 I think you would, there, see
6 that there's potential for rather
7 considerable engagement and intervention in
8 the outcomes of the research program. Now,
9 where beyond that it would fit into a fuel
10 cycle research or waste research or anything
11 this Commission has taken on, I think, is,
12 is hypothetical.

13 But it would be something you
14 could find out by trying. And here, I would
15 think as well, the scale of social science
16 research is relatively small. As an
17 experiment, it's not a costly one. And there
18 are folks at NSF who have experience in
19 science technology and society studies who
20 could surely give advice here.

21 CHAIR PETERSON: Thank you. My
22 next, my, my--

1 CHAIR DOMENICI: Could I engage in
2 the second witness, Dr. Carson, for one
3 moment? You mentioned in your remarks two
4 things that might, might be looked at in
5 terms of looking at, at big program, took a
6 long time. You mentioned a genome, genome
7 program. Let me, so, so, so I can inject in
8 the record something that's, that's way
9 beyond this record but, interesting.

10 You know, the genome project of
11 the U.S. is heralded. And at the same time,
12 earmarks are the opposite. What's the
13 opposite of heralded, very much held in
14 disregard. Well, let's, the record show that
15 the genome project was an earmark, and guess
16 who earmarked it? I did.

17 Because the executive Branch
18 would not fund the genome. So we just, kid
19 of just wrote it in. The first time through
20 was nineteen million, the second time
21 through was about seventy. And then, Bush
22 One saw the light and funded it and said

1 okay, we're in here.

2 And Mark Hatfield saw it get,
3 getting funded and he came down and said
4 "set aside X percent", which I didn't, I
5 wasn't for, but it wasn't my business. He
6 said five percent should be held from that
7 fund to look at the ethics of the problem,
8 which I imagine is, let the people see
9 what's going on.

10 And that's, continues to this
11 day, to be set aside, to be used in that
12 regard. But I don't know whether it's either
13 that or the other one you mentioned have
14 been effective. Do you know, whether they've
15 solved, they've served any purpose?

16 DR. CARSON: Effectiveness is hard
17 to define I this field. Thought experiments,
18 for instance, how would the human genome
19 project have been received if social
20 scientists were not out there thinking
21 through the difference between genomics and
22 eugenics and making those clear for the

1 public.

2 I think that's a useful thought
3 experiment to go through. Again, it's hard
4 to demonstrate, at least--I'm a qualitative
5 social scientist, so I don't take that on.
6 But it would be interesting, I think, to go
7 back to the managers of the ELSI part of
8 human genome, as to the NSF folks doing
9 National Nanotechnology Initiative, and see
10 what, what measures they've come up with for
11 success or failure.

12 CHAIR DOMENICI: Again, I'd say,
13 that would be good to do. My own, my own
14 observation, being on the sidelines once we
15 got it earmarked, it was not my baby
16 anymore, we got it through and it belonged
17 to somebody else. But I don't believe that
18 the part you're referring to worked. But,
19 nonetheless, it would be good to see what
20 you think, sometime, maybe. Anything else,
21 Mr. Chairman?

22 CHAIR PETERSON: Can I just take

1 us one or two minutes into overtime?

2 There's, I think, one additional question
3 I'd like to ask, which is important. The,
4 the discussion here in this panel, related
5 to the potential for technical changes to
6 substantively or at least marginally effect
7 the cost and difficulty of waste disposal.

8 This actually couples to an
9 important question, which is, how much
10 should we charge, and how should we base the
11 charge in terms of fees and other things, to
12 utilities who are generating these wastes,
13 such that we have some confidence that there
14 will be enough money to pay for these future
15 activities.

16 And I, I actually, I, I, I have a
17 related experience, last week I got a notice
18 from the city of Berkeley that my trash bill
19 is going to go up by another forty dollars
20 per year, this coming year, because we have
21 a new target of diverting 75% of our refuse
22 to recycle and it's going to be more

1 expensive to do that.

2 We also have a progressive
3 system, so you can get a really tiny refuse
4 bin for much less cost than a bigger refuse
5 bin, and so on, so all of these things aimed
6 at incentivizing behaviors. My, my, my
7 question is, when you look at the various
8 different technical options that are
9 available that could effect waste disposal,
10 are there low hanging fruit that one might
11 start picking if there was at least some
12 relationship between how much you pay and
13 how difficult the disposal actually is?

14 And then, are there other things
15 which actually probably wouldn't touch? Just
16 because it wouldn't be worthwhile
17 economically even though it might be
18 technically possible, it's a technical
19 question, so maybe, just a few thoughts from
20 the technical people. Actually may be a
21 social dimension to it, as well.

22 DR. MCCARTHY: Let me just touch

1 on that very briefly. One thing I didn't
2 talk at all about is cost, and, and it was a
3 matter of time constraints. We had done
4 quite a bit of studies looking at
5 sensitivities to various costs.

6 We have looked at things like,
7 for example, incentivizing certain outcomes
8 with carbon taxes. We have looked at
9 sensitivity on cost of electricity,
10 depending on repository costs. We've looked
11 at it depending on reactors.

12 We have looked at several of
13 these things, and so, there's, there's
14 actually a report that I can give to you
15 that covers a lot of these topics. I don't
16 think I can do it justice in my one minute
17 answer.

18 But, suffice it to say, if you
19 look at studies out there, in, in, as to
20 what is the cost associated with recycling,
21 you'll find a huge range of estimates out
22 there. There's a lot of uncertainty. You'll

1 see that the costs are overlapping.

2 And, to be perfectly honest,
3 until you actually do something, build a,
4 for example, engineering scale facility,
5 it's going to be difficult to reduce the
6 uncertainty and the costs. I think it's fair
7 to say that on the order of 10-to-15%
8 increasing cost due to recycling is
9 reasonable.

10 But you can also find studies out
11 there, depending on what you say is an
12 economic advantage, you'll see studies out
13 there that reduce that cost. It all depends
14 on what's important to you, as, as a, as a
15 society. But I will provide that report.

16 DR. ABKOWITZ: I was going to just
17 piggyback on that. I think Dr. McCarthy's
18 last comment is spot-on, which is it really
19 depends on your objectives. I presented a
20 list of different criteria that people have
21 talked about being the important drivers in
22 this process, and depending upon which ones

1 you believe are the most important, and how
2 important they are, that's going to drive
3 whether it's low hanging fruit or not.

4 And, and then correspondingly,
5 whether or not the investment is worth it.
6 And I think that's one of the big challenges
7 for this Commission is to try to figure out,
8 what are we trying to achieve.

9 CHAIR DOMENICI: We, we're in
10 recess for fifteen minutes. Ten minutes?
11 We're in recess for ten minutes.

12 (Whereupon, the above-entitled
13 matter went off the record at 10:19 a.m. and
14 resumed at 10:32 a.m.)

15 MR. FRAZIER: So, we'll get
16 started with the next panel session, and
17 I'll turn it over to Dr. Peterson.

18 CHAIR PETERSON: Thank you, Tim.
19 I'm going to briefly introduce our
20 panelists, and then we will follow the same
21 prompt procedure as we did with the first
22 panel.

1 Again, reminding panelists that
2 we're going to do our very best to try to
3 keep within the ten minute time frame,
4 because the question and answer period is
5 also very important and valuable.

6 So, so, I will, I will crack a
7 whip in addition to the beep and the red
8 light. Our second panel is entitled
9 "Evaluating the Advantages and Disadvantages
10 of New Fuel Cycles".

11 Our first speaker will be Dr.
12 Eric Schneider. Dr. Schneider is an
13 Assistant Professor in the Department of
14 Mechanical Engineering at the University of
15 Texas at Austin. Thank you, Dr. Schneider.

16 Our second speaker will be Dr.
17 Everett Redmond. Dr. Redmond was recently
18 named Director of Non-Proliferation and Fuel
19 Cycle Policy at the Nuclear Energy
20 Institute. Thank you, Dr. Redmond.

21 Our next speaker then will be Dr.
22 Andrew Sowder. Dr. Sowder is a Senior

1 Project Manager at the Electric Power
2 Research Institute. The next speaker, then,
3 will be Mr. Christopher Paine. Mr. Paine is
4 the Nuclear Program Director at the Natural
5 Resources Defense Council.

6 And then, finally, the, the final
7 speaker will be a good friend of mine, Dr.
8 Mujid Kazimi. Dr. Kazimi is currently the
9 TEPCO Professor of Nuclear Engineering,
10 Professor of Mechanical Engineering,
11 Director and Director of the Center for
12 Advanced Nuclear Energy Systems at MIT.
13 Thank you also, Mujid.

14 With that, Eric, if you could
15 start.

16 DR. SCHNEIDER: All right, so,
17 before I move on into my--before I move onto
18 my prepared statement, I'd just like to
19 speak to a couple of the points that the
20 Committee members raised in the first
21 session that really go to, do go to
22 measuring fuel cycles, which is the topic of

1 this panel discussion.

2 And the first of the points had
3 to do with discount rates, decision making
4 going forward. And, while it would
5 certainly, obviously, a cost analysis is an
6 essential component of any decision making
7 process here, and the costs need not be
8 limited to direct costs, external costs will
9 also play an important role, and I'll get to
10 that in a moment.

11 But, I mean, short of using a
12 discount rate of one, post eight years,
13 something must, some reasonable choice must
14 be made. And I think, was it Albert Einstein
15 who said, "compound interest is the most
16 powerful force in the universe". Right, so
17 it's an important choice.

18 I guess I'd like to, in thinking
19 about this context, that has an
20 intergenerational consequence, I'll say the
21 standard discount rates that are used in,
22 let's say, governmental decision making may

1 be 7% per year, would indicate that all
2 measures should be put off.

3 Right, there is no urgency
4 whatsoever. But Kenneth Arrow at Stanford
5 University won a Nobel Prize in Economics in
6 the seventies for introducing the concept of
7 an intergenerational discount rate.

8 Right, and specifically, his
9 words, when he introduced this concept, one
10 of the societal problems that he indicated
11 it should be applied to was nuclear waste.
12 His words, in his seminal paper, that
13 essentially won him a Nobel Prize.

14 And, so, what does an
15 intergenerational discount rate mean? Well,
16 it takes into account our responsibility to
17 future generations, respecting the fact that
18 in the future, as population growth takes
19 place, economic growth takes place, right,
20 that the relevant discount rate to choose,
21 right, is still non-zero.

22 Right, it's small, but non-zero.

1 Right, and lots of folks have filled lots of
2 papers trying to estimate what an
3 appropriate rate would be, maybe 1-to-3% is
4 a consensus. Right, but I'd say that
5 whatever decision comes out of quantitative
6 analyses having to do with cost, right, is
7 extremely sensitive of that.

8 And, you know, I commend to the
9 Committee's attention careful thought on
10 that issue. Okay. And the second point I'd
11 like to respond to, Dr. Peterson raised the
12 question of incentives, right, at the end of
13 the last panel discussion. And again, that
14 gets to the issue of measures of fuel cycle
15 performance, specifically cost.

16 Right, so, nuclear power, as we
17 all know, is unique in some sense, being the
18 only resource consuming electricity
19 generation technology that internalizes, one
20 could claim fully, although that's not, that
21 will only be clear in the fullness of time,
22 that internalizes the costs associated with

1 managing it's wastes. Right, in the United
2 States through the Nuclear Waste Trust Fund.

3 Right, and so, the Trust Fund is,
4 is, I'll say it give sone a lot of
5 interesting options going forward, All
6 right, to redesign how the fund is assessed.
7 Right, for instance, right now, systems
8 analysis we all know, it's assessed on a
9 basis of a one mil per kilowatt-hour, right,
10 as a cost per Unit.

11 Electricity generated by nuclear
12 fuel, right, and I think we're aware that
13 there are interesting possibilities, right,
14 in terms of providing incentives to
15 utilities to going over to a mass basis,
16 right, assessing a cost per Unit mass of
17 fuel discharged.

18 Right, and what this does is it
19 gets to some of the points raise by the
20 earlier speakers, right, it fosters
21 incentives to, on the utility side, to
22 extract more energy, right, per Unit mass of

1 spent fuel, so that their fee, right, per
2 Unit mass goes down.

3 Right, but then one could make a
4 counter argument that this is unfair to
5 certain cycles, right, that produce low
6 specific energy per Unit mass, but also
7 relatively little waste, at least of the
8 type that may be difficult to dispose of in
9 certain geological repository concepts.

10 Examples of such cycles are the
11 CANDU, the Pressurized Heavy Water Reactor
12 cycle, which is a low burn-up cycle, right,
13 but there's no enrichment involved, so
14 there's no waste of depleted uranium.
15 There's no stream along those lines.

16 Right, and thorium based cycles,
17 right, seed-blanket cycles in general.

18 Right, so then, one could also consider,
19 I'll say, designing that feed to assess, to
20 assess costs or payments on an isotope by
21 isotope basis depending on, again, on the
22 scope of the fuel cycle and the repository

1 concept that's germane.

2 Right, depending on which of the
3 highest or low, had the highest impact, you
4 know, right, for, on the capacity of the
5 repository on the utilization and subsequent
6 reactors downstream. Right, so, so, I think
7 that there are interesting possibilities for
8 incentivization that the commercial sector
9 could, down the road, respond to.

10 Okay, so now to briefly go
11 through my prepared statements, the mandate
12 here is wide. So what I've chosen to do is
13 to focus on a relatively narrow part of this
14 broad question, how to measure the
15 performance of fuel cycles. IF you could go
16 to the next slide.

17 I'm going to start out with kind
18 of a zinger of a quote, and I'll read it out
19 for you. "Nuclear power results in up to
20 twenty-five times more carbon emissions than
21 wind energy, when reactor construction and
22 uranium refining and transport are

1 considered".

2 Right, then that quote is from a
3 paper by Dr. Jacobson of Stanford
4 University, that appeared in Scientific
5 American last year. Right, then, I bring up
6 that quote to introduce a family of measures
7 of, of performance of nuclear fuel cycles
8 that people call without really getting into
9 what it means, environmental and resource
10 sustainability measures.

11 Right, I bring those to your
12 attention because I feel that they're a very
13 poorly understood corner of the family of
14 measures of fuel cycles. I'll show you some
15 illustrations of why I believe that to be
16 the case. Right, and it's also difficult to
17 understand not only how to define them,
18 right, but also how to use them.

19 Because the costs associated with
20 them are often external, right, in other
21 words, they're not directly or easily
22 monetized.

1 And some brave folks have tried
2 to monetize these costs in the past, the
3 ExternE project by the European Union is one
4 example where they tried to take, I'll say,
5 environmental measures of fuel cycle
6 performance, not just nuclear.

7 All right, this was across the
8 entire energy sector, and turned those into
9 monetary equivalents, considering public
10 health impacts, occupational health impacts,
11 land use impacts, including farming,
12 ecological impacts, and others, right, to
13 monetize those.

14 Right, so it's a difficult
15 challenge. But I'd say, even before getting
16 to that stage, there's a, a interesting
17 dilemma that crops up over the course of me
18 looking at these, I'll say, environmental
19 sustainability metrics over the past few
20 months.

21 Right, and what this quote
22 indicates here, right, I believe, is that

1 there's really a poor understanding in this
2 area of the environmental footprint, if you
3 will, of the fuel cycle, right, or our fuel
4 cycle choices.

5 Right, and he wasn't specifically
6 referring to the fuel cycle in this quote,
7 but the fuel cycle produces the lion's share
8 of the impacts that he's describing. Right,
9 and, and finally I'll conclude my statements
10 by talking about maybe the most important
11 component of all this, the uranium resource
12 footprint.

13 Okay, so, this illustration here
14 really provides the background for why the
15 individual who made that quote was able to
16 do so in a respected forum. Right, and so
17 this is a review, and I'm not suggesting
18 that CO2 emissions is the sole, or only, or
19 best measure of the environmental footprint
20 of a fuel cycle.

21 Right, but it's one that's maybe
22 more heavily studied than some of the

1 others. Right, and so therefore I'm able to
2 present some nice data to you. Right. So,
3 this is from a review that appeared in the
4 journal Energy Policy a couple of years ago,
5 of nineteen estimates of CO2 emissions
6 associated with out contemporary fuel cycle.

7 Right, from the literature,
8 right. And so as you can see there is a
9 range that, you know, if we had uncertainty,
10 or, I'll say, lack of confidence to this
11 degree in some of our other metrics, the sky
12 would be falling, right, and maybe the sky
13 is falling in some sense.

14 Right, there's a real lack of
15 understanding here, I think. These are all
16 based on what the authors claim as life
17 cycle analyses, right, but life cycle
18 analysis like sustainability is a term that
19 can mean different things depending on who's
20 using the term.

21 Right, so I'll get back to that
22 in a moment. But as you can see here, there

1 are order of magnitude variations, right, in
2 this measure, the CO2 emissions measure,
3 between these nineteen different studies,
4 from, basically the lowest estimates that
5 are so close to zero that you can't see them
6 on there, and the highest estimates are what
7 gave rise to that rather astounding claim I
8 showed on the first slide.

9 Right, so, to the extent that
10 measures like this are incorporated in
11 decision making, they first need to be
12 understood, is my takeaway message. Right,
13 and I could show you similar data for other
14 environmental measures--land use, water
15 withdrawals, and, and really what this is,
16 what the carbon footprint is based upon is
17 energy consumed per Unit energy produced, ro
18 energy return on investment.

19 Right, which is, I'd say maybe a
20 more fundamental measure than CO2 emissions
21 because that folds in what's producing the
22 energy that's used. Right. So, even the task

1 of defining these measures, right, as I
2 said, was complicated.

3 It's eased because there are
4 international protocols for defining them.
5 Let's go ahead, actually, because I'm
6 running out of time. Okay, so, finally, I
7 promised you I'd speak briefly about
8 uranium. I'm running out of time.

9 So, this plot looks like a plate
10 of spaghetti with some meatballs on it, the
11 reason for that is, again, because of a lack
12 of concordance between estimates of our
13 understanding of a fundamental physical
14 property. Right, and so what I'm plotting
15 here--shoot, I'll be very quick--uranium ore
16 grade, right, and right now, we're currently
17 mining at .1% U-308, versus energy consumed
18 in mining.

19 The dotted line, we have control
20 over. Right, that's, that's 10% of the
21 energy we get out of the uranium we've
22 mined, right, that I choose 10% somewhat

1 arbitrarily to say, well, if we go above
2 that level, then the energy return on
3 investment is no longer satisfactory.

4 And what each of those lines
5 indicate is somebody's, right, a geologist,
6 estimate of the energy intensity of uranium
7 mining versus the ore grade. So, as we
8 deplete the resource, the energy intensity
9 of uranium mining will rise, right, but when
10 it rises to exceed some unacceptably large
11 share of the energy produced by here of the
12 once-through fuel cycle, we have control
13 over that, is of a, a, of great uncertainty.

14 Right, two orders of magnitude
15 almost. Right, if the higher value proves
16 true, to .02 percent U-308, that means that
17 resources like phosphates, that are
18 currently uneconomic to mine, will always
19 remain so, barring major technological
20 innovation.

21 Right, and if the most optimistic
22 estimates are correct, then the resource

1 problem is really a will of the wisp, it
2 doesn't exist. So, I'll conclude with that.

3 CHAIR PETERSON: Thank you. The
4 next speaker?

5 DR. REDMOND: Thank you. I want to
6 thank the Committee for the opportunity to
7 speak on some of the considerations
8 associated with transitioning from an open
9 fuel cycle to one or more advanced fuel
10 cycles.

11 All nuclear fuel cycles require a
12 robust used fuel management program.
13 However, the technical details of these
14 programs will vary depending on the
15 specifics of the fuel cycle. For example,
16 reactor design, thermal or fast, and degree
17 of recycling, one or multiple recycling
18 cycles, are some of the factors that will
19 effect used fuel management.

20 While the technical details of
21 the fuel cycles may differ, there are some
22 common themes. First, consistent, sustained,

1 political and policy support is required to
2 create the foundation upon which private
3 entities will consider investing in advanced
4 fuel cycle technology.

5 Second, only mature and reliable
6 technologies will be adapted--adopted on a
7 commercial scale by the nuclear power
8 industry, and the transition to a new fuel
9 cycle or fuel cycles will take decades to
10 accomplish.

11 Lastly, geologic disposal of used
12 fuel or used fuel byproducts will be
13 necessary for all fuel cycles. Moving beyond
14 the open fuel cycle, currently in use in the
15 U.S., will require a combination of
16 recycling, advanced reactors, durable
17 Federal policies, and sustained financial
18 investment.

19 The sustained support and
20 investment will only be justifiable if the
21 advanced fuel cycle provides significant
22 value compared to the open cycle. The

1 question is, how to determine if the
2 advanced fuel cycle offers significant
3 value.

4 One could develop detailed
5 metrics by which the various fuel cycles
6 could be compared to an existing open cycle.
7 Metrics would probably included items such
8 as cost to construct and operate, cost to
9 the consumer, reliability, impact on the
10 environment, including disposal, and non-
11 proliferation characteristics.

12 An exercise such as this, such as
13 this, would certainly be informative, but in
14 the end I think the decision to move away
15 from an open cycle will be based more on a
16 policy determination about the value of
17 advanced fuel cycles rather than a technical
18 comparison.

19 For example, recycling and using
20 fast reactors would enhance the
21 sustainability and economic viability of the
22 nuclear fuel supply in the United States by

1 reducing the demand for uranium ore.

2 However, the current availability of uranium
3 ore is not being challenged, and is not
4 expected to be challenged for approximately
5 fifty to 100 years, based on current
6 estimates.

7 As another example, recycling and
8 using fast reactors could enhance the
9 management and siting of a geologic disposal
10 facility by altering many of the materials
11 destined for disposal. Reducing the heat
12 load and radiotoxicity are two examples of
13 altering this material.

14 However, when considering the
15 potential benefit, it should be recognized
16 that used fuel, in its current form, can be
17 disposed of in various geologies with a
18 combination of natural and engineered
19 barriers, and it is highly unlikely that the
20 entire inventory of used fuel, currently
21 60,000 metric tons and growing, would be
22 recycled.

1 In both of these examples, there
2 does not appear to be a technical case for
3 switching fuel cycles at this time, based on
4 my oversimplified assessment. However, there
5 is still potential value, as I discussed, in
6 enhancing nuclear fuel supply
7 sustainability, and enhancing management of
8 siting of a geologic disposal facility.

9 Another policy area that should
10 be considered when discussing nuclear fuel
11 cycles is non-proliferation, a topic for
12 this afternoon's panel. Considerations and
13 goals in this area will influence the
14 implementation, if not the choice, of an
15 advanced fuel cycle.

16 Once a policy decision is made to
17 move beyond the open cycle, the task is to
18 create the foundation upon which the
19 commercial nuclear industry can successfully
20 develop, finance, and implement advanced
21 fuel cycles in a competitive marketplace.
22 The foundation will primarily be based on

1 economics and maturity, reliability, and
2 ease of implementing the advanced
3 technologies.

4 Regardless of the value added by
5 and advanced fuel cycle, the ability of the
6 nuclear fleet to produce electricity
7 reliably and efficiently must be maintained.
8 Currently, the Light Water Reactor fleet in
9 the United States has a greater than a 90%
10 capacity factor.

11 This capacity factor should be a
12 design goal, if not a requirement, for
13 reactors operating in an advanced fuel
14 cycle. Experience to date indicates that
15 additional research and demonstration is
16 necessary to achieve this goal for fast
17 reactors.

18 Research, development, and
19 demonstration of advanced recycling
20 technology and advanced reactors should be
21 pursued in a timely manner with a goal of
22 creating real, practical approaches that

1 will be successful in the marketplace. The
2 RD&D should not necessarily strive for a
3 single viable technology. Rather, it is
4 conceivable that more than one technology
5 could be commercialized in the United
6 States, to create advanced fuel cycles.

7 With the large number of
8 operating reactors, 104, and a substantial
9 inventory of used fuel, 60,000 and growing,
10 more than one recycling will be necessary.
11 Since alternate fuel cycles create different
12 types of used fuel and byproducts, for
13 example, used MOX fuel and vitrified waste,
14 geologic disposal of these alternate waste
15 forms should be considered to the extent
16 practical when contemplating the change from
17 the open cycle.

18 As an illustration, if a policy
19 decision is made to simplify the disposal of
20 high level waste by recycling currently
21 available used fuel and creating MOX fuel
22 for use in Light Water Reactors,

1 consideration should be given to the
2 ultimate disposition of the used MOX fuel.

3 Will it be placed in a geologic
4 disposal without being recycled, or will it
5 be recycled into fuel for use in a Light
6 Water Reactor or fast reactor? In this
7 scenario, direct disposal in a geologic
8 disposal facility seems unlikely, since the
9 challenges associated with disposal of used
10 MOX fuel are larger than those associated
11 with disposal of current used fuel.

12 Therefore, it would appear that a
13 key element to a fuel cycle which utilizes
14 MOX fuel and Light Water Reactors with the
15 goal of simplifying disposal will be more
16 advanced recycling technology and possibly
17 fast reactors.

18 In contrast, if the policy
19 decisions primarily to enhance the
20 sustainability of nuclear fuel supply,
21 direct disposal of used MOX fuel may be
22 desirable. Research and support of advanced

1 fuel cycles should continue and be conducted
2 with target dates specified for phase
3 development and demonstration of commercial
4 scale ventures based on advanced--advances
5 of current day technology.

6 Consistent with the evolutionary
7 manner of technological changes in the
8 commercial nuclear power industry, it is not
9 necessary to wait for decades of research to
10 be complete before implementing new
11 technologies.

12 If fast reactors are to become an
13 element of advanced fuel cycles, a
14 demonstration project should be conducted in
15 the United States. Under any scenario, the
16 efforts currently underway to revise the NRC
17 regulatory framework for licensing of
18 recycling facilities must be completed to
19 permit industry to license commercial
20 facilities at the appropriate time.

21 Thank you, and I'm happy to
22 answer questions.

1 CHAIR PETERSON: Thank you. Our
2 next panelist is Christopher Paine. Sorry,
3 excuse me, Andrew Sowder. Just a little
4 excitement to spice things up in the
5 morning. I came in on the redevye, so I
6 needed to wake myself up, if nobody else.

7 DR. SOWDER: Good morning, and I
8 want to thank the Commission and the co-
9 Chairs and the staff for the opportunity to
10 speak today on challenges and strategic
11 choices for sustainable nuclear fuel cycle.

12 And, the content of this
13 presentation is largely based on a report
14 that EPRI put out last month that examines
15 the key attributes of a sustainable nuclear
16 fuel cycle and attempts to identify
17 promising options and approaches as well as
18 key challenges and barriers in light of
19 National energy contexts.

20 So, let's see here. Any button
21 will do? Oh. Okay. Simple enough. So, the
22 intent of this presentation is, of course,

1 to answer some questions. I took the liberty
2 of paraphrasing them a little bit, but I
3 have structured the talk around them, so, I
4 won't repeat them here.

5 Okay. First, before going into
6 the presentation itself, I want to just give
7 basically a perspective on the current U.S.
8 energy context for electrical generation of
9 power. And, this is mainly from a utility
10 perspective. EPRI is comprised of U.S. and
11 international utilities, as are members.

12 First and foremost, Light Water
13 Reactor technology is the current workhorse
14 and will likely remain so for the coming
15 century. Industry is comfortable with the
16 technology. It works, it's available, and
17 it's reliable.

18 Secondly, the once-through fuel
19 cycle is the current reference in the U.S..
20 And again, for the coming, at least next
21 fifty years or so, it appears to be the most
22 economic option. Uranium resources are not

1 limiting for the near term, and at current
2 prices, in fact, most U.S. resources remain
3 untapped, for example.

4 Introduction of advanced fuel
5 cycle technology such as recycle of
6 plutonium as MOX is not economically
7 competitive unless it is driven by external
8 factors, such as the need to manage a
9 plutonium stockpile, and there's also
10 arguments to be made for gaining industrial
11 experience, given that recycling and
12 reprocessing is not a trivial endeavor.

13 Let's see here. So, what are the
14 performance criteria? EPRI's September
15 report presents four principle criteria for
16 evaluating a fuel cycle. They are economic
17 comeptitiveness, natural resource
18 sustainability, waste management, non-
19 proliferation, and I've listed here a fifth,
20 safety, because it, it is essentially
21 assumed to be a global requirement that must
22 be satisfied regardless of which fuel cycle

1 you choose, and the industry accepts this as
2 the cost of doing business in this area.

3 Now, the relative ranking of
4 these criteria depends on the National
5 context. For the U.S., cost competitiveness
6 is the primary driver. However, when energy
7 security is heavily embedded in the National
8 policy such as in France, Japan, other
9 places, natural resource sustainability may
10 well rise in its importance.

11 So, in terms of economic
12 competitiveness, EPRI has done some
13 modeling, as have many people, examining a
14 number of fuel cycle scenarios. Here, I'm
15 just presenting one as an example, comparing
16 the once-through fuel cycle in the black
17 line with two regions of interest, the red
18 representing single recycle in PWRs, that's
19 MOX and current Light Water Reactor
20 technology. And the blue region of interest
21 would be an advanced fuel cycle partially
22 closed in which plutonium is recycled in

1 fast reactors.

2 Again, I said an economic case
3 could be made, but--and the buts are big
4 here--because capital costs for example, for
5 the reactors are not included and that,
6 there's a good reason for that. First of
7 all, is, people don't really know how much
8 those will cost, so it's difficult to really
9 incorporate those.

10 But this recycling is, I mean,
11 this modeling is strictly for the fuel cycle
12 costs. But again, I'm using it for purposes
13 of a comparison. Now, the take home message
14 here is that recycling of plutonium as MOX
15 can be shown to be economically feasible when
16 uranium prices rise.

17 But again, that's as long as your
18 reprocessing costs and your fast reactor
19 technology costs are, first of all, known,
20 and reasonable. And finally, for the
21 industry, probably one of the most important
22 things is that the technology is reliable

1 and available when you need it.

2 I mentioned earlier that current
3 uranium supplies are projected to be
4 adequate for the next fifty to 100 years,
5 and here I'm just illustrating that through
6 a simple calculation that relates basically
7 years of supply to projected growth rates.
8 And so I've, from one to three and a half
9 percent, using a simple relationship.

10 And the three colors here
11 correspond to three different bins, if you
12 will, that you can subdivide uranium
13 resources per the IAEA NEA red book. So, for
14 example, for projected constant growth rate
15 of nuclear in the world, you have,
16 essentially, fifty and 100 years of supply
17 at present.

18 Now, again, the key thing here,
19 is as time goes on, one, more uranium
20 resources are identified, but the fact
21 remains that Light Water Reactors use less
22 than 1% of the energy content of the mined

1 uranium.

2 And, so, consequently, should the
3 fuel supply become limiting, or become a
4 concern, this is a compelling case for a
5 RD&D program on advanced reactors and fuel
6 cycle technologies.

7 So, again, the availability of
8 uranium is not a call for inaction in terms
9 of, of a, a prudent research and development
10 program. Now, for waste as a criteria. Waste
11 management is often emphasized as a
12 principle criterion for fuel cycle
13 selection.

14 But the actual impacts and
15 consequences are far more nuanced. And so,
16 what I would posit to you today, is that,
17 really as a criterion for distinguishing one
18 fuel cycle from another, on a technical
19 basis, waste management is really a
20 secondary criteria at best.

21 And, to illustrate, for example,
22 I, EPRI worked with Electricite de France,

1 using their state of the art dynamic fuel
2 cycle codes to model a specific scenario
3 here of GNEP type fast burner reactors with
4 a conversion rate of about 0.5, I believe,
5 with the intent expressly of maximizing the
6 burning of the actinides in the fuel cycle.

7 Now, you can burn the actinides,
8 but as you can see here, on the vertical
9 axis, you have the number of years it takes
10 to achieve a stated goal. So to achieve
11 about 50% takes on the order of seventy
12 years, and this is again for the U.S. fleet,
13 the U.S. situation.

14 But once you start talking about
15 significant reductions on the order of 90%
16 or above, you're looking at hundreds, to a,
17 to a, hundreds of years to a thousand years.
18 The other thing that's important to notice
19 is that, should you decide to move away
20 from, or cease this activity, you will be
21 left with the inventory in the reactors.

22 So, during this process, you're

1 not sending the actinides to a repository
2 while the fuel cycle is operating. You are
3 actually managing the actinide inventory in
4 reactors. Which, is maybe a prudent action.

5 Now, in terms of non-
6 proliferation, and again, it's a topic for
7 this afternoon, certainly a critical
8 consideration, and, by many, I think, many a
9 primary consideration. But in terms of
10 technically distinguishing one fuel cycle
11 from another, we would argue that it's
12 probably not that useful on it's own.

13 Because the institutional issues
14 tend to really dominate the non-
15 proliferation concerns, whereas it's the
16 intrinsic characteristics that tend to make
17 it into these technical debates, such as the
18 attractiveness of the material, et cetera.

19 Again, not to, not to downplay
20 the importance of non-proliferation, but the
21 take home message here that we would like to
22 leave is there is no silver, technological

1 bullet for non-proliferation. All fuel
2 cycle, as with safety, require adequate
3 safeguards and measures.

4 And so, these can be accomplished
5 through a combination of both intrinsic and
6 extrinsic measures. So, to answer your
7 second question, this is how these various
8 criteria rank. For the U.S., economics is,
9 or cost competitiveness is number one.

10 Basically, someone has to build,
11 operate, and maintain the technologies, the
12 reactors, and other facilities. For, and to
13 not be forgotten, for the actual, reliable,
14 affordable power generation, that's often
15 forgotten in the debates.

16 Secondly, resource utilization.
17 Uranium is more of a medium concern. Uranium
18 supply is not limiting for the next fifty or
19 so years. But resources amplification is the
20 primary feature of advanced fuel cycles and
21 is a compelling driver for future fuel
22 supply, beyond fifty years.

1 Waste management is really, we
2 would consider it a low priority. Technical
3 solutions exist for waste management for all
4 fuel cycles, and again, we move, basically,
5 the non-proliferation issue off more to the
6 safety realm that it must be adequately
7 addressed regardless of the fuel cycle
8 option.

9 And again, those institutional
10 issues tend to dominate. I know my time is
11 up, but the question was asked in terms of
12 what the community is doing of research in
13 terms of modeling, et cetera. So, in terms
14 of what's, most importance, is really to
15 understand the benefits, the issues for
16 consideration, and provide a framework for
17 supporting a phase adaptive technology
18 deployment.

19 This is the EPRI approach. Of
20 primary importance is your decision analysis
21 framework, but it's supported by both risk
22 assessment for human and environmental risks

1 of all aspects of the fuel cycle, your
2 dynamic fuel cycle modeling.

3 For example, EPRI has licensed
4 code from Argonne National lab, but we
5 certainly are in communications with Idaho
6 National Lab and others. Again, it's a
7 relatively small community worldwide. You've
8 got to incorporate your economic modeling as
9 well as some metrics of proliferation
10 resistance.

11 So, in summary, the focus has to
12 be on cost competitiveness power generation.
13 Better utilization of your natural resources
14 is a desirable feature and may be needed,
15 depending on your resource identification
16 and nuclear growth in the future.

17 Ultimately, waste management,
18 non-proliferation, and safety can and must
19 be appropriately addressed for all fuel
20 cycle options. So, with that, I thank you
21 for your time, apologize for running over.
22 Thank you.

1 CHAIR PETERSON: Thank you. And
2 now, Christopher Paine.

3 MR. PAINE: Thank you for
4 providing the NRDC the opportunity to
5 present its views today on the advantages
6 and disadvantages of new nuclear fuel
7 cycles. Since it's founding in 1970, NRDC
8 has been engaged in a wide variety of
9 nuclear fuel cycle and advanced research
10 reactor and development issues.

11 All too often, I think,
12 discussions about the future of nuclear fuel
13 cycles occur in a kind of economic and
14 energy policy void, where all that matters
15 at their discussed are the alleged technical
16 advantages of the nuclear technologies under
17 review.

18 We need to look comprehensively
19 at the economic rationality, broader
20 benefits, and collateral risks for society
21 and the environment that are often
22 neglected, when, in fact, these are the

1 essential questions.

2 Going forward, all nuclear fuel
3 cycle options and indeed, all available
4 technologies that can supply energy services
5 should be measured against five primary
6 criteria. Does the technology present a cost
7 effective path for abating carbon emissions
8 relative to other available low carbon
9 energy technologies?

10 Given the reality that carbon
11 emissions accumulate in the atmosphere and
12 therefore abatement options have a time
13 value, how soon can the technology be
14 deployed, compared to other low carbon
15 options?

16 What are the available non-
17 carbon--what are the harmful non carbon
18 environmental impacts of the technology
19 compared to other low carbon technologies,
20 and can these impacts be sufficiently
21 mitigated to provide wider use?

22 The fourth criterion, is the

1 technology socially and geopolitically
2 sustainable, which in nuclear's case, we're
3 worried about aggravating regional security
4 concerns or having to invoke invidious
5 political distinctions between states.

6 And fifth, what other electricity
7 resources will the technology either support
8 or displace on the grid? We never seen to
9 talk about that, and how will this affect
10 the overall rate at which genuinely clean,
11 renewable energy and efficiency resources
12 are deployed?

13 So, let me just briefly discuss
14 each of these criteria in turn. With respect
15 to the first criterion, the cost
16 effectiveness in cutting carbon, I think
17 everyone understands that all full and
18 partial recycle options today are quite
19 distant from the cutting edge of cost
20 effectiveness in reducing carbon emissions.

21 The only new nuclear fuel cycle
22 option in the running today is the current

1 LWR cycle. But, electrical end-use
2 efficiency, industrial waste heat co-
3 generation, combined heat and power systems,
4 wind, bio-gas, are all currently cheaper and
5 faster targets for new carbon reducing
6 investment, the new build LWRS.

7 So, where does this lead advanced
8 fuel cycles? Adding a twenty-five billion
9 dollar reprocessing plant, MOX recycle, and
10 fast reactor development program would add
11 nothing to nuclear power's decarbonization
12 potential over what might be achieved with
13 LWRS alone, and it would represent a very
14 heavy tax on the National decarbonization
15 effort for at least several decades, if not
16 indefinitely.

17 I believe that in a few years,
18 and the data, the recent data shows this,
19 before construction of the U.S., the first
20 U.S. nuclear new build is on, is online,
21 that we will have achieved grid parity for
22 solar energy in many electricity markets

1 around the world, including parts of the
2 U.S..

3 And solar is going to become a
4 ubiquitous feature of our energy supply
5 system by, I believe, the end of this
6 decade. This does not mean that solar and
7 wind are going to displace nuclear, but
8 rather that nuclear will be operating in the
9 future on a grid with a high market
10 penetration of variable renewable resources.

11 And we have to think about what
12 this means for the type of nuclear plants we
13 should be looking to build. I'll come back
14 to this point later.

15 With respect to the second
16 criterion, the relative time value of
17 alternative, low carbon investments, that
18 number from the Stanford researcher that
19 showed a very high carbon penalty for
20 nuclear, a large part of that is derived
21 from the time delay of actually implementing
22 nuclear plants.

1 And, a large nuclear, large new
2 build LWRS have historically required about
3 six to nine years to construct, and even
4 longer when you include the whole project
5 management time frame. Almost every other
6 low carbon technology beats nuclear in this
7 criterion.

8 During this long gestation
9 period, power's being procured from carbon
10 emitting sources and the low carbon nuclear
11 asset is not producing. If you add
12 reprocessing facilities and fast reactors to
13 this mix, it would only further delay
14 nuclear's contribution and add to a nuclear
15 project's carbon debt.

16 Japan's Rokkasho plant, for
17 example, has been under construction for
18 seventeen years, costs more than twenty
19 billion dollars, and commercial operation
20 has been postponed again until October 2012.

21 This criterion suggests that DOE
22 should focus its development program on more

1 cost effective LWRS with a reduced, with
2 reduced construction times, and or modular
3 plants that can begin generation within
4 three years and add bankable capacity
5 increments when they are needed going
6 forward.

7 The third criterion involves
8 assessment of non--carbon environmental
9 impacts of various nuclear fuel cycles. The
10 current new fuel, nuclear fuel cycles
11 cleanly, in my view, preferable to coal
12 mining and burning. But that does not, that
13 comparison is not the end of the comparison.

14 You have to compare the current
15 LWR cycle to the current range of renewable
16 energy options. These, too, have
17 environmental impacts that must be
18 considered and compared. This obviously
19 doesn't mean that we should discard nuclear
20 as an option, but only that it's near term
21 investment priority for the nation should be
22 lower than clean energy technologies and

1 energy efficiency.

2 And the near term R&D focus
3 should be on reducing the non--carbon
4 environmental impacts of nuclear power and
5 improving its cost competitiveness. These
6 non--carbon impacts, we really don't focus
7 on very much. Mill tailings that leak radon
8 and heavy metals, pollution of aquifers,
9 mined, mined by in, in situ leaks mining.

10 Overheating of inland fresh water
11 bodies and coastal estuaries, huge fish
12 kills in some reactors, massive consumptive
13 use of fresh water for evaporative cooling,
14 and tritium leaks from operating the
15 reactors and spent fuel storage pools.

16 And then of course there's the
17 task of storing and ultimately disposing of
18 spent fuel and other nuclear waste forms, a
19 task that I believe, with patience and good
20 will, will be soluble, I view as eminently
21 soluble.

22 Now, in theory, a full

1 implementation of the closed cycle could
2 reduce the uranium impacts. But shifting to
3 a closed cycle, shifting to a closed cycle
4 on that, on a large scale, is not likely to
5 occur for many, many years.

6 And, more likely, we're going to
7 see a deployment in parallel with existing
8 LWR cycle for a long time, in which case you
9 aren't going to get the uranium reduction,
10 the uranium mining benefits, anytime soon.

11 And so, you should really think
12 in the short term, or, in the medium term,
13 about reducing the environmental impacts of
14 the LWR fuel cycle, which DOE spends no
15 money on, as far as I can tell.

16 And that's one of the, you know,
17 getting to, efficient air cooling of units,
18 and eliminating the pollution that occurs in
19 the uranium mining cycle, to me, are two
20 very high priorities if we're serious about
21 making nuclear power relevant in the current
22 era.

1 The fourth criterion is social and
2 geopolitical sustainability. That's a very
3 broad criterion, and, obviously in the case
4 of nuclear power, we're talking about the
5 proliferation impacts.

6 But I want to just dwell on this
7 problem of making invidious distinctions
8 between states. That's one of the problems
9 with nuclear power today, forces us,
10 especially when we think about advanced
11 cycles, about trying to make distinctions
12 between states.

13 The U.S. Government is already
14 tied up in knots, if you've been reading the
15 news lately, confronting the problem of
16 making invidious and politically
17 unsustainable distinctions in the case of
18 Jordan and Vietnam, to Section 123
19 agreements where one agency is leaning
20 heavily towards giving Vietnam access to
21 enrichment technology, whereas we're trying
22 to deny Jordan the same prerogative.

1 So, irrespective of the fuel
2 cycle option, this criterion on social and
3 geopolitical sustainability, suggests that
4 international institutional innovation to
5 provide stronger non-proliferation
6 insurance, is the key path going forward.

7 It's more important than
8 technological innovation, and I think that's
9 also, EPRI came to the same conclusion.

10 Finally, let me say a word about the fifth
11 criterion, the effect of large nuclear
12 deployments on the electricity supply
13 system.

14 If new reactors have excess
15 capacity at night, will that be used to
16 recharge legions of electric cars, or result
17 in taking cleaner, less costly wind
18 generation offline? Rather than debating the
19 future evolution of the fuel cycle in
20 isolation, we should be discussing it in
21 terms of alternative grid paradigms.

22 And then planned--and then in

1 terms of concrete plans for transforming the
2 energy sector into an environmentally
3 sustainable configuration. What we're trying
4 to optimize is the overall grid, it's not to
5 maximize the deployment of nuclear power,
6 although some in the community might want to
7 be doing that.

8 The social objective is a
9 sustainable energy grid, and how to make
10 nuclear relevant and sustainable within that
11 context. The Department of Energy needs an
12 indicative National energy plan that's
13 comprised of sustainable, Regional plans,
14 and within those plans, some of our regional
15 grids may escape coal and nuclear
16 altogether.

17 I think the prospect of the
18 western United States escaping both coal and
19 nuclear dependence is quite bright. Other
20 parts of the country may decide to sustain
21 both or one of those technologies.

22 But in all cases, application of

1 the criteria I've been suggesting suggests
2 that it's the LWR cycle that we're talking
3 about, and possibly innovative extensions of
4 it, such as small modular reactors or
5 thorium substitution in the existing fuel
6 elements. And that should be the primary
7 focus going forward.

8 CHAIR PETERSON: Thank you. The
9 final speaker for this panel session is Dr.
10 Mujid Kazimi from MIT. Mujid?

11 DR. KAZIMI: I also suffer from
12 jet lag, arriving less than thirty six hours
13 ago from Abu Dhabi, where a new city that is
14 deriving its energy from solar is being
15 built, as well as a plan to house, to, six
16 reactors are being made simultaneously.

17 I think the world has realized
18 that we need all sources of energy, and the
19 continuous building of criteria to, or,
20 shall we say, shifting criteria to one angle
21 or the other, is not really going to lead to
22 the most optimum approach in securing the

1 energy we need in the future.

2 Particularly when it comes to
3 clean energy, nuclear gives us a vast source
4 of energy, as well as wind and solar, and
5 each has its strong points and its weak
6 points. But, let me, let me respond to what
7 I just heard from Andrew, relative to the
8 question of, you know, which one, which
9 approach will demand more of the grid.

10 If you wish to go to 80%
11 reliance, let's say, on renewables, it is
12 clear to me that we can't even implement
13 this, even if we wish to, today, because we
14 don't have the investment and, and the
15 storage technology that will tell us what we
16 can do in order to benefit from the
17 intermittent sources of solar and wind in a
18 really comprehensive way.

19 Until we solve the storage
20 problem, the renewables will have a role,
21 but it will have to be a complimentary role
22 to other sources on the grid. Let me start

1 with my presentation. There are many
2 interesting discussions perhaps that will
3 occur afterwards.

4 Can I have the first slide,
5 please? Maybe I have it here, okay. More or
6 less, you've heard this from other speakers
7 already. We have to look at economics, we
8 need to look at the overall environmental
9 impact. We need to look at the maximization
10 of resource utilization, and finally, we
11 need to be concerned about the implications
12 for non-proliferation.

13 So, in looking at fuel cycles for
14 the future, to me, these are the major
15 criteria that we should note. If you look
16 outside the nuclear, than you can add few
17 other factors to them. But, with, with this
18 in mind--next slide--we have, let's see,
19 okay.

20 Today, we have an economic system
21 based on Light Water Reactors and the once-
22 through cycle, which has proven itself. It's

1 a predominant choice all over the world for
2 a nuclear power option, mostly because it
3 proved to be an economic option and a
4 reliable option.

5 The fact that we can provide more
6 than 90% capacity factor in the U.S. is
7 because the choice of the utilities to
8 exercise their lowest option for producing
9 electricity, and this is another thing that
10 we can note, that once the investment in the
11 plants have been recovered, the operation of
12 nuclear power plants are among the least
13 costly options in, in the energy sector.

14 So, we do have a fairly large
15 technology base for Light Water Reactors, it
16 shares that technology with other plants as
17 well, and therefore it is something that is,
18 that will benefit the future fuel cycle if
19 it is to be based on Light Water Reactors.

20 Now, we could say that, at some
21 point in the future, we're going to need to
22 look into alternatives that make better use

1 of uranium internal energy or potential
2 energy. And, I think I'm going to come back
3 to that one once we describe, you know, why
4 did we think we need to go outside that
5 technology for a choice of our fast
6 reactors.

7 But, let me, let me say before I
8 got to that, is I don't think we have
9 reached the optimum prize or optimum
10 economic positioning of Light Water
11 Reactors. There are many ways by which we
12 can further reduce the cost of Light Water
13 Reactors. I listed some of them here.

14 Standardization, we know, Korea
15 and France have applied them, they have
16 realized the benefit of that. Power uprates,
17 you know, if we can extract 20% more energy
18 from the same volume as France, and this
19 requires some design innovations and
20 improvements and monitoring and so forth.

21 Construction techniques, you
22 know, in Japan, they build their plants in

1 48 months. Here, we haven't done it yet, but
2 at least there are demonstrated fact that
3 you can build a very large Light Water
4 Reactor, the ABWR was built in approximately
5 48 months with prior planning.

6 So, the, what we have done in
7 terms of streamlining the licensing process
8 and in terms of trying to get the
9 construction techniques also embedded here,
10 so that we can, perhaps use prepoured
11 concrete and so forth for the containment,
12 that's going to lead to a reduction of costs
13 as well.

14 The elimination of the premium on
15 the financing of power plants is another
16 important difference between, you know, in
17 order for us to achieve more economic
18 nuclear power. And hopefully, this is going
19 to be happening with the demonstration of
20 the first few plants coming online in the
21 next few years. Next.

22 Now, if we look at the fuel cycle

1 to try to differentiate between them, we
2 have to realize that there are some
3 similarities as well as some differences.
4 And, to choose the path forward is somewhat
5 dependent on what is the expected growth
6 rate.

7 If our growth rate is going to be
8 relatively low, I think sticking with the
9 Light Water Reactor and not worrying too
10 much about introducing recycling and recycle
11 is the best plan for forward marching.

12 On the other hand, if our needs
13 imply that we're going to use nuclear energy
14 in a sizable way, expanded from its 20% or
15 so today to about 40% or so in the future,
16 that might require at some point in the
17 future looking into recycling in order to
18 increase utilization of the uranium energy.

19 And, luckily, we don't have to do
20 that this decade, we have time to do it,
21 because of, from all, what we have heard
22 already, uranium is available to satisfy the

1 demand for decades before we have to worry
2 about the uranium recycling.

3 Now, from the back end point of
4 view, all fuel cycles produce approximately
5 the same amount of fissile energy per Unit,
6 energy per, derived. And therefore, for the
7 first 200 years, the care of the spent fuel,
8 if you wish, is going to be somewhat
9 similar, because of the amount of decay
10 heat, the amount of high level radioactivity
11 is going to be roughly similar.

12 It's only after the first two
13 centuries that differences will start to
14 appear that will make a difference in the
15 system.

16 And, finally, I want to say it's
17 going to take quite while to get to a new
18 system for nuclear energy, moving nuclear
19 energy from what we know today to a nuclear
20 energy system that is based on a different
21 technology, recycling reactors or high
22 temperature reactors, whatever it's going to

1 take, a long, long time, because the
2 penetration rate is dependent on the demand
3 rate, as well as what feed to we give to
4 that fuel, to, what fuel do we give into the
5 reactor.

6 And if we look at a couple of
7 characteristics--next slide--you find that
8 it takes quite a bit of time to just prepare
9 the fuel needed if we're going to start the
10 new technology on the basis of extracted
11 plutonium from Light Water Reactors. It
12 takes Light Water Reactor to operate for
13 almost thirty years to produce enough
14 plutonium to constitute one core in a fast
15 reactor.

16 So, it takes a long time to, to
17 get there if we're going to depend on
18 plutonium to supply that fuel. And we have
19 to look for alternatives to make this
20 penetration somewhat more fast if we need it
21 in the future. Next slide.

22 So, as you know, we have been

1 looking at fuel cycles in a dynamic way at
2 MIT, and we released some of the results
3 recently. We looked in particular at the
4 impact of limited recycle, in a, at a, MOX
5 like, and then recycle in fast reactors with
6 three different conversion ratios, .75, 1,
7 and 1.23.

8 And the results are--can you see?

9 Next slide, please. Yes. That, because of
10 this dependence on the fuel derived from the
11 reprocessing of Light Water Reactors, you
12 will find that the Light Water Reactor is
13 always a sizeable part of the total capacity
14 in the system.

15 Even if we introduce fast
16 reactors, let's say by 2040 or so, there is--
17 -I don't have it, but you can see in the
18 bottom two lines, these are conversion ratio
19 1 and 1.23 fast reactors. They, they allow
20 us to move faster into the new technology,
21 but we still depend more on, at the end of
22 the century, more than half of the energy is

1 derived from Light Water Reactors. Next
2 slide.

3 In terms of the demand for
4 uranium, there certainly will be a reduction
5 in the demand for uranium if we recycle. But
6 it's not going to come very quickly, and it
7 will be limited if we only have, let's say,
8 a dependence on recycling in thermal
9 reactors the way we do it now.

10 If we go to a fast reactor, it
11 would be better, as you can see, but
12 frankly, going to a conversion ratio of 1 is
13 all that it takes to fully utilize the
14 energy in uranium, and to enable a new era
15 of recycling in reactors to occur.

16 And, going to a higher breeding
17 ratio will have implications for us. It will
18 restrict the technologies that we can use,
19 it will demand more fuel to be supplied,
20 because to breed in those reactors or to
21 have a higher conversion ratio requires that
22 you fuel them also with larger amounts of

1 energy.

2 So, on balance, reaching the
3 critical, the conversion ratio of 1 is
4 potentiality better for us in the long term.
5 Next slide. This shows, basically, the same
6 picture, whether you're looking at 2.5% or
7 even a more aggressive 4% growth, where you
8 think that the breeding will be needed in a
9 bigger way.

10 But it's about the same effect,
11 this shows the 1.0 conversion ratio. Next
12 slide. The other thing that sometimes people
13 discuss is that recycling is a way to
14 consume the transuranics that are produced
15 in Light Water Reactors. And while it is
16 true that we recycle we consume
17 transuranics, but we also need much more
18 transuranics to be stored in the reactors
19 after we use for recycling.

20 So, on, when you add all the
21 transuranics in the system, you end up
22 having less of a reduction than one might

1 thought in the overall system, and that
2 shows the variation of all these scenarios
3 in terms of transuranics. Where it will be
4 different is where the location of that
5 amount of transuranics--next slide.

6 You see that the amount of
7 transuranics in reactors, that's a, a fast
8 reactors will be the red, the black is the
9 Light Water Reactors, and then in the
10 storage and fabrication, that's a green and
11 the blue, with, that's where the
12 transuranics would be.

13 And, it is still a growing system
14 in terms of total transuranics. Next slide.
15 The amount of transuranics that goes to the
16 repository will be distinctly different.
17 There will be quite a bit of reduction in
18 the amount of transuranics that goes to the
19 repository and therefore if one is to look
20 at a payoff for the investments in
21 recycling, it will be for a while in that
22 area as opposed to in the area of reduction

1 of the total transuranics in the system.

2 With that, let me conclude by
3 saying, I think--one more slide--in our
4 looking at the fuel cycle in the future, we
5 have to try to amplify the performance of
6 Light Water Reactor to benefit the fuel
7 cycle. We have to take the time that we have
8 before we, our energy demand becomes much
9 higher and try to perfect the technologies
10 that we'll deploy for recycling.

11 And, this way, we, we can look at
12 the future that might be brighter. In
13 particular, because nuclear energy costs are
14 mostly in reactors, depending on a more
15 expensive reactor for recycling technology
16 will be an unoptimum way of moving into new
17 reactors.

18 Yes, recycling is going to be a
19 costly endeavor, but it's relatively a small
20 portion of the total system cost. The total
21 system cost depends much more on the reactor
22 cost and we have to look for ways to reduce

1 the reactor costs and the cycles for the
2 future. Thank you.

3 CHAIR PETERSON: Thank you. We now
4 have time for questions. Why don't I start
5 at the end and work towards me. Yes?

6 MEMBER MESERVE: I have just a few
7 questions. Dr. Sowder, you made the case
8 that non-proliferation should not be a
9 differentiator among these various fuel
10 cycles, and I know from looking ahead that
11 many of our presenters this afternoon are
12 going to talk about the disadvantages in
13 proliferation risks associated with
14 separated plutonium. And, I'm puzzled at
15 your assertion, given that perspective.

16 DR. SOWDER: Yes. And I did not
17 mean to say that non-proliferation was not
18 an important concern. But in terms of a,
19 seeking a technological solution, I think
20 the concern is that, given that the security
21 situation and non-proliferation concerns
22 tend to evolve over time.

1 And you also are looking ahead in
2 terms of advances in technologies, that if
3 you use, if you use the technology as a
4 primary driver for your, addressing your
5 non-proliferation concerns, you may find
6 further down the road that the issues have
7 become decoupled almost entirely from the
8 fuel cycle.

9 For instance, you could have, you
10 could have technologies that allow folks to
11 enrich uranium that is just not related to
12 the fuel cycle, for example. So, pinning
13 all, pinning a lot of, putting a lot of your
14 confident or interest into the technology
15 itself to solve the problem, you could end
16 up solving the, using the wrong tool.

17 For instance, using a, using a
18 sledgehammer when a tack hammer will do.
19 That's not to say that, you know, non-
20 proliferation is, could not be considered
21 once you get your fuel cycle in place. But
22 again, you have both extrinsic and intrinsic

1 measures that you can apply.

2 For instance, no matter what fuel
3 cycle you choose, you're going to require
4 safeguards and security. I'll just use
5 another example, is the issue of separating
6 plutonium. Let's say you extract or separate
7 uranium with plutonium. You're still one
8 step away from separating plutonium.

9 And I'm not going to make too
10 many comments about the, the challenges
11 involving separating uranium from plutonium,
12 but basic radiochemistry shows that it's a
13 fairly straightforward process.

14 So, again, I, I did not mean to
15 say that non-proliferation wasn't a concern,
16 but in terms of differentiating on a
17 technology basis, it may not be as useful.
18 That's, that's what I was trying to posit.

19 MEMBER MESERVE: I guess I agree
20 that, obviously, there are dimensions to the
21 non-proliferation issue that extend way
22 beyond technology and they're very

1 important, maybe more important than the
2 technology issues.

3 I think that the discussion has
4 been very much on recycling or not. And, the
5 dangers of recycling having non-
6 proliferation dimensions that are not
7 associated with the once-through fuel cycle.
8 And that, and that, that, and your talk
9 suggested that was not a factor, or not,
10 should not be a significant differentiator.

11 I take your point that, we all
12 agree that proliferation is important. I'm
13 pushing you on the point that, that one
14 can't distinguish between fuel cycles on
15 that basis.

16 DR. SOWDER: And, you, you can,
17 and certainly that could be the path you
18 choose to select your technology. But in
19 terms of looking, when we're talking about
20 the time frames involved, fifty to 100 years
21 down the road, if it becomes a primary
22 differentiator, I guess the concern is that

1 you may not have really solved anything when
2 you, when you actually get to the point
3 where you deploy the technology, that you,
4 you focus on the wrong issue when in fact
5 the primary matter is, is more the extrinsic
6 measures such as safeguards, international
7 regimes, et cetera.

8 And, again, if we're talking
9 about the U.S. situation, I, I think it
10 comes down to--well, I'll, I'll just leave
11 it at that. Thank you.

12 MEMBER MESERVE: Dr. Kazimi, I,
13 your presentation, of course, was consistent
14 with the MIT report that you've issues and
15 your discussion was consistent obviously
16 with that. I'm familiar with it.

17 I, I'd be interested in knowing
18 whether there has been any controversy or
19 criticism of your conclusions that have come
20 out for the ones you've described today,
21 including, since you've issued the report.
22 And, what has proven to be controversial,

1 what, what seems to be contested by others?

2 DR. KAZIMI: Let me summarize what
3 I remember, basically. Two, two types of
4 criticism seem to come more than, in one
5 source. One is, people worry that the
6 recommendation for taking our time to
7 develop a path forward and relying more on
8 storing this spent fuel now without trying
9 to dispose of it or recycle it, is simply
10 delaying an action item that would be useful
11 for the country to move into in order to
12 build experience with technologies that are
13 needed, whether its disposal or recycling.

14 So, that's one type of the
15 criticism, are we simply delaying the
16 action. And, by and large, our reaction is
17 that, you know, if the delay buys us
18 improvements in understanding the choices
19 and therefore making better choices for the
20 future.

21 And if the delay does not imply
22 that the future generations are being

1 deprived of any option that suits the
2 technologies they would be having at the
3 time, then, there is really no harm in, in
4 the delay.

5 The other type of criticism came
6 from those, a little bit more, you know, on
7 the technology costs and its implications
8 for recycling, you know, there are certain
9 countries, that say, industrial outfits,
10 that are more confident about containing the
11 costs and the consequences of recycling than
12 others, as, as you can imagine.

13 MEMBER MESERVE: I was more
14 interested in your system modeling and the
15 number of reactors that were needed and the
16 flows back and forth, that dimension of it
17 has not been challenged?

18 DR. KAZIMI: No. I, I haven't
19 heard any criticism from the system
20 description point of view.

21 MEMBER MESERVE: I--you also made
22 the point that you believe with existing, or

1 at least conventional, Light Water Reactors,
2 that 20% power uprates are feasible.

3 Obviously we're doing a lot of that now, but
4 you pointed at, in particular, the new fuels
5 and new fluids, nanoparticle fluids.

6 And I presume the fuels you may
7 be talking about, they're annular fuels. I'm
8 quite curious about the time line in which
9 you think that those, that capacity might be
10 available, and the level of certainty that
11 those are going to be acceptable from a
12 safety perspective.

13 DR. KAZIMI: The new fuels
14 certainly could be in the form of annular
15 fuel, but there are other ideas that could
16 be implemented. With the basic premise being
17 increasing surface to volume ratio of the
18 fuel, and water, as a coolant, that gets you
19 a long way towards more power extraction if
20 you let it run.

21 But, we can also go into more
22 compact conditions. For example, Hitachi is

1 known to have developed a system that has a
2 much higher power density than typical
3 boiling water reactors. They developed it
4 more with a purpose of going to a hot
5 spectrum so that they will improve the
6 conversion ratio.

7 But I don't see why the same
8 principles can't be applied for regular BWR.
9 So, it's a type of lattice, and it almost
10 has two and a half times the power density
11 that BWRs have today. If, you know, you can
12 prove all the safety features will work
13 right.

14 So, I would say that there are
15 ideas on the table. Development takes
16 testing, that's a matter of time. On the
17 order of fifteen years would be the minimum
18 to get the testing needed to be comfortable.
19 And as far as the nanotechnology is
20 concerned, I think that could be a little
21 bit less than that.

22 There are two aspects there. One

1 is the thermal hydraulic characteristics,
2 another one is the material implications.
3 And I know that some of the industrial
4 outfits are looking at both, but I don't
5 know whether they put the time line for
6 application.

7 MEMBER MESERVE: Good. Thank you.

8 MEMBER CARNESALE: Thank you. Dr.
9 Sowder, I'd like to return to the same
10 thing, because I too found it rather
11 remarkable, especially given that in
12 previous sessions we were told that the,
13 that the National Waste Technological Review
14 Board uses stockpiles of plutonium as the
15 surrogate for the proliferation risk.

16 So, it, it focuses largely on
17 that aspect of the fuel cycle. Tell me how
18 it could be better, from a proliferation
19 point of view, to have separated out the
20 plutonium rather than not having done so.

21 DR. SOWDER: I wouldn't
22 characterize it in that simple fashion, but,

1 the point I was making was, in terms of
2 distinguishing between your fuel cycles--
3 well, let me go to the other extreme.

4 If you are to use non-
5 proliferation as your primary--and this was,
6 the purpose here was actually ranking, to
7 answer the question, and not to remove it
8 completely from the table, but, in terms of
9 ranking your technologies, one, one, one
10 thing that can happen is if you make your
11 fuel cycles so complicated, again, looking
12 at someone being able to operate it, deploy
13 it, reliably, not incur enormous workers
14 doses, et cetera.

15 You run the risk of actually
16 making your technology practically unusable.
17 So, the idea here isn't that non-
18 proliferation isn't important, but in terms
19 of, I think, as a primary driver, it's not
20 as useful in terms of selecting your
21 technology.

22 That, if, if your primary driver,

1 and, again, that was the premise of my
2 presentation, was the primary driver is
3 simplicity, cost effectiveness, et cetera.
4 Never, I don't, did not mean to ever imply
5 that non-proliferation should ever not be a
6 consideration, but that the primary drivers
7 there are the extrinsic factors.

8 You always will need security,
9 you will always need your safeguard regimes
10 in place, they'll need to be effective. And
11 the concern is to not believe that your
12 technology, whatever it is, whether,
13 bringing neptunium in, or carrying
14 everything through the cycle is going to
15 somehow magically alleviate concerns.

16 So, again, in terms of answering
17 the question that was posed, my attempt was
18 to rank them in terms of giving you some
19 practical approaches, and maybe, perhaps,
20 at, at minimum, it is least, allow you to
21 look at, at things from a different
22 perspective.

1 But again, this was, from a
2 viewpoint of actually using technology as
3 your primary non-proliferation tool. And
4 again, I would posit that it's actually,
5 it's your extrinsic measures. And again, the
6 two work together.

7 But you'll never have a fuel
8 cycle where it's, where you can walk away
9 from it, you don't need some measure of
10 material accounting and control, et cetera.
11 So, again, I did not mean to diminish the
12 importance of non-proliferation but in terms
13 of the ranking, I, I, I meant to--

14 MEMBER CARNESALE: Well, then, it
15 may just simply be a distraction from your
16 presentation, because the simplest cycle,
17 the most economical--

18 DR. SOWDER: Right.

19 MEMBER CARNESALE: --right now,
20 is the once-through--

21 DR. SOWDER: Sure.

22 MEMBER CARNESALE: --in which you

1 don't separate plutonium. So, it may be that
2 they all go in the same direction right now,
3 so it simply distracts from your
4 presentation. Dr. Kazimi, 2.1 is just a
5 point, and that is, it's just something
6 that's always concerned me somewhat, is the
7 notion of standardization, to reduce cost.

8 I mean, Toyota standardized on
9 the braking system. And one of the great
10 dangers of standardization is if you
11 standardize on the wrong design, and in five
12 to ten billion dollar a piece facilities,
13 that could be--I understand the other side
14 of the argument.

15 Standardization has it's own
16 risks, as well as rewards. I did want to ask
17 you a little bit about the, the figures you
18 show about how much TRU waste would have to
19 go to the repository at different stages.

20 That's true, but it strikes me as
21 a little bit, could be misinterpreted quite
22 easily. The problem of the TRU waste, if

1 instead of being in a reactors, you could
2 just store it.

3 And so, the, therefore the
4 requirements for the repository, since it's
5 going to be the same in the end anyway,
6 could look the same at any stage, instead of
7 insisting to have the repository available
8 for the TRU waste that's not in reactors
9 immediately. Is that, is that a reasonable
10 interpretation?

11 DR. KAZIMI: Yes, I'm not so sure
12 I put any time line on when this is have to
13 be going to the repository--

14 MEMBER CARNESALE: But don't the
15 same amount--

16 DR. KAZIMI: I, what I--

17 CHAIR PETERSON: --eventually have
18 to go to the repository?

19 DR. KAZIMI: No, no. Certainly
20 not. With recycling, multi recycling, there
21 is potential for reducing by orders of
22 magnitude, at least one or maybe two. No,

1 the issue of when to, when do you need it to
2 go to the repository.

3 Because, this is a, an activity
4 that's going to be around for a long time,
5 taking a few decades to decide how to do it,
6 I don't think, is going to have a big impact
7 on the overall consequences of the system.

8 And, basically we do have a,
9 proper technology for storage of spent fuel
10 including the TRU, so we can handle it that
11 way.

12 MEMBER MACFARLANE: Thanks. Okay.
13 Do you want to jump in?

14 DR. SCHNEIDER: If I may, just to
15 add to Dr. Kazimi's point. I think what your
16 figures showed, with a substantial inventory
17 of transuranics still in the reactor at the
18 end of the century, would indicate that
19 something that needs to be borne in mind, I
20 believe, is that if that recycle strategy is
21 committed to, right, to achieve the order of
22 magnitude or two orders of magnitude

1 burndown.

2 Right, it's not just the century
3 long enterprise, right, it's a multi century
4 long enterprise.

5 MEMBER MACFARLANE: Right. Yes.

6 DR. SCHNEIDER: Because one has to
7 continue recycling and feeding the material
8 back into the reactor, getting maybe a 10-
9 or-20% burn each time.

10 MEMBER MACFARLANE: Many
11 centuries. Okay. Let me first make a
12 comment, and then I have a couple questions.
13 And my comment comes from my expertise as
14 being a geologist, and it's about uranium
15 availability and uranium resources.

16 And, we've been having a lot of
17 discussion about that, with no geologic
18 basis in reality yet. I just want to point
19 out that there's been very little geologic
20 investigation into uranium resources for
21 over twenty-five years, okay? We haven't
22 looked for this stuff for over twenty-five

1 years.

2 So, and, and I know, because I've
3 looked into it a little bit myself, I
4 haven't looked for it, but I have looked
5 into the literature, uranium is distributed-
6 -and I've done a little bit of my own
7 research, a long time ago, on this, but.

8 Uranium is distributed very
9 widely in a variety of different geologies,
10 in a variety of different aged rocks, and in
11 a variety of different rocks in different
12 settings all over the planet, even in the
13 ocean water. So there's a lot of it out
14 there.

15 And, I think when we really start
16 putting money into looking for it, we'll
17 find that there's a lot more than we
18 understand there to be now. And so, all of
19 the analyses that we've been presented so
20 far have been based on Red Book numbers, for
21 the most part.

22 Red Book numbers have a political

1 aspect to them, because countries don't
2 always like to disclose all that they think
3 they have. And we need to keep that in mind,
4 as well.

5 So, I guess, I, this is sort of
6 just a, a general plea to maybe hear from an
7 economic geologist on this topic at some
8 point in time. Because it is an important
9 aspect to whether, whether, you know, a
10 number of you have made the point that one
11 of the, and the previous panel, and other
12 panels that, that one of the advantages to
13 recycling or closed cycle is the uranium
14 resource one.

15 And I think we, that's still an
16 open question. So, and let me ask a couple
17 questions, or. And then one is to, is to Dr.
18 Sowder. You showed, and this is, okay, so I
19 may know a little bit about uranium
20 resources but I don't know anything about
21 economics, I don't like money. So help me
22 here.

1 You had, you showed this economic
2 competitiveness plot, and it seems to me
3 that there are many assumptions in this. And
4 what I want to understand is whether you've
5 included in your analyses, clearly you
6 haven't included capital costs for reactors,
7 but have you included the costs for the
8 repositories for the high level waste?

9 For dealing with the other waste
10 streams? Have you included the storage costs
11 for plutonium? Have you included the
12 additional transportation costs to come up
13 with the two analyses? Because they seem
14 pretty optimistic, maybe, is one way of
15 putting it. So, that's my first question.

16 DR. SOWDER: Thank you. And,
17 again, I, there could probably be several
18 pages of assumptions --

19 MEMBER MACFARLANE: Yes.

20 DR. SOWDER: I certainly would be
21 happy to follow up with those reports. These
22 were fuel cycle costs only, but they do

1 incorporate both front end and back end fuel
2 cycle costs.

3 This was, the OECD/NEA's model
4 was utilized, so it does attempt to include
5 everything from front end uranium mining,
6 milling, processing, and then once you get
7 out of the reactor, the back end as well--
8 waste management, including disposal.

9 MEMBER MACFARLANE: That means a
10 repository?

11 DR. SOWDER: Yes.

12 MEMBER MACFARLANE: Okay.

13 DR. SOWDER: So --

14 MEMBER MACFARLANE: But -- you
15 know, I think some of these other analyses
16 that I've seen often don't include things
17 like storage costs for plutonium and the
18 additional security involved, and
19 transportation costs and things like that,
20 so.

21 DR. SOWDER: One of the key things
22 here is that once you factor in the costs,

1 the capital costs of the reactor, though,
2 given that it's the big, the 800-lb gorilla
3 in the room, we have done the parametric
4 sensitivity analysis on what if your
5 repository is ten times more expensive than
6 you initially thought it was going to be.

7 Waste management is still a very
8 small component of your overall electricity
9 costs.

10 MEMBER MACFARLANE: Right. You
11 know, I understand that.

12 DR. SOWDER: So --

13 MEMBER MACFARLANE: I just, you
14 know, okay --

15 DR. SOWDER: But, the model,
16 again, and it's the model --

17 MEMBER MACFARLANE: So, I
18 understand the results here.

19 DR. SOWDER: -- all, you know, all
20 models are wrong, some are useful. The point
21 of this model was to tease out the basic
22 argument when, possibly, plutonium recycle,

1 for example, could be economically feasible.
2 That doesn't mean it is, but this, based on
3 solely, fuel cycle costs alone, was what we
4 are using this for.

5 And it -- basically what it's
6 showing you is, based on your uranium costs,
7 those fuel cycles that maximize resource
8 utilization do better. But, that's, that
9 does, that's just based on whether or not
10 your uranium costs are --

11 MEMBER MACFARLANE: Right.

12 DR. SOWDER: -- your concern.

13 MEMBER MACFARLANE: Right, and if
14 you have plenty of uranium, its probably a
15 moot point.

16 DR. SOWDER: Right.

17 MEMBER MACFARLANE: Okay. Second
18 question is for Mujid. Nice to see you. And
19 it's another economics question. So, early
20 on, you claimed that, you know, that the
21 economics for nuclear will improve and are
22 improving.

1 But, I'm thinking about the
2 recent Constellation Calvert Cliffs
3 decision, which seems to go in the opposite
4 direction. And then, in terms of the
5 standardization issue, which Al also brought
6 up, it seems to me that standardization
7 really hasn't helped France, at all, vis-a-
8 vis Korea.

9 Because the French deal to the
10 UAE was fifteen billion dollars,
11 approximately, more than the Korean deal.
12 And so, standardization didn't really help
13 them. Maybe there's not much to say, but.

14 DR. KAZIMI: You know,
15 standardization is not going to replace the
16 cost, the design, or the cost of the labor
17 assumed, engineering costs, and so forth.
18 So, standardization has, and it certainly
19 helped France because that's how they built
20 their fifty reactors.

21 They standardized, essentially,
22 on two designs. And each twenty or so

1 reactors are built with one identical
2 design.

3 MEMBER MACFARLANE: I think that's
4 a good plan in general, definitely.

5 DR. KAZIMI: Yes. So, but it's not
6 to say that you can gold plate a reactor and
7 then try to compete with a silver-plated
8 one. So, you have to have a design that is
9 adequate --

10 MEMBER MACFARLANE: Fair enough.

11 DR. KAZIMI: -- that provides a
12 safety, and. The UAE deal, sort of, is an
13 interesting one because the Koreans are
14 offering a reactor that they haven't built
15 yet. It's a new design, but they think that
16 -- but this is their choice for their new
17 build, and they are counting on at least ten
18 of these reactors of the same size.

19 So, certainly, and in answer or
20 response to an earlier comment, you know, we
21 should never plan to standardize forever. I
22 mean, technology changes. We learn from

1 operation.

2 Therefore, standardization would
3 work for a number of reactors, let's say ten
4 to twenty. But, we should make use of
5 improvements that we learn about in our
6 other reactors.

7 CHAIR PETERSON: Okay. I have
8 three questions I'd like to pose to
9 panelists. The first is for Andrew Sowder.
10 Going back to the same economic
11 competitiveness graph that Allison was
12 referring to, and with the big caveat on it
13 that the reactor cost is left out.

14 Would it be fair to say that in
15 fact those costs associated with the fuel
16 are second order drivers for the economics?
17 This would be an important point, that the
18 major element of economic decision making
19 with reactors is the capital cost and the
20 reliability of operation once built.

21 If that's the first order driver,
22 would this then have some connection to the

1 discussion of what the future is likely to
2 hold, which is more Light Water Reactors for
3 the foreseeable future?

4 DR. SOWDER: I think the answer is
5 -- it kind of depends on probably the time
6 frame you're speaking of, but certainly
7 reactor costs, including construction and
8 operating them, maintaining them, is about
9 80-to-90% of the nuclear electricity costs.

10 So, the remainder are these other
11 things, including the fuel cycle costs. So,
12 from the front end, yes, the fuel cycle
13 costs -- that's one, actually, one benefit
14 of the nuclear energy, is, really fuel costs
15 are a small fraction compared to the
16 volatility you see in natural gas.

17 But as the costs of those
18 reactors are largely amortized, as you pay
19 them off, the fuel cycle costs do suddenly
20 become larger and larger components. So, you
21 know, I think it depends on where you are
22 moving down the road in terms of fifty years

1 form now, once you've paid off your
2 reactors, and suddenly the world growth rate
3 scenario changes, et cetera.

4 You know, that's when you start
5 worrying about your uranium supply. If
6 indeed there -- the other thing that happens
7 with uranium is that as it gets more
8 expensive, people start looking for it, and
9 certainly got a lot in the oceans, and if
10 you can recover it from the oceans, for
11 example, then you don't have a problem.

12 Right, and I totally, would
13 totally agree with that, even though it's
14 often a matter of cost.

15 CHAIR PETERSON: Next question is
16 for Mujid. And, I want to challenge on one
17 of the statements that, that you had made,
18 which was that the fission product burden is
19 not affected by the fuel cycle, certainly,
20 but, I'd like to put in a plug for MIT's
21 work on supercritical CO2 power conversion
22 systems.

1 It's an interesting point that,
2 looking at those various different curves,
3 you could get as large or possibly even
4 larger effects on spent fuel inventories and
5 other things simply by transitioning from
6 ranking cycle to supercritical CO2.

7 So, is that an area of leverage
8 that may be just as important as the fuel
9 cycle area?

10 DR. KAZIMI: Yes. I am glad you
11 mentioned this, Per. Certainly, the CO2
12 cycle will give us a much higher efficiency
13 in converting thermal energy to electrical
14 energy, and that in turn will reduce the
15 amount of waste, including fission products,
16 that are needed for production of a certain
17 amount of electricity.

18 But that also goes for other
19 improvements. As you know in the Gen 4
20 exercise of reactors, supercritical water
21 was also proposed as a way to get to a
22 higher efficiency. If that was to be

1 achieved, then we would get that benefit of
2 reduction of fission products per unit
3 electricity produced.

4 And, very recently, we just
5 finished a study of achieving superheat
6 within a light water, BWR type reactor,
7 which looked feasible from this conceptual
8 stage point of view, but of course, it would
9 take a while to develop.

10 Of these three items, I would say
11 the supercritical CO2 one is one that
12 depends on the availability of reactors that
13 can reach that temperature. Water, we're a
14 little bit more accustomed to and perhaps we
15 can manage to change it, to either superheat
16 or supercritical.

17 But certainly if reactors can
18 achieve the appropriate temperature, which
19 is probably on the order of 600 or 650
20 degrees C, then the CO2 cycle would be very
21 attractive.

22 CHAIR PETERSON: All right. Thank

1 you. The final question I have will be for
2 Christopher Paine, and it relates to this
3 list of things that we do need to consider
4 in terms of comparing different energy
5 options.

6 There's two dimensions to the
7 question. One is sort of the crystal ball of
8 what's going to happen with the costs of
9 these different technologies.

10 And there I'd like to push back a
11 little bit on some of the projections about
12 potential increases in Light Water Reactor
13 costs from the, sort of the first of a kind
14 costs that we're seeing today, for the first
15 few that are being built by noting that the
16 experience in Japan, Korea, and in China has
17 been that replication brings down costs,
18 substantially, over time.

19 And so, if you look at the
20 overnight costs today maybe for an AP1000,
21 might be around \$4,000, \$4,000-4,500 is what
22 Westinghouse might charge. Very reasonable,

1 one might expect that you could see those
2 prices coming down by similar percentages,
3 possibly, or not, depending on the
4 experience, which would affect the mix.

5 The other dimension of this is
6 how to try to internalize this large list of
7 additional externalities, with, I think, you
8 know, Eric would probably agree, the
9 security related dimensions are really tough
10 to do, but when we get to public health and
11 environmental impacts, NRDC has essentially
12 done analysis that shows that, for example,
13 particulate air pollution from fossil and
14 biomass combustion is causing somewhere on
15 the order of perhaps around 63,000 premature
16 deaths per year in the United States alone,
17 which is catastrophic in terms of the
18 magnitude, if you compare it with other
19 things.

20 So, when it comes to this list of
21 other things, you have the mill tailings,
22 the fish kills, the fresh water consumption.

1 If we try to scale that to the power
2 production, does that sort of change the
3 criteria or not, in terms of trying to pick
4 between different technologies?

5 MR. PAINE: Well, with respect to
6 the coal cycle, I think I say in my
7 statement that I believe the nuclear fuel
8 cycle is superior, even with the fish kills
9 and the excessive thermal discharges. The
10 point is that I think that, you know, with
11 more focused attention by the regulators and
12 DOE on the specific problems that nuclear
13 has, the current incarnation or reasonable
14 extensions of the Light Water Reactor cycle
15 with some concerted attempt to focus on
16 those problems, we could make nuclear better
17 and thereby enhance its near term
18 contribution.

19 The problem with DOE is that it
20 has this genetic code built into its
21 laboratory structure that always carries it
22 into the next generation of reactors, or

1 three generations down the road. And we
2 spend billions over time.

3 If you look at the billions of
4 dollars that we've expended on fuel cycle
5 research in this country, to no tangible
6 effect, when we sort of learn that these
7 cycles aren't economic. You know, why
8 doesn't the DOE focus, for example, on a
9 major environment hurdle for nuclear power
10 and it will be a significant environmental
11 hurdle, people are not anticipating how
12 serious it's going to be, which is the
13 thermal discharges.

14 You know, let's build an LWR
15 that's scaled appropriately so that each
16 unit can be air cooled. That will also, you
17 know, that should facilitate deployment of
18 nuclear power in certain instances, and it
19 should improve the economics.

20 CHAIR PETERSON: That's certainly
21 a good plug for supercritical CO2. Eric, or
22 Everett? Any thoughts on this question?

1 DR. SCHNEIDER: I had, I guess
2 maybe a followup on the uranium issue that,
3 that Allison raised. An update for the
4 Commission. Actually, later today I'm
5 hopping a train to go to Boston for a
6 workshop on uranium resources that'll
7 actually have substantial participation from
8 economic geologists.

9 So, I think there is awareness,
10 maybe the Commission would like to hear from
11 this uranium resources task area within DOE
12 that's formed up. Also, the USGS is starting
13 a five year reassessment of uranium supply
14 in the United States, that's just spinning
15 up now.

16 So, I think that a lot of
17 concerns you raised, we haven't looked at it
18 for twenty-five years, are resonating in, in
19 many areas. That having been said, your
20 point is well taken, that there's a great
21 deal of uranium out there.

22 We kid ourselves sometimes that

1 it's an exceptional or exceptionally rare
2 element in the crust that it's not, right,
3 it is not at all. Right, it's rather an
4 average element, in fact, on the list of
5 elemental concentrations in the Earth's
6 crust, it's almost dead in the middle.

7 Right, and, so, I think a key
8 part of the question, which neither remains
9 out there, as we look harder, the Red Book
10 itself states, correct, in the 2007 Red
11 Book, I wish I could remember the exact
12 quote. Right, they are aware that people are
13 misusing the Red Book in the way that you
14 described, as this is the be-all and end-all
15 of what's out there.

16 Right, the 2007 Red Book itself
17 makes very clear, these are snapshot
18 estimates only, right. They're not meant to
19 convey what may be discovered in the future.
20 So, we have to be aware of misusing the Red
21 Book data that way.

22 Right, but I think the flip side

1 of what else will be discovered as we look
2 harder, and certainly there will be a great
3 deal of uranium, is how recoverable will it
4 be? Right, and to take seawater uranium as
5 an example, that's going to be addressed at
6 the workshop as well that's coming up.

7 Right, MIT did good work in the
8 seventies and eighties that showed that an
9 earlier incarnation of seawater uranium
10 extraction using anhydrous titanium oxide
11 didn't meet energy balance requirements.

12 Right, it would take more energy to recover
13 the uranium from the seawater than you could
14 get from a reactor.

15 Right, so I think that this side
16 of the picture is the more poorly understood
17 side. If it's feasible to extract that
18 uranium that is a little less economically
19 desirable right now.

20 CHAIR DOMENICI: Mr. Chairman, is
21 the time up? Have we used all the time?

22 DR. REDMOND: If I may, just for a

1 second. One thing I just want to touch on
2 again is the research. And I would agree
3 with Christopher that research needs to be
4 focused on certain areas, certainly
5 applicable to Light Water Reactors nowadays,
6 but also in terms of long term recycling
7 processes.

8 As I said, if we're doing fast
9 reactors as part of that, that's something
10 that needs to be focused on in the short
11 term, I think, or focus a little bit more
12 research in that area because we need to
13 make sure that they're going to be reliable
14 and can meet the same sort of performance
15 criterias that are currently existing. Thank
16 you.

17 DR. KAZIMI: May I, Mr. Chairman,
18 add to this. Sometimes, we have embedded
19 assumptions and we talk about fast reactors
20 and people have images of sodium-cooled
21 reactors immediately in their heads.

22 Fast reactors goes beyond sodium-

1 cooled reactors. So, we should encourage
2 looking at the broad spectrum of options for
3 hard spectrum or fast reactors, and not
4 assume this is a sodium-cooled reactor.

5 CHAIR DOMENICI: Mr. Chairman,
6 could I have a couple of questions? Thank
7 you very much. First, I want to thank the
8 panel for the way you've presented the facts
9 and the evidence to us. I think it's been
10 very exceptional, and in particular, I want
11 to thank, I think this was a very
12 interesting approach, and thank you for it.

13 When it was finished and I looked
14 at it, I, no offense to anyone, but I said
15 to my co-Chairman, this is the kind of
16 presentation you would expect from somebody
17 who was working in the field, and I think
18 that's correct, and that's what you all do
19 up there at your place, is you help each one
20 of these decide what the facts are all the
21 time, and I assume that's what you're giving
22 us.

1 And I want to say to the
2 professor from MIT, I was very impressed,
3 and thank you for your testimony. I hope
4 you'll give us written remarks --

5 DR. KAZIMI: I will send it in, I
6 haven't yet.

7 CHAIR DOMENICI: I know you didn't
8 have, need them, you're very skilled, but we
9 need them, some of us who are not so
10 skilled, need them. Like me. Let me ask you,
11 Doctor, if you would answer this for us.
12 First, let me talk about uranium
13 reprocessing.

14 Why are the countries in Europe
15 in such a hurry to quote get recycling and
16 reprocessing, and here we're talking about,
17 it may never be needed in America? What's
18 the difference between them and us?

19 DR. KAZIMI: One of the major
20 differences, say, in the case of France, is
21 they already have the facilities that they
22 need to recycle, and they don't have to

1 design it and build it from scratch. And,
2 the other difference may be that they don't
3 rely on uranium that is extracted from
4 within their country.

5 They're on uranium imported from
6 other parts. We have -- we're endowed with
7 uranium that's present, perhaps today it's
8 not economic to extract it, but we can, we
9 can be more assured of the availability of
10 uranium in the future than they do.

11 CHAIR DOMENICI: So you're saying
12 there is a degree of concern about the
13 adequacy of supply or the reliability of
14 supply, and that's why they are on this bent
15 of reprocessing, even though it's difficult
16 and expensive? Is that what you're telling
17 us, that's why?

18 DR. KAZIMI: Yes, I would say
19 that's part of it, yes.

20 CHAIR DOMENICI: What's the other
21 part?

22 DR. KAZIMI: Knowing that they

1 already have the recycling facilities. They
2 invested in the past --

3 CHAIR DOMENICI: It's already
4 done.

5 DR. KAZIMI: It's already done.

6 CHAIR DOMENICI: Okay. Now, let
7 me, let me make an observation here about
8 uranium supply. I don't know if any of you
9 know where America got all of its uranium,
10 to win the war with, but it was New Mexico.
11 They found it out there, and it's a very
12 famous story about it, an Indian man who
13 brought the rock into the store, to the
14 trader, and put it on there, and it was
15 radioactive. That's where the first gigantic
16 field was.

17 It's all closed down now, and it
18 will open up again, I assume, and
19 inventoried, depending upon political
20 leadership whether it will be open or stay
21 closed, it's not -- has nothing to do with
22 the availability of lots of uranium there.

1 I do want to say, Dr. Schneider,
2 I met, met you while you were washing your
3 face, you were certainly intent on waking
4 up, and you did. I saw people wash their
5 face before, but might I tell you, you are
6 really a face washer. No question about it,
7 you look very good, too.

8 I wanted to ask you, Doctor,
9 what, tell us, if you would, how would you
10 articulate the situation that you described
11 to us? You said, so long as we stay at
12 around 20% of the electricity that comes
13 from nuclear, we will get by with Light
14 Water Reactors, and we won't have to worry.

15 But if it got to forty, he said,
16 40%, he would have to have something else,
17 like recycling or reprocessing. Is that not
18 what you told us? Or something like that?
19 Tell me more.

20 DR. KAZIMI: I think if we get to
21 40% we will need the recycling faster than
22 if we stay at 20%.

1 CHAIR DOMENICI: Yes. But if
2 that's the case, how would we decide to be
3 serious about recycling? It looks like we've
4 got nothing to get serious because it's not
5 economic, we have plenty of -- between
6 uranium and what we've got stockpiled
7 already, we have plenty. So, so how are we
8 going to get the impetus to get going with
9 recycling?

10 DR. KAZIMI: You know, my
11 recommendation is, first, we have to
12 reexamine our technology options for
13 reactors, because reactors will make the
14 largest cost contribution. So, to move into
15 recycling requires a reactor that is
16 competitive in the market.

17 And, at the moment, we can't say
18 that about the technology options that have
19 been developed. So, I think one of the
20 things that will be needed will be an
21 investment in examining options for less
22 costly advanced reactors that enable

1 recycling.

2 The second thing is, we have to
3 make also some assessment of what kind of
4 recycling would make sense for us, you know,
5 the last five years, they reinvested in the
6 various fuel cycle programs and there are
7 ideas on the table, which have been
8 experimented with in small quantities but
9 one question is whether you can extrapolate
10 that into the engineering phase.

11 The third thing I would say is,
12 to move into a recycling fast reactor
13 technologies require a much higher fission
14 rate in the fuel and the confidence that we
15 have in the fuel to be deployed in the fast
16 reactors is now -- not at the same level as
17 it is in the Light Water Reactors.

18 We prefer, for example, metal
19 fuel, whereas in France the experience has
20 been always with the oxide fuel. And there
21 is this debate as to which way we should
22 move. So, at least our three enemies, at

1 least, that I think, we can use the time
2 that we now and when we really need it, to
3 try to make a choice in technology.

4 CHAIR DOMENICI: Thank you very
5 much. Thank you, Mr. Chairman.

6 CHAIR PETERSON: Thank you. I
7 would like at this point to thank all of our
8 panelists for their excellent presentations
9 and insightful answers to questions. At this
10 point, it is time for us to draw this
11 session to a close.

12 We will take a lunch break. We
13 will reconvene at 1:15 p.m. sharp for the
14 next session, which will be on the topic of
15 limiting future proliferation and security
16 risks. Thank you everyone.

17 (Whereupon, the above-entitled
18 matter went off the record at 12:19 p.m. and
19 resumed at 1:17 p.m.)

20 MR. FRAZIER: Okay, we really are
21 going to get started now, so if I could have
22 everybody grab a seat. Okay, everybody is

1 going to sit down. Yes, Senator Domenici,
2 take it away, sir.

3 CHAIR DOMENICI: Yes, thank you
4 very much. Hello, everybody. Panelists are
5 seated, and if not, they're in the process
6 of doing so. And as with other panels, let
7 me remind each of you to keep your
8 presentations to ten minutes, if you can.

9 Our last panel of the day is
10 entitled, and I quote, "Limiting Future
11 Proliferation and Security Risks," close
12 quote. Our first speaker is Dr. James Acton.
13 Dr. Acton is an associate in the Nuclear
14 Policy Program at Carnegie Endowment and a
15 Stanton Nuclear Security Fellow. We thank
16 you very much, Dr. Acton.

17 Our second speaker is Dr. Robert
18 Bari. Dr. Robert Bari, he's a Senior
19 Physicist at Brookhaven National Laboratory.
20 Thank you for coming. I met you today, and
21 thank you for what you do up there at the
22 laboratory.

1 Our next speaker is Dr. Richard
2 Garwin. He's currently a Fellow Emeritus,
3 IBM Fellow Emeritus at the Thomas J. Watson
4 Research Center. Thank you for giving us
5 your time, Doctor.

6 Our next speaker is Dr. Edwin
7 Lyman. He is the senior scientist of the
8 Global Security Program of the Union of
9 Concerned Scientists. Thank you very much,
10 Doctor, for coming.

11 And our next speaker is Dr.
12 Robert Gallucci. He's currently the
13 President of John D. and Catherine T.
14 MacArthur Foundation, and prior to that he
15 spent many years in the service to our
16 country in a senior diplomatic position
17 focused on issues of non-proliferation and
18 nuclear safety. Thank you, Doctor.

19 Now, with that -- do you have
20 comments, or do we go right to the
21 witnesses?

22 CHAIR PETERSON: I think we can

1 start.

2 CHAIR DOMENICI: All right, we'll
3 start, go to the witnesses. And we'll start
4 in the order that I introduced you.

5 DR. ACTON: Thank you, Senator.
6 Let me say, first of all, that it's an Honor
7 to appear before this Committee today. And
8 let me also add, by way of introduction,
9 that I am a strong supporter of nuclear
10 power. I believe that if we are to
11 significantly and meaningfully mitigate the
12 effects of climate change, nuclear power
13 must be part of the solution.

14 The challenge we face is how to
15 expand nuclear power safely and securely.
16 And I'd like to focus my remarks today on
17 the question of non-proliferation, and
18 specifically whether a policy -- a
19 continuing policy of the United States
20 restraint of not reprocessing spent fuel is
21 likely to prove an effective non-
22 proliferation tool.

1 In sixty-eight years since the
2 first nuclear reactor went critical in a
3 squash court at the University of Chicago,
4 in that time the U.S. has adopted three
5 basic strategies for managing sensitive
6 nuclear technology.

7 Its first strategy, employed from
8 1946 to 1954, might be labeled "develop and
9 deny." That is, the U.S. developed sensitive
10 fuel cycle technologies, and denied them to
11 everybody else.

12 A variant of this strategy, in
13 which sensitive technologies were to be
14 shared with just a few carefully selected
15 safe states, was embodied in the Global
16 Nuclear Energy Partnership.

17 A second, different strategy, was
18 first adopted by the Ford Administration for
19 reprocessing, was subsequently supported by
20 both the Carter and Clinton administrations,
21 and that is, desist and discourage. The
22 United States desisted from developing

1 reprocessing and discouraged other people
2 from doing so, too.

3 There's a third strategy, develop
4 and disseminate, which has been applied,
5 quite rightly, to Light Water Nuclear
6 Reactors and other types of reactors. But
7 for obvious reasons, it's not on the card
8 for reprocessing.

9 The choice facing the U.S. when
10 it comes to reprocessing is therefore
11 between develop and deny, and desist and
12 discourage. Or, put more simply, between
13 denial and restraint.

14 Critics of restraint argue that
15 it has done very little to slow domestic
16 reprocessing programs in China, in France,
17 in India, in Japan, in Russia, and in the
18 United Kingdom. This is correct, although
19 the U.K. program is slowly dying of it's own
20 accord, for other reasons, anyway.

21 However, it misses the point. And
22 this is the central point that I want to

1 make today. The real value of restraint by
2 the U.S. is not that it encourages existing
3 reprocessors to stop. It's that it doesn't
4 encourage new ones to start.

5 The seminal 1976 study, "Moving
6 Towards Life In a Nuclear-Armed Crowd,"
7 which was conducted by a team led by Albert
8 Wohlstetter, actually, observed that, given
9 contemporary plans, seventeen states would
10 have a significant reprocessing capability
11 within ten years.

12 Today, thirty four years later,
13 just the six aforementioned states have
14 reprocessing programs.

15 CHAIR DOMENICI: Sir, sir, would
16 you go back thirty seconds?

17 DR. ACTON: Sure. The seminal 1976
18 study, "Moving Towards Life In a Nuclear-
19 Armed Crowd", which was led by Albert
20 Wohlstetter, observed that, given
21 contemporary plans for reprocessing,
22 seventeen states would have a significant

1 reprocessing capability within ten years,
2 that is, by 1986.

3 Today, thirty four years later,
4 only the six states I mentioned above have
5 civilian reprocessing programs. The fact
6 that the growth in the number of
7 reprocessors have been much smaller than
8 anticipated is, I believe, the primary mark
9 of U.S. -- of the success of the United
10 States policy of restraint to date.

11 To understand why a U.S. decision
12 to procure sensitive nuclear technologies
13 might encourage others to do likewise, it's
14 necessary to realize that states make
15 procurement decisions based on reasons other
16 than cold, hard economic analysis
17 demonstrating that some fuel cycle choice is
18 the cheapest way to produce electricity.

19 Or even that it provides other
20 essential economic benefits, such as energy
21 security or simplified radioactive waste
22 management. The decision making of states is

1 more complicated. They are strongly affected
2 by non-economic factors, in particular,
3 prestige and what I term "received wisdom."

4 I think prestige is probably a
5 well understood phenomenon, I mean, I don't
6 want to belabor the point. I do want to talk
7 a bit more about received wisdom though. And
8 this is where states make decisions about
9 nuclear technology, because they see other
10 states doing it, so they assume that it's
11 got to be the right thing to do.

12 Received wisdom, particularly
13 from the U.S. but also from the U.K.
14 explains why, prior to the mid-1970s, every
15 state with a nuclear power program outside
16 the Soviet bloc, apart from Canada, planned
17 to reprocess spent fuel.

18 Few, and I don't think any, of
19 these states surveyed their uranium
20 resources to work out whether they needed to
21 close the fuel cycle for reasons of energy
22 security. They didn't make detailed cost

1 estimates of the cost of nuclear energy from
2 fast reactors.

3 They just copied the U.S. and the
4 U.K. because they were the global leaders at
5 the time, and that is a classic example of
6 the role of received wisdom. Indeed, when
7 the U.S. changed its policy in 1976 and
8 opposed reprocessing, Japanese diplomats
9 apparently were very fond of remarking that
10 our belief in the necessity of the plutonium
11 cycle is based on American teaching.

12 My concern, therefore, is that if
13 the United States makes a decision to renew
14 domestic reprocessings, it will create more
15 received wisdom that separating plutonium is
16 the right way to go. It will confer prestige
17 on this technology and make it likely that
18 other states will follow and go down this
19 route.

20 And these concerns that I have
21 would not be mitigated if the U.S. were to
22 adopt a technology such as UREX plus, that

1 does not completely separate plutonium but
2 leaves it mixed with minor actinides. Even
3 this fuel cycle choice would send out
4 essentially the same message, that a modern
5 nuclear state needs to close the fuel cycle.

6 And my concern is that a U.S.
7 decision to go for UREX plus would encourage
8 other states to go for more sensitive
9 technologies, such as PUREX. New reactor
10 technologies, I don't think, provide a
11 solution to this problem either.

12 The Global Nuclear Energy
13 Partnership provides a cautionary tale, I
14 think, about trying to focus on one type of
15 nuclear reactor and ignore others. When it
16 was launched in 2006, GNEP advocated the
17 development of burner reactors, reactors
18 that could consume more transuranics than
19 they would produce.

20 This was a reflection of U.S.
21 waste management concerns, but was also
22 argued to be consistent with U.S. non-

1 proliferation goals. I think it's true that
2 burners, the argument advanced by GNEP that
3 burners aren't proliferative is correct, but
4 only if you ignore the reprocessing
5 technology that's necessary to make the fuel
6 for burners.

7 In any case, the essential
8 premise of GNEP was that the U.S. was going
9 to focus on developing burners and not
10 breeders. Realistically, however, it proved
11 impossible just to focus on one reactor type
12 and not the other.

13 The challenges to the development
14 of burners and breeders are, certainly, at
15 this stage of the research and development
16 cycle, rather similar. So providing support
17 and funding for the burner necessarily
18 contributed to the development of its more
19 proliferative sibling, the breeder.

20 Indeed, I point out that in 2002
21 when the Generation 4 International Forum
22 Roadmap was launched, that stated explicitly

1 that all of the technologies under
2 consideration were equally appropriate to
3 burning and breeding, and the only way it
4 was possible to get political consensus
5 amongst all the participating states who had
6 lots of different goals.

7 So, just as I think that moving
8 to a technology such as UREX plus does not
9 solve the problem that the message sent out,
10 the received wisdom and the prestige, so I
11 think, new reactor technologies also don't
12 provide a technical solution to the problem
13 of proliferation.

14 This raises one final issue,
15 which I want to touch on briefly, which is
16 how can proliferation risks be assessed.
17 Everything should be very clear by now. I
18 believe that assessing proliferation risks
19 is not just a technical exercise.

20 Criteria such as safeguard
21 ability and material attractiveness matter.
22 But so too do political factors, like

1 prestige and received wisdom. I don't rule
2 out the possibility of adapting
3 methodologies designed for quantitatively
4 assessing proliferation risks, and adapting
5 them to be able to take these political
6 factors into account.

7 But it seems to me an
8 exceptionally difficult and long term task.
9 In the final analysis, proliferation is a
10 political problem, and the key to assessing
11 proliferation risks, I believe, is political
12 judgment. Thank you very much.

13 CHAIR PETERSON: Dr. Bari?

14 DR. BARI: Well, thank you for
15 inviting me. It's an honor to present to you
16 today. I should note that in this morning's
17 session, the technologists tend to stand up
18 the podium and show you view graphs, while
19 the social scientists sat and read prepared
20 statements, for the most part.

21 I'm not sure what that means
22 about our relative paradigms, but in any

1 case, today I'm going to talk about a
2 methodology that's been in place now for
3 most of the decade for assessing
4 proliferation and security risks.

5 Also note that several times this
6 morning, the idea of proliferation came up
7 even though we're talking about America's
8 nuclear future. But clearly the interest is
9 global, and our impacts on going beyond just
10 what we're doing here are very important.

11 So, what do I push. There we go.
12 Okay, so, to that point of proliferation,
13 there are really two topics here in this
14 session. The proliferation and the security.
15 The proliferation issues are ones, as we've
16 defined in our methodology, ones in which
17 the host state of a peaceful nuclear
18 technology tends, is interested in going
19 beyond the peaceful and proliferating to a
20 weapons type of situation.

21 The security one is connected
22 with physical protection, and here I show

1 some distinctions between the two. So, for
2 proliferation, think, host state acquires a
3 facility and then is interested in doing
4 things other than using it for peaceful
5 purposes.

6 Whereas, in the case of physical
7 protection, the actor is a substate,
8 subnational or terrorist or somesuch. The
9 threats on the proliferation side are
10 diversion of materials of interest, misuse
11 of facilities to make materials of interest,
12 and possibly, not mentioned explicitly this
13 morning, breakout scenarios where a country
14 has a peaceful nuclear capability and then
15 decides to break out for weapons purposes.

16 On the physical protection, on
17 the subnational side, the threats are
18 material theft, information theft, and
19 sabotage of facilities. On the proliferation
20 side, it's really international controls
21 that come into play, like the ones put forth
22 by the IAEA.

1 On the physical protection side,
2 it's the security and the domestic
3 safeguards put forth by the nation state to
4 protect its assets.

5 The, on the proliferation side,
6 the events tend to be slow moving. There's
7 planning ahead for these events. The events
8 themselves may be carried out very slowly,
9 for example, a protracted diversion
10 scenario.

11 On the physical protection side,
12 it tends to be fast moving, an event occurs
13 and something is damaged or stolen. But
14 that's also not always the case, there may
15 be insiders working with outsiders, and
16 there might be extended planning in place.

17 Clearly, on the proliferation
18 side, there are international implications
19 on physical -- for physical protection, its
20 regional implications, at least for physical
21 effects that would be realized.

22 Okay, so, our approach to this

1 problem is to -- is that we call it a
2 science-based approach. It was developed
3 under the GEN4 program over the last decade
4 by an international group, and what we did
5 was we strived to attain consensus on our
6 methodological approach.

7 And the one that we took was one
8 in which there are challenges to the system
9 that we recognized, so we pinged the system,
10 so this is where the science comes in,
11 you're probing a system. You look at the
12 system response, and then you measure the
13 outcomes and make an assessment of that.

14 And, for the threats, I think
15 I've gone through these already. For
16 Proliferation Resistance, acronym is PR and
17 PP for Physical Protection. So, they're
18 clearly, diversion, misuse, breakout. Also,
19 possibility of replicating a facility
20 clandestinely for nefarious purposes and
21 theft and sabotage come to play, on the, for
22 Physical Protection.

1 The system response, one needs to
2 recognize both the intrinsic and the
3 extrinsic capabilities for the system. And
4 this is not just an additive idea that you
5 have intrinsic and extrinsic, but, in
6 working with some of the stakeholders in
7 this area, we quickly realized that there is
8 a very dynamic interaction between the two.

9 The designers are concerned that
10 their facility, which they designed for
11 performance, is not overburdened by
12 institutional measures that would tend to
13 detract from a performance.

14 And, conversely, folks at the
15 IAEA have said, well, when they design these
16 facilities, we want to make sure that we can
17 still effectively and efficiently inspect
18 them.

19 The assessment is done in terms
20 of measures. The first six that you see
21 there, and I don't think you can see all of
22 them, they, with the fine print. But the

1 first six represent the, what we mean by
2 Proliferation Resistance. It's the, we
3 measure material type, detection
4 probability, technical difficulty of
5 carrying out a proliferation activity, the
6 time for the proliferation, the cost of it,
7 and we've also added the cost of safeguards
8 since this involves both a proliferator and
9 the defender.

10 For the physical protection side,
11 we very quickly recognized that we're
12 dealing with lots of sensitive information
13 very quickly here, and we've taken a broader
14 view of measuring it in terms of adversary
15 success probability and consequence, and the
16 secure -- the cost of providing that
17 security.

18 And we've used these measures to
19 then develop metrics and guide our
20 methodology through a inductive process
21 here, which leads one into scenarios in
22 which one looks at each of the threats and

1 assesses each threat for its various
2 outcomes in terms of the measures.

3 So, in terms of threat
4 considerations, we have threats that are for
5 the host state and ones for the outsider,
6 the non-state actor, and one has to
7 recognize the actor's capabilities,
8 strategies, and objectives in this.

9 And these could be multiple, and
10 this will determine the initiating
11 scenarios. One needs to make assumptions
12 about these, or needs to analyze as many of
13 them as are relevant to the particular
14 analysis.

15 The evaluations, when they're
16 done, should consider several points. First
17 of all, what is the question that one wants
18 to answer in the analysis? What -- and this
19 would come from some policy statement, what
20 is of interest to the, to the problem
21 holder.

22 The adversary context, what is

1 the adversary -- what does it look like,
2 what are the objectives, capabilities, and
3 strategies? What's very important here is
4 country context. Who, for example, is the
5 proliferator? Who is attacking a facility?
6 These are the type of things that need to go
7 into an analysis to, to make it meaningful.

8 One size does not fit all. One
9 needs the system design features that are
10 appropriate to the proliferation, or
11 physical protection scenario. The fuel cycle
12 architecture itself, is it a once-through or
13 a recycle scenario?

14 The safeguards and security
15 context are very important here. When,
16 typically, in analyzing a system, would need
17 to have a reference or baseline to compare
18 with. Also, recognize that there are three
19 broad stages in this process, the
20 acquisition of materials, its processing,
21 and then finally weaponization.

22 Proliferation threat and sabotage

1 scenarios, it involves at least two players,
2 the actor, the adversary, and the defender.
3 And both of these need to be recognized in
4 the analysis.

5 We've performed a few studies
6 since the development of this process. For
7 the, in the international case, in the GEN4
8 arena, we very quickly adopted a model,
9 it's, it's, in developing a methodology, you
10 need some context, and we, we developed a
11 model of a sodium fast reactor, we called it
12 the example sodium fast reactor.

13 Loosely modeled on the integral
14 fast reactor, which includes a full fuel
15 cycle. SO that helped us to develop the
16 methodology along the way, and we did a
17 series of case studies for that.

18 The, the remaining bullets on
19 this few graph refer to studies that have
20 been done by a U.S. team for the NNSA
21 connected with the GNEP program that went on
22 from, I guess, about 2006 to 2008.

1 We started a first study where we
2 compared the, the UREX plus 1A separations
3 technology to COEX and PUREX as a baseline.
4 Then, we broadened the study quite a bit to
5 consider the entire suite of UREX
6 technology, separation technologies, and
7 COEX and the pyroprocessing technology, and
8 compared all of those to PUREX.

9 We also, as part of the support
10 for the programmatic environmental impact
11 statement for GNEP, looked at specific
12 reactors that were considered in that
13 program as well, and they're shown here,
14 sodium fast reactor, high temperature gas
15 reactor, the CANDU and an Advanced Light
16 Water Reactor.

17 In addition, we looked at, in
18 another study, small modular reactors. One
19 was, specifically, the IRIS reactor, an
20 integral PWR, small PWR. And the other one
21 was a barge reactor that the Russians are,
22 are promoting, and implementing right now.

1 And we compared these as a baseline to the
2 advanced large LWR.

3 So, observations from this
4 evaluation process. Multiple pathway
5 scenarios highlight that there's no simple
6 answer. The, the analysis helps to give us,
7 even at the qualitative stage, some insights
8 before quantification is done. And given
9 that it's a holistic approach, it tends to
10 put the whole system together and, and look
11 at it in a bigger context.

12 Finally, well, I'll go over this
13 very quickly. Policy, technology, context,
14 some of that was alluded to earlier. Start
15 with policy to formulate what the questions
16 are, do the technical analysis, and then
17 policy should come in again to make choices
18 based on the results and other information
19 of interest.

20 And it's important not to put
21 these policy ideas into the analysis up-
22 front, because you might end up getting the

1 answer that you wanted. Questions and issues
2 of future studies, since we're talking about
3 America's nuclear future, relative
4 advantages of alternative nuclear energy
5 systems for various applications, system
6 architectures, once, for example, once-
7 through versus closed fuel cycles.

8 Looking at international
9 arrangements like fuel leasing, we didn't
10 discuss much lately. And then, melding the
11 proliferation and security information into
12 the broader context of performance,
13 environment, economics, and safety. So the
14 many stakeholders here, one of the
15 challenges to get the information in a form
16 that's understandable and clear to the
17 stakeholders. Sorry for going over.

18 CHAIR DOMENICI: That's all right.
19 Thank you very much. Next witness. Dr.
20 Garwin?

21 DR. GARWIN: Thank you. I do have
22 a paper, and I will read part of it. These

1 are thoughts on proliferation and security
2 risk.

3 I say that U.S. policy and
4 programs for commercial nuclear power should
5 be guided by economic analysis and choice,
6 including the internalization of costs of
7 barriers to proliferation for any technology
8 and fuel cycle, not proof against
9 proliferation.

10 And that's all of them, none of
11 them is proliferation proof. Domestic
12 suppliers should not be given over foreign
13 sources, and those, and subsidies, if any,
14 should reflect objective estimates of risks
15 and benefits, not the kind of automatic,
16 triple-a rating that polluted the mortgage
17 backed securities bubble.

18 In the discussion, which I will
19 not address in detail, I emphasized
20 proliferation by non-state actors. So, that
21 was part of what Robert Bari spoke of. And,
22 also, not part of the discussion here, the

1 overall risk of high-impact sabotage, so,
2 the acquisition of nuclear weapons is not
3 the only way to cause large damage to the
4 society.

5 The decision process should
6 recognize proliferation resistant as a
7 slogan, not a description, and the U.S.
8 should reject reprocessing of Light Water
9 Reactor fuel. It's costly, it has tiny
10 benefits in reduced uranium feed, and it has
11 no benefit in reducing heat load to the
12 repository as practiced technically very
13 well in France.

14 We should encourage dry cask
15 storage for 100 years or more, if necessary,
16 with realistic and imaginative evaluation of
17 the risks of attack and of defense of the
18 cask fields. And with the recognition of
19 possible, if unlikely, reprocessing of that
20 spent fuel when the technology and the
21 economics favor it.

22 The United States should lead in

1 the supply of Light Water Reactor fuel under
2 conditions of prompt take back and
3 commitment to interim dry cask storage and
4 eventual regional commercial competitive
5 disposal in mined geologic repositories.

6 The United States should do the
7 research and demonstration to benchmark
8 current costs of acquiring uranium from
9 seawater, where there are four billion tons,
10 four thousand million tons, enough to
11 support a thirty-fold expansion of Light
12 Water Reactors in the world for 2,000 years,
13 while exploring means to reduce future costs
14 of seawater uranium.

15 And we should help initiate a
16 cooperative world program to analyze and
17 simulate several types of breeder reactors,
18 complete with their detailed individual fuel
19 cycles to result in the eventual building of
20 a prototype, if it can be established to be
21 safe, and economically competitive with the
22 common Light Water Reactor, as it evolves.

1 And I note that if breeder
2 reactors are to supplant the world's burner
3 reactors, uranium burners, their rapid
4 expansion would need to be fueled by
5 uranium-235 from large-scale enrichment
6 plants.

7 The autogenous growth rate
8 breeder reactors is far from sufficient to
9 take over from Light Water Reactors, let
10 alone to take over from non-fission sources.
11 Now, in order to save time, I'm just going
12 to make a few comments from the discussion
13 that I provide.

14 First, that I endorse the
15 informative and authoritative testimony to
16 the Commission by Matt Bunn and Frank von
17 Hippel, especially the involvement of the
18 local citizenry and benefitting local
19 citizenry in the siting of repositories.

20 Furthermore, in the choice of
21 repository types that can readily be
22 expanded, which means a, a, a below ground

1 water reducing environment, rather than the
2 oxidizing environment of Yucca Mountain. Of
3 course, there is plutonium in all of this
4 spent fuel that has been produced, about 200
5 kilograms of plutonium a year from the
6 typical gigawatt electric reactor.

7 And if, when extracting that
8 plutonium, you could make more than twenty
9 nuclear explosives from it. But, the
10 plutonium is 1% intrinsic he spent fuel, so
11 to get ten kilograms of plutonium you would
12 need to dissolve and reprocess a ton of
13 spent fuel.

14 And there is intense, essentially
15 self protecting radiation field that makes
16 it difficult to steal either in little bits,
17 or, you know, a chunk, enough plutonium for
18 nuclear weapons. It's unreasonable to
19 imagine that any terrorist organization is
20 likely to be able to steal a large fraction
21 of accumulated plutonium in spent fuel.

22 But it's entirely reasonable to

1 imagine that such an organization could make
2 off with twenty or so of the two kilogram
3 welded steel cans, in which the plutonium
4 oxide is placed after extremely clean
5 separation from fission products in the
6 conventional PUREX process.

7 Direct terrorist attack to
8 acquire the weapon usable materials is not
9 the only threat. Violent criminal gangs
10 motivated by financial gain are also a
11 problem. So, they can specialize in that
12 aspect and other people can specialize in
13 the fabrication of the nuclear weapons.

14 I think a mechanism should be
15 established by which a facility operator
16 contributes to the IAEA funds adequate for
17 the inspection and monitoring of the
18 facility and of the process. And that would
19 give the operator the incentive to adopt
20 approaches do design, operation and to
21 monitoring that would minimize the overall
22 cost, including that IAEA monitoring.

1 The influence that the United
2 States and the blue ribbon Commission can
3 have on proliferation is modest. I agree
4 that adopting a policy of, of reprocessing
5 and recycle of Light Water Reactor fuel
6 would have a bad impact on proliferation,
7 because it would encourage the reprocessing
8 worldwide, and other countries may have less
9 capable protection for their reprocessed
10 material than one could expect in the United
11 States.

12 But, since there's no benefit,
13 that extra cost associated with
14 reprocessing, it's not something that we
15 should consider now. I did analyze GNEP
16 several times in publications that are on my
17 website, which is shown on the cover page of
18 my presentation, www.fas.org/rlg or just
19 plain www.garwin.us.

20 And there, I analyze the heat
21 load on the repository, the size of the
22 reactor park that would be required with

1 reasonable conversion ratio, not 100% or
2 zero conversion of the fuel into additional
3 plutonium but 70% or 60% so one gets to a
4 system in which, if these so called burner
5 reactors are producing electricity, which
6 they could do at higher efficiency than the
7 water reactor, more electrical power is
8 being obtained from the part of burner
9 reactors in GNEP than would be obtained from
10 the water reactors.

11 And that's as it should be, if
12 one can have safe, economical burner or
13 breeder reactors, that's what we ought to
14 have, but we are far from that at present.

15 I've also published a but on,
16 analysis on the terrapower, so called
17 traveling wave reactor. I say so-called
18 because last year, it was indeed a linear
19 traveling wave breeding burning reactor, and
20 with stationary fuel.

21 And this year, it is similar to a
22 lot of conventional uranium 238, plutonium

1 239 breeder reactors with fuel shuffling
2 with a stationary density of neutrons and
3 fissions.

4 For all that, there is a lot to
5 be said for the kind of analysis that
6 they've been doing so far, but it needs to
7 be carried much further in an open,
8 collaborative effort, and that's why I
9 propose a world reactor laboratory, much
10 like the CERN, the European particle physics
11 laboratory in Geneva, where people could
12 share ideas, make progress as fast as
13 possible, advance the state of the art in
14 analysis, not only of the burning of
15 neutrons and fission products, but
16 especially the really difficult part.

17 In the evolution of accidents as
18 fuel may melt, overheat, glow coupled to
19 temperature can cause problems, despite the
20 best efforts of designers. So we have to
21 find these things out in simulation before
22 we build large numbers of such reactors, or

1 even the, take the big expense of building a
2 single prototype. Thank you.

3 CHAIR DOMENICI: Thank you very
4 much, Professor. Now, next witness. Do you
5 want to stand, or--

6 DR. LYMAN: Yes, I'll stand.

7 CHAIR DOMENICI: All right.

8 DR. LYMAN: Thanks. Do you have my
9 presentation?

10 CHAIR DOMENICI: Here it is.

11 DR. LYMAN: It's the one I just--
12 the one you just loaded from the memory
13 stick here. Thanks. All right. I don't know
14 what the problem is. I don't know what it is
15 with me and Powerpoint in this Commission.
16 All right.

17 I appreciate the opportunity to
18 address the Commission again on the issues
19 of reprocessing and the relationship to
20 nuclear proliferation nuclear terrorism.
21 You've given us a lot of questions today,
22 and I do hope to touch on all of them in my

1 ten minutes. But I'm not sure I'll be able
2 to.

3 Oh, something happened--All
4 right, I give up. Anyway, I'd like to--the
5 overarching theme of my presentation--sorry,
6 let's give a--

7 CHAIR DOMENICI: Can we help you
8 in some other way?

9 DR. LYMAN: If I had two seconds,
10 I could try to load it again.

11 CHAIR DOMENICI: Sure, go ahead.
12 Maybe we could give you a little more time,
13 and take the next witness. Would that help
14 you? All right. We're going to go with--Mr.
15 Gallucci, are you ready? Can you speak from
16 there? All right, I mean, really need,
17 we'll, we'll take the other gentleman after
18 you've finished. Thank you very much for
19 accommodating us.

20 DR. GALLUCCI: Not at all. Thank
21 you, Senator. Thank the Commission, I thank
22 the Commission for the opportunity to be

1 with you today.

2 I have submitted two pages for
3 the record, and I would, I would not propose
4 to read from it, but to speak about the
5 topic, hopefully not inconsistent with what
6 I've provided you.

7 I believe that the President of
8 the United States, the current one and the
9 one before this President, essentially got
10 it right, that nuclear terrorism, nuclear
11 terrorism is the greatest threat to
12 America's National security.

13 I think there's a pretty broad
14 consensus about that, and the consensus goes
15 a little further, that nuclear terrorism,
16 the idea that a, a terrorist organization
17 would introduce a nuclear weapon into the
18 United States clandestinely, is a very high-
19 consequence event, but a very low
20 probability event.

21 I would submit to you, to members
22 of the Commission, that you should do

1 nothing that would increase the probability
2 that this event would occur, and if
3 possible, your recommendations should
4 decrease the probability of that event
5 occurring.

6 With that focus, I, I propose to
7 leave to others the question of the impact
8 of these, of America's nuclear choices, with
9 respect to the back end of the fuel cycle.

10 The impact of those choices on nuclear
11 proliferation, as it is normally understood,
12 is the spread of nuclear weapons to
13 additional countries.

14 I, I propose not to address that,
15 except to make one note, and that is the
16 linkage between the nuclear terrorism issue
17 and the nuclear proliferation issue. And
18 that is to observe that the nuclear
19 proliferation issue is very often miscast,
20 in my view, as, as a question of when a
21 country will acquire nuclear weapons.

22 Such as, for example, when will

1 Iran have the bomb. This, to me, is the
2 wrong question. The right question is, when
3 will Iran, or some other country, have
4 fissile material, and what will be the
5 propensity of that country, to transfer the
6 fissile material?

7 Because, again, I say, my
8 principal focus is not on the National
9 capability, but on the nuclear terrorism
10 threat. Now, about nuclear terrorism and the
11 work of the Commission.

12 The most plausible scenarios, I
13 think, for most observers, involving nuclear
14 terrorism, are scenarios that involve an
15 improvised nuclear device, and the
16 clandestine introduction of that device into
17 the United States of America.

18 In other words, not the theft of
19 a nuclear weapon, but the manufacture of an
20 improvised device. If that is the dominant
21 view of the most plausible scenario, then
22 that scenario in turn turns upon fissile

1 material availability more than anything
2 else.

3 The first concern, if that's
4 true, ought to be highly enriched uranium.
5 And, indeed, I think it has been for this
6 Administration. Leakage from research
7 reactors, submarine programs, nuclear
8 weapons programs, think Russia, think
9 Pakistan.

10 Second is transfer from a nuclear
11 weapons state. Think North Korea now, think
12 Iran, possibly in the future. One state
13 helping others, other entities. It's good,
14 therefore, to see the focus at the summit in
15 the spring, held by the President, the focus
16 on highly enriched uranium.

17 That was welcome. What was not
18 welcome, at least by me, was, a, a, an
19 absence of any substantial reference to
20 plutonium, as there was this concern about
21 nuclear terrorism, the emphasis was,
22 emphasis was entirely on highly enriched

1 uranium, leading me to ask, how come.

2 And, it seemed to me, that there
3 were at least three important ways in which
4 the plutonium, as a fissile material, is
5 different than highly enriched uranium as a
6 fissile material for our concerns here
7 today.

8 The first is, we should
9 stipulate, it is harder to make an
10 improvised nuclear device if you're a
11 terrorist with plutonium as a core than with
12 highly enriched uranium as a core.

13 Having said that, I would like to
14 submit to you that the incremental
15 difference between making an improvised
16 nuclear device with plutonium versus highly
17 enriched uranium should not be thought of as
18 an obstacle that could not be overcome,
19 should not be thought of as an obstacle that
20 could not be overcome, two negatives.

21 It is an obstacle that could be
22 overcome by the determined terrorist. This,

1 to explore this, requires going into nuclear
2 weapons design, and I think if we want to
3 explore it, we should meet after class and
4 have a conversation.

5 But, but I, that's, I put that
6 out there as the first proposition. Second,
7 plutonium can't be blended down the way
8 highly enriched uranium has been blended
9 down, to the benefit of humanity.

10 Saying that immediately tells
11 that I do not believe COEX, UREX, UREX plus,
12 and it's various varieties, pyroprocessing,
13 produce anything other than more direct use
14 material or material that may not be direct
15 use but does not have inherent in it, that
16 obstacle, again, that prevents the
17 determined terrorist from producing a
18 weapon.

19 Indeed, the Brookhaven study, in
20 their, obvious, but having to read that one
21 last night, the Brookhaven study says "yes,
22 a little bit of an obstacle, something of an

1 obstacle for the terrorist group, the non
2 National actor, not much for a nation".
3 Something of an obstacle, don't depend on
4 it, is the point here.

5 Third difference. There are
6 really a number of plausible reasons for
7 reprocessing and for extracting plutonium
8 that are non-weapons related, unlike highly
9 enriched uranium, which we're kind of down
10 to naval reactors.

11 And the reasons are usually four.
12 For radioactive waste management, to save
13 uranium and possible separated work, third,
14 to prepare for a fast reactor economy, and
15 fourth, to regain world leadership in
16 nuclear energy, to put it bluntly.

17 But each one of these, and others
18 have addressed these, I think, can be dealt
19 with. The radioactive waste management
20 argument has been a debatable one for forty
21 years.

22 I personally have been debating

1 this for forty years. And now we actually
2 have local, dry storage, which everyone
3 tells me is good for a couple hundred or so.
4 I recognize that's not long-term storage.
5 Sounds like a long time to me, but not in
6 your business.

7 Okay, it's something that one can
8 engage in for quite a long time. Second, the
9 uranium, savings in uraniums and the SWUs
10 all depend on economics. The cost of
11 uranium, the price of uranium, the cost of
12 enrichment, the cost of reprocessing, the
13 cost of recycle, mixed oxide fabrication.

14 Experience so far, and the
15 projections, don't seem to support the
16 economics of doing this, particular if
17 you're not already involved in a lot of sunk
18 costs. So it doesn't seem like this is a
19 compelling argument. Third, fast reactors
20 may come, but they're not going to come
21 quickly.

22 Fourth, if I can use some

1 technical diplomatic language now, on the
2 fourth question, it seems to me absolutely
3 nuts to do what is politically dangerous,
4 economically unwise, technically
5 unnecessary, just so we can lead other
6 countries in precisely the wrong direction.

7 I just don't get that leadership
8 argument at all. What does all this mean for
9 the Commission and your choices? I'd make
10 three points.

11 First, you will not be surprised
12 to hear, I don't think the United States
13 should recycle plutonium. I'm even, would
14 even question, and this is kind of an
15 asterisk, or a footnote, whether that mixed
16 oxide fuel fabrication facility being
17 constructed at Savannah River is such a good
18 idea.

19 Recognize some of my colleagues
20 in non-proliferation think it's a great idea
21 to burn, quote, "Excess plutonium", but I, I
22 wonder, since I don't think you have a

1 reactor now that is prepared to take this,
2 this fuel, when the fabrication facility is
3 finished and fuel rods are produced.

4 It's just, strikes me as a bad
5 example for us. Second, I think large scale
6 recycle in thermal reactors anywhere in the
7 world will make it impossible to achieve
8 plutonium accountability at the kilogram
9 level.

10 The physical security, if you
11 think about fuel moving from a reprocessing
12 facility to a fuel fabrication facility to a
13 reactor, and the transit involved in each of
14 those, is going to be costly, difficult, and
15 I think, fundamentally unconvincing that we
16 can achieve that necessary level of physical
17 security.

18 In a way, politically, to me, it
19 nullifies a lot of what Nunn-Lugar and
20 cooperative threat reduction has done over
21 twenty years. It makes a kind of, and I say
22 this with hesitation, a mockery of IAEA

1 safeguards, which you'll be left to
2 safeguard that which is easier to do, but
3 not the most valuable and threatening of
4 things.

5 This applies, this argument, to
6 every country. It applies to recycle in the
7 United States, to France, to India, south
8 Korea, Japan, Russia, and especially China,
9 given the number of reactors that are being
10 planned.

11 Finally, would seem to me that it
12 is simply not enough for the Commission to
13 say the U.S. will not reprocess and recycle
14 for the foreseeable future for economic
15 reasons. I don't think that's enough.

16 I think the Commission needs to
17 say more, it needs to say that as a matter
18 of policy, reprocessing and thermal recycle
19 of plutonium is too dangerous and thus
20 unsupportable in any country, even the most
21 advanced country. Thank you.

22 CHAIR PETERSON: Thank you. Next

1 up will be Ed Lyman, this time with slides.

2 DR. LYMAN: I apologize, looks
3 like technical difficulties are corrected.
4 I'll get right to the point. In our view, as
5 I stated before the Commission before, we
6 believe the risks of reprocessing today are
7 already unmanageable.

8 And so the thought of actually
9 expanding reprocessing either domestically
10 or overseas could quickly escalate out of
11 control. The reasons are fourfold.

12 First, the, the production and
13 utilization of plutonium are not in balance
14 today, and we've had large and growing
15 stockpiles of surplus plutonium accumulating
16 around the world in forms and locations
17 where it cannot be adequately protected.

18 Material accountancy goals at
19 both handling plants reprocessing plutonium
20 simply cannot be met. The detection of, the
21 timely detection of the diversion of eight
22 kilograms of plutonium from a large scale

1 bulk handling facility is simply not
2 technically possible, and, despite
3 allocation of significant inspection
4 resources.

5 Complimentary measures, like
6 containment and surveillance, which are
7 intended to compensate for inadequacies in
8 material accountancy, cannot fully
9 compensate for these, as I'll explain later.

10 And, finally, physical protection
11 systems in place today do not provide
12 adequate assurance against current and
13 anticipated future threats. Yet, the
14 industry continues to fight increases in
15 security requirements, and in some cases,
16 are pressing for reductions for cost
17 reasons.

18 This does not bode well, I think,
19 for the future. A reprocessing system that
20 would have adequate safeguards and security.
21 So, we feel that the biggest message the
22 U.S. could provide at this juncture is to

1 discourage reprocessing around the world.

2 And the way it could do that is,
3 first of all, to reinforce the geologic
4 disposal of spent fuel to get the repository
5 back on track and to demonstrate that it can
6 be done both, that it's both technically and
7 politically feasible to achieve direct
8 disposal of spent fuel, thus ending,
9 resolving some of the confusion around the
10 fuel cycle that leaves the door open for
11 reprocessing.

12 Both domestic and international
13 standards for that plutonium, it's already
14 been separated, have to be set at the
15 highest levels, and they have to be set
16 based on threat assessments that are
17 conservative, both today and for the
18 foreseeable future.

19 Because, plutonium is forever,
20 and the capabilities of terrorist groups who
21 are illegally conceiving inquiries over
22 time. And, I think it would also be helpful

1 if the U.S. would be realistic about the low
2 potential for technological fixes that will
3 render reprocessing proliferation resistant,
4 or improve material accountancy technologies
5 to the extent that we can resolve, through
6 technical means, some of the problems that
7 I've described before.

8 It simply appears that the, from
9 an engineering perspective, you're never
10 going to be able to get down to that eight
11 kilogram level despite all the energy being
12 spent today and the Next Generations
13 Safeguards Initiative, other approaches.

14 Finally, the U.S. could, if it
15 chose, use its bilateral nuclear cooperation
16 authority much more effectively than it has.
17 When people question the U.S. ability to
18 lead, it had the tools, it has many of the
19 legal tools, but it simply uses them with
20 one hand tied behind its back.

21 Just to provide some more
22 details, the IAEA still believes that

1 nuclear material accountancy is the
2 safeguard's measure of fundamental
3 importance.

4 Yet, over the last couple of
5 decades, numerous examples have come to
6 light of significant failures in material
7 accountancy at plutonium bulk handling
8 facilities, where there have been undetected
9 and unresolved anomalies for months, years,
10 or even decades.

11 One of the most notorious was the
12 plutonium fuel production plant, or PFPP, in
13 Japan, a MOX fuel fabrication facility which
14 could not account for about seventy
15 kilograms of plutonium for a number of
16 years. That was not fully resolved until the
17 plant was shut down and cleaned out, at a,
18 a, a cost of many hundreds of millions of
19 dollars.

20 The Tokai Reprocessing plant in
21 Japan lost track of over 200 kilograms of
22 plutonium over a many decade period, and it

1 still has not resolved that discrepancy down
2 to below eight kilograms. More recently, the
3 THORP reprocessing plant in the United
4 Kingdom had an incident a few years ago
5 where they spilled a solution containing
6 about 190 kilograms of plutonium outside of
7 the processing lines.

8 That was not detected for many
9 months. And, finally, the Cadarache MOX
10 plant in France, when it was shut down for
11 decommissioning, it was discovered that they
12 had underestimated the amount of plutonium
13 that was stuck in the process areas of the
14 plant, that, as much as thirty-nine
15 kilograms were unaccounted for and it's not
16 clear how long that was, since they didn't
17 even know it was missing. It could have been
18 for decades.

19 Now, these examples indicated or
20 result from significant technical issues
21 including the residual holdup in process
22 equipment, the accumulation of scrap and

1 waste and hard to assay forms, the
2 inaccuracies in material estimates, which
3 have not really improved over several
4 decades, and operator complacency and
5 incompetence.

6 Even in new plants, the Rokkasho
7 Reprocessing Plant, which, if it ever starts
8 up, will separate almost eight tons of
9 plutonium a year, simple calculations
10 indicate that unless almost 200 kilograms of
11 plutonium were diverted, that you would not
12 be able to detect that to a 95% confidence
13 level and 5% false alarm rate.

14 And, for this reason, the IAEA
15 requires containment surveillance and other
16 methods to compensate for this inadequacy.
17 But, I, I don't believe those, that you can
18 ever compensate for poor material
19 accountancy with containment surveillance.

20 And the reason is simple. If
21 there is a loss of continuity of knowledge,
22 the containment surveillance system fails

1 for some period of time, and you have to
2 account, you have to demonstrate that you
3 have not lost a significant quantity of
4 plutonium if you don't have a timely and
5 accurate material accountancy systems.

6 You simply can't do that. So, in
7 the case of an alleged diversion or theft,
8 which is an issue that needs to be
9 addressed, someone calls in and says "we've
10 diverted two bomb's worth of plutonium and
11 we're going to blow up New York if you don't
12 respond to our ransom demands within twenty-
13 four hours".

14 No facility in the world would be
15 able to actually resolve that anomaly and
16 say that it couldn't have happened, and
17 that's, that's the problem. Theft, for, as
18 we heard before, in response to subnational
19 group attacks, binding international
20 standards for protection of weapons, using
21 material against theft do not exist.

22 Attempts to introduce binding

1 international standards failed in the
2 international arena. The IAEA only has an
3 advisory role, and even in the United
4 States, which probably has the most well-
5 developed regulatory system for enforcing
6 physical protection of nuclear facilities,
7 does not do a good enough job.

8 And, the standard which is not as
9 a design basis threat, which is the
10 instrument by which physical protection
11 systems are developed and instituted at U.S.
12 facilities, remain below the threat levels
13 that we know exist today, which could be
14 reasonably anticipated for the neat future.

15 In terms of the number of
16 adversaries, the weaponry, the tactics, and
17 the insider characteristics, there is enough
18 public information to demonstrate that all,
19 and with respect to all of these, they fall
20 short of the kinds of threats that we know
21 exist today that have been employed by
22 paramilitary groups in, in the middle east

1 and elsewhere.

2 Just to give an example of the
3 level of protection of U.S. nuclear power
4 plants, and there is no public data for the
5 two fuel cycle facilities that are regulated
6 by the NRC, but there is some aggregate data
7 for the performance of security systems at
8 nuclear power plants.

9 When force on force tests are
10 conducted, in, between, prior to September
11 11th, it was known that about half the
12 nuclear plants failed force on force tests,
13 meaning that the guard force and the
14 security plant could not prevent a mock
15 adversary team from doing enough damage to
16 the plant to cause radiological sabotage.

17 After September 11th, those
18 standards were increased, but we're still
19 seeing a ten to fourteen percent failure
20 rate every year, and I don't believe that's
21 an adequate, I think that that number is too
22 high, certainly, for protection against

1 sabotage.

2 And you can only imagine if theft
3 of special nuclear material were involved.
4 And here's an example of a particularly
5 egregious security failure at the Peach
6 Bottom Nuclear Power Plant. It's a serious
7 issue because it's indicative of a lot of,
8 it, workforce issues associated with the
9 private guard forces at nuclear power
10 plants.

11 Overtime, fatigue are all serious
12 issues that have to be dealt with. We were
13 asked, can security be risk informed? I
14 would say the answer is no. Risk informing,
15 generally refers to a quantitative, using
16 quantitative risk information and safety
17 analyses.

18 There is no way to adequately
19 quantify the threat of a terrorist attack,
20 either through the initiating event
21 probabilities or the probabilities of self
22 correction during the event. Risk informing

1 generally means, in NRC parlance, weakening
2 security on nuclear materials because of
3 the, the belief that they are less
4 attractive to terrorists.

5 And I just want to point out one
6 example before the NRC today is an attempt
7 to weaken security on the transport of mixed
8 oxide fuel because it's regarded by some as,
9 as less vulnerable to theft than separated
10 plutonium.

11 If this proposal goes through, I
12 would say it provides a terrible example for
13 other countries that have large plutonium
14 stockpiles and are planning to go into MOX
15 fuel.

16 I'd just like to point out that
17 one NRC commissioner dissented from the
18 approach, but he appears to have lost the
19 overall vote and the NRC is going ahead with
20 examining that.

21 With regard to safeguards by
22 design, I'd like to point out that the MOX

1 plant that Dr. Gallucci referred to, there's
2 public information, that there are serious
3 design problems that may impact the ability
4 to apply material accountancy, accurate
5 material accountancy at that plant.

6 I can't say anything more about
7 that, but safeguards by design should
8 certainly be a requirement of any regulation
9 for fuel cycle facilities in the future.
10 And, I would--I'll stop there. Thank you.

11 CHAIR DOMENICI: Thank you, very
12 much. I think that's it on the witnesses.
13 Let's see if the commissioners have any
14 questions. We'll start at that end. Dick?

15 MEMBER MESERVE: Let me, first of
16 all, apologize to the panel, that I had,
17 one, scheduled another appointment, which
18 means I have to leave in a few minutes, but
19 I did want to pursue just one question.

20 We've had an abundance of
21 testimony from a variety of sources,
22 including from industry, that recycling is

1 not anything we should contemplate
2 undertaking now.

3 And I think that it does, I to
4 detect the possibility of a difference in
5 view among the panel on the issue of what
6 role is appropriate for the Department of
7 Energy or others in contemplation over the
8 long term of possible alternative fuel
9 cycles that might involved recycling.

10 That, Dick Garwin's presentation,
11 it advocated, for example, we ought to be
12 preparing for the possibility in the long
13 term for a, different technologies that
14 would involved reprocessing, and I got the
15 implication from several of the others of
16 you is even opening that door might be too
17 dangerous in that--

18 I mean, one could argue that
19 we're saying it's not ready now, that, that
20 might have a deterrent effect on others in
21 pursuing it now. But I suspect you may have
22 a different view. I just am curious as to

1 whether there is a legitimate disagreement
2 among the panel on the question of whether
3 even R&D on the fuel cycle is inappropriate.

4 CHAIR DOMENICI: Who wants to take
5 that first? Go ahead, Mr. Gallucci.

6 DR. GARWIN: This proposal is, you
7 know, not R&D on--Light Water Reactors. But,
8 in the, the long term future, a breeder
9 reactor requires recycling, you cannot throw
10 away the high enrichment or high plutonium
11 fuel.

12 So, you must reprocess it in some
13 way. But what we should do is lab scale
14 design, we should do simulation with tools,
15 which require generations of improvement,
16 like the tools that we use for simulation of
17 nuclear weapon explosions now.

18 So, a whole new capability to
19 simulate in computers what we now do
20 experiment on. And we shouldn't
21 underestimate how long it will take to do
22 this, but we need to simulate accidents. We

1 need to take inputs for a simulated reactor
2 and simulated fuel with little wires wound
3 around it, and at all scales, see what
4 happens.

5 So, that's what we ought to be
6 doing, and, yes, reprocessing would be
7 necessary if we're ever going to have a
8 breeder reactor. But, we may never. It may
9 take a long time. We may have uranium from
10 seawater in such amounts that we won't need
11 to have breeders until somebody has a really
12 good idea in the great by and by.

13 CHAIR DOMENICI: Mr. Gallucci, I,
14 this is in psych 101 terms, an approach-
15 avoidance conflict for me. Because I do not
16 see a circumstance in which, in thermal
17 reactors, recycle can be done safely, given
18 the movement of material from a reprocessing
19 plant to fuel fabrication plant to reactors
20 that are dispersed.

21 And, I am most concerned with the
22 Commission think about the, the negative

1 consequences of anything it says about
2 preserving the option of recycle. If it is
3 entirely in the context of breeder reactors,
4 then I'm not certain even of what Dick
5 Garwin was saying about whether there are
6 implications of that for what we do with the
7 plutonium that has now been produced and is
8 contained in all that spent fuel.

9 The approach-avoidance conflict
10 for me, is that I would be happy in, on one
11 hand, if you discovered permanent disposal
12 in a once-through fuel cycle, but I don't
13 think you will. I, I think that dry local
14 storage is the easy thing to continue doing.

15 That, that does preserve the
16 option in the future of access to this
17 material and recovering it, the plutonium
18 from, from the spent fuel. An option I say,
19 which does not appeal to me on energy terms,
20 but if it makes storage, as opposed to
21 reprocessing, more attractive, then I'm
22 prepared to embrace it for that reason.

1 I think at the, at the end of the
2 day for me, what's most important is what
3 signal we send to the rest of the
4 international community. Yes, I worry about
5 reprocessing in the United States, and
6 thermal recycle.

7 But I'm even more worried about
8 it being carried out around the world and it
9 becoming the standard for how the back end
10 of the fuel cycle is managed.

11 MEMBER MESERVE: Let me just
12 observe that it's going to be an option, in
13 fact be an option in the future, you need,
14 it's not going to happen magically. That
15 there is some work that needs to happen in
16 the interim.

17 CHAIR DOMENICI: Mr. Meserve, can
18 you recognize the chair in this exchange so,
19 so, are you finished--Mr. Meserve, are you
20 finished with your comment?

21 MEMBER MESERVE: Some of the
22 others wanted to react to my comment--

1 CHAIR DOMENICI: That's correct.

2 MEMBER MESERVE: I see a hands up
3 from Mr. Acton, and--

4 CHAIR DOMENICI: I was going to
5 call oh him just now. Going to call on him.
6 Mr. Lyman, you're next.

7 DR. LYMAN: Okay. I think there's
8 been substantial Government R&D on
9 reprocessing and fast breeder reactors. My
10 sense is that the, the DOE establishment,
11 that's sort of, that's been the dominant
12 focus.

13 And I think other approaches
14 should be given more of a chance, you know.
15 I think advanced once-through systems with
16 high internal conversion like the reactor
17 formally known as the traveling wave
18 reactor, even, deserve further exploration.

19 And, as long as the door is open
20 to consideration of reprocessing, I think it
21 might complement people's vision on how to
22 improve the once-through cycle, and perhaps

1 achieve some of the advantages that people
2 attribute to reprocessing.

3 So, I think, in the future, I'd
4 like to see a greater focus on advanced
5 once-through R&D and diminished focus on
6 closed fuel cycle R&D.

7 CHAIR DOMENICI: Who else--who
8 else wanted to--yes? Go ahead, Mr. Acton.

9 DR. ACTON: I guess that, I find
10 it very hard to see, over the medium term,
11 say, the next fifty years, the circumstances
12 that would make reprocessing attractive.
13 Over the longer term, I think it's much
14 harder to judge.

15 I mean, you could imagine a world
16 in which, hopefully, proliferation risks are
17 significantly lower, in which fast reactor
18 technology has become economic and
19 competitive, in which uranium resources are
20 depleted, maybe in which the process of
21 extracting uranium from seawater hasn't,
22 hasn't demonstrated any economic promise.

1 And in that kind of world,
2 reprocessing in fast reactors might look
3 attractive. The question that I think, as
4 you rightly say, is now, when we are a
5 number of decades out from that possible
6 world, what kind of research and development
7 should be done?

8 And, there was a, I think,
9 there's a number of different considerations
10 here, and I don't have an easy answer to
11 that question. But firstly, there's the
12 simple cost benefit analysis, which is, if
13 you have a limited resource, limited budget
14 available, where is that technology best,
15 where are those research and development
16 dollars best used?

17 Are they best used in technology
18 that might take, the, the, might, and, and,
19 and, and nothing stronger than might, be the
20 right thing to do fifty or 100 years, or are
21 they best used on nuclear technologies that
22 are, are much more needed in the short term,

1 including some of these other once-through
2 options?

3 And then, the second issue, which
4 is coming back to the, to the, to the focus
5 on the evidence that I presented today about
6 the message the U.S. sends out. You know, I
7 think there's all the difference in the
8 world between the research and development
9 process largely based on computer
10 simulations of the kind that Professor
11 Garwin has, has, has outline, which seems to
12 me to be making it very clear that this is
13 nothing more than a basic research and
14 development pro, program.

15 And there's no intention of
16 deploying this technology in the short term
17 versus, on the other hand, the much more
18 extensive kind of research and development
19 process in which you're kind of going into
20 the wet labs and you're, and you're actually
21 trailing this technology on a pilot scale.
22 Which does look like, that you're trying to

1 deploy in the short term.

2 CHAIR DOMENICI: Any, any
3 questions from the Commissioners, any
4 questions? Yes, go ahead.

5 MEMBER MACFARLANE: Great. Thank
6 you. I have, I have three questions. So, let
7 me see. My first one is for Dr. Acton and
8 Dr. Gallucci. And, so, let's leave aside the
9 idea that the U.S. can, you know, what the
10 U.S. chooses to do might influence what
11 other countries do. Okay, let's just leave
12 that aside for a second, pretend that
13 doesn't exist.

14 And, I just want to, you both to
15 explore a little bit what's wrong with
16 James' develop and deny strategy? So, what
17 if the U.S. says, well, we're going to do
18 this, but we don't think the rest of you
19 should do this.

20 What, you know, is that, is that
21 reasonable? Is there a way to support that?
22 Or, if it's not reasonable, then why not? Is

1 that--does that make sense?

2 CHAIR DOMENICI: They don't know
3 what you're talking about.

4 DR. GALLUCCI: I'm--what I'm, I'm
5 confused about is that, the antecedent to
6 this was "let's make believe there isn't a
7 rest of the world".

8 MEMBER MACFARLANE: No. No, the
9 rest of the world is there--

10 DR. GALLUCCI: Yes.

11 MEMBER MACFARLANE: --just, you
12 know, there's two parts to what the, in my
13 mind, there's two parts to what the U.S.
14 does. If the U.S. decides to reprocess, or
15 holds that option open for the future, it
16 might, as you so clearly outlined, influence
17 other countries to do the same thing.

18 But, you could also imagine the
19 U.S. advocating a two-tier world, and I'm
20 saying, well, let's say, the U.S. advocates
21 this two tier world. We can have it, but you
22 can't. And play out that scenario a bit for

1 me.

2 DR. GALLUCCI: I think we've got
3 that scenario. I mean, we do that quite a
4 bit. We can have nuclear weapons and you
5 can't. Right?

6 MEMBER MACFARLANE: Right?

7 DR. GALLUCCI: We can have fissile
8 material production facilities, enrichment
9 plants and reprocessing plants, but--

10 MEMBER MACFARLANE: Well, the, the
11 non-proliferation treaty says--

12 DR. GALLUCCI: Yes, but we're
13 talking about the real world and United
14 States policy. And we have taken a position
15 for forty years, or more, that, and
16 beginning with what was called the London
17 Group before it became the Suppliers Group,
18 the whole point of that London Group in 1976
19 was to say, a bunch of other things, but
20 essentially we wanted to get to say "look,
21 suppliers, we know there are good guys and
22 bad guys, and we, it's okay for the good

1 guys to have enrichment, you know who they
2 are. And, while we don't like reprocessing,
3 it's better that it be done at a small
4 number of good guy plant, places, than bad
5 guy places". Right?

6 So, and then we, but we took this
7 position, and the question was, could we
8 hold the technology that way, comparably to,
9 not exactly patterned after, but comparable
10 to, could we hold the weapons technology.

11 In both cases, we worried that we
12 couldn't because the other countries would
13 notice. Okay? And they would resent it and
14 all the things that go with the declaratory
15 policy of the United States which generally
16 is, we respect the sovereign choices of
17 other countries, et cetera.

18 There are enormous political
19 problems with managing that kind of world.
20 One can do it if one has, through the
21 cartel, control over the technology with a
22 death grip. But as soon as that begins to

1 change, and there are huge economic
2 incentives for it to change, as well as
3 political disincentives to sustain it, then
4 it's very hard.

5 MEMBER MACFARLANE: So, the death
6 grip is no longer in existence.

7 DR. GALLUCCI: I think the death
8 grip is not there, and it, it's slipping.
9 But I will tell you that, quite frankly,
10 what I'm arguing here, in part, is that we
11 be serious about our belief that we do not
12 wish to live in a world in which there is a
13 lot of plutonium in motion in a civilian
14 nuclear fuel cycle.

15 And, and, that we get together
16 with other suppliers and say "you should not
17 be doing this either, this will make the
18 international community less safe and we
19 will not be able to recover from it". So,
20 it, yes, it's harder now, but I am for
21 regenerating with, with the proper politics,
22 an argument that the international community

1 should embrace the control of this material.

2 MEMBER MACFARLANE: And James,
3 you--go ahead.

4 DR. ACTON: And I would very
5 strongly agree with that. I don't believe
6 that a discriminatory system can be a
7 sustainable system over the long-term. And
8 let me give you some very recent, real
9 examples of where this has happened.

10 The United States decided to make
11 an exception for India, and the NSG waiver.
12 Now, we can argue over whether that was a
13 good thing or a bad thing, that's, that's,
14 that's not the point here.

15 The point is that there was a
16 very clear prediction at the time that if
17 the U.S. makes an exception for India, China
18 is going to supply to Pakistan, and that is
19 going to happen.

20 MEMBER MACFARLANE: Right.

21 DR. ACTON: The U.S. is trying as
22 hard as it possibly can to prevent that

1 sale, and I really hope the U.S. succeeds in
2 preventing that sale, but at the end of the
3 day, there's almost no leverage the U.S.
4 has, short of kicking China out the NSG,
5 which is probably a solution that is worse
6 than the problem it's designed to solve.

7 So, so, so that's a very clear
8 example of where trying to change, to
9 introduce a discriminatory system proved not
10 to be sustainable. Let me give you another
11 example.

12 The United States has given Japan
13 prior consent rights to reprocess spent
14 nuclear fuel. I think it is undeniable that
15 one of the reasons, and I don't argue this
16 is the only reason, but one of the reasons
17 why South Korea wants the pyroprocessing,
18 wants to go down the road to pyroprocessing,
19 is because, you know, it strongly objects to
20 the fact that its long-term, historical
21 rival, Japan, is allowed by the U.S. to
22 separate plutonium, and it wants that kind

1 of formal equality, it wants the prestige,
2 of being able to do so as well.

3 So, the reality is that we, we,
4 we have a discriminatory system at the
5 moment. It doesn't seem to me to be
6 particularly stable, and we don't want to
7 make that problem worse.

8 MEMBER MACFARLANE: Great. Okay.
9 No, sorry, do you want to piggyback on that,
10 or? I've got two more.

11 MEMBER CARNESALE: Go ahead.

12 MEMBER MACFARLANE: All right, so-
13 -

14 MEMBER CARNESALE: --in the queue.

15 MEMBER MACFARLANE: Okay, in the
16 queue. You're in the queue. All right. So,
17 Dr. Bari, I just wanted to, to say, and see
18 if we can get into our record, a nice little
19 paper that you authored in 2009 called
20 Proliferation Risk Reduction Study of
21 Alternative Spent Fuel Processing, where, I
22 think, you implemented this modeling that

1 you were discussing and got to some of the
2 punchline there, which I think is very
3 interesting, where you looked at all these
4 different reprocessing technologies,
5 pyroprocessing, all the different UREX's,
6 COEX, PUREX, blah. And you found that there
7 is very little difference among them. Is
8 that correct?

9 DR. BARI: Yes, that is correct.
10 What's very important also to emphasize in
11 that paper is, I mention my talk, that there
12 is country context here, that part of the
13 assumption is that the would-be proliferator
14 or, or the person who is going to abuse the
15 technology is a non weapons state, a nuclear
16 non weapons state, but with a, a, insisting
17 PUREX type capability.

18 So they're fairly capable in what
19 they're doing. And I think in the paper we
20 also mention the other end of the spectrum,
21 where it's a subnational or terrorist, and
22 they're, there are more opportunities for

1 abuse. So, it, it, the country context is
2 very important in all of this.

3 But, yes, that was the statement
4 that--

5 MEMBER MACFARLANE: So, and we
6 can--

7 DR. BARI: Oh, yes, by all means--

8 MEMBER MACFARLANE: --get this.

9 Great.

10 DR. BARI: Yes, that's--it's open
11 literature.

12 MEMBER MACFARLANE: Great.

13 DR. BARI: Yes.

14 MEMBER MACFARLANE: Okay. Very
15 much appreciated. And, final question is to
16 Dick and Ed. So, you know, I'm not an expert
17 on the nuclear engineering here, so I just
18 want you guys to help me, and, especially,
19 Dick, because you have such great and
20 wonderful wisdom on all of this.

21 What technically has held us back
22 from reliably operating burner or breeder

1 reactors? Why don't we have them yet? We've
2 been working on them for fifty years?

3 DR. GARWIN: Well, they were a
4 matter of course. Every red blooded
5 physicist reactor engineer knew that after
6 the uranium reactors and the enrichment, the
7 next step was this marvelous breeder
8 reactor.

9 Because there are enough neutrons
10 per fission not only to carry on the chain
11 reaction and support the structure in the
12 material, but to breed another fissile atom.
13 And so, it's a marvelous gift of nature, it
14 was a natural thing.

15 But, in order to do that, you
16 need for, for the most part to have fast
17 neutron reactors. You cannot thermalize the
18 neutrons. That means you can't use water,
19 either heavy water or light water as the
20 coolant, with all of it's marvelous
21 properties.

22 And so, you go to an open sodium,

1 or an open lead, or lead bismuth ally--
2 alloy, or sodium potassium alloy. And in
3 sodium, the alkaline metals that are highly
4 reactive chemically, they react with air and
5 water, we live, as Frank von Hippel said in
6 his testimony, in, in a world of air and
7 water.

8 And they're opaque, so when you
9 have your reactor full of molten sodium and
10 you want to lower a camera into it, have the
11 reactor shut down to see what's wrong, you
12 can't. So, the, even the people who were and
13 have been enthusiasts for breeder reactors
14 recognize that it's a very difficult
15 technology.

16 In principle, it's fine, but
17 everything has to be extremely reliable.
18 Molten lead doesn't have that problem. It
19 has other problems of chemical reactivity.
20 It dissolves iron at high temperature.

21 So, there we are. We have the
22 material problems, then we have the lower

1 margin of error because the, the prompt
2 delayed threshold for plutonium is
3 considerably smaller than it is for uranium.
4 So there's half the margin between delayed
5 critical, which is how reactors work, and
6 prompt critical.

7 And, it, it's a difficult--Edward
8 Teller, who was a big fan of reactors, said
9 even of breeder reactors, said that nobody
10 could persuade him that 1% of the fuel in a
11 breeder reactor could be somehow melt and
12 get together and form a prompt critical,
13 that is a nuclear explosion, not just a
14 thermal steam explosion.

15 MEMBER MACFARLANE: That would be
16 bad. So, so, do you think we can solve these
17 problems in the next two decades then?

18 DR. GARWIN: Not to deploy a large
19 number of these things, no.

20 MEMBER MACFARLANE: Okay.

21 DR. GARWIN: But we may be able to
22 be on our way to having the simulation

1 capabilities so that we can have, in
2 principle, a very, a much more varied scope
3 of reactor fuels and reprocessing and
4 reactor configurations, all of which go
5 together, versus TerraPower, it is a metal
6 fuel.

7 But, the problem is that when you
8 fission half of the heavy atoms, instead of
9 having a density of eighteen or so, you have
10 a density of six. And so the fuel has to
11 expand. And, sometimes a little bit of
12 reprocessing or repurposing will help,
13 compared with making a fuel which I
14 sufficiently expansible to do that.

15 MEMBER MACFARLANE: Okay. Ed, did
16 you want to add anything?

17 DR. LYMAN: Yes, just briefly.
18 And, in, with regards to the reactivity
19 issues that Dick just mentioned, the NRC has
20 a general design criterion that any reactor
21 that's licensed has to have a negative,
22 negative coefficient, negative feedback.

1 And, it's very challenging to try
2 to design a fast reactor that has a negative
3 void, void coefficient over all the
4 operating regimes. And when you try to
5 engineer around that problem, you end up
6 creating other problems.

7 So, there are a couple of designs
8 that claim, the Hyperion reactor claims that
9 it has a negative void coefficient, but they
10 still haven't work out all the details. And,
11 so I think that, that's one constraint, at
12 least in the United States.

13 MEMBER MACFARLANE: Great, thank
14 you.

15 CHAIR DOMENICI: Al, are you next?
16 You are next. Yes, have at it.

17 MEMBER CARNESALE: I'd, I'd like
18 to try and capture in, in simple terms some
19 of what I've heard, not just from this
20 panel--tell me if, if I have it right, or if
21 I'm missing important things. Because then I
22 can, very briefly.

1 One, when it comes to, as you
2 look at the back end of the fuel cycle and
3 worry about it, it's the plutonium. It's the
4 plutonium, stupid, right? That's the,
5 simple.

6 Secondly, with regard to
7 reprocessing and recycle, I think it's
8 important that we're reminded, there are two
9 problems. One is physical security as it
10 relates to terrorism, or the, and the other
11 is proliferation to states.

12 These are related but they're not
13 the same. In that sense, it could go either
14 way. Third, when it comes to U.S. grade
15 processing and recycle, we seem to have two
16 concerns. One is physical security and
17 terrorism from our supply.

18 Secondly, is the example we set
19 for others that may, may reinforce those in
20 those countries who would choose to go to
21 reprocessing and in the other countries, got
22 both problems. You've got the terrorism

1 problem and you have the fact that they may
2 choose to use this material to produce
3 nuclear weapons.

4 So, that, as I understand it, is
5 how you, just summarize what the problem is,
6 on the upside, on the other hand, for
7 reprocessing and recycle, we hear two
8 different kinds of things. One read is about
9 reprocess and recycle in thermal reactors,
10 the other is in fast reactors, whether they
11 be burners or breeders.

12 For recycle in in thermal
13 reactors, the first approximation we hear,
14 it's not economical, that the conservation
15 of uranium is very small, and the waste
16 management column is not changed
17 significantly. That's simply for recycle in
18 thermal. LWRS, basically.

19 If you go to fast reactors, the
20 economy, we don't know, right, because we
21 don't know what the reactor would cost, so
22 that seems, we just don't know. It's worth

1 trying to find out. But we don't know.

2 On the conservation of uranium,
3 over time, yes, not any time soon, we don't
4 know how important it is, but it would
5 certainly conserve substantial amounts of
6 uranium if you had these, well, especially
7 if you had breeders. But, going for a long
8 time.

9 And when it comes to the waste
10 management, here too the bless transuranic
11 elements, that rip your in burner reactors,
12 but it takes literally centuries before you
13 see a very substantial difference because
14 the inventory is in the reactors instead of
15 in the ground.

16 So that's the summary on what I
17 think, I've heard, from your perspective. Do
18 I have it roughly right? Or, well, I don't
19 know, that's an unfair question. How would
20 you make it better?

21 DR. GARWIN: I assume, Al, you did
22 all it that way, there's no passion here.

1 You know, there's just, there's just--

2 MEMBER CARNESALE: Sorry, I was
3 trying to be analytical.

4 DR. GARWIN: This was, this was
5 pretty cold. And, and when--if, in your
6 shorthand, you were taking a count of the
7 downsides, and you meant you could lose
8 cities, but you didn't say you could lose
9 cities, that countries that are non nuclear
10 weapons states now could become, and we
11 could have, instead of a world of nine, you
12 could look and see we have a number of
13 twenty-nine, instead of no nuclear
14 terrorism, we could be losing cities. So
15 long as you've got that, I'm okay.

16 MEMBER CARNESALE: Yes.

17 CHAIR DOMENICI: How long do we
18 have?

19 CHAIR PETERSON: We have twenty-
20 five minutes. We have plenty of time. I
21 would like to take advantage of the very
22 strong background of the set of panelists

1 that we have in front of us to explore three
2 areas where non-proliferation and security
3 probably link fairly strongly into waste
4 policy for U.S. in terms of what the U.S.
5 might do in changing direction or adopting a
6 new approach or somewhat modified approach
7 to how it's going to manage storage,
8 transport, disposal, and possibly, also,
9 some type of recycle and reprocessing of
10 used fuel and high level waste.

11 And, so, there, I think there's
12 three key areas where that, at least three
13 key areas, where that coupling exists, and
14 I'd like to just explore each of them
15 quickly.

16 The first would be the, the
17 question of whether or not the U.S. might,
18 might at some point in the future undertake
19 to import foreign spent fuel. In cases
20 where, in limited quantities and in cases
21 where that might be a benefit, judged to be
22 a benefit to the, the U.S. National

1 security.

2 Of course, that's politically
3 difficult to do if we don't have a domestic
4 capacity to manage the material. But if you
5 envision coupling this ability to, to,
6 import limited quantities compared to
7 domestic production, totally unsuccessful in
8 having capacity to manage domestic as well.

9 Would that be of substantive
10 value from the perspective of achieving non-
11 proliferation and security goals? Would you
12 be able to comment on that? Because it's
13 clearly one way in which U.S. waste policy
14 could couple to non-proliferation security.
15 James, if you have a--

16 DR. ACTON: So, I strongly agree
17 with the premise of the question. I think it
18 would be an incredible non-proliferation
19 good if the U.S. were able to take that
20 spent fuel.

21 I do think reprocessing makes
22 that harder, for the following reason, which

1 is if the U.S. has a once-through fuel
2 cycle, there is the political opposition to
3 whatever final waste disposal solution there
4 is, or no final waste disposal and interim
5 storage at reactor sites.

6 Whatever it is, there is the
7 political opposition to that. If you have
8 reprocessing, you essentially create
9 political opposition to two different
10 things. You have the political opposition to
11 the high level waste storage you still need,
12 even with a reprocessing facility.

13 Plus, the political opposition to
14 the reprocessing facility itself. I mean,
15 it, it wouldn't that the residents would
16 kind of, northern Georgia and southern South
17 Carolina welcome Barnwell with open arms. I
18 mean, there, there was a huge amount of
19 litigation and complexity and opposition to
20 that site.

21 And I can see people in the
22 audience who would also probably start the

1 lawsuits as well, against, against, against
2 the, against the reprocessing facility
3 itself. So, I kind of find it funny as
4 somebody with a background in physics to say
5 this.

6 But, you can't solve a political
7 problem with a technical solution. The, the
8 barrier to the U.S. importing waste from
9 abroad is political, and you need a tech--I
10 mean, you need a political solution to that,
11 not a technical solution to that.

12 DR. GARWIN: I am in favor, not of
13 importing and reprocessing, but of importing
14 and direct disposal. But, the prerequisite
15 is, as Matt Bunn says, in Sweden and
16 Finland, people sue when they don't, when
17 they are not allowed to host a disposal
18 site.

19 So, what you need to do is
20 somehow to turn this on its head, and I've
21 always thought that competitive, commercial,
22 direct disposal into mined geologic

1 repositories should be popular. People
2 should make money out of it, not only those
3 who do it, but those who host it.

4 So, if we can do that, then it's
5 another way to make money. We would be
6 buying other countries in order to put the
7 nuclear spent fuel underground. But, to
8 reprocess it, absolutely not.

9 DR. LYMAN: Yes, just briefly.
10 Per, you envision that would be, that offer
11 would be coupled with a commitment on the
12 part of the state that would be shipping
13 spent fuel, not to engage in domestic
14 enrichment and--or reprocessing?

15 CHAIR PETERSON: I think that that
16 is quite open. The, the general question is--
17 -

18 DR. LYMAN: Right, because I, I, I
19 don't, I don't see what the non-
20 proliferation benefit would be unless, as
21 part of that contract, and that's a
22 significant sweetener, that we would be able

1 to extract maximum constraints on the, you
2 know, if we're offering to take back the
3 nuclear waste, we should be able to expect
4 significant commitments on their part.

5 Without that, I don't think just
6 taking, physically taking back the spent
7 fuel necessarily has a significant benefit
8 if the country doesn't have reprocessing
9 abilities.

10 DR. GALLUCCI: Just wondering, if
11 the United States Government took
12 responsibility for, what is now, utility
13 managed, as I understand it, local dry cask
14 storage, if after thirty or forty years, is
15 that reverted to U.S. Government
16 responsibility, so the Government was in the
17 spent fuel storage business.

18 Then it might be more of a
19 political solution to a not very demanding
20 technical problem of managing an incremental
21 amount of spent fuel coming to the United
22 States. We have never thought that real

1 volumes were, were physically challenging to
2 any country's space.

3 It's a, it's a political issue. I
4 mean, try Australia, for a start. And I
5 think, certainly, the United States. But I
6 think, it's correct to say that you'd have
7 to get over substantial dustbin argument
8 politically. But if, if, if the Government
9 was in the business of doing this, that
10 might, might be a lesser included problem.

11 CHAIR PETERSON: Okay. Thank you.
12 Another area coupling to the waste policy is
13 in the area of whether or not one deploys
14 some reprocessing or research laboratory
15 related activities coupled to centralized
16 storage and or disposal to increase the set
17 of incentives if you have a voluntary
18 process for siting, to, to, to get more
19 local communities and states to, to seat,
20 to, to host these types of facilities.

21 And, of course, the panel here
22 has thought very deeply about issues related

1 to security, but, you know, we've looked
2 more broadly across the spectrum of people
3 who are both, say, technologists as well as
4 the public, the concepts and ideas behind
5 recycling actually have a high degree of
6 popularity.

7 And this can be reflected, for
8 example, in the fact that when you do, you
9 know, we had Hank Jenkins Smith speak to the
10 disposal Subcommittee. There was a huge
11 impact on the level of public acceptance for
12 storage or disposal if one has couple to it
13 the idea that you'll also deploy
14 reprocessing with some type of research
15 facilities.

16 So, certainly, this is, this is
17 a, a question that has to be taken up in, in
18 trying to develop a policy that if you're
19 going to go down the voluntary siting path.

20 And I guess my question is, given
21 that, first of all, I presume that the
22 majority of the panel would not advocate for

1 deploying reprocessing, but that would leave
2 you in the area of advocating for
3 potentially, some type of research
4 laboratories.

5 What, what would be reasonable
6 activities if you did decide to have this as
7 a part of the overall incentive package for
8 voluntary participation in siting?

9 DR. GARWIN: I am not familiar
10 with the basic facts as to whether you need
11 to have research interview processing in
12 order to make people accept disposal sites.
13 It's not like that in, in Finland or Sweden.

14 So, I, I suspect it's not really
15 a constant of nature. In France, they've
16 always called their candidate disposal sites
17 underground laboratories. And, there's a lot
18 to do there before they decide on which is
19 going to be the definitive disposal site.

20 But, what you do is to study
21 different packaging techniques. You study
22 the migrate of, of transuranics and fission

1 products under various conditions in the
2 shale, or whatever is the underground
3 environment. So, there are a lot of, lot to
4 do there and reprocessing doesn't really fit
5 very well.

6 Although, a disposal site should,
7 in my opinion, accept previously reprocessed
8 and packaged waste as well as direct
9 disposal of, of fuel rods, given appropriate
10 packaged, under appropriate IAEA regulation.
11 So, if somebody has already reprocessed, and
12 they have no place to put the stuff, then
13 commercial repositories ought to be open for
14 that, too, at an appropriate fee.

15 CHAIR DOMENICI: Thank you very
16 much. Let me, let me, I have a few questions
17 here, some observations that may be, we're
18 getting close to the end. First of all, I
19 want to apologize again for my voice, which
20 is separate and apart from, that's a problem
21 I discussed with you this morning.
22 Something's going on with my speaking and I

1 already know what it is, if you can believe
2 it, I have to exercise my vocal chords so
3 you can hear me out in the halls singing.

4 Except what I was singing is "A,
5 E, I, O, U", and then "Sunday, Monday,
6 Tuesday, Wednesday, Thursday, and Friday".
7 Sing those real hard. That's the exercise, I
8 have to do that, so you'll excuse me if you
9 hear that.

10 First, I want to say, for the
11 record and for these distinguished
12 witnesses, I was in the Senate with all
13 kinds of Senators from all over, for thirty
14 six years. I chaired some Committees here
15 and there, and did a few things.

16 But, I'll tell you, to assemble a
17 Committee like this, where the member who
18 has excused himself is a PhD, the man
19 sitting next to him is a PhD, the woman
20 sitting next to him is a PhD, the man
21 sitting next to the woman is a PhD, head of
22 a Department in California.

1 And the last time I studied math
2 or took anything in, in chemistry or math,
3 was a freshman in college, and then I taught
4 eighth grade math before I went to law
5 school. So, I'm, I'm the youngster in the
6 crowd that doesn't quite understand some of
7 these things that, especially Al speaks of.

8 He's so proficient in these
9 things. But I do want to tell you that I
10 don't, I don't agree with a lot of your
11 testimony. And I can't tell you, each one of
12 you, what I heard that I don't agree with,
13 but I disagree wholeheartedly with you that
14 the Americans, American people and the
15 Government of the United States should not
16 engage in activities that deal with energy,
17 because it might influence the world to do
18 likewise.

19 I just, in this case, I think
20 that's a lark. The Europeans and others are
21 hellbent to do reprocessing. And they
22 haven't asked us and they don't care what we

1 think, they think it's the greatest thing
2 they can do, and they're doing it in their
3 own interest.

4 And regardless of what you say,
5 Mister, Dr. James Acton, we have little
6 impact on them by doing it or not doing it.
7 And I question significantly your statement
8 that there were seventeen that wanted to and
9 it turned out six, only six did it after
10 they made a commitment.

11 And I'll bet you, if you remind
12 me to look that up, that that disparity in
13 number, that disparate number between the
14 two. There are many reasons they didn't do
15 it, it was clearly not just because America
16 chose not to.

17 Over here on this side, we hear
18 Gallucci, and the only thing about him that
19 I agree with is his is that we're both from
20 Italy. His folks must have been born there,
21 like mine. But other than that, has there
22 ever been a Democrat or Republican President

1 of the United States since we had the
2 nuclear weapon that ever wanted, that ever
3 chose anything other than we don't want
4 nuclear weapons in the hands of others?

5 Even though we have them, has
6 there ever been a President, we had them,
7 they didn't, and that's the way the world
8 was, and you tend to think that's wrong,
9 because America has something and, the, and
10 the other part of the world doesn't.

11 We did pretty well with our
12 stewardship of nuclear weapons and I think
13 the world still thinks we're pretty good
14 stewards of it, and they still would follow
15 us, and we still don't want anybody else to
16 have them, and they're getting them anyway.

17 So, those are the kind of side
18 issues that, Gallucci versus Domenici would
19 make a good movie. You could be anti-
20 America, and I could be pro-, for a change.
21 That's good. And I throw a good right hand,
22 all that's, I signed pro, even, I signed

1 with the Brooklyn Dodgers.

2 But anyway, let me proceed for a
3 minute. The charge to this Committee is--not
4 the Subcommittee, this Committee--is that
5 we're supposed to conduct a comprehensive
6 review of policies for managing the back end
7 of the nuclear fuel cycle, including all
8 alternatives for the storage, processing,
9 and disposal of civilian and defense used
10 nuclear fuel, high level waste, and
11 materials derived from them.

12 And then our co-Chairman has, for
13 this Subcommittee, pulled out what it is
14 now, it had nothing to do with most of what
15 you all were saying. It, this charge is,
16 should we do any of these things that I just
17 described regarding the tail end of the fuel
18 cycle.

19 You certainly, well, I'm not
20 advocating that we proceed with any kind of
21 dispatch to, to reprocess. I'm not doing
22 that. But certainly, we don't have to bend

1 over backwards to avoid the use of the word,
2 because, my God, it's the, that's what we're
3 supposed to do.

4 We're supposed to take a position
5 and tell the American people the if's,
6 and's, and don'ts about these things I just
7 read, which I think any reading of it would
8 include that you ought to look at these tail
9 end of the fuel cycle options that the
10 country has.

11 You ought to look at them and say
12 something about them. You know, I choose to
13 do that, and I don't choose in any respect
14 to figure out what I ought to do based upon
15 what the world might do or not do because
16 America is going to do something or not do
17 it.

18 That's not going to be part of my
19 thinking. I regret you have not convinced me
20 a bit on that. It may be the other things I
21 have heard that will convince me that we can
22 not proceed with reprocessing exploration at

1 this point. Maybe I will agree with that
2 pretty soon, if you come up with something
3 that we all can agree upon.

4 Now, having said that, I, I just
5 want to ask Mr. Gallucci, do you think that
6 a, not proving years ago, that the United
7 States of America in terms of reprocessing
8 and if we don't reprocess, what's going to
9 happen, what's going to happen good in the
10 world if we don't reprocess, could you
11 explain that to me one more time?

12 DR. GALLUCCI: Senator, I think if
13 we make a decision, we recommend as
14 America's position that we will not
15 reprocess, and that will mean that we will
16 not have separated plutonium in the United
17 States. It means that we will not be
18 fabricating mixed oxide fuel at maybe one or
19 more different facilities, away from
20 reprocessing plant, and we will not be
21 shipping it--

22 CHAIR DOMENICI: I want to know

1 what, I want to know what the world is going
2 to do, not us.

3 DR. GALLUCCI: I said, I'm talking
4 about the United States of America.

5 CHAIR DOMENICI: What?

6 DR. GALLUCCI: You asked me,
7 Senator, if I've got it straight, you want
8 to separate out what happens in the United
9 States.

10 CHAIR DOMENICI: No, sir. I said,
11 what does the world do that it would not do--
12 -

13 DR. GALLUCCI: Oh, so now you do
14 want to link, what, how do you think the
15 world will respond--

16 CHAIR DOMENICI: You, you had
17 already read it, at least I could say it
18 again.

19 DR. GALLUCCI: I see.

20 CHAIR DOMENICI: What you said,
21 you said, if we decided to do it, you were
22 going to follow suit. And if we didn't do

1 it, some would be more apt not to do it. I
2 don't agree with either statement.

3 DR. GALLUCCI: I understand. I, I,
4 Senator, I actually don't, don't know what
5 South Korea, Japan, Russia, how these
6 countries will respond if this Commission
7 recommends to the President and it becomes
8 U.S. policy that the United States is not
9 going to reprocess.

10 You may be right that these
11 countries march to their own drummer, and
12 they don't care one whit about what we do.
13 That's, that's possible. I don't know.

14 CHAIR DOMENICI: You won't even
15 make that probable?

16 DR. GALLUCCI: I beg your pardon?

17 CHAIR DOMENICI: You won't even
18 make that probable in today's market--

19 DR. GALLUCCI: No, no, I will make
20 it probable. I will say, I will say I don't
21 know. I mean, and there may be people who do
22 know. But I, I, for me, it would be the

1 wrong thing for the United States to do, for
2 the United States, and it's the wrong thing
3 for these countries to do, for the
4 international community.

5 I, I would, my objective here,
6 would have an outcome in which countries
7 decided for economic and security reasons
8 that thermal recycle was a bad idea. That's
9 the outcome I'd likely get to.

10 CHAIR DOMENICI: Let me, let me
11 just say so my fellow commissioners won't,
12 because they don't know me, and you don't
13 know me either, but I don't have to work
14 with any of you anymore, but I do with these
15 people, so I, I have to make a statement so
16 they'll know who I am.

17 First of all, if you want to look
18 up the record on terms of non-proliferation,
19 you might find that the Senator who did more
20 for non-proliferation next to Sam Nunn, and
21 he was my buddy, next to me, is this fellow.
22 I went into a Subcommittee one afternoon

1 with a piece of paper that was an Amendment,
2 and I got 535 million dollars appropriated
3 and got it back from the Subcommittee.

4 You know what it was for? It was
5 to buy plutonium that the Russians had
6 stored and wanted money for, and to buy
7 highly enriched uranium, money for
8 reprocessing into weapons. We still are
9 using the electric lights work, in America,
10 ten percent of the electricity comes from
11 the highly enriched uranium that was
12 purchased with that money.

13 Russia wanted dollars, and they
14 don't like it now, but they're still
15 delivering that highly enriched uranium on
16 boats. It comes over here and it gets mixed
17 and it turns out being feed stock for the
18 nuclear power plants.

19 The plutonium, for the united
20 states, I would like to tell you ended up
21 with us building a MOX plant as a result. I
22 know you don't like that, but it did. And

1 the Russians were supposed to get rid of
2 thirty-eight tons of plutonium. They haven't
3 done those yet, they've got it buried in a
4 mountain.

5 But it's, it's been fused so they
6 can't be used in the bombs, you know what
7 they did to it, you all know that, it, it
8 changed, they had, turned it around, can't
9 be used. So, I'm not, I'm not anti-these
10 things, I'm pro.

11 It's just that, you got to know,
12 I don't believe any of you that testified,
13 that America shouldn't do this because if
14 we're good boys, we're good boys if we don't
15 and the world will follow us. I don't
16 believe, and that colors my belief in the
17 rest of your testimony.

18 That at your mature ages, you
19 would be that naive really bothers me.
20 Unless you were to tell me you were that
21 naive since you were twenty-one, and I'd say
22 you'd been naive right to the bone. It's

1 been acquired in college and I, I, don't
2 know whether I forgive you or not.

3 But naivete creates what you all
4 say, with reference to these things, so.
5 It's hard to believe that, substantively,
6 and in particular, Mr. Acton, I think you're
7 far too positive about the reaction that we
8 get in the world. It almost makes it feel
9 like, like you, you don't know what you're
10 talking about.

11 But I, since you want me to be
12 honest with you, because I, I did take this
13 kind of with testimony for thirty six years,
14 and I sometimes got off base like I am
15 today. And most of the time I didn't. But
16 anyway, I'm the co-Chair, and that means
17 that the meetings are not over until I've
18 had a word.

19 Dr. Garwin would like to burn me
20 instead--

21 DR. GARWIN: I would like to point
22 out that I have always objected to

1 reprocessing by the U.S. for the reason that
2 we would be a hundred billion or two hundred
3 billion poorer if we did it, and that's the
4 reason--

5 CHAIR DOMENICI: I praise you, I
6 praise you for that.

7 DR. GARWIN: --not, not to do it.

8 CHAIR DOMENICI: I praise you for
9 that.

10 DR. GARWIN: Thank you. But I
11 think that if we did it for some other
12 reason, in order to be a leader in nuclear
13 energy or whatever, then surely reprocessing
14 fans elsewhere would take that to mean that
15 the United States sees benefit in
16 reprocessing and they would do it to.

17 And I don't know anybody who says
18 that other people reprocessing is good for
19 us, so, whether or not we have a big
20 influence on them, we ought to do what's
21 right for ourselves and try to encourage
22 them to do what's right for themselves.

1 In my testimony, I take really
2 quite a skeptical view of this rational
3 approach. I say, you know, so much of so
4 called economic activity is stealing from
5 one another.

6 So, it's really hard to believe
7 that we are in our system going to be able,
8 you know, with all the lobbyists and
9 advertising, to make correct decisions. But
10 at least we can lay it out and try to make
11 the right decisions and go down fighting if
12 necessary.

13 CHAIR DOMENICI: Well, we can make
14 the right decisions, we've made some in the
15 Congress, at least, in spite of the mess
16 we're in, we've made some. We've had two
17 balanced budgets, if you go look at that, I
18 was the sponsor who worked on that all alone
19 as the Senator, done in a little back room.

20 We had a Democrat President and
21 two Republicans, and we did that, so it's
22 not, it's not like we don't, don't do those

1 kind of things. I just wanted you all to
2 know how, an opinion of the comment you made
3 to me effects the rest of your testimony. I
4 just wanted to make sure you all knew that.

5 And I think with that, as one of
6 the co-Chairs, and the time is up, I thank
7 the witnesses profusely for their terrific
8 testimony. It was well received by others.
9 Thank you.

10 CHAIR PETERSON: I have been--I
11 have been asked that we have a short break
12 and then we will return in just five minutes
13 to, to move to, we have, basically we have
14 public, statements from the public at this
15 point.

16 MR. FRAZIER: There aren't any.

17 CHAIR PETERSON: There aren't any?
18 Okay. So, then--so then--okay. Thank you
19 very much. At this point, we can finish up.
20 We're closed. Thank you very much.

21 (Whereupon, the above-entitled
22 matter went off the record at 3:12 p.m.)

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