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CHARTING THE COURSE FOR AMERICAN NUCLEAR TECHNOLOGY: EVALUATING THE DEPARTMENT OF ENERGY'S NUCLEAR ENERGY RESEARCH AND DEVELOPMENT ROADMAP

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

MAY 19, 2010

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May 19, 2010

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CHARTING THE COURSE FOR AMERICAN NUCLEAR TECHNOLOGY: EVALUATING THE DEPARTMENT OF ENERGY'S NUCLEAR ENERGY RESEARCH AND DEVELOPMENT ROADMAP

WEDNESDAY, MAY 19, 2010

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Committee met, pursuant to call, at 10:02 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

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U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

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Committee on Science and Technology
Hearing on

Charting the Course for American Nuclear Technology: Evaluating the Department of Energy's Nuclear Energy Research and Development Roadmap

Wednesday, May 19, 2010
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Witness List

Panel I

Dr. Warren P. Miller
Assistant Secretary
Office of Nuclear Energy
U.S. Department of Energy

Panel II

Mr. Christofer Mowry
President and CEO
Babcock & Wilcox Nuclear Energy, Inc.

Dr. Charles Ferguson
President
Federation of American Scientists

Dr. Mark Peters
Deputy Director for Programs
Argonne National Lab

Mr. Gary M. Krellenstein
Managing Director
Tax Exempt Capital Markets
JP Morgan Chase & Co.

Dr. Thomas L. Sanders
President
American Nuclear Society

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Charting the Course for American Nuclear Technology: Evaluating the Department of Energy's Nuclear Energy Research and Development Roadmap

WEDNESDAY, MAY 19, 2010
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Wednesday, May 19th, 2010 the House Committee on Science & Technology will hold a hearing entitled: "*Charting the Course for American Nuclear Technology: Evaluating the Department of Energy's Nuclear Energy Research and Development Roadmap*."

The Committee's hearing will explore the Administration's strategy for research and development to advance clean and affordable nuclear technology. Amongst the issues to be considered will be how the Federal Government will enhance the safety and economic viability of nuclear power and what programs it recommends for managing nuclear waste, advancing reactor design, sustaining the existing nuclear fleet, and minimizing risk of proliferation of nuclear materials.

Witnesses

Panel I

- **Dr. Warren P. Miller is the Assistant Secretary for the Office of Nuclear Energy at the U.S. Department of Energy**. Dr. Miller will testify on the Department of Energy's recently released *Nuclear Energy Research and Development Roadmap* and provide additional guidance on the Office of Nuclear Energy's technology and innovation initiatives.

Panel II

- **Mr. Christofer Mowry is the President and CEO of Babcock & Wilcox Nuclear Energy, Inc**. Mr. Mowry will testify on Small Modular Reactors and provide an overview of B&W's reactor operations. He will provide information on the role Small Modular Reactors can play in reducing capital costs and improving the safety of nuclear power. Mr. Mowry will also comment on DOE's *Nuclear Energy Research and Development Roadmap*.
- **Dr. Charles Ferguson is the President of the Federation of American Scientists**. The Federation of American Scientists (FAS) is a public policy think-tank that was originally founded by scientists from the Manhattan Project. Currently FAS is conducting a project titled the *Future of Nuclear Energy in the United States* to explore and analyze the direction of nuclear energy technology innovation. Dr. Ferguson will provide an overall analysis and critique of the *Nuclear Energy Research and Development Roadmap* and Small Modular Reactor technology.
- **Dr. Mark Peters is the Deputy Director for Programs at Argonne National Lab**. Dr. Peters will testify on the *Nuclear Energy Research and Development Roadmap* with particular attention to the Administration's strategy for waste management technology. He will also present a summary of new waste management technologies currently under development at Argonne National Lab.
- **Mr. Gary M. Krellenstein is a Managing Director in JPMorgan's Energy and Environmental Group and is a former nuclear engineer at the Department of Energy and Nuclear Regulatory Commission**. Mr.

Krellenstein's areas of focus are municipal utilities, Rural Electric Cooperatives, alternative energy technologies and project financing, and is also involved in JPMorgan's "carbon" policies. Mr. Krellenstein will testify on private capital interest in nuclear power including how Small Modular Reactors and other new technologies may attract private capital investment.

- **Dr. Thomas L. Sanders is the President of American Nuclear Society**. The American Nuclear Society is a nuclear professional society dedicated to promoting the awareness and understanding of the application of nuclear science and technology. Dr. Sanders will provide an overall evaluation of the *Nuclear Energy Research and Development Roadmap* and provide recommendations of policy areas to more fully develop or explore.

Background

According to the Department of Energy's Energy Information Agency (EIA), the nation's 104 commercial nuclear reactors currently provide 70 percent of the emissions-free energy in the United States and approximately 20 percent of the country's electricity generation. However, nuclear power as it exists today relies on a "once-through" fuel cycle that produces high level radioactive waste from enriched uranium. In the United States there exists a stockpile of approximately 63,000 metric tons of nuclear waste from reactors and generates roughly 2,000 more tons per year. Furthermore, the capital costs of nuclear plants have risen steeply and present a high hurdle to deployment of new reactors. Some have argued that without a fully developed strategy to deal with these challenges, nuclear power will be unable to compete with other fuel sources.

The Obama Administration recently proposed a substantial modification of Federal nuclear energy policy which may have widespread implications for the nation's energy portfolio and for the focus of the Department of Energy's nuclear energy research, development, demonstration and commercial application initiatives. The *Waste Policy Act of 1982* requires the Federal Government to construct a nuclear waste repository, and Yucca Mountain was later designated as the site for a permanent waste repository in 1987. However, in its Fiscal Year 2011 budget request, the Administration proposes to terminate funding for Yucca Mountain. To address the growing backlog of nuclear waste and the environmental concerns surrounding this issue, the President convened the bipartisan Blue Ribbon Commission on America's Nuclear Future. This Commission shall evaluate the best path forward for managing nuclear waste. Also reflected in the Fiscal Year 2011 budget request is a reorganization of the Office of Nuclear Energy to account for the cancellation of the Yucca project and a priority shift towards a "goal-oriented, science-based approach" that will include a larger focus on research & development in addressing post-generation nuclear waste. Furthermore, the Administration proposes to increase loan guarantees for nuclear power by $36 billion. This is intended to provide funding guarantees for construction of at least six new nuclear plants and will likely result in development of the first new U.S. commercial reactor in decades.

The Administration's Roadmap

On April 15, 2010 the Department of Energy (DOE) published the *Nuclear Energy Research and Development Roadmap* (Roadmap) with the goal of providing a guide to the Office of Nuclear Energy's internal programmatic and strategic planning going forward. The report lays out four objectives: 1) establish solutions that can improve reliability and safety of the current fleet of reactors and extend their life; 2) advance reactor technology to both improve affordability and performance; 3) develop sustainable nuclear fuel cycles; and 4) understand and minimize the risks of proliferation and terrorism.

Objective 1: Safety and Life Extension

While nuclear power today accounts for twenty percent of all electricity consumed in the United States, the plants supplying that energy are nearing retirement age. By 2035 most of the 104 operating reactors will have surpassed their 60 year life expectancy. Should new nuclear plants not be constructed in the interim, it is possible that retiring nuclear plants will be replaced by fossil fuel generation in order to meet rising demand. The Roadmap outlines a list of research initiatives that will explore how to extend reactor life and how to increase their safety and efficiency.

Objective 2: Improve Reactor Technology and Reduce Costs

According to Moody's Investors Service, the current cost to construct a nuclear power plant is around $5000 to $7000 per kWe of capacity in comparison to the $1625 per kWe for a traditional pulverized coal plant. The Roadmap highlights a series of programs to reduce the capital cost of nuclear and create advanced, clean reactors. Among DOE's priorities is the creation of a dedicated Small Modular Reactor (SMR) program. SMRs by definition are smaller than conventional reactors, which can be as large as approximately 1500 mWe. Furthermore, certain SMR designs allow for in tandem or "stackable" use of multiple units to achieve large generation capacity. As envisioned by SMR supporters, this technology should reduce capital costs related to nuclear deployment as well as increase overall safety of nuclear generation. What is unclear is if the private capital and finance community will embrace SMRs as a worthwhile and acceptable risk investment.

Objective 3: Sustainable Nuclear Fuel Cycles

In the Roadmap, DOE provides a broad outline of its strategy for nuclear waste management which focuses largely on the development of a suite of options that future decision makers may pursue. This approach reflects the uncertainty created by the pending Blue Ribbon Commission decision and its two year investigation. Until its resolution the Department will endeavor to establish the programs that will serve as the basis to implement the Commission's recommendations. The Roadmap provides three potential strategies for waste management: 1) advanced once-through; 2) modified-open; and 3) full recycle. Advanced once-through cycle is similar in process to the fuel cycle used by commercial nuclear power today, but will develop fuels for use in current reactors that will increase efficiency and reduce waste output. A modified open cycle would use innovative fuel-forms and advanced reactors to increase the use of the energy content of fuel and reduce waste output. This approach would also employ some technologies to separate waste products from reusable isotopes. A full recycle approach endeavors to create a cost-effective and low proliferation risk process of repeatedly cycling fuel waste products to reduce radioactivity and decay heat and increase total energy consumption. All approaches will require some degree of waste storage.

Objective 4: Understanding and Addressing Proliferation

To address the concern that civilian nuclear power resources could be used by foreign entities for weapons applications, DOE recommends a strategy to better account for and understand proliferation risks. The Roadmap advises that any technology innovation and development program must be informed by development of more advanced risk assessment tools to limit, mitigate and manage the risks of nation-state proliferation and lead to innovation of next generation physical security technologies.

Conclusion

The Obama Administration's Roadmap is intended to demonstrate its commitment to encouraging wider use of current nuclear energy and to innovation of advanced nuclear technology. Specifically through Federal research and development, the Administration seeks to address the widely known risks and concerns that have hampered the industry since its inception, including waste management, capital cost reduction, and proliferation security.

Chairman GORDON. Good morning, and welcome to today's hearing to review the Department of Energy's recently published *Nuclear Energy Research and Development Roadmap*. I look forward to learning from the witnesses how this policy framework will shape Federal R,D&D policy for nuclear technologies.

I would like to welcome our expert panelists, who will discuss and evaluate the four main objectives highlighted in the Roadmap and help us to understand how innovation and nuclear energy can affect our national energy portfolio, our economic competitiveness, and our national security.

As I have said before, I am a supporter of nuclear power, as I believe it is a part of the solution to challenges of our energy independence and climate change. Our 104 commercial reactors today produce 20 percent of our electricity and 70 percent of our emissions-free energy.

However, the decision by the Administration to cancel funding for the Yucca Mountain Repository has served to highlight a continuing question with nuclear power. How can we best manage the waste?

Furthermore, as capital costs continue to rise for construction of new plants, the future of the U.S. domestic industry, that in the 1970s seemed so promising, now appears wholly dependent on loan guarantees, subsidies, and is losing pace to foreign powers pursuing advanced nuclear technology.

The Roadmap at issue or the roadmap at issue in today's hearing proposes solutions to these and other problems affecting the nuclear power. It outlines four R&D objections.

First, to establish solutions that can improve reliability and safety for the current fleet of reactors and extend their life expectancy, second, advance reactor technology to both improve affordability and performance, third, develop sustainable and efficient nuclear fuel cycles, and fourth, understand and minimize the risk of proliferation and terrorism.

This hearing is a continuation in a series of discussions on nuclear power that will culminate in the Committee moving R&D legislation later this year. I am hopeful that today's panelists will shed some light on the past—best path forward for our research and development and strategy, and I want to, again, thank these very talented, multiple panels for being here today.

Let me also give a quick apology. I am going to have to watch part of this on our award-winning website later on this afternoon. We have a suspension bill that is on the floor now. I need to go attend to that, and for my Republican Members that are here, it is the *America COMPETES Act* that we are bringing up on suspension. I got the message, and it is being reduced from a five-year to a three-year authorization. The funding authorization will also be reduced by 50 percent from what we voted for.

So we have done that, and you will be pleased to know that those individuals that are watching pornography on Federal systems will be punished and that no child molesters will be eligible for any of these fundings. So hopefully we have covered the concerns.

And so I am going to yield to my friend from California, Mr. Rohrabacher. I used to be his Ranking Member when he chaired and I was the Ranking Member of the Space and Aeronautics subcommittee, and he was a chairman that dealt with me very fairly. And I will ask Subcommittee Chairman Baird to take over. I hope to be back with you later.

Please, witnesses, this is a very important issue. There is a lot going on this morning, and so the lack of attendance here and certainly my temporary lapse does not diminish the importance of this issue. Our staffs are here, this is going to be part of our record, and your testimony will play an important role in developing the basis for what I hope will be a really excellent R&D authorization that we will be able to get into law this year. Thank you.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

Good morning and welcome to today's hearing to review the Department of Energy's recently published "Nuclear Energy Research and Development Roadmap." I look forward to learning from the witnesses how this policy framework will shape Federal RD&D programs for nuclear technologies.

I would like to welcome our expert panelists who will discuss and evaluate the four main objectives highlighted in the Roadmap and help us understand how innovation in nuclear energy can affect our national energy portfolio, our economic competitiveness, and our national security.

As I have said before, I am supportive of nuclear power as I believe it is a part of the solution to the challenges of energy independence and climate change. Our 104 commercial reactors today produce 20 percent of our electricity and 70 percent of our emissions free energy and have run with a strong record of safety and operating efficiency.

However, the decision by the Administration to cancel funding for the Yucca Mountain repository has served to highlight a continuing question with nuclear power: how can we best manage the waste? Furthermore, as capital costs continue to rise for construction of new plants, the future of a U.S. domestic industry that in the 1970s seemed so promising, now appears wholly dependent on loan guarantees and subsidies, and is losing pace to foreign powers pursuing advanced nuclear technology.

The Roadmap at issue in today hearing proposes solutions to these and other problems affecting nuclear power. It outlines four R&D objectives. First, establish solutions that can improve reliability and safety of the current fleet of reactors and extend their life expectancy. Second, advance reactor technology to both improve affordability and performance. Third, develop sustainable and efficient nuclear fuel cycles. And fourth, understand and minimize the risks of proliferation and terrorism.

This hearing is a continuation in a series of discussions on nuclear power that will culminate in the Committee moving R&D legislation later this year. I am hopeful that today's panelists will shed some light on the best path forward for our research and development strategy and will highlight the challenges that must be addressed as we proceed towards once again becoming a global leader in nuclear energy.

Again, I would like to thank the witnesses for their participation today and I look forward to your testimony.

Chairman GORDON. And I recognize Mr. Rohrabacher.

Mr. ROHRABACHER. I thank you very much, Mr. Chairman. I would wish you good luck on the floor, but we will wait and see.

This following statement is a statement by Ranking Member Ralph Hall, who is also on the floor right now to be involved with the debate on the COMPETES Act. I will be adding a few thoughts of my own, but this is basically Chairman Hall's opening statement and also would like to welcome Mr. Baird to the Chairman's seat. On this issue I know that he can do a great job because he is very well known and respected for his understanding of this particular issue, as well as others I might add.

So Mr. Baird, thank you for holding this hearing, and thank you to our Chairman as well for holding this hearing today on nuclear energy R&D. After several decades of setbacks and inaction, a growing consensus is finally emerging in support of expanding the role of nuclear power in our Nation's energy portfolio. Electricity demand in the United States is expected to grow by 30 percent in the 25 years, and nuclear energy provides a safe, reliable, and cost-competitive source of base load power to meet this demand.

While much of the nuclear revival revolves and involves around licensing and building more reactors, using existing light-water reactor technology, there are a host of longer-term activities that must also be pursued.

First and foremost among those are dealing with the management of spent nuclear fuel, and number two, supporting R&D to facilitate advances and licensing of new reactor designs and to extend the life of the current reactors that we have in operation.

With respect to waste management, I have been very clear, and I am speaking for Congressman Hall now but also for myself, about my objections to the Administration's attempt to shut down the Yucca Mountain Project, particularly given the cancellation was done without serious consideration of alternative options. You might say this—well, I will have my own comment later.

The Federal Government is legally obligated to deal with this waste, and the current absence of a path forward threatens to jeopardize growing public support for expanding nuclear power while increasing taxpayer liabilities. This needs to be addressed as soon as possible.

With respect to research and development, there are numerous advanced nuclear designs and technologies that hold promise to address the longer-term cost, safety, and security challenges facing the nuclear industry, and the Administration's R&D roadmap provides a useful outline of Federal efforts in this area.

I support strengthening this R&D effort, and I am particularly interested in the potential of small modular reactors that are a focus of this hearing. I look forward—and this is Ranking Member Hall, I look forward to working with the Chairman, Mr. Gordon, as we consider crafting nuclear energy R&D legislation later this year, and I thank him for assembling this excellent panel of witnesses today. That is the statement from Mr. Hall.

I would add a few thoughts of my own, and that is I believe that it has been an historic disservice to the American people that we have not used nuclear energy to the degree that we could have in these last few decades to provide the energy for the American people. By eliminating, by not moving forward on nuclear energy we have spent perhaps a trillion dollars overseas for oil and other energy sources that didn't need to be spent, and when one looks at the serious nature of our economy today, I think we can trace it back to this type of non-sensical policymaking in Washington. And let us remember that this is a result of a scare tactic that happened after Three Mile Island that frightened the American people away from this incredibly positive alternative that we had to sending all of our money overseas, and also it was not only—not only was it economically important to do that but it was also environmentally important.

So I would like to make sure I am on the record as saying that, and also when we talk about Yucca Mountain and this type of activity, we have to be responsible rather than just do things by impulse. It appears to me, and it will be interesting to hear what our witnesses have to say, that Yucca Mountain, the closure of Yucca Mountain was on par with the closing of Guantanamo. No alternative, not well thought out, and perhaps with some consequences that were very negative in the long run.

And finally, Mr. Hall, Ranking Member Hall, talked about the small modular nuclear plants. I would like to—I am anxious to hear from the witnesses what they have to say about the roadmap in the future; whether we are going to be relying on old technology. I mean, these water-cooled reactors seem to me to be things that are 50 years old, and I want to know why it is new technology even when especially we have alternatives like the gas turbine modular helium reactor, which—and the gas cool reactors, which do not rely on water, that are available to us today as an alternative. So I will be looking forward to hearing the witnesses who are going to give us their expert opinion, and thank you, Mr. Baird.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Mr. Chairman, thank you for holding this hearing today on nuclear energy R&D.

After several decades of setbacks and inaction, a growing consensus is finally building in support of expanding the role of nuclear power in our Nation's energy portfolio. Electricity demand in the U.S. is expected to grow by 30 percent in the next 25 years, and nuclear energy provides a safe, reliable, and cost-competitive source of baseload power to meet this demand.

While much of the "nuclear revival" involves licensing and building more reactors using existing light water reactor technology, there are a host of longer-term activities that must also be pursued. First and foremost among these are (1) dealing with the management of spent nuclear fuel, and (2) supporting R&D to facilitate advances and licensing of new reactor designs and to extend the life of the existing reactor fleet.

With respect to waste management, I have been very clear about my objections to the Administration's attempts to shut down the Yucca Mountain Project, particularly given that the cancellation was done without serious consideration of alternative options. The Federal Government is legally obligated to deal with this waste, and the current absence of a path forward threatens to jeopardize growing public support for expanding nuclear power while increasing taxpayer liabilities. This needs to be addressed as soon as possible.

With respect to research and development, there are numerous advanced nuclear designs and technologies that hold promise to address the longer-term cost, safety, and security challenges facing the nuclear industry, and the Administration's R&D Roadmap provides a useful outline of Federal efforts in this area. I support strengthening this R&D effort,

and am particularly interested in advancing the potential of small, modular reactors that are a focus of this hearing.

I look forward to working with the Chairman as we consider crafting nuclear energy R&D legislation later this year, and I thank him for assembling an excellent panel of witnesses today.

I yield back the balance of my time.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Thank you, Mr. Chairman, for holding today's hearing to assess the Department of Energy (DOE) Nuclear Energy Research and Development (R&D) Roadmap and the future of nuclear energy in the United States.

Since coming to Congress, I have supported a sustainable energy policy that will provide American homes and businesses the power they need and reduce our dependence on foreign oil. Nuclear energy, which currently provides 20% of U.S. power and 49% of Illinois' power, will play a role in this policy as a domestic, clean energy source. However, DOE must first overcome a variety of R&D, safety, and investment barriers before nuclear plays a central role in our energy policy.

President Obama's Fiscal Year 2011 budget requests $503 million for the Office of Nuclear Energy (NE), an increase of $37 million over FY 10. This increased funding, in addition to $54.5 billion in loan guarantees for the construction of new reactors, demonstrates the administration's support for the expansion of nuclear power. However, the administration decided to eliminate funding for the Yucca Mountain nuclear waste storage facility while expanding R&D, leaving the U.S. without a central depository for nuclear waste. I would like to hear from our witnesses what steps are being taken to store nuclear waste now and what proposals are being considered for adapting our storage capability as more reactors come online.

In addition, DOE's Nuclear Energy R&D Roadmap identifies roadblocks to an expansion of nuclear energy and develop means of overcoming them. I would like to hear from our witnesses what the timeline is for achieving these objectives and what role they see Congress playing in achieving those goals.

If DOE achieves the objectives outlined in their roadmap, they may still face public opposition to the use of nuclear energy and, as we saw with Yucca Mountain, the storage of waste. I am interested if DOE or our witnesses have plans for overcoming this opposition and increasing the public's awareness and acceptance of nuclear energy.

I welcome our witnesses, and I look forward to their testimony. Thank you, Mr. Chairman.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Thank you, Mr. Chairman.

I strongly believe that we must refocus our energy priorities to the production of alternative sources of energy, like solar power, that will not be harmful to our environment.

Nuclear power generation also has the potential of generating electricity without increasing greenhouse gas emissions.

Nuclear power is a critical electricity source in Arizona where we have the largest nuclear generation facility in the nation, the Palo Verde Nuclear Generating Station.

Today we will discuss the Administration's strategy for research and development to advance clean and affordable nuclear technology.

According to the Nuclear Regulatory Commission, there are commercial nuclear power reactors licensed to operate in 31 states. These reactors provide approximately 20 percent of our nation's electricity supply. Furthermore, according to the Department of Energy's Energy Information Agency (EIA) commercial nuclear reactors provide approximately 70 percent of the emissions-free energy in the U.S.

However, as these nuclear power reactors continue to operate, spent nuclear fuel continues to accumulate without a clear strategy of how to store this waste.

I look forward to hearing more from our witnesses on strategies for managing nuclear waste as well as how to enhance the safety and economic viability of nuclear power.

At this time, I yield back.

Mr. BAIRD. [Presiding] Thank you, Mr. Rohrabacher. I don't know if you have heard the rumor, but my understanding is they are moving the prisoners from Guantanamo into Yucca Mountain. So we are going to kill two birds with one stone.

At this point I recognize Mr. Luján, who will introduce our first witness.

Panel I:

Mr. LUJÁN. Thank you very much, Mr. Chairman. It is my honor today to introduce Dr. Miller, who spent many years working in the district that I represent. A native of Chicago, Dr. Miller is a graduate of the U.S. Military Academy. He served in Vietnam, where he earned a U.S. Army Bronze Star, an accommodation medal. After his military service he received a Ph.D. in nuclear engineering from Northwestern University. After two years as a professor there, he began his career at Los Alamos National Laboratory in my district within New Mexico.

Over the course of his 27-year career at Los Alamos, Dr. Miller held a variety of leadership positions, including Associate Laboratory Director for Energy Programs, as well as for Physics and Mathematics, where he supervised the work of over 2,000 scientists. Following his tenure at Los Alamos, Dr. Miller was a research professor in the Department of Nuclear Engineering and Associate Director of the Nuclear Security Science and Policy Institute at Texas A&M University. He was elected as a fellow of the American Nuclear Society in 1982, and to membership in the National Academy of Engineering in 1986.

Dr. Miller was nominated by President Barack Obama as the Assistant Secretary for Nuclear Energy in June of 2009, and confirmed by the Senate in August. As Assistant Secretary, Dr. Miller is responsible for all programs and activities of the Office of Nuclear Energy.

Today he is here to discuss with us the DOE's Nuclear Energy R&D Roadmap. Thank you, Dr. Miller, for being here, and I look forward to your testimony.

Thank you, again, Mr. Chairman.

Mr. BAIRD. Thank you, Mr. Luján. You have been a staunch, strong and effective advocate on behalf of Los Alamos and the labs there.

Dr. Miller, we appreciate your presence and your service. It turns out my father actually went to Los Alamos Boys' School, and before he could graduate the government came in and said, kids, you are going to have to leave, we have got something else to do here. And so I know that beautiful country, and I appreciate your work.

As you know, we have five minutes for your oral testimony. Your written testimony will be entered into the record as well, and that will be followed by questions. So thank you for your distinguished service and your presence today, and please begin.

STATEMENTS OF WARREN P. MILLER, ASSISTANT SECRETARY, OFFICE OF NUCLEAR ENERGY, U.S. DEPARTMENT OF ENERGY

Dr. MILLER. Thank you very much. Thank you for the introduction, Congressman Luján, and I do miss the Land of Enchantment, so say hello when you are back there.

Chairman Baird, Ranking Member Rohrabacher, Members of the Committee, it is a pleasure to appear before you today to discuss the Office of Nuclear Energy's recently-released Nuclear Energy R&D Roadmap. Input from national laboratories, universities, and industry were used to develop this document, which we intend to guide the Department of Energy's nuclear energy activities in both the near term and the long term.

Identifying the nuclear energy needs of the Nation and the appropriate roles for the Department of Energy, we developed four R&D objectives to guide our activities. One, develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of the current fleet of reactors.

Two, develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Nation's energy security and climate change goals. Three, develop sustainable nuclear fuel cycles, and four understand and minimize the risks of nuclear proliferation and terrorism.

In my written testimony I have described each of these R&D objectives in greater detail. Given my limited time this morning, I would like to focus on two new programs that we are proposing and their relation to the Roadmap; the Small Modular Reactor Program and the Modified Open Cycle Program.

In the past few years there has been great interest in smaller modular reactors for several reasons. To identify just one, their lower capital costs makes them potentially attractive to smaller entities that have difficulty financing the larger reactors. Capacity could be added at a site unit by unit, allowing the income from early deployed units to help finance subsequent additions.

For fiscal year 2011, we have proposed a new multiple year Small Modular Reactor Program that would include a cost-shared program element intended to accelerate the availability of SMRs. We intend to accomplish this by cost sharing design certifications for up to two LWR-based SMR designs. This directly supports our R&D objective number two, which is to improve the affordability of new reactors.

We are holding a workshop on June 29 and 30, 2010, to inform stakeholders on the status of planning for this SMR Program and to engage the civil nuclear energy community in open discussions. What we hear from industry, academia, and the national labs will help us in developing criteria for program implementation.

As I mentioned earlier R&D objective number three is to enable sustainable fuel cycles, which are defined to be those that improve uranium resource utilization, minimize waste generation, improve safety, and limit proliferation risks. The United States currently operates on a once-through strategy where used nuclear fuel is not recycled after leaving the reactors. There is still research to be done on the once-through cycle to improve the efficient use of uranium resources and reduce the amount of used fuel produced, and we are pursuing this work.

At the opposite end of the spectrum from once-through is the so-called "full recycle" or "closed-cycle" option, where the long-lived actinide elements in the used fuel would be repeatedly recycled. The intent is to dramatically increase uranium utilization to virtually 100 percent and greatly decrease the remaining long-lived radioactive waste burden.

The federal government has pursued research in this direction in the past, and we will continue to do so. I think it is important to emphasize, however, that there is a whole range of potential options in between once-through and full recycle, and it is too early to settle on the optimum choice for the United States to pursue.

Since dry-cask storage of used fuel has been deemed to be safe and secure for many decades, there is no need to rush the commercial scale deployment, and we have time to understand the options. In order to fully explore the options in between once-through and full recycle, we have proposed a new R&D program called Modified Open Cycle. The research under this program will give future decision makers a full suite of options to select from when deciding the country's fuel cycle.

Our research could yield game-changing approaches that will let us optimize reprocessing technologies in terms of resource utilization, proliferation resistance, waste management, and costs.

For reasons of time I have singled out only two programs from our roadmap, but there are many other elements that together form a balanced R&D suite. Each research activity supports at least one R&D objective from the Roadmap. Both the strategic thinking in the Roadmap and the R&D programs we have proposed will guide the Office of Nuclear Energy for many years to come. They will help ensure that nuclear power remains a vital component of America's energy future.

Thank you, Mr. Chairman, and I am pleased to take any questions.

[The prepared statement of Dr. Miller follows:]

PREPARED STATEMENT OF WARREN F. MILLER, JR.

Chairman Gordon, Ranking Member Hall, and Members of the Committee, thank you for the opportunity to appear before you today to discuss the Office of Nuclear Energy's R&D Roadmap. We have been working hard for a long time to produce a document that will guide the Department of Energy's nuclear energy activities for many years to come, and I think the resulting plan meets that criterion.

Nuclear energy is a key component of a portfolio of technologies that can be used to help meet the nation's goals of energy security and greenhouse gas reductions. This roadmap will guide research, development, and demonstration activities to help ensure that nuclear energy remains a viable option for the United States.

Our planning for developing the FY 2012 budget request will be informed by this report, and our proposed FY 2011 budget for the Office of Nuclear Energy is also consistent with the R&D objectives outlined in this roadmap. Earlier in the development process, we had been calling the objectives "imperatives", and in my December 15 testimony to the Senate Energy and Natural Resources Committee, I described five of them. We have since merged two of those areas of R&D into one (R&D Objective 2).

There are several challenges to the increased use of nuclear energy:

- The capital cost of new large plants is high and can challenge the ability of electric utilities to deploy new nuclear power plants.
- The exemplary safety performance of the U.S. nuclear industry over the past thirty years must be maintained by an expanding reactor fleet.
- There is currently no integrated and permanent solution to high-level nuclear waste management.
- International expansion of the use of nuclear energy raises concerns about the proliferation of nuclear weapons stemming from potential access to special nuclear materials and technologies.

The four R&D objectives outlined in the roadmap will address these challenges.

R&D OBJECTIVE 1: Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors

The existing U.S. nuclear fleet has a remarkable safety and performance record, and today these reactors account for 70 percent of the low greenhouse gas (GHG)-emitting domestic electricity production. Extending the operating lifetimes of current plants beyond sixty years and, where possible, making further improvements in their productivity will generate near-term benefits. Industry has a significant financial incentive to extend the life of existing plants, and as such, R&D activities related to life extension of nuclear facilities will be cost shared. Federal R&D investments are appropriate to answer fundamental scientific questions and, where private investment is insufficient, to help make progress on broadly applicable technology issues that can generate public benefits. The DOE role in this R&D objective is to work in conjunction with industry and where appropriate the Nuclear Regulatory Commission (NRC) to support and conduct the long-term research needed to inform major component refurbishment and replacement strategies, performance enhancements, plant license extensions, and age-related regulatory oversight decisions. DOE will focus on aging phenomena and issues that require long-term research and are common to multiple reactor types.

R&D OBJECTIVE 2: Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals

If nuclear energy is to be a strong component of the nation's future energy portfolio, barriers to the deployment of new nuclear plants must be overcome. Impediments to new plant deployment, even for those designs based on familiar light-water reactor (LWR) technology, include the substantial capital cost of new plants and the uncertainties in the time required to license and construct those plants. Although subject to their own barriers for deployment, more advanced plant designs, such as small modular reactors (SMRs) and high-temperature reactors (HTRs), have characteristics that could make them more desirable than today's technology. SMRs, for example, have the potential to achieve lower proliferation risks and more simplified construction than other designs. The development of next-generation reactors could present lower capital costs and improved efficiencies. These reactors may be based upon new designs that take advantage of the advances in high performance computing while leveraging capabilities afforded by improved structural materials. Industry plays a substantial role in overcoming the barriers in this area. DOE provides support through R&D ranging from fundamental nuclear phenomena to the development of advanced fuels that could improve the economic and safety performance of these advanced reactors. Nuclear power can help reduce GHG emissions from electricity production and possibly in co-generation by displacing fossil fuels in the generation of process heat for applications including refining and the production of fertilizers and other chemical products.

R&D OBJECTIVE 3: Develop Sustainable Nuclear Fuel Cycles

Sustainable fuel cycle options are those that improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and limit proliferation risk. The key challenge is to develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors. The Administration has established the Blue Ribbon Commission on America's Nuclear Future to inform this waste-management decision-making process. DOE will conduct R&D in this area to investigate technical challenges involved with three potential strategies for used fuel management:

- *Once-Through*—Develop fuels for use in reactors that would increase the efficient use of uranium resources and reduce the amount of used fuel requiring direct disposal for each megawatt-hour (MWh) of electricity produced. Additionally, evaluate the inclusion of non-uranium materials (e.g., thorium) as reactor fuel options that may reduce the long-lived radiotoxic elements in the used fuel that would go into a repository.
- *Modified Open Cycle*—Investigate fuel forms and reactors that would increase fuel resource utilization and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per MWh), with limited separations steps using technologies that substantially lower proliferation risk.
- *Full Recycling*—Develop techniques that will enable the long-lived actinide elements to be repeatedly recycled rather than disposed. The ultimate goal is to develop a cost-effective and low proliferation risk approach that would dramatically decrease the long-term danger posed by the waste, reducing uncertainties associated with its disposal.

DOE will work to develop the best approaches within each of these tracks to inform waste management strategies and decision making.

R&D OBJECTIVE 4: Understand and minimize the risks of nuclear proliferation and terrorism

It is important to assure that the benefits of nuclear power can be obtained in a manner that limits nuclear proliferation and security risks. These risks include the related but distinctly separate possibilities that nations may attempt to use nuclear technologies in pursuit of a nuclear weapon and that terrorists might seek to steal material that could be used in a nuclear explosive device. Addressing these concerns requires an integrated approach that incorporates the simultaneous development of nuclear technologies, including safeguards and security technologies and systems, and the maintenance and strengthening of non-proliferation frameworks and protocols. Technological advances can only provide part of an effective response to proliferation risks, as institutional measures such as export controls and safeguards are also essential to addressing proliferation concerns. These activities must be informed by robust assessments developed for understanding, limiting, and managing the risks of nation-state proliferation and physical security for nuclear technologies. NE will focus on assessments required to inform choices for domestic fuel cycle technology. These analyses would complement those assessments performed by the National Nuclear Security Administration (NNSA) to evaluate nation state proliferation and the international nonproliferation regime. NE will work with other organizations including the NNSA, the Department of State, the NRC, and others in further defining, implementing and executing this integrated approach.

R&D Areas

The Department expects to undertake R&D in a variety of areas to support its role in the objectives outlined above. Examples include:

- Structural materials
- Nuclear fuels
- Reactor systems
- Instrumentation and controls
- Power conversion systems
- Process heat transport systems
- Dry heat rejection
- Separations processes
- Waste forms
- Risk assessment methods
- Computational modeling and simulation

R&D Approach

A goal-driven, science-based approach is essential to achieving the stated objectives while exploring new technologies and seeking transformational advances. This science-based approach combines theory, experimentation, and high-performance modeling and simulation to develop the fundamental understanding that will facilitate advancements in nuclear technologies. Advanced modeling and simulation tools will be used in conjunction with smaller-scale, phenomenon-specific experiments informed by theory to reduce the need for large, expensive integrated experiments. Insights gained by advanced modeling and simulation can lead to new theoretical understanding and, in turn, can improve models and experimental design. This R&D performed by NE must be informed by the basic research capabilities in the DOE Office of Science (SC).

The Modeling and Simulation Hub led by NE, for which proposals are currently under review, will integrate existing nuclear energy modeling and simulation capabilities with relevant capabilities developed by the Office of Science, the NNSA, and others. Existing advanced modeling and simulation capabilities (e.g., computational fluid dynamics) will be applied through a new multi-physics computational capability to provide predictive capability for life extension and power uprates calculations. After five years, the Hub is intended to produce a multi-physics computational environment that can be used by a wide range of practitioners to conduct predictive calculations of the performance of reactors in the future for both normal and off-normal conditions. The results will be used to communicate the potential role of science-based modeling and simulation to address technology issues concerning nuclear energy in the near, mid, and long terms.

NE maintains access to a broad range of facilities to support its research activities. Hot cells and test reactors are at the top of the hierarchy, followed by smaller-scale radiological facilities, specialty engineering facilities, and small non-radiological laboratories. NE employs a multi-pronged approach to having these capabilities available when needed. The core capabilities rely on DOE-owned irradiation, examination, chemical processing and waste form development facilities. These are supplemented by university capabilities ranging from research reactors to materials science laboratories. In the course of conducting this science-based R&D, infrastructure needs will be evaluated and considered through the established planning and budget development processes.

There is potential to leverage and amplify effective U.S. R&D through collaboration with other nations via multilateral and bilateral agreements, including the Generation IV International Forum. DOE is also a participant in Organization of Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) initiatives that bear directly on the development and deployment of new reactor systems. In addition to these R&D activities, international interaction supported by NE and other government agencies will be essential in establishment of international norms and control regimes to address and mitigate proliferation concerns.

Conclusion

Thank you, Mr. Chairman, that concludes my written testimony. I would be pleased to take any questions at this time.

BIOGRAPHY FOR WARREN F. MILLER, JR.

Dr. Warren F. Miller was nominated by President Barack Obama as the Assistant Secretary for Nuclear Energy in June of 2009, and confirmed by the Senate in August. As Assistant Secretary, Dr. Miller is responsible for all programs and activities of the Office of Nuclear Energy.

Before becoming Assistant Secretary, Dr. Miller was a Research Professor in the Department of Nuclear Engineering and Associate Director of the Nuclear Security Science and Policy Institute at Texas A&M University.

A native of Chicago, Dr. Miller is a graduate of the U.S. Military Academy. He served in Vietnam where he earned a U.S. Army Bronze Star and a Commendation Medal.

After his military service he received a Ph.D. in nuclear engineering from Northwestern University. After two years as an assistant professor there, he began his career at Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico. His first research interest was in the area of Reactor and Transport Theory. Over the course of his 27-year career at LANL, Dr. Miller held a variety of leadership positions, including Associate Laboratory Director for Energy Programs, as well as for Physics and Mathematics. As Associate Lab Director, he supervised the work of 2000 scientists. He also served as Senior Research Advisor, with the responsibility of deciding which research projects to pursue, recruiting the talent to pursue them, and providing the facilities to enable success.

Dr. Miller is the author of many research papers and journal articles, including, with a colleague, the book *Computational Methods of Neutron Transport*, published in 1984, which became a standard textbook for engineering students around the world.

Dr. Miller was elected as a Fellow of the American Nuclear Society in 1982, and to membership in the National Academy of Engineering in 1996.

DISCUSSION

Mr. BAIRD. Dr. Miller, thank you for your expert testimony, and again, for your service. I will now recognize myself for five minutes.

COST SHARING

In your testimony, Dr. Miller, you mentioned the cost sharing, and I am glad to hear that. I am very interested in SMRs. One of the questions I have, though, is it is my understanding, and I may be incorrect, that the cost sharing would be largely limited to NRC fees and might not be applicable to other parts of the design certification. Some of the folks I have contacted seem to believe that that is perhaps excessively restrictive, and they won't spend all that much money on the NRC fees, but there may be other things.

Could you talk about that for a moment?

Dr. MILLER. Sure. Thank you for the question. So an example of a program that the Department of Energy did have in the last decade or so was the NP 2010 Program, which involved cost sharing much further than design certification. It went through engineering, it went through COLAs, Construction and Operating License Applications, and so it went further down the chain than is proposed in the President's budget for 2011.

So there is a precedent for doing that. Let me say that the R&D Roadmap is, first, not just in the Nuclear Energy Office roadmap. It is an Administration roadmap. So it is coordinated through the interagencies, so it is our Administration's plan. Similarly as you know, that 2011 is the Administration's plan. And I am here to support the President's budget.

Mr. BAIRD. Let me just for the record suggest that if the goal is to get these things underway a little faster than they might otherwise, and if we are setting aside I think it is roughly $38 million——

Dr. MILLER. Yes.

Mr. BAIRD. —but only a small portion of that could be used for the fees, if we are prepared to spend the money and the goal is to accelerate development of these, maybe we ought to expand the possible uses for that money.

CREATING AN EXPORT MARKET

A second question. It is my understanding that our competitors, global competitors, are receiving substantial government subsidies for their efforts to expand nuclear power: France, Korea, Japan. That seems to tip the competitive market internationally against some of our producers, and I think one of our hopes would be that if we can produce a safe and effective and cost-effective system, especially in the SMRs, that might lead to export.

But if we are on an unlevel competitive playing field financially, that could impede that development. Any thoughts about how we might address that, either by additional government support or WTO actions or other things to make sure that there is a fair playing field?

Dr. MILLER. Yes. This has been an issue related to nuclear energy almost from the beginning, that certain countries—in fact, I was in both countries that you mentioned, Japan and France, in the last few months—see a situation in which they view the world somewhat differently than we do in the sense that neither country has a large number of natural resources, energy resources, oil, coal, the rich things that the United States is blessed with. And so they see nuclear energy as a national security issue.

And for those reasons the model they use is a model in which they invest, as you point out, government national resources in these entities to a much greater degree than we do in our country. Certainly we invest as well, and if they are more than willing to go much further down the chain of deployment, I think that it is certainly a debatable question of where in our system is the right place for government to end and industry to begin. I think it is debated a lot within the Administration. I am sure it will be debated a lot within the Congress, and other than that I can only say I support the President's budget.

Mr. BAIRD. I think one of the issues there particularly as we look towards possible export, if we are going to compete globally, which would presumably give us some economies of scale, the whole premise I understand of SMRs is that you could not quite assembly line, but you could build them in a factory-type setting, then transport them. If we are going to compete in that fashion, we may need more help both domestically and internationally just to try to level that playing field.

So I would hope we would look at that.

That will conclude my questions for the moment, and I will recognize Mr. Rohrabacher for five minutes.

Mr. ROHRABACHER. I am sorry. Mr. Chairman, with your permission we would like—Mr. Sensenbrenner actually has seniority to me.

Mr. BAIRD. My apologies. Mr. Sensenbrenner.

Mr. SENSENBRENNER. Thank you very much, Mr. Chairman. Welcome, Dr. Miller.

Dr. MILLER. Thank you, sir.

YUCCA MOUNTAIN NUCLEAR WASTE REPOSITORY

Mr. SENSENBRENNER. I want to talk about Yucca Mountain. We have invested billions of dollars in Yucca Mountain, and it has been found to be safe, and now this Administration has taken that option off the table and wants to start from scratch.

It has taken a long time to reach this point on Yucca Mountain, and the Department of Energy has given us no assurances that a new form of storage will be found within the next 30 years without more money being wasted.

Now, I want to ask a question specifically about Secretary Chu's motion to withdraw the license application with prejudice, and does this mean that if this motion is granted, Yucca Mountain will never even be considered for the storage of nuclear waste?

Dr. MILLER. So——

Mr. SENSENBRENNER. All I need is a yes or no answer on that.

Dr. MILLER. Well, unfortunately, I don't know what the legal implication is with prejudice, but we can get back to you.

Mr. SENSENBRENNER. Legal—you know, I am a lawyer, you know. I haven't practiced recently, but the legal implication with prejudice means is that there can never be a license application submitted again——

Dr. MILLER. Uh-huh.

Mr. SENSENBRENNER. —for storing nuclear waste in Yucca Mountain. Now, you know, I want to know what justification there was made, file the application or dismiss the motion with—or the motion to dismiss the application with prejudice. So that means that we can never even consider Yucca Mountain in the future.

Dr. MILLER. Congressman, I understand the concern. Let me just say under advice from General Counsel, the Secretary made that decision. I can't—I don't have any other way to give you——

Mr. SENSENBRENNER. Okay.

Dr. MILLER. —anymore information on that.

Mr. SENSENBRENNER. Well, you know, a lawyer's ethical obligation is to attempt to minimize the financial exposure of his client, in this case the United States government to a decision that is made. Now, we have already spent about $10 billion out of the $30 billion collected through the Nuclear Waste Fund, studying the site and preparing the application. And it is estimated that the Federal Government's liability is now about 12.3 billion and will grow annually by about a half a billion dollars.

Aren't you a little concerned given that liability that your General Counsel isn't doing the right thing?

Dr. MILLER. Well, first of all, again, Congressman, I am going to have to give it to you the best I know. I am in NE, not in RW, so from the best I know, the liability is associated with taking title to the used fuel, not necessarily tied to the place that we place the used fuel. So it is not directly tied to Yucca Mountain. It is tied to taking title.

Mr. SENSENBRENNER. But if the Federal Government has no place to put it, you know, taking title means that we are going to have all this used fuel that the Federal Government owns and no place to put it, and that is where I see the liability is. And, you know, I have reached the conclusion that there is no economic justification to closing Yucca Mountain.

Now, let me go into one other area. There was a letter that DOD sent on February 26 that directed that certain office civilian radioactive waste management activities, including data collection and performance confirmation activities at the Yucca Mountain site, will cease as of March 1. And specifically, the power communications system for all surface and sub-surface work and data processes will be shut down.

Now, if the DOE rules against—or excuse me, the NRC rules against DOE's motion to dismiss with prejudice, does this hiatus in terms of collecting this data mean that even if you go and lose before the NRC, you can't put nuclear waste in Yucca Mountain because we don't have the data?

Dr. MILLER. I can't answer your question, Congressman. We will get back——

Mr. SENSENBRENNER. Well——

Dr. MILLER. —for the record.

[Additional material submitted for the record follows:]

PREPARED RESPONSE OF ASSISTANT SECRETARY MILLER

No, as the Department explained in its April 23, 2010, response to the State of Washington's request to the United States Court of Appeals for the District of Columbia for a preliminary injunction, any hiatus in record collecting should not cause any harm if DOE were forced to continue the licensing process. First, large data-bases already exist for the three suspended data collection and performance confirmation activities (seismicity, precipitation, and tunnel deformation), and their suspension will not have a material effect on the understanding of the Yucca Mountain site. The National Academy of Sciences found that the period of geologic stability for Yucca Mountain is on the order of one million years, so one would not expect any sudden changes in seismicity, precipitation, or tunnel deformation. Second, even in the absence of active data collection by the Office of Civilian Radioactive Waste Management for seismicity and precipitation, other entities do monitor activities in the vicinity of Yucca Mountain and would indicate any change in seismicity or precipitation. For tunnel deformation, little to no change is expected; moreover, any deformation would be found only after the fact. In the past, the Office of Civilian Radioactive Waste Management has not done continuous data collection on tunnel deformation and, in fact, had periods of more than a year between successive measurements. Third, if ordered, restart of activities would be relatively simple with the resupplying of electric power.

Mr. SENSENBRENNER. —okay. Well, you know, let me say, sir, with all due respect, you know, this is an extremely arrogant motion on the part of the Department of Energy because it ignores the billions of dollars that Congress has appropriated, it does so unilaterally in a way that even if you lose before the Nuclear Regulatory Commission, the thing is so screwed up that you are not going to be able to deposit nuclear waste, and you have added, you know, a huge amount of liability, not to talk about the $10 billion that has been wasted simply because of something that was done by the Department of Energy.

Now, the last question I have is did either the President or Secretary Chu promise Senator Reid that Yucca Mountain would be shut down?

Dr. MILLER. I do not know.

Mr. SENSENBRENNER. Okay. Well, maybe before making huge decisions like this that would end up costing the American taxpayer billions and billions of dollars, people who come and testify before Congress ought to know, and I thank the Chairman for the time.

Mr. BAIRD. Mrs. Dahlkemper is recognized for five minutes.

URANIUM AND THORIUM

Mrs. DAHLKEMPER. Thank you, Mr. Chairman, and thank you, Dr. Miller. I appreciate you being here today.

I want to ask you about the issue of the supply of uranium.

Dr. MILLER. Uh-huh.

Mrs. DAHLKEMPER. There have been some issues raised in testimony before the Committee that the supply issue is something we need to discuss. So what are the most current estimates on how much uranium is available for nuclear reactors? And how long is it estimated that supply will reasonably be there for us to use?

Dr. MILLER. Uh-huh. So there are quite a few studies about the uranium resource, and most estimates would argue with reasonable projections of the growth nuclear energy throughout the world, that there is sufficient uranium resource at reasonable prices, meaning close to today's prices, that would last throughout the rest of this century.

Now, there are lots of caveats on that. One is as resources become more difficult to extract, what tends to happen is technology develops to allow you to extract those, as the price goes up, and technology gets developed, and then you are able to extract from different types of mineral deposits, and the price starts going down, and so it is really hard to estimate these things.

And one other thing I wanted to mention is the Japanese. While I was in Japan I got a chance to get a briefing on the Japanese research on uranium extraction from seawater, and their estimate is it is about three to five times more expensive than present extraction methodologies.

If that could be reduced by quite a bit, then it is a whole new ballgame. Then you are really talking huge amounts of uranium. So it is a very difficult issue, but I don't think most of us believe uranium resources will stop the development of nuclear energy.

Mrs. DAHLKEMPER. Can you maybe address—so you are saying there is really no concern with the supply, that the supply is there?

Dr. MILLER. I don't think——

Mrs. DAHLKEMPER. —as the thirst for energy increases globally and we look at, obviously, more nuclear energy being produced not only here but across the globe?

Dr. MILLER. In addition, there is also the thorium possibility. Thorium is actually more prevalent in the crust than uranium is worldwide. There is also the possibility of breeder reactors that would use much more of the uranium as I mentioned before. It is— my personal opinion is that the uranium resource will not be a show-stopper for nuclear energy.

Mrs. DAHLKEMPER. Thorium isn't currently used in any process.

Dr. MILLER. Thorium is only used in an experimental and a research way, but in theory it could be used for reactors, and I think the country that is leading the research effort is India actually, which has large amounts of thorium, and so they are very interested in it.

Mrs. DAHLKEMPER. Can maybe you address the link with the supply issue, if there is none, or if there is, with the need to reprocess, and where you see that as maybe extending even further the life of using uranium?

Dr. MILLER. Yes.

Mrs. DAHLKEMPER. With the current, available technology obviously.

Dr. MILLER. Yes. Presently the once-through fuel cycle that is used largely, well, it is not used exclusively worldwide, the uranium utilization is only .6 percent. So that means of the uranium that is mined, we actually fission about .6 percent because in the enrichment process we have all these tails left in the enrichment process, and then the used fuel has all this uranium left in the used fuel.

And so maybe the price of uranium or the resource isn't a driver that much, but what is, is there is a certain environmental stewardship responsibility that if we have a natural resource and we are using .6 percent, throwing the rest of it away, that doesn't fit well in our own view of what is responsible. So increasing uranium utilization makes a lot of sense from that point of view.

The second point of view that makes a lot of sense is the backend of the fuel cycle. The amount of energy we can get out of a per unit of waste created, you know, has an impact on how many repositories we need to how much repository capacity we need as a country over the next 50 to 100 years.

So it makes a lot of sense to increase uranium utilization, even if the price of uranium is low.

Mrs. DAHLKEMPER. Thank you. My time is up. I yield back.

Mr. BAIRD. Mr. Rohrabacher.

WATER-COOLED VS. GAS-COOLED REACTORS

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. Just one or two thoughts before I ask the witness some questions.

Let us just again note that it was hysteria that was created over an incident at Three Mile Island decades ago that caused great harm to our country's economy, and let me not that from my reading that the only people who lost their lives due to Three Mile Island were coalminers who now we had to rely on coal rather than safer nuclear energy and those people who perhaps have contracted diseases from air pollution using coal as a means of energy production rather than nuclear energy, which would have given us clean skies and clean air.

So it is important when we start making policy not to be basing it on hysteria and to be very steely-eyed about these decisions that we have to make.

I might ask you this, but we do know that technology has made great leaps, and the potential technology since Three Mile Island, Three Mile Island was a water-cooled reactor, and almost all—I believe all the reactors we have in the United States currently are water-cooled reactors.

Now, what you have in mind and what we are trying to move forward, would water-cooled reactors be, still be the focus, or are we moving onto gas-cooled reactors?

Dr. MILLER. Some of the small modular reactor ideas don't require water cooling, which would be excellent in many ways, not the least of which that it helps with siting if you don't have to worry about water cooling.

In addition, the High-Temperature Gas Reactor Program, the flagship of which would be NGNP, is a helium-gas-cooled reactor. That allows you to go to much higher temperature and therefore, a higher efficiency for electricity production as well as potentially using that heat as a heat source for industrial processes.

So——

Mr. ROHRABACHER. Uh-huh.

Dr. MILLER. —and then some of the advanced small modular reactors look at liquid-metal cooling, sodium cooling. So, yes, the business is moving in other directions.

Mr. ROHRABACHER. I think it is vitally important that leaders like yourself insist that we move forward with new technology, newer concepts like the one you are outlining right now. There is a weakness in our system, and the weakness in our system is that people who make money make money from what they have right now.

Dr. MILLER. Yeah. Right.

Mr. ROHRABACHER. And they will fight change in order to make money from what they already have in their hands. So it is up to us to overcome that flaw in the capitalist system.

And I think your point about only utilizing .6 percent of the actual power that you can get from uranium, our current systems only get—so it is less than one percent effectiveness, and I do understand that the new helium reactors that you are referring to actually have the potential of bringing that way up, if not making it almost 100 percent effective in terms of utilizing that potential.

Dr. MILLER. Well, that would require changing the fuel cycle, not just the reactor design. You would have to do something with the used fuel to get that much uranium utilization out. You would have to reprocess or recycle——

Mr. ROHRABACHER. Uh-huh.

Dr. MILLER. —to increase it much beyond .6 even if you change the reactor design.

Mr. ROHRABACHER. Have you seen at all the General Atomics? They are, by the way, they are not in my district just for the record. General Atomics has this gas turbine modular helium reactor, which they believe will be very cost effective and be accomplishing the things you are talking about.

Dr. MILLER. General Atomic has discussed with us their advanced reactor called EM2, but I have not talked with them about the reactor design you are referring to.

Mr. ROHRABACHER. Uh-huh. I would suggest that that would be something that would be very beneficial to take a look at their option.

Dr. MILLER. Uh-huh.

Mr. ROHRABACHER. I believe—does this mean my time——

Mr. BAIRD. The clock has blacked out.

Mr. ROHRABACHER. The clock has blacked—does that mean I have unlimited time?

Mr. BAIRD. Heaven forbid.

Mr. ROHRABACHER. Thank you, Mr. Chairman.

Mr. BAIRD. Thank you, Mr. Rohrabacher.

Mr. Luján is recognized.

SPECIFIC ISSUES IN THE DOE ROADMAP

Mr. LUJÁN. Thank you very much, Mr. Chairman, and Dr. Miller, I am just going to jump right into it as well. I think that there has been a lot of conversation in some areas of interest to myself as well, namely around the reprocessing and recycling aspect of what we are talking about, and the report outlines it in a few areas. I will just point to the page numbers quickly.

Page 22 is where it talks about R&D topics for enabling new builds. My question along that line, Dr. Miller, and I am just going to put a few out there and that way you can touch on them, is we talk about new builds. Shouldn't we be talking about the closed cycle associated with new builds incorporating the aspects of the recycling so that it is on location in the same position, eliminating the need for even transportation of any of the spent fuel so that way it is able to be integrated into the system there? It is something we should consider, including on page 30 of the report as we talk about the major challenges associated with fuel cycle options.

The bottom of page 30, top of page 31 talks about the fuel cycle and the end of that reads, "In order for a fuel cycle strategy to be considered, the waste benefits and improved resource utilization produced by such a system must outweigh the complication, expense, and potential proliferation concerns associated with it."

And I would pose, isn't that true already today with what other nations are doing as a result of the accords put forth under President Carter, with what we have seen with other nations move forward with recycling and reprocessing?

On page 31 we continue to talk about the R&D for sustainable fuel cycle options, ending with the transportation systems, which is reprocessing, recycling, and that ends with "R&D would focus on broadly-applicable issues, including areas such as materials and energy conversion. In addition, studies may be conducted to review the technical and economic aspects of external neutron, source-driven transportation systems to inform whether future investigation on this approach is warranted."

So, again, do you have the budget you need for R&D to move forward with recycling programs under the conditions you have? You know, with the billions spent on Yucca, had that been used for recycling, would we already have the answer today? I think that is a fair question that needs to be asked.

Lastly, on page 34, under the R&D objective "understanding and minimizing the risks of nuclear proliferation and terrorism," it says, "The final R&D objective," and I hope that they are not ranked in priority. I would hope that this would be the primary objective of what we are talking about here, which talks about, "achieving economic public health and safety and environmental goals which are critically important."

And lastly, Dr. Miller, I am only going to give you about two minutes to respond. I apologize, but anything that we might be able to get submitted into the record for review later would be important. I would hope as I looked through the report, one thing that I did not see is the importance of uranium legacy abandon mine cleanup that we have around the country. I know there is this whole discussion as to whether it was for weapons or if it was for energy. Whatever the uranium was mined for originally, there are still problems across the country, namely in New Mexico with the Navajo Nation, of some areas that need to be cleaned up, and I would hope that that could be part of the order and some serious consideration that we could have going forward, because there are some serious health issues that need to be addressed and people have been impacted.

So any of that, Dr. Miller, in a minute and a half, whatever you can give us I would appreciate it. Then we will yield back to the Chairman as time expires.

Dr. MILLER. Thank you very much, Congressman. Thank you for your attention to detail as you read our report.

So, first, let me say that security and proliferation risk is not meant to be the last, you know, the least important thing. They are just listed in no particular ranked order. So that is that question.

The budget. In I think fiscal year 1999, the nuclear energy R&D budget was zero in DOE, and it has gradually over the last 20 years or so, well, ten years, 1999, yeah, ten years or so, it has come up to a reasonable level and counting the infrastructure support for Idaho National Laboratory and other places, it is $900 million.

Now, I feel that we are going to have to make choices. We are going to have to establish priorities as we move forward, and so part of our plan is to do down selects, and we are going to have to explore a wide range and then say, look, these are the most promising. We can't pursue those. We have to make choices of what we are going to be able to do within that framework of that budget.

Mr. LUJÁN. Thank you, Dr. Miller, and as time has expired, I look forward to further conversations on this.

Mr. Chairman, I would just close with saying that I think it is important that as we look at what is being talked about with energy generation, that there is a waste issue that needs to be addressed as well, and I certainly hope that we can use the brightest minds that we have in the world right here in this great Nation of ours to solve this problem. When the Manhattan Project was moving forward, they did this in a short period of time at the direction of Congress, support from the President, and they made something happen, some things that still are a concern to many of us, but nonetheless, made something happen. I think this is an area as well with the direction and support from Congress that we could see some action in this area.

Thank you.

Mr. BAIRD. Living down river from Hanford Nuclear Reservation I share that concern.

Mr. Smith.

MORE ON URANIUM SUPPLY

Mr. SMITH OF NEBRASKA. Thank you, Mr. Chairman, and thank you, Dr. Miller.

I was wondering if you could help paint a picture of our uranium supply, some numbers, import, export, how we are doing in that area.

Dr. MILLER. Okay. So uranium supply from everything I have read about estimates of resources are sufficient to supply nuclear power in the world, especially if one assumes uranium is a commodity to be bought and sold in the free market. I only say that, as I mentioned earlier, there are some countries that view uranium as a national security issue, that if we don't have uranium in our borders, then we have to do something about that.

And that is certainly true, well, I won't mention the particular countries, but that is true of some countries. In our country we view it as a commodity to be bought and sold on the free market.

And right now uranium is selling reasonably, for reasonably low level, about $40 per pound of U308. I think that what happens is when easily-mined uranium starts getting scarce, the price goes up, and then we develop new technologies to look at new ore bodies and then the price starts to come down again.

So I don't believe uranium supply is an issue.

Mr. SMITH OF NEBRASKA. What percent do we import?

Dr. MILLER. I don't have that number with me. I will have to get it to you. I don't know.

[Additional material submitted for the record follows:]

PREPARED RESPONSE OF ASSISTANT SECRETARY MILLER

According to the most recent edition of the Energy Information Administration's "Uranium Annual Marketing Report," which was published in 2008, the United States imported 92 percent of its commercial uranium requirements in 2007 and 86 percent in 2008.

Mr. SMITH OF NEBRASKA. Do you have any concerns about how reliant we are perhaps on importing uranium?

Dr. MILLER. It is my understanding that the uranium that we import comes from countries like Canada and Australia, which are countries that we generally don't have national security or supply security problems with, and we also have our own uranium resource here in the United States. And we have a lot of uranium in reserve. As a matter of fact, in the form of depleted uranium.

So I guess I don't feel concerned about uranium supply.

Mr. SMITH OF NEBRASKA. Okay. Thank you. I do want to just add that I am encouraged by some of the advancements politically, unfortunately, of nuclear power and the advocacy. I am still concerned, though, that there are too many politics involved with some of these issues. So I hope that you can work with us to move forward on nuclear power and the opportunity to build our energy supply so we can create jobs and more opportunity for Americans.

Thank you, Mr. Chairman.

Dr. MILLER. Thank you.

Mr. BAIRD. Ms. Kosmas.

INFORMATION ON FULL RECYCLING

Ms. KOSMAS. Thank you very much, and thank you for being here.

Like the others, I have mixed feelings obviously, but mostly I look forward to what I know we can do well in this country, which is to take advantage of the scientific knowledge that we have to produce energy through nuclear opportunities.

What my concern is, with my limited amount of scientific knowledge, of course, relates back to the sustainable fuel cycles that you referred to, and specifically you talked about the options that range between once-through and full recycling and how many different ways you might be able to accomplish the goal.

I guess my questions would go to the full recycling specifically. Is it being done anywhere in the world, and if so, do we have access to that knowledge, and if not, how far along would you say we are in the development of an opportunity to repeatedly recycle, rather than dispose of the product?

Dr. MILLER. So the first question is anyone actually implementing full recycle. I think it is fair to say that there are two major countries that have decided full recycle is part of their policy, but they haven't fully implemented it because they don't have a commercial fast reactor yet, which is key to having and implementing a full recycle. But those countries, which are Japan and France, hope to and plan to implement commercial scale fast reactors. So I would say that no country has implemented it, but several countries have planned to implement it and are on the way to implementing it.

So then the second question is would we have access. I think for sure if—and I should have mentioned earlier that part of our plan is clearly to take into consideration and look very carefully at the recommendations of the Blue Ribbon Commission that is going to help us decide what to do with the back-into-the-fuel cycle. But if this country decided that its direct or its path forward is full recycle, I don't think there is any question we know how to rebuild a reprocessing plant using the PUREX approach used by France and Japan.

The problem is we have not accepted that approach based upon the principle of proliferation because it has a step in which plutonium is bare and could be diverted. So we could do it in our country if we so decided to do it. I don't see any question about that.

Ms. KOSMAS. So there is a risk involved then in making the decision to move forward and the Blue Ribbon Commission is expected to weigh that risk against the gain and make some recommendations, policy recommendations in that regard?

Dr. MILLER. Yes. I can't speak for precisely how the Blue Ribbon Commission is going to take its charter and what it is going to say, but I will say from our point of view in DOE a realistic R&D plan includes trying to reduce proliferation risk of the full recycle and reduce costs and reduce environmental burden of that approach, but we have not rejected an option of doing full recycle.

Ms. KOSMAS. Okay. If it were decided to move in that direction, would you have any projection of either time or resources necessary to make that happen?

Dr. MILLER. So in our plan what we would attempt to do is to go beyond the PUREX approach, look at other approaches, one of which has made a lot of progress called pyroprocessing, but there are other kinds of approaches that we would look at. And we would attempt again to come up with ways that are improved, and I would say that we could implement it certainly over the next, let us say, 20 to 30 years. We could certainly implement full recycle if we decided to do it now.

Ms. KOSMAS. And the costs generally?

Dr. MILLER. Most cost estimates would say that full recycle is considerably more expensive than once-through. Having said that, it is hard to take into account how many repositories we would need and what the cost of repositories would be. If you implemented full recycle, the hope would be you would need many fewer geologic repositories.

So there needs to be system studies that we are carrying out that compare these things with what we call modified open cycle that tries to take into account the cost, the waste burden, the proliferation risk, all of these things to make suggestions as to what the Nation ought to do in its future decisions.

Ms. KOSMAS. Okay. Thank you very much.

I yield back.

Mr. BAIRD. Ms. Biggert.

SMALL MODULAR REACTORS

Ms. BIGGERT. Thank you, Mr. Chairman, Dr. Miller.

When I first came to Congress, we were looking at the electrometal allergical process and it was at Argonne National Lab, and the first year that I was here the program was cut by $20 million, so I felt like I had the 800-pound gorilla on my back and got the funding back. And we have been moving since then. We have had—in 2005, I think we wanted the systems analysis, the reprocessing. We have six reprocessing plants in this country that were shut down before they even opened, and, you know, they are now used for storage in the most part.

It is very frustrating that we haven't moved with the recycling as fast as I think we should, and you are talking about another 20, 30 years. I mean, that really is discouraging. Maybe with some of the modeling and things we will be able to move a lot faster and at lesser expense. I am sorry I can't be here for all of this because I have a markup, but I did want to ask you about small modulars and as we heard from you, or as I was told in your exchange with Mr. Rohrabacher, there are several types of small modular technologies out there in the market, and all of them different designs, and each have various production capacities outside the range defined in the Atomic Energy Act either because some designs are smaller than the 100 megawatts and—or larger than 300 megawatts.

At this early stage of development do you believe that more study should be given to the production capacity of smaller modular reactors and if that capacity limit needs to be adjusted to reflect the diversity of technology in the market?

Dr. MILLER. Certainly I believe we ought to look at what the market penetration could be for small modular reactors, and I am sure my colleagues in the private sector who are advocating certain designs have looked very carefully at the business case associated with it. Now, they haven't shared—some of that is probably proprietary information, they haven't shared it with us, but I think it is certainly appropriate as we begin our SMR Program. Hopefully if it gets funded in fiscal year 2011, that we also with our systems people within the national laboratories will take a look at what the issues are related to market penetration.

MODELING AND SIMULATION OF REACTORS

Ms. BIGGERT. Well, you have noted in your testimony that the Department is increasingly using modeling and simulation to predict reactor performance and assess new technologies. How will this effort leverage or complement actual experimentation, and how might it reduce or eliminate the need for expensive demonstration or otherwise assist the NRC's licensing process?

Dr. MILLER. Uh-huh. So there are a couple of comments I could make. We have the most progress I think in fuels designs, in modeling the performance of fuels, and I think we have the promise of being able to significantly accelerate the amount of time it takes to develop a new fuel.

I mean, new fuels are really important. If you get more burn-up for existing reactors, for fresh fuel, the more burn-up you get, the better off you are from the point of view of the uranium utilization efficiency. A whole bunch of reasons this is a good thing to do.

And I think we have done a really good job of understanding with high performance computing how these fuels operate, and I think it is going to really help us in the future. And there are other examples that relate to the Modeling and Simulation Hub that was funded in fiscal year '10, that we hope to soon announce a winner for. There we would do a full reactor design with advanced modeling tools that would be validated with experiment.

So I think we are really moving out in the computational arena, and it is quite heartening to me to see it happen.

Ms. BIGGERT. All right. Thank you. I yield back.

Mr. BAIRD. Mr. Davis.

GENERAL COMMENTS

Mr. DAVIS. Mr. Chairman, thank you very much and certainly, Dr. Miller, thank you for being here today as well and giving the testimony you have and taking questions from those of us who serve unique Congressional districts, very similar yet somewhat very different in the different areas of the country that we serve. And I live in an area that—Tennessee Valley Authority, the TVA was established in the '30s, so provides the generation of electricity so that folks who live in my district are able to flip a switch and have a certainty that that light bulb is going to come on, unless the filament is shot and so they have to replace that from time to time.

The Atomic Energy Commission from the '40s and '50s and '60s, '70s basically was the agency that oversaw the development of nuclear energy. Obviously weapons was the main thrust of the Manhattan Project, and then we started moving more and more toward energy from nuclear sources.

Through the '70s we actually licensed close to 100 nuclear reactors that were built from '75, basically to '85, that provides today roughly 20 percent of the energy that is produced, electricity produced in this country.

Three Mile Island did change things in the minds, in our commitment and our focus to becoming more and more energy independent. I think nuclear energy took the brunt of that, and it suddenly became Chernobyl in the minds of a lot of folks. That never happened at Three Mile Island. The reactor acted as it should, it shut down. The other reactor that was onsite, I understand, continued to produce electricity for folks to use.

And so we have had 30 years, 25 to 30 years of a flare of nuclear energy. We suddenly realized that when you drive by places like Kingston, Tennessee, and you see in Ashville that there are difficulties with other types of generating electricity as well. I am excited about this Administration and the commitment that has been focused on again looking at nuclear energy as a viable source for us to become more energy independent, and for me that does two things. It gives us economic security, and it gives us national security that we don't have today as a result of our dependence on foreign sources, and in many cases, foreign sources for carbon-based fuels.

So I encourage you and this Administration and others and Members of Congress to take a serious look at nuclear energy as being that bridge that puts us into the area of economic security and a stronger national security.

LICENSING FOR SMRs

The question I have to you: I am hearing a lot about the small nuclear reactors that might be 1,200 megawatts, 125 megawatts. They will be easy to located, they can be basically the size of a box car. They can be moved from the place where they are being built, but it also does something else. It creates jobs in America. I don't think there is any country in the world that if they are talking about a nuclear reactor, if they had the choice to buy it from America, they wouldn't buy it from us.

So we have to move more rapidly in that direction. I hear folks say it might take 15 or 20 years to get a small nuclear reactor approved and licensed. We can't wait that long. So how do we expedite the licensing requirements to be sure that we have a safe small nuclear reactor that we can use in our Nation and export to other countries throughout the world? How do we expedite that?

Dr. MILLER. Okay. Thank you, Congressman. So let me begin by saying I sure hope it doesn't take 15 or 20 years. So we in our fiscal year 2011 budget have a program, half of which, $20 million, is directed toward LWR SMRs, and there the approach we have taken is to do a cost share with industry up to two plants and up to design certification.

Now, as I said in my opening comments, we are going to have a workshop in June at which we are going to hear from our industry colleagues, and I am sure if I would guess correctly, I am sure they will tell me that that is not enough, that we should do more.

Certainly we will listen to that. We will certainly take it back, but at this point as I have had to say several times, I support the President's budget.

Mr. DAVIS. We have national labs all across this Nation; one is in Oak Ridge. Wouldn't it be a responsible move for this Nation on the facilities that we occupy today to actually build a small nuclear reactor and let that be the source of energy that we use at our national labs or our reservations?

Dr. MILLER. There are several exciting ideas, Congressman, out there of how one might—or ideas of bringing together the right companies like, for example, TVA and B&W, to bring a consortium together to do just as you have described. There are ideas of doing a similar thing in Washington near the Hanford Reservation. There are ideas within the Department of Defense of using small modular reactors for base power.

So I think all of these are interesting ideas. We encourage this discussion, we encourage—they have actually been in to see us. We have been encouraging. In fact, Secretary Chu, I think, was briefed on the ideas in Tennessee when he was there.

So I think we should move forward with these ideas. It is not clear yet to us what is the government role, what the Federal Government role is, but certainly we are encouraging.

Mr. DAVIS. I think it is time to fish. We have been cutting bait long enough. Let us move forward with it.

Mr. BAIRD. Thank you. I have just one—we want to make sure we have time for the next panel. I have just one question, and that has to do with the economics of nuclear power.

COST COMPETITIVENESS

There has been a lot said about it was Three Mile Island or Chernobyl that caused the decline in nuclear power. Coming from a state that had the public power supply system——

Dr. MILLER. Uh-huh.

Mr. BAIRD. —it did not fail because of those accidents. It failed because of the financing and the largest public bond default in history of the country at that time, because nuclear power simply was not cost competitive.

Dr. MILLER. Yeah.

Mr. BAIRD. My understanding is even now, even as we look at the light water reactors, their cost competitiveness relative to say coal depends fairly significantly on a price on carbon. Is that your understanding, Dr. Miller?

Dr. MILLER. So first of all, let me say that we are proposing $54 billion worth of loan guarantees to try to help the first movers get going and get them out there, but eventually they have got to stand on their own. The Federal Government can't loan guarantee forever.

So if, in fact, we are competing in an environment in which there is not a level playing field. If we are doing standards, renewable standards, we are doing things that are encouraging the application and the commercialization of certain resources, and there is no price on carbon, and we can't get to the point of coming up with a business model like small modular reactors, and gas is $4 a million BTU, I think it is going to be a tough sled for these reactors to make it.

Mr. BAIRD. I appreciate that. I raise it because it is fairly common on this committee and maybe in the public discourse that the greatest proponents of nuclear power are also opponents of a carbon tax, and my understanding from the MacKenzie curves and elsewhere is that map doesn't pencil out. If you have a carbon tax, it makes nuclear power much more attractive, and I think that is a reasonable approach because there is a cost of carbon, and nuclear power may actually reduce that.

Any other colleagues, further questions before we move to our next panel?

Mr. ROHRABACHER. I will refrain from refuting that last statement.

Mr. BAIRD. I appreciate that, Mr. Rohrabacher.

With that, Dr. Miller, thank you, again, for your service and your testimony. We will proceed immediately to seat the next panel, take just a brief moment for the staff to set up their name tags, et cetera, and we will move with alacrity here.

Panel II:

I want to welcome our second panel of witnesses. I will briefly introduce them, and I understand Mr. Lipinski will introduce our final witness.

It is my pleasure to introduce Christofer Mowry, President and CEO of Babcock & Wilcox Nuclear Energy Incorporated, Dr. Charles Ferguson, President of the Federation of American Scientists, Dr. Mark Peters, Deputy Director for Programs at Argonne Lab, Mr. Gary Krellenstein is a Managing Director of Tax Exempt Capital Markets of JP Morgan and Chase, and I will yield to my colleague from Illinois, Dr. Lipinski, to introduce our last witness.

Mr. LIPINSKI. Thank you, Chairman Baird.

Dr. Thomas Sanders is the current President of American Nuclear Society, which is headquartered in La Grange, which is in my district. The ANS is a preeminent nuclear professional society representing about 11,000 members from the private sector, national labs, and universities. Dr. Sanders has a Ph.D. in nuclear engineering, is a licensed reactor operator, and a qualified electrician. He knows just about every aspect of the industry from personal experience, having served in the Navy on two nuclear submarines and as a researcher at the University of Texas and Sandia National Lab. In his role as ANS President, as Chairman of the Trade Promotion Coordinating Committee, of the Civil Nuclear Trade Advisory Committee, Dr. Thomas has been a leading advocate of rebuilding our domestic nuclear manufacturing base and has been an outspoken critic of our current dependence on imports.

I am delighted to welcome him to this hearing and look forward to his testimony.

Mr. BAIRD. Thank you, Dr. Lipinski. As we mentioned in the prior testimony, you will have five minutes for your spoken testimony, however, we are not operating atomic clocks here and our digital system seems to be going on the fritz. So if we get around five minutes, I will let you know, but you should have—somewhere up there you have got some red light, green light, et cetera. When the yellow light comes on, you are running out of time. When the red light comes on, a trap door appears below you, you disappear, and we move to the next witness.

So at this point, Mr. Mowry, please begin and thanks to all of you for your expertise and your presence here.

STATEMENTS OF CHRISTOFER MOWRY, PRESIDENT AND CEO, BABCOCK & WILCOX NUCLEAR ENERGY, INC.

Mr. MOWRY. Well, Mr. Chairman and Members of Congress, my name is Chris Mowry, and I am the President of B&W Nuclear Energy, Division of the Babcock & Wilcox Company. I ask that my written statement be entered into the Committee record.

I am honored to be part of this hearing to discuss modular reactors, and I applaud the DOE for supporting SMR development in their Nuclear Energy R&D Roadmap.

The Babcock & Wilcox Company has a rich legacy of innovating energy solutions. We have more than 50 years of continuous nuclear engineering and manufacturing expertise. Today B&W provides both industry and government customers with nuclear manufacturing and services from more than 17 locations across North America. We employ directly and through our joint venture companies approximately 12,000 nuclear professionals.

The DOE's Roadmap stresses the need to deploy clean, affordable, domestic energy quickly to achieve energy security and reduce emissions and cites capital costs as a significant challenge to deploying new nuclear plants. These issues are central to industry's motivation to develop SMRs as a compliment to large gigawatt-sized reactors. Industry sees values in a more incremental approach to project financing and low growth.

Our utilities want a smaller reactor that uses proven technology, existing nuclear infrastructure, and conventional nuclear fuel, and they want this option near-term.

The B&W mPower reactor is a scalable modular light water reactor which can be deployed within today's regulatory framework, domestic supply chain, and utility infrastructure. It provides capacity in 125 megawatt increments. It has a four and a half year operating cycle between refueling. It will be manufactured in North American at B&W facilities, and it has a secure underground containment with a spent fuel pool to securely store spent fuel for the life of the reactor. The plant is also air cooled to address water resource concerns.

The B&W mPower reactor is intended to be a competitive source of power generation. Our current analysis of the levelized cost of electricity indicates that the economics range from 47 to $95 a megawatt hour. This range is competitive with new fossil generation and renewable power alternatives, even without a carbon tax.

We plan to submit our design for certification to the NRC in 2012 and have joined in an industry consortium, including among others, the Tennessee Valley Authority, First Energy, and Oglethorpe Power. The stated goal of this consortium is to deploy one or more demonstration plants before 2020.

The B&W mPower reactor will be fully supported by a North American supply chain and has the potential to create thousands of jobs across North America. When used to repower aging coal facilities, the B&W mPower reactor creates a net increase in high-quality jobs at the plant site. Nuclear power plants trade lower, very stable fuel costs for more high-quality jobs. We believe this is a great tradeoff for our country's economy and its employment challenges.

B&W is not alone in the emerging SMR industry. There are several other companies pursuing small modular reactors based on a range of technologies. The DOE's Roadmap properly recognizes that research needs for light water technology are minimal and focuses instead on identifying priorities that enable their near-term development and demonstration. Simultaneously, the DOE plans to support a range of R&D activities for longer-term technologies.

It is my view that the Roadmap strikes a good balance between near-term and long-term efforts and creates a broad foundation for supporting SMR technologies.

B&W believes that SMRs such as the B&W mPower reactor offer America a practical and affordable near-term, domestically-produced, clean energy source. Delivering on the promise of these reactors, that these reactors hold will depend on leadership and foresight from both the industry and government. Public-private partnership is, therefore, critical to help reduce risk and accelerate deployment of a promising new SMR technology.

A successful cost-sharing program stemming from such a partnership should encompass all important development activities, including design and licensing necessary to programmatically address the first-mover risks inherent in technology demonstration programs.

In 1957, the first commercial nuclear power plant at Shippingport, Pennsylvania, achieved full power operation. It was the result of a partnership between the Atomic Energy Commission and Duquesne Light Company. This cooperation between industry and government set in motion the development of the U.S. commercial nuclear industry, which for 50 years provided technology leadership to the world and today supplies 20 percent of our electricity.

Our government's investment in this first-of-a-kind technology provided lasting and significant value to the Nation.

Today we have a new opportunity, an opportunity to reestablish America's leadership role in the commercial nuclear industry that we first launched in 1957. A new public-private partnership will enable the U.S. to demonstrate the promise which SMR technology holds for our industry by the end of this decade.

The DOE's Roadmap has created a strong foundation from which to pursue this goal, and I look forward to working with the Committee on legislation to implement it. Thank you for the privilege of testifying before the Committee. I am happy to answer questions.

[The prepared statement of Mr. Mowry follows:]

PREPARED STATEMENT OF CHRISTOFER M. MOWRY

Chairman Gordon, Ranking Member Hall, and Members of the Committee:

My name is Chris Mowry and I am the President of Babcock & Wilcox Nuclear Energy, a division of The Babcock & Wilcox Company. I would ask that my entire statement and supplemental information be entered into the Committee record. My prepared remarks will be a summary of this statement.

It is my privilege to present this testimony today regarding the Department of Energy's (DOE's) Nuclear Energy Research and Development Roadmap (Roadmap). I will focus my testimony on Small Modular Reactors (SMRs) and the promise they hold to provide carbon-free, base-load nuclear power in a more flexible, affordable form, while generating a lasting increase in high quality jobs for America. I applaud the DOE for recognizing the real potential of SMRs and including significant support for their development in the Roadmap.

The Babcock & Wilcox Company has a rich legacy of innovating energy technology solutions for efficient and reliable electricity generation throughout the United States, North America and across the globe. We grew our business over the past 140 years by developing and commercializing practical solutions to the evolving challenges of the power generation industry. We provide a comprehensive portfolio of clean energy technologies, including such coal-based systems as oxy-coal combustion, post-combustion CO_2 scrubbing, and environmental control systems. We supply a wide range of renewable energy systems including biomass, concentrating solar power, and waste-to-energy. And, important to today's testimony, we consistently lead the development and deployment of new nuclear energy technology solutions for industry and government.

B&W has more than 50 years of continuous nuclear engineering and manufacturing experience. Seven of the large nuclear power plants operating in the U.S. today were designed, manufactured and installed by B&W, including reactors in Arkansas, Florida, Ohio, Pennsylvania and South Carolina. Many other operating reactors incorporate major B&W nuclear steam supply components. Today, we provide customers with nuclear manufacturing and nuclear-related services from more than 17 facilities across North America. These locations are engaged in everything from manufacturing major components for nuclear power plants, to operating the Nation's nuclear energy laboratory in Idaho, to fabricating fuel for the High Flux Isotope Reactor at Oak Ridge National Laboratory and the University of Missouri's research reactor, both of which provide critical research and material testing services. Two of our manufacturing facilities maintain the only privately held NRC Category 1 nuclear fuel licenses to manage Highly Enriched Uranium in the United States. We also down-blend Highly Enriched Uranium into Low Enriched Uranium, which is then delivered into the marketplace for commercial reactor fuel.

B&W operates significant nuclear manufacturing facilities in Indiana, Ohio, Virginia and Tennessee, as well as in Ontario, Canada. We are the only American manufacturer accredited and capable of producing large N-stamped components for commercial nuclear power plants. We have fabricated more than 1,100 large Nuclear Steam Supply System (NSSS) components and pressure vessels, including approximately 300 nuclear steam generators worldwide. And, we employ directly and through joint venture companies approximately 12,000 U.S. nuclear professionals.

Nuclear Power and Small Modular Reactors

The DOE Nuclear R&D Roadmap correctly states that "To achieve energy security and greenhouse gas (GHG) emission reduction objectives, the United States must develop and deploy clean, affordable, domestic energy sources as quickly as possible." It is clear that nuclear energy will play a critical role in achieving these objectives. The report also concludes that "The capital cost of new large plants is high and can challenge the ability of electric utilities to deploy new nuclear power plants." This concern is central to industry's motivation to develop and deploy SMRs as complements to large, gigawatt-sized reactors.

More than two years ago, B&W began evaluating the shifting nuclear industry landscape. Several factors, including the potential for climate change legislation and carbon emission regulation, the need for increased energy independence, the constraints on the nuclear component supply chain, the increasingly restrictive capital markets, and the growing concerns about water rights and transmission capacity were pushing the industry to innovate new approaches to nuclear energy. Over these past several years, it has become increasingly clear that when it comes to nuclear power generation technology, one size does not fit all.

As part of our SMR market evaluation, we drew on the experience and expertise of electric utilities themselves to help us define the type of SMR technology best suited to meet their near-tern needs. Their guidance caused us to recognize that many utilities are not comfortable financing large, gigawatt-sized nuclear power projects. For example, some smaller electric cooperatives, which have historically been unable to include nuclear power plants in their own generation portfolios due to size and cost, now view SMRs as a realistic way to increase their carbon-free baseload generation capacity. Larger utilities see significant value in small reactors as well, particularly in providing a more incremental approach to project financing and to meeting projections of modest system load growth. In the near term, our utility customers want a smaller reactor that uses proven light-water nuclear technology, that can lever their substantial investment in existing nuclear infrastructure, and that can draw on the well-established conventional nuclear fuel supply chain. They also want a practical carbon-free option that can be used to "repower" aging coal power plants. In response to this broad range of emerging energy industry needs, we have developed the B&W mPower™ reactor.

B&W mPower Reactor

The B&W mPower reactor (Figure 1) is a scalable, modular, Advanced Light Water Reactor (ALWR) system, which can be certified, manufactured and operated within today's existing regulatory framework, domestic industrial supply chain, and utility operational infrastructure. The B&W mPower reactor has the capacity to match utility customer requirements in meaningful 125 MWe increments, while providing a 4.5 year operating cycle between refueling outages (compared to 18 or 24 month refueling cycles for currently operating large reactors). The scalable size of the B&W mPower reactor will allow industry to utilize existing electrical transmission line infrastructure and, when used to repower aging fossil-power plants, reuse existing power plant assets.

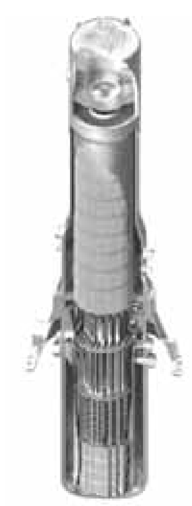

Figure 1

The use of conventional fuel, structures and power conversion equipment contributes to reliable, efficient plant operations within the existing Light Water Reactor (LWR) experience base of the industry. We plan on manufacturing the entire B&W mPower reactor in B&W facilities across North America, with the completed integral nuclear module then shipped by rail to plant construction sites. Factory assembly permits site infrastructure to be constructed simultaneously, reducing construction time. The reactor is designed to be installed in a secure underground containment structure (Figure 2), addressing aircraft impact concerns. The design also includes a spent fuel pool capable of holding 60 years' worth of spent fuel inside the underground containment. In other words, the spent fuel is stored securely for the life of the reactor. Additionally, the B&W mPower reactor plant is specifically designed to be air-cooled, thereby addressing concerns—particularly in the Southwest and Southeast—about local and regional water resources. These capabilities make the B&W mPower reactor a suitable power generation option for market segments such as replacement of aging fossil power plants, incremental additions to existing nuclear sites, power sources for energy intensive industrial manufacturing sites, potential energy parks, as well as developing countries and remote areas with limited transmission and access infrastructure.

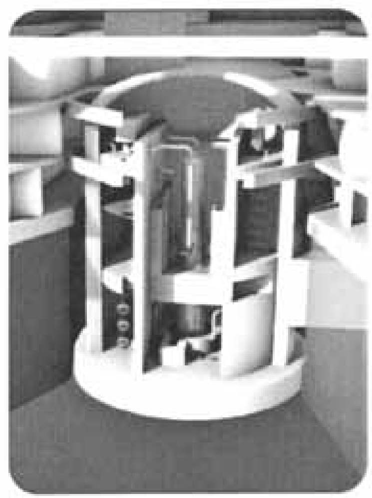

Figure 2

We are currently well into the design phase for the B&W mPower reactor and plan to submit our Design Certification Application (DCA) to the U.S. Nuclear Regulatory Commission (NRC) in 2012. Our initial efforts focus on obtaining NRC Design Certification and lead plant deployment in America. The NRC is already engaging us in Design Certification and licensing activities for the B&W mPower reactor. In support of these goals, we have developed a B&W mPower Consortium made up of B&W and leading U.S. utilities, including the Tennessee Valley Authority, First Energy and Oglethorpe Power Corporation. The Consortium is dedicated to addressing the proper regulatory framework, design requirements, and licensing infrastructure necessary to support the commercialization of the B&W mPower reactor. The ultimate goal of the Consortium is to deploy one or more demonstration plants in the U.S. by 2020, if not earlier.

This is an aggressive but realistic goal, one which will require industry leadership from B&W and its utility partners, the right balance between the promise of innovation and the certainty of proven ideas, and consistent support from the DOE, NRC, and Congress. A high-level version of the lead plant schedule, leading to initial deployment by 2020, is included in Figure 3.

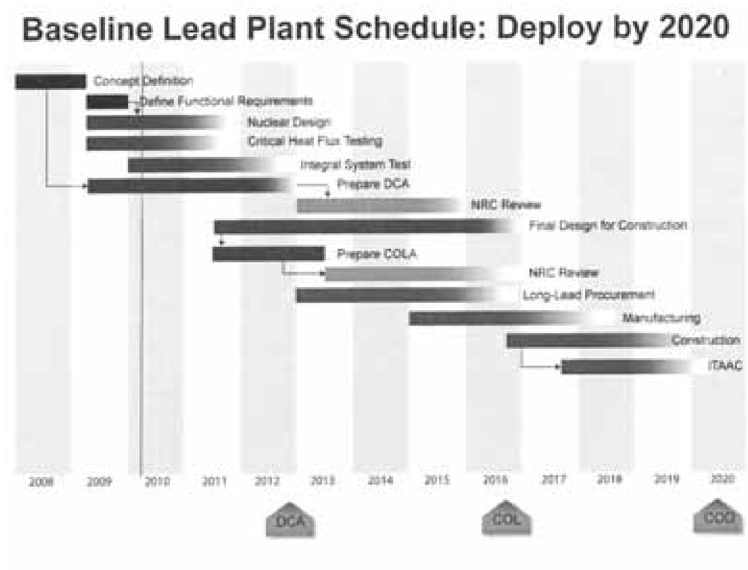

Figure 3

The B&W mPower reactor is intended to be a competitive source of power generation. Our current analysis of the levelized cost of electricity (LCOE), an industry standard metric for total cost of ownership, indicates that the economics range from 47 $/MWh to 95 $/MWh (Figure 4) for a nuclear plant composed of 4 B&W mPower modules generating 500MWe, depending on the deployment configuration. This LCOE range is competitive with new fossil generation and renewable power alternatives, even without a carbon "tax".

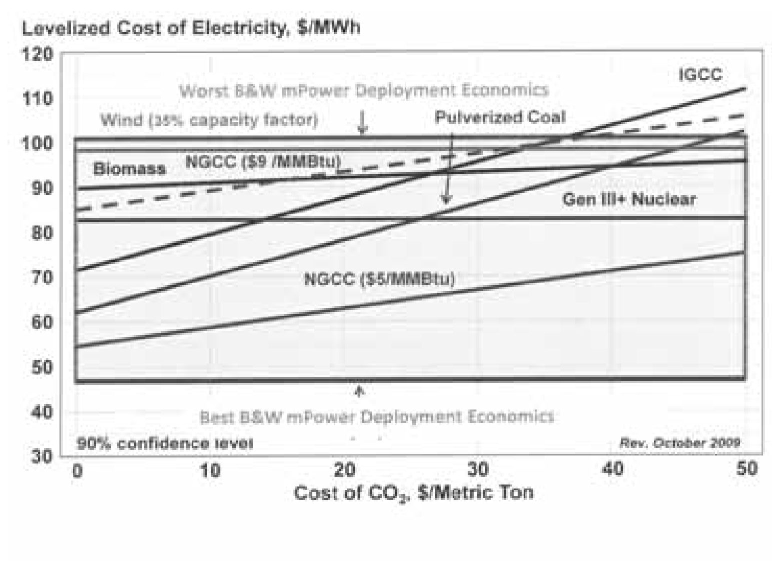

Figure 4

Manufacturing of the B&W mPower reactor has the potential to create thousands of jobs in the next 10–15 years across North America, including Ohio, Indiana, Virginia and Tennessee. The B&W mPower reactor will be fully supported by a North American supply chain, including all forgings. Current estimates of manufacturing job growth are variable based on broad predictions of the market for small reactors. As more of the development and final design work is completed, and fabrication and assembly methods are defined, good estimates of manufacturing job growth will become available.

When used to repower aging coal facilities, the B&W mPower reactor creates a net increase in high-quality jobs at the power plant. On an equivalent basis, approximately four times as many jobs are created per unit of power generated by a B&W mPower plant compared with an aging coal plant. Nuclear power plants trade lower, very stable fuel costs for more high-quality jobs. This is a great trade-off for our country's economy and its employment challenges.

The B&W mPower reactor will also generate significant indirect jobs in the areas of engineering, project management, field construction and plant operations. Engineering and design work for the B&W mPower program has already created more than 100 full-time positions in Virginia and Ohio and led to the establishment of dedicated facilities in Virginia.

Generation III Light-Water and Generation IV Technologies

B&W is not alone in the emerging SMR industry. There are many companies currently pursuing the development of small reactors, based on a range of technologies from light water design to more long-term "Generation IV" concepts. The DOE's R&D Roadmap recognizes the importance of both near-term light water-based SMRs, as well as the longer-term, non-light water technologies. In the Roadmap, the DOE properly recognizes the relative maturity of these various technologies, acknowledges that basic research needs for light water technology are minimal, and focuses the Roadmap on identifying priorities that enable their development, demonstration and commercial application. Simultaneously, the DOE rightly plans to support a range of R&D activities for longer term non-light water technologies. The DOE has struck a good balance between near-term and long-term efforts. It has prudently created a broad programmatic foundation supporting SMR technologies that meet market realities and effectively complement large nuclear power plants and other sources of energy.

Federal Support for SMRs

This Committee recognized the value of public-private partnerships when it established the Nuclear Power 2010 program in the Energy Policy Act of 2005. Today, NP 2010, a 50–50 cost-shared program between the Department of Energy and utility industry partners, effectively addresses the technical, regulatory, and institutional barriers to building new, gigawatt-class nuclear power plants in the United States, providing the framework for industry decisions to construct and operate those plants. A similar model will also help reduce risk and accelerate deployment of promising new SMR technologies into the energy industry.

In its Fiscal Year (FY) 2011 budget request, the DOE requested funding for a new SMR program, to include both a cost-sharing initiative supporting near-term Design Certification of light water SMR technologies and R&D activities for longer-term technologies. There are also several bills under consideration in both the House and Senate that incorporate cost-sharing programs for SMRs, all articulating strong support for their development. A meaningful SMR cost-share program is vital to the energy industry. The timeline, scope and competitive selection criteria of such a program will have a significant impact on the ultimate success of SMRs in meeting our emergent energy industry challenges. To "develop and deploy clean, affordable, domestic energy sources as quickly as possible," as DOE states in the Roadmap, an SMR costshare program should support the near-term deployment of scalable, modular nuclear power in a way that enables the market adoption of practical, affordable carbon-free nuclear power. This program must foster development of technology that domestic utilities are likely to construct, own, and operate in quantity, while accelerating the creation of stable, high quality American jobs. We believe the B&W mPower reactor meets these criteria today.

To deploy SMRs by the end of this decade, it is important that the cost-share program scope span the spectrum of necessary industry development activities—including Design Certification, final design engineering, as well as Early Site Permit and Combined Operating License activities—rather than being confined simply to offsetting NRC fees. In any industry, unique risks are inherent in being a technology "first-mover". Recent worldwide experience in nuclear construction projects has shown that successful efforts to deploy new nuclear plant designs rely on government and industry cooperation encompassing support, design, licensing, and first-of-class plant construction. Government cooperation is essential to realistically address the licensing and schedule risks inherent in such demonstration projects. Through public-private cooperation, government and industry can share the risks and benefits of deploying the first SMR plants by the end of this decade.

As mentioned previously, B&W believes a reasonable programmatic goal is to deploy light water-based SMR technology in this country by the year 2020. Working outward from that goal, NRC Design Certification should be completed for one or two SMR designs by the year 2016. DOE has requested $39 million in FY 2011 for the SMR program, with funding split between the near-term, cost-shared Design Certification of two light-water SMR designs and the longer-term R&D for more conceptual SMR designs. Both program components are valuable. However, we are concerned that any reasonable split of this $39 million between the near-term Design Certification work and the longer-term R&D would significantly slow building industry momentum supporting a near-team SMR demonstration program, risking achievement of the goal to deploy a lead plant by 2020. This is why we have encouraged a number of Congressional Members to support a programmatic increase of the overall SMR program account to $55 million for FY 2011, which would leave adequate funds for long-term R&D while also providing reasonable funding to initiate meaningful Design Certification and licensing activity for up to two light water SMR technologies.

As this Committee considers legislation relating to SMRs, I would offer that a successful cost-sharing program must rely on competitive selection criteria that support our Nation's energy and security goals. Emphasis should be placed on:

- Modularity that enables factory manufacture of the integral nuclear steam supply system,
- Domestic utility commitment to near-term deployment of the technology,
- Economic competitiveness of the design without long-term government support,
- Domestic supply chain maturity to support near-term manufacturing, and
- Ability for the design to be certified and licensed within the existing regulatory structure.

These criteria will ensure that the SMR design selection is market-driven, and that public funding used to support those designs will ultimately be well spent on a successful program—one that enables a significant and long-lasting reduction in America's carbon emissions, that increases America's energy independence, and that creates substantial high-quality American jobs. In other words, these program selection criteria will help ensure that America leads innovation in this new technology and enhances its global competitiveness in the energy industry.

Closing Comments

B&W believes that SMRs such as the B&W mPower reactor offer America a practical and affordable source of near-term, domestically produced, clean energy. Delivering on the promise these reactors hold will depend on leadership and foresight from both the nuclear industry and government.

In 1957, the first commercial nuclear power plant at Shippingport, PA achieved full power operation, the result of a partnership between the Atomic Energy Commission and Duquesne Light Company. This cooperation between industry and government set in motion the development of the U.S. commercial nuclear industry, which for 50 years provided technology leadership to the world and today supplies 20 percent of all electricity generated in America, and 70 percent of our carbon-free electricity generation. America's nuclear industry owes its existence to a successful public-private partnership which first demonstrated the commercial application of nuclear energy. Our government's investment in this first-of-a-kind technology more than 50 years ago provided lasting and significant value to the Nation.

Today we have a new opportunity—an opportunity to reestablish America's leadership role in the commercial nuclear power industry that we first launched in 1957. A new public-private partnership will enable the U.S. to demonstrate the promise which SMR technology holds for our energy industry by the end of this decade. The DOE's Nuclear Energy R&D Roadmap has created a strong foundation from which to pursue this goal, and I look forward to working with the Committee on legislation to implement it.

Thank you for the privilege of testifying before the Committee. I am happy to answer any questions the Committee may have.

BIOGRAPHY FOR CHRISTOFER M. MOWRY

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a McDermott company

Christofer M. Mowry
President
Babcock & Wilcox Nuclear Energy

Christofer M. Mowry is the President of Babcock & Wilcox Nuclear Energy (B&W NE), an operating group of the The Babcock & Wilcox Company (B&W). Headquartered in Lynchburg, Virginia, B&W provides products and services to power generation and government operations customers. B&W has more than 20,000 employees in locations worldwide.

As President of B&W NE, Mr. Mowry is responsible for all commercial nuclear power business activities, including development and deployment of the B&W mPower™ reactor. He is also overseeing B&W NE's commercial manufacturing activities as well as nuclear construction and inspection services.

Before joining B&W, Mr. Mowry served as President and Chief Operating Officer of Welding Services, Inc. (WSI) in Atlanta, Georgia from 2005 – 2008. WSI is leader in the global energy infrastructure marketplace for specialty robotic in-situ repairs and related mechanical integrity solutions.

Prior to this position, he held several high-level management positions with GE Energy. Mr. Mowry joined the company a Program Manager and subsequently as a Sales Executive for GE Nuclear Energy in San Jose, California and Stockholm, Sweden, respectively. He went on to serve as President of GE Reuter-Stokes in Cleveland, Ohio; General Manager of GE Management Systems in Atlanta, Georgia; and General Manager of GE Hydro Projects and Services in Oslo, Norway and Atlanta, Georgia. Mr. Mowry began his career with the Philadelphia Electric Company, holding positions of increasing responsibility in nuclear operations and engineering at the Limerick Generating Station.

Mr. Mowry holds a Master of Science in Mechanical Engineering from Drexel University in Philadelphia, Pennsylvania. He also earned a Bachelor of Science in Engineering and a Bachelor of Arts in Astronomy from Swarthmore College in Swarthmore, Pennsylvania. Mr. Mowry speaks German and Swedish. He also holds four U.S. patents related to digital control systems.

Mr. BAIRD. Thank you, Mr. Mowry.
Dr. Ferguson.

STATEMENTS OF CHARLES FERGUSON, PRESIDENT, FEDERATION OF AMERICAN SCIENTISTS

Dr. FERGUSON. Thank you, Mr. Chairman and other Members of the Committee. Thank you for the opportunity to testify on behalf of the Department of Energy's—comment on the Department of Energy's Roadmap. I request that my submitted written testimony be entered into the record.

In my limited time I want to focus on four issues, four themes. One, the U.S. ability to compete, the issue of proliferation, proliferation resistance, waste disposal, and finally systems analysis compared to other energy sources and the various fuel cycles being considered.

Other countries such as China, India, and Russia could already manufacture small to medium-power reactors. The Indian reactors, in particular, present proliferation concerns. So the United States confronts an economic competitive disadvantage. Because the U.S. has yet to license such reactors towards domestic use, it has placed itself at additional market disadvantage. By the time the U.S. has licensed such reactors, China, India, as well as other competitors may have established a stronghold on this emerging market.

Given the differences in design philosophy among the six or seven reactors, SMRs, being considered in the U.S. market, none of these designs have yet penetrated the market, it is too soon to tell which, if any, will emerge as market champions.

Nonetheless, because of the early stage of development, the United States has an opportunity to state clearly the criteria for successful use of SMRs. Because of the head start of these other countries, the United States should not procrastinate and should take a leadership role in setting the standard for safe, secure, and proliferation-resistant SMRs that can compete in the market.

About 12 years ago a systems analysis was begun at Lawrence Livermore National Laboratory looking at what should be the criteria, especially in developing countries. The reactors that we would market here, the SMRs in the United States, would set an example for those in the developing world, and there are three issues that need to be addressed. Can we achieve reliable, safe operation with a minimum of maintenance and supporting infrastructure? Can we offer economic competitive sources of energy that can compete with alternative energy sources available to those candidate countries and the sites the reactors would be located? And finally, could we demonstrate significant improvements in proliferation resistance relative to existing reactor systems?

And these two researchers, Dr. Brown and Dr. Hasberger of Lawrence Livermore, pointed out that currently-available technologies fail in one or more of those standards. So they put forward what one would consider kind of an ideal type of situation. One would be that we can eliminate the need for onsite refueling of the reactor, and that would minimize the risk of seizure of fissile material, and secondly, they recommend finding a disposal pathway so you don't have plutonium and other fissile material lingering onsite in that country.

Unfortunately, because of the situation with waste disposal in the United States and other countries, you know, no country has a repository for spent nuclear fuel or nuclear waste. There is no clear pathway to take back that material from these client countries. Nonetheless, we do have a precedent under the Atoms for Peace Program. We supplied highly-enriched uranium research reactors and now we have been taking that material back under the Global Threat Reduction Initiative from various client states and taking it back and securing it in Oak Ridge, Tennessee.

So we might be able to play off that precedent. We also need to establish market incentives for disposal of nuclear waste from these client countries. Perhaps if the fee is right, we could achieve public acceptance here in the United States to take back some of that fuel or find other locations, very secure locations for those materials.

And concerning systems analysis for the DOE Roadmap, I think we need to look very seriously at the economic costs of the various fuel lifecycles; the once-through cycle, the modified cycle, and the closed cycle. Right now there is an economic disadvantage for the once-through recycling and for the full closed recycling methods, and considerable work needs to be done to figure out what industry is willing to do to help share the cost, whether industry is really very supportive economically of that approach.

So in closing, I would say that we really need to determine how much industry is willing to contribute to cost sharing and looking at the economic advantages of these new small modular reactors and the other systems being considered under the DOE's Roadmap.

Thank you.

[The prepared statement of Dr. Ferguson follows:]

PREPARED STATEMENT OF CHARLES D. FERGUSON

Introduction

Thank you, Chairman Bart Gordon, Ranking Member Ralph Hall, and Members of the Committee. I appreciate the opportunity to appear before you and comment on the Department of Energy's Nuclear Energy Research and Development Roadmap.

In his invitation letter, Chairman Gordon requested that I begin by providing a very brief overview of the Federation of American Scientists (FAS) and its *Future of Nuclear Energy in the United States* project. FAS was founded in 1945 by many of the atomic scientists who had developed the first atomic bombs in the Manhattan Project. They dedicated themselves to preventing nuclear war and reducing nuclear dangers by stopping the further spread of nuclear weapons to more states and terrorist groups. Several of the founders such as physics Nobel laureate Hans Bethe supported widespread use of peaceful nuclear energy. They realized, however, that to achieve safe and secure use of nuclear power, governments needed to make stopping nuclear proliferation a top priority. Because misuse of commercial nuclear technology to make weapons may harm business and the prospects for further expansion of commercial nuclear power, industry also has a vital stake in ensuring peaceful use.

Building on this legacy of more than six decades, FAS has recently begun the *Future of Nuclear Energy in the United States* project in partnership with Washington and Lee University. With generous grant support from the Lenfest Foundation, Professor Frank Settle of Washington and Lee University and I are leading a multiple author-project. The goal of the project is to assess lessons learned from the past, examine the present status of U.S. nuclear energy, and explore where nuclear energy development in the United States is headed. The main product will be a book-length report with chapters on licensing, financing, safety, security, the fuel cycle, waste management, comparison of nuclear energy to other energy sources, and nuclear energy's role in transportation and the smart grid. The publication date is early next year. Immediately after publication, Dr. Settle, the authors, and I will disseminate the results through briefings to Executive and Legislative officials, the news media, and other analysts. We will keep the House Committee on Science and Technology apprized of the progress of the project.

Small Modular Reactors

Because of the renewed attention to small modular reactors (SMRs), I will start my analysis of the Department of Energy's proposed plans with this subject.[1] In many respects, small power reactors are not new technologies but the potential for modularity, efficient factory construction, relatively quick deployment once built, and applications other than electricity generation offer the promise of cost competitive energy sources for markets that are not appropriate for large power reactors. As a matter of liability insurance, small power reactors are defined as generating 300 Megawatts (MWe) or less of electrical power. Medium power reactors range in power from greater than 300 MWe to 700 MWe. The typical large power reactors now being marketed can generate from 1,000 MWe to 1,600 MWe.

The United States and several other countries have considerable experience in building and operating small and medium power reactors. The U.S. Navy, for example, has used small power reactors since the 1950s to provide propulsion and electrical power for submarines, aircraft carriers, and some other surface warships.

[1] Steven Chu, "America's New Nuclear Option: Small Modular Reactors will Expand the Ways We Use Atomic Power," *Wall Street Journal*, March 23, 2010.

China, France, Russia, and the United Kingdom have also developed nuclear powered naval vessels that use small reactors. Notably, Russia has deployed its KLT–40S and similarly designed small power reactors on icebreakers and has in recent years proposed building and selling barges that would carry these types of reactors for use in sea-side communities throughout the world. China has already exported small and medium power reactors. In 1991, China began building a reactor in Pakistan and started constructing a second reactor there in 2005. In the wake of the U.S.-India nuclear deal, Beijing has recently reached agreement with Islamabad to build two additional reactors rated at 650 MWe.[2]

One of the unintended consequences of more than 30 years of sanctions on India's nuclear program is that India had concentrated its domestic nuclear industry on building small and medium power reactors based on Canadian pressurized heavy water technology, or Candu-type reactors. Pressurized heavy water reactors (PHWRs) pose proliferation concerns because they can be readily operated in a mode optimal for producing weapons-grade plutonium and can be refueled during power operations. Online refueling makes it exceedingly difficult to determine when refueling is occurring based solely on outside observations, for example, through satellite monitoring of the plant's operations. Thus, the chances for potential diversion of fissile material increase. This scenario for misuse underscores the need for more frequent inspections of these facilities. But the limited resources of the International Atomic Energy Agency have resulted in a rate of inspections that are too infrequent to detect a diversion of a weapon's worth of material.[3]

The opening of the international nuclear market to India may lead to further spread of PHWR technologies to more states. For example, last year, the Nuclear Power Corporation of India, Ltd. (NPCIL) expressed interest in selling PHWRs to Malaysia.[4] NPCIL is the only global manufacturer of 220 MWe PHWRs. New Delhi favors South-to-South cooperation; consequently developing states in Southeast Asia, sub-Saharan Africa, and South America could become recipients of these technologies in the coming years to next few decades.[5] Many of these countries would opt for small and medium power reactors because their electrical grids do not presently have the capacity to support large power reactors and they would likely not have the financial ability to purchase large reactors.

What are the implications for the United States of Chinese and Indian efforts to sell small and medium power reactors? Because China and India already have the manufacturing and marketing capability for these reactors, the United States faces an economically competitive disadvantage. Because the United States has yet to license such reactors for domestic use, it has placed itself at an additional market disadvantage. By the time the United States has licensed such reactors, China and India as well as other competitors may have established a strong hold on this emerging market.

The U.S. Nuclear Regulatory Commission cautioned on December 15, 2008 that the "licensing of new, small modular reactors is not just around the corner. The NRC's attention and resources now are focused on the large-scale reactors being proposed to serve millions of Americans, rather than smaller devices with both limited power production and possible industrial process applications." The NRC's statement further underscored that "examining proposals for radically different technology will likely require an exhaustive review" . . . before "such time as there is a formal proposal, the NRC will, *as directed by Congress*, continue to devote the majority of its resources to addressing the current technology base."[6] Earlier this year, the NRC devoted consideration to presentations on small modular reactors from the Nuclear Energy Institute, the Department of Energy, and the Rural Electric Cooperative Association among other stakeholders.[7] At least seven vendors have proposed that their designs receive attention from the NRC.[8]

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[2] Agence France Presse, "China to Build Two Nuclear Reactors in Pakistan," April 29, 2010.

[3] Thomas B. Cochran, "Adequacy of IAEA's Safeguards for Achieving Timely Detection," Chapter 6 in Henry D. Sokolski, editor, *Falling Behind: International Scrutiny of the Peaceful Atom* (Strategic Studies Institute, U.S. Army War College, February 2008).

[4] P Vijian, "India Keen to Sell Nuclear Reactors to Malaysia," BBC Monitoring Asia Pacific—Political, April 27, 2009.

[5] More in depth analysis on Asia and nuclear energy developments will appear later this year in a book chapter I am writing for the National Bureau of Asian Research.

[6] U.S. Nuclear Regulatory Commission, "For the Record: 'Small' Reactor Reviews," December 15, 2008. [Emphasis added.]

[7] See, for example, presentations for the panel "Increasing Interest in Small Modular Reactors" at the RIC 2010 conference, March 11, 2010.

[8] U.S. Nuclear Regulatory Commission, "Advanced Reactors," *www.nrc.eov/reactors/advanced.html*, November 4, 2009.

Given the differences in design philosophy among these vendors and the fact that none of these designs have penetrated the commercial market, it is too soon to tell which, if any, will emerge as market champions. Nonetheless, because of the early stage in development, the United States has an opportunity to state clearly the criteria for successful use of SMRs. But because of the head start of China and India, the United States should not procrastinate and should take a leadership role in setting the standards for safe, secure, and proliferation-resistant SMRs that can compete in the market.

Several years ago, the United States sponsored assessments to determine these criteria.[9] While the Platonic ideal for small modular reactors will likely not be realized, it is worth specifying what such an SMR would be. N. W. Brown and J. A. Hasberger of the Lawrence Livermore National Laboratory assessed that reactors in developing countries must:

- "achieve reliably safe operation with a minimum of maintenance and supporting infrastructure;
- offer economic competitiveness with alternative energy sources available to the candidate sites;
- demonstrate significant improvements in proliferation resistance relative to existing reactor systems." [10]

Pointing to the available technologies at that time from Argentina, China, and Russia, they determined that "these countries tend to focus on the development of the reactor without integrated considerations of the overall fuel cycle, proliferation, or waste issues." They emphasized that what is required for successful development of an SMR is "a comprehensive systems approach that considers all aspects of manufacturing, transportation, operation, and ultimate disposal."

Considering proliferation resistance, their preferred approach is to eliminate the need for on-site refueling of the reactor and to provide for waste disposal away from the client country. By eliminating on-site refueling the recipient country would not need to access the reactor core, where plutonium—a weapons-usable material—resides. By removing the reactor core after the end of service life, the recipient country would not have access to fissile material contained in the used fuel. Both of these proposed criteria present technical and political challenges.

Ideally, the reactor would have a core life of 30 or more years. Such reactors are presently in use in the U.S. Navy. But the problem from a proliferation standpoint is that these reactors are fuel led with weapons-grade uranium. Thus, if a client country seized such a reactor and if it could break into the reactor's core, it could have bomb-usable fissile material. While the transfer of U.S. naval reactor technology is not advisable, perhaps there are other methods to achieve lifetime cores. A Japanese group of researchers, for example, examined a conceptual design for a small lead-bismuth cooled fast neutron reactor that computer simulations indicate the fuel could last for 30 years.[11] Fast reactors, however, have had a history of poor performance and have generally cost much more than thermal reactors.[12] Only Russia presently has a large commercial fast reactor in operation although China, Japan, and India have active fast reactor programs. A more promising method for lifetime cores may involve thorium, a fertile element that can be used to make fissile fuel. Depending on the reactor design, thorium-based fuels offer favorable proliferation-resistant properties. Concerning long-lived cores, a research group has recently shown via computer simulations that thorium-type small reactors may not need refueling until after ten years and further design may result in even longer lived cores.[13]

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[9] See, for example, U.S. Department of Energy, Office of Nuclear Energy, Science, and Technology, Report to Congress on Small Modular Nuclear Reactors, May 2001.

[10] N. W. Brown and J. A. Hasberger, "New Concepts for Small Power Reactors Without On-Site Refueling for Non-Proliferation," Paper for the Advisory Group Meeting on Small Power and Heat Generation Systems on the Basis of Propulsion and Innovative Reactor Technologies, Obninsk, Russian Federation, Convened by the International Atomic Energy Agency, July 20–24, 1998.

[11] Yoshitaka Chikazawa et al., "A Conceptual Design of a Small Natural Convection Lead-Bismuth Cooled Reactor Without Refueling for 30 Years," *Nuclear Technology*, Vol. 154, 2006, pp. 142–154.

[12] Thomas B. Cochran, Harold A. Feiveson, Walt Patterson, Gennadi Pshakin, M. V. Ramana, Mycle Schneider, Tatsujiro Suzuki, and Frank von Hippel, *Fast Breeder Reactor Programs: History and Status*, A Research Report of the International Panel on Fissile Materials, February 2010.

[13] Iyos Subki et al., "The Utilization of Thorium for Long-Life Small Thermal Reactors Without On-Site Refueling," *Progress in Nuclear Energy*, March–August 2008, pp. 152–156.

But these concepts will likely require many years of development before they are ready for the commercial market. And although thorium reactors, in principle, look promising, the dominant paradigm has been to favor uranium-fueled reactors.[14] Marketplace inertia and comfort level with the uranium-based technologies have erected barriers to different concepts. Moreover, the small reactor designs that are further along in development do not have long-lived cores.

Even if proliferation-resistant lifetime core reactors were available, the other challenge is to provide a proliferation-resistant pathway to nuclear waste management. As indicated by Brown and Hasberger, the ideal would be to remove as soon as possible the used fuel from the recipient country. But then the question is: What country will accept the used fuel and the other radioactive materials? No country has opened up a permanent repository for domestically generated nuclear waste. However, Russia has accepted used fuel from client states under the condition that Russia reprocesses the used fuel to extract plutonium for reuse. Also, Britain and France have reprocessed used fuel from client states under the condition that high level waste is returned to the clients.

Another option is to send used fuel from SMRs and perhaps other reactors fueled under a fuel leasing agreement to territory designated as an international zone. Such a zone would have to have rigorous security. In addition to making the difficult decision as to where to site this zone, supplier states would also have to reach agreement on whether to just store the used fuel or to reprocess it in order to recycle the plutonium and other fissionable materials. The political obstacles to creating this option for used fuel disposal appear formidable.

Market-based incentives may offer the way forward to convince clients to buy SMRs. If a client especially one without an existing nuclear waste storage facility wants to save costs, its government may be willing to pay a fee for disposal of the waste in a supplier state. Doing so will obviate the need for the client to pay for the expenditure of a disposal facility. But achieving agreement will require a major policy shift on the part of supplier states. Their governments will have to convince their publics to accept the waste. If the disposal fee were large enough but also fair to the client, then a market could be created. If the populace near the disposal site were assured that the project would create considerable number of jobs and would uphold the highest safety and security standards, then acceptance may follow. Because the used fuel from SMRs would be much more compact than used fuel from large reactors, the barrier to acceptance of the SMR used fuel may also be lower. As a possible precedent, the United States has repatriated used U.S.-origin fuel containing highly enriched uranium. This material has fueled research reactors provided to client states under the Atoms for Peace Program.

A systems analysis of the economics of SMRs is considerably different than the economics of more traditional large reactors. On a per kilowatt cost basis, a large reactor is more cost competitive as compared to a single SMR. But as two researchers for the International Atomic Energy Agency have pointed out, it is futile to make such a comparison because "SMRs are suitable for those locations that might not be appropriate for larger plants."[15] Such locations include countries with weak electrical grids, remote places, and locales favoring having the reactor near a population center to provide electrical and non-electrical needs such as district residential heating, industrial heating, or desalination. The researchers note that "SMRs have a potential to be competitive by employing alternative design strategies, taking advantage of smaller reactor size, offering a less complex design and operation and maintenance, relying on deployment-in-series approaches, taking an advantage of the accelerated learning, multiple unit factors and shorter construction duration." They caution that "the economic data does not exist or is not available at a fine enough level of detail to perform the complex comparative analyses normally associated with 'business models.'"[16]

Nonetheless, the IAEA has sponsored research that has assessed the cost competitiveness of constructing several SMRs at a site versus building one large reactor.[17]

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[14] Leslie Allen, "If Nuclear Power Has a Promising Future . . . Seth Grae Wants to be the One Leading the Charge," *Washington Post*, August 9, 2009.

[15] V. Kuznetsov and N. Barkatullah, "Approaches to Assess Competitiveness of Small and Medium Sized Reactors," *Proceedings of the International Conference on Opportunities and Challenges for Water Cooled Reactors in the 21st Century*, October 27–30, 2009, IAEA, Vienna, Austria, Paper 1S01.

[16] Ibid.

[17] IAEA Nuclear Energy Series Report "Approaches to Assess Competitiveness of SMRs," *Status: submitted for pre publication review and clearances; Targeted publication date: 2010; draft available at*: *http://www.iaea.org/NuclearPower/Downloads/SMR/docs/Approaches-to-assess-competitiveness-of-SMR-Draft.pdf*

In particular, the IAEA study has estimated the overall cost of four SMRs of 300 MWe each to one large 1,200 MWe reactor. Thus, the cumulative power ratings are equivalent. The SMRs would be built sequentially so that once one has been completed another will begin construction nine months later. The estimated construction time for each SMR is less than half the time to build one 1,200 MWe reactor. While the economy of scale economic factor alone would indicate that the 1,200 MWe reactor has a 1.74 ratio cost advantage, other factors even the playing field for the combined SMRs. By building multiple units, the SMRs are estimated to achieve a 0.78 cost reduction. The speedier construction schedule per SMR gives an advantage, but balanced over the total construction time of the four SMRs, the cost reduction is only 0.94. The factory-built modular design provides a significant cost reduction of 0.85. The timing of the units to achieve favorable financing may result in another factor reduction of 0.95. Combining these cost reductions, the IAEA study indicates that the overall cost of the four SMRs is only 1.04 times greater than one large reactor, meaning nearly equivalent. It is important to underscore that these estimates are based on computer studies and have not been field tested by actual construction. As with practically all first-of-a-kind endeavors, the first SMRs will most likely exceed cost estimates. But with learning and deploying enough of these reactors, costs may very well come down.

It is also worth pointing out that in the United States, Alaska and Hawaii may derive the most benefit from SMRs. Based on a 2001 DOE assessment, "SMRs could be a competitive option" in those states because "the industrial rate for electricity charged by selected Alaska and Hawaii utilities varied from 5.9 to 36.0 cents per kWh" and for a generic 50 MWe SMR, "the range of electricity cost is estimated at 5.4 to 10.7 cents per kWh," while the "range of cost for a 10 MWe SMR is 10.4 to 24.3 cents per kWh."[18] Moreover, SMRs could help Hawaii reduce its substantial dependence on imported oil to generate electricity. According to the Energy Information Administration, petroleum provides about three-fourths of Hawaii's electricity.[19] In comparison, petroleum is used in the United States as a whole to generate about two percent of the nation's electricity.

Nuclear Energy Research and Development Roadmap

Because the United States relies on nuclear power to provide about 20 percent of its electricity and because this energy source provides the largest share of near-zero carbon emission electricity, the United States has a clear interest in protecting its investment in the current fleet of 104 commercial reactors. Many of these reactors have already reached their nominal 40-year lifespan. Dozens of these reactors have been recently receiving 20-year license extensions. Because the United States has not constructed a new reactor since 1996 with the completion of TVA's Watts Bar I, which was ordered in the early 1970s, the existing fleet is relatively old. If no new reactors are built in the next 20 years and if there are no further life extensions beyond 60 years, within a few years after 2030 about 40 percent of the current fleet will have to be decommissioned. While 20 years may appear to be a long time away, understanding the science and engineering demands for extended reactor life will require at least several years of R&D. Consequently, I concur with DOE's emphasis in R&D Objective 1 to invest in improving the reliability, sustaining the safety, and extending the life of the current fleet. The challenges in this objective are largely technical and play to DOE's strength.

The challenges in R&D Objective 2 to make nuclear power more affordable are more complex in that they are a mix of political, technical, regulatory, and financial factors. Factors outside DOE's control include streamlining the regulatory process for new reactors and placing a price on carbon emissions. The latter factor would likely have the greatest effect in making nuclear power and other low carbon emission sources more cost competitive with fossil fuels.

Factors primarily within DOE's control include: R&D into new reactor fuels that can provide more efficient use of fissionable material and can create isotopic compositions of fissile material that are less desirable for weapons-use, R&D into very high temperature reactors that can produce hydrogen for fuel cells and process heat for industrial applications, advanced computer modeling and simulation, fundamental research in materials science, and systems analysis. While the R&D Roadmap emphasizes "systems design for revolutionary new reactor concepts," there is an urgent need for systems analysis along at least two fronts.

[18] U.S. Department of Energy, Office of Nuclear Energy, Science, and Technology, *Report to Congress on Small Modular Nuclear Reactors*, May 2001, p. iv.

[19] U.S. Energy Information Administration, "Hawaii," Updated May 13, 2010, *http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=HI*

First, DOE should, if not already doing so, examine the competition among currently available reactor designs and the newer designs envisioned in the roadmap. An investment in a new nuclear reactor is at least a 60-year commitment in operations. Financial incentives for utilities to buy the currently available technologies may result in little or no demand for the more innovative technologies outlined in the roadmap.

Second, DOE should, if not already doing so, continually perform a systems analysis of the competition among the various electricity sources. Particular attention should be made in assessing how future changes in the electrical grid using "smart" systems may allow for greater use of decentralized sources of renewable energies and how developments in energy storage systems could affect the use of large and small power generators.

The third R&D objective seeks to develop sustainable nuclear fuel cycles. I agree with the general principles specified in the roadmap to "improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and limit proliferation risk." It makes sense to "enable future decision makers to make informed choices about how best to manage the used fuel from reactors." A long term R&D program that seriously examines all three types of nuclear fuel cycles is needed. While the plan outlined in the roadmap appears sound in terms of fundamental R&D, I would encourage DOE to perform a systematic economic analysis of the lifecycles of all three fuel cycles. Similarly, it is important to determine the extent to which industry will provide financial support for the two types of fuel cycles currently not used in the United States: the modified open cycle and full recycling.

Recommendations

- Determine the proportion of cost sharing industry can commit to in developing the Department of Energy's roadmap.
- Provide adequate R&D funding for development of lifetime core SMRs that do not use or produce fissile material that would be desirable for nuclear weapons production.
- Determine what resources the Nuclear Regulatory Commission will require to continue with rigorous evaluations of the many applications for large reactors while expediting the examination of small modular reactors.
- Implement a variable fee structure for NRC license applications in order to lower the financial barrier for SMR applicants. In March 2009, the NRC published an advanced notice of a proposed rulemaking to institute such a structure.[20]
- Provide flexibility for the combined construction and operating license (COL) process to facilitate adding multiple SMRs to a site over a several years to few decades period.
- Reevaluate the requirement for all Emergency Planning Zones (EPZs) to be 10 miles in radius from the reactor site. Even a "large" SMR will have a power rating one-fourth or less than the rating of a typical large reactor. Because an SMR is less powerful, its radioactivity content is considerably less than for a large reactor. Emergency Planning Programs may then require smaller EPZs for SMRs. But as more SMRs are added to a site, the EPZ may need to change to scale with the growth in power capacity.
- Request the Obama administration to provide a strategy for international sales of SMRs that only meet high standards of safety, security, and proliferation-resistance. Achieving adoption of these criteria will likely face resistance from states that have available small and medium power reactors that fall short in one or more of the standards.
- Require clear pathways for safe and secure disposal of used fuel and other radioactive waste before selling SMRs to countries without disposal facilities or to countries where regional security concerns may increase the likelihood of diversion of fissile material into weapons programs.

[20] Charles F. Rysavy, Stephen K. Rhyne, and Roger P. Shaw, K&L Gates LLP, "Small Modular Reactors," Special Committee on Nuclear Power, American Bar Association Section of Environment, Energy, and Resources, December 2009.

BIOGRAPHY FOR CHARLES D. FERGUSON

Dr. Charles D. Ferguson is the President of the Federation of American Scientists (FAS). He is also an Adjunct Professor in the Security Studies Program at Georgetown University and an Adjunct Lecturer in the National Security Studies Program at the Johns Hopkins University. Prior to FAS, he worked as the Philip D. Reed Senior Fellow for Science and Technology at the Council on Foreign Relations, where he was the project director of the *Independent Task Force on U.S. Nuclear Weapons Policy*, chaired by William J. Perry and Brent Scowcroft. Before his work at CFR, he was the Scientist-in-Residence in the Monterey Institute's Center for Nonproliferation Studies, where he co-wrote (with William Potter) the book *The Four Faces of Nuclear Terrorism* (Routledge, 2005). While working at the Monterey Institute, he was the lead author of the report *Commercial Radioactive Sources: Surveying the Security Risks*, which was the first in-depth, post-9/11 study of the "dirty bomb" threat. This report won the 2003 Robert S. Landauer Lecture Award from the Health Physics Society. Dr. Ferguson has consulted with Sandia National Laboratories and the National Nuclear Security Administration on improving the security of radioactive sources. He also serves on the advisory committee for Oak Ridge National Laboratory's Energy and Engineering Sciences Directorate. He has worked as a physical scientist in the Office of the Senior Coordinator for Nuclear Safety at the U.S. Department of State. He is writing a book for Oxford University Press titled *Nuclear Energy: What Everyone Needs to Know* (forthcoming, January/February 2011). He graduated with distinction from the United States Naval Academy and served in the U.S. nuclear Navy, receiving training as a nuclear engineer at the Naval Nuclear Power School. He earned a Ph.D. in physics from Boston University.

Mr. BAIRD. Thank you, Dr. Ferguson.

Dr. Peters.

STATEMENTS OF MARK PETERS, DEPUTY DIRECTOR FOR PROGRAMS, ARGONNE NATIONAL LAB

Dr. PETERS. Mr. Baird, Mr. Rohrabacher, and Members of the Committee, thank you for the opportunity to testify before you today on advanced nuclear fuel cycle research development and demonstration and the Department of Energy's Nuclear Energy Roadmap. Mr. Chairman, I ask that my full written testimony be entered into the record, and I will summarize it here.

First, some remarks on sustainable nuclear energy. Nuclear energy must experience significant growth to support the goals of reliable and affordable energy in a carbon-constrained world. Expansion of nuclear energy will increase the need for effective nuclear waste management. Any advanced nuclear fuel cycle aimed at meeting the challenges of nuclear waste management must simultaneously address issues of economics, uranium resource utilization, nuclear waste minimization, and a strengthened non-proliferation regime.

As we heard from Dr. Miller, there are two basic fuel cycle approaches: an open or once-through fuel cycle, which is current U.S. policy, which involves treating used nuclear fuel as waste with ultimate disposition of the material in a geologic repository. In contrast, a closed or recycle fuel cycle as currently planned by other countries, for example, France and Japan, involves treating used nuclear fuel as a resource whereby separations and actinide recycling in reactors work with geologic disposal.

In our view, to maximize the benefits of nuclear energy it will ultimately be necessary to close the fuel cycle. Note, while geologic repositories will be needed for any type of fuel cycle, the use of a repository could be quite different for a closed fuel cycle. That said, there is no urgent need to deploy recycling today. Fortuitously it is conceivable that the decade's long hiatus in U.S. investment circumvents the need to rely on dated recycling technologies. Rather, we have the option to develop and build new technologies and develop business models using advanced systems.

So now for some comments on the Nuclear Energy Roadmap. The Nuclear Energy R&D Roadmap provides a comprehensive vision for advancing nuclear energy as an essential energy source. Argonne strongly supports the R&D objectives described in the Roadmap. Argonne also agrees with the R&D approach described in the Roadmap and particularly the synergistic use of experiment, theory, and modeling and simulation to achieve the foregoing objectives.

In collaboration with other DOE laboratories and universities, Argonne is advancing a new science and simulation-based approach for optimizing the design of advanced nuclear energy systems and assuring their safety and security.

A robust and effective R&D demonstration strategy for an advanced fuel cycle must include several components; a fuel cycle system development activity to guide and appropriately focus the research; science and discovery contributions to technology and design, increased role of modeling and simulation and nuclear energy research and system design; advances in separations, fuel, and nuclear reactor technologies; advancement of safe and secure use of nuclear energy on an international basis; education and training of future nuclear energy professionals; support for modernization of aging research facilities for conducting experimental work; coordination and integration of R&D and separations of wastes sponsored by different government agencies and offices; and finally, close cooperation with industry in R&D, demonstration, and commercialization efforts as part of robust public-private partnerships.

Concerning objective three of the Roadmap, namely the sustainable fuel cycle, Argonne supports a greater emphasis on coupling the science-based approach that is articulated in the roadmap, and coupling that with an active design and technology demonstration effort that would guide and appropriately focus the R&D and enable assessment of programmatic benefits in a holistic manner.

This would be accompanied by close cooperation of DOE, its national laboratories, universities, and industry. These efforts would allow for fuel cycle demonstration in a timeframe that could influence the course of fuel cycle technology commercialization on a global basis.

In particular, Argonne believes that advanced fast neutron reactors, recycle processes, and waste management technologies should be developed and demonstrated at engineering scale during the next 20 years.

I should also say that the Blue Ribbon Commission is evaluating options for the management of using nuclear fuel, which we hope will result in recommendations for changes in U.S. nuclear past policy. In parallel with these efforts, advances in used fuel processing and waste storage and disposal technologies will support the development of an integrated policy for nuclear waste management in the U.S.

So in summary, the United States should conduct a science-based advanced nuclear fuel cycle R&D and demonstration program to evaluate recycling and transmutation technologies that minimize proliferation risks and environmental public health and safety impacts. This would provide a necessary option to reprocessing technologies deployed today and supports evaluation of alternative national strategies for nuclear fuel disposition, effective utilization and deployment of advanced reactor concepts, and eventual development of a permanent geologic repository. This should be done as part of robust public-private partnerships involving the Department of Energy, its national laboratories, universities and industry, and conducted with a sense of urgency and purpose consistent with the U.S. retaining its intellectual capitol and leadership in international nuclear energy community.

That concludes my remarks, Mr. Chairman. I thank you and would be pleased to answer any questions.

[The prepared statement of Dr. Peters follows:]

PREPARED STATEMENT OF MARK T. PETERS

Summary

The United States should conduct a science-based, advanced nuclear fuel cycle research, development, and demonstration program to evaluate recycling and transmutation technologies that minimize proliferation risks and environmental, public health, and safety impacts. This would provide a necessary option to reprocessing technologies deployed today, and supports evaluation of alternative national strategies for commercial used nuclear fuel disposition, effective utilization and deployment of advanced reactor concepts, and eventual development of a permanent geologic repository(s). This should be done as part of robust public-private partnerships involving the Department of Energy (DOE), its national laboratories, universities, and industry; and conducted with a sense of urgency and purpose consistent with the U.S. retaining its intellectual capital and leadership in the international nuclear energy community.

Introduction and Context

Sustainable Nuclear Energy

World energy demand is increasing at a rapid and largely unsustainable pace. In order to satisfy the demand, reduce greenhouse gas emissions, and protect the environment for succeeding generations, energy production must evolve from the current reliance on fossil fuels to a more balanced, sustainable approach based on abundant, clean, and economical energy sources. Therefore, there is a vital and urgent need to develop safe, clean, and secure global energy supplies. Nuclear energy is already a proven, reliable, abundant, and "carbon-free" source of electricity for the U.S. and the world. In addition to contributing to future electricity production, nuclear energy could also be a critical resource for "fueling" the transportation sector (i.e. electricity for plug-in hybrid and electric vehicles and process heat for hydrogen and synthetic fuels production) and for desalinating water. However, nuclear energy must experience significant growth to support the goals of reliable and affordable energy in a carbon-constrained world.

Key challenges associated with the global expansion of nuclear energy include: assurance of ample uranium resources for fuel; the need for increased numbers of trained engineers and technicians to design, build, and safely operate the plants; the need for increased industrial capacity for manufacturing and construction; the need to expand the regulatory infrastructure requisite for safe and secure operations; the need for integrated waste management; and the need to control proliferation risks associated with greater access to sensitive nuclear technologies.

Moreover, domestic expansion of nuclear energy will increase the need for effective nuclear waste management in the U.S. Any advanced nuclear fuel cycle aimed at meeting these challenges must simultaneously address issues of economics, uranium resource utilization, nuclear waste minimization, and a strengthened nonproliferation regime, all of which require systems analysis and investments in technology research and development, demonstration, and test and evaluation. In the end, a comprehensive and long-term vision for expanded, sustainable nuclear energy must include:

- Safe and secure fuel-cycle technologies,

- Cost-effective technologies for an overall fuel-cycle system, and
- Closed fuel cycle for waste and resource management.

Used Nuclear Fuel Management

It is the composition of used nuclear fuel that make its ultimate disposal challenging. Fresh nuclear fuel is composed of uranium dioxide (about 96% Uranium-238, and 4% Uranium-235). During irradiation, most of the Uranium-235 is fissioned, and a small fraction of the Uranium-238 is transmuted into heavier elements (known as transuranics). The used nuclear fuel contains about 93% uranium (mostly Uranium-238), about 1% plutonium, less than 1% minor actinides (neptunium, americium, and curium), and about 5% fission products. Uranium, if separated from the other elements, is relatively benign, and could be disposed of as low-level waste or stored for later re-use, but some of the other byproducts raise significant concerns:

- The fissile isotopes of plutonium, americium, and neptunium are potentially usable in weapons and, therefore, raise proliferation concerns. However, used nuclear fuel remains intensely radioactive for over one hundred years. Without the availability of remote handling facilities, these isotopes cannot be readily separated, essentially protecting them from diversion.
- Three isotopes, which are linked through a decay process (Plutonium-241, Americium-241, and Neptunium-237), are the major contributors to long-term radiotoxicity (100,000 to 1 million years), and hence, potential significant dose contributors in a repository, and also to the long-term heat generation that is a key design limit to the amount of waste that can be placed in a given repository space.
- Certain fission products (notably cesium and strontium) are major contributors to any storage or repository's short-term heat load, but their effects can be mitigated through engineering controls.
- Other fission products (Technetium-99 and Iodine-129) also contribute to long-term potential dose in a repository.

The time scales required to mitigate these concerns are daunting: several of the isotopes of concern will not decay to safe levels for hundreds of thousands of years. Thus, the solutions to long-term disposal of used nuclear fuel are limited to three options (not necessarily mutually exclusive): the location of a geologic environment that will remain stable for that period; the identification of waste forms that can contain these isotopes for that period; or the destruction of these isotopes. These three options underlie the major fuel cycle strategies that are currently being developed and deployed in the U.S. and abroad.

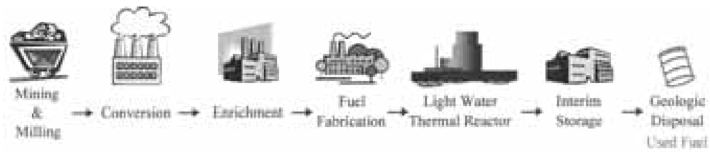

Figure 1. Open (or once-through) nuclear fuel cycle

The nuclear fuel cycle is a cradle-to-grave framework that includes uranium mining, fuel fabrication, energy production, and nuclear waste management. There are two basic nuclear fuel-cycle approaches. An open (or once-through) fuel cycle, as currently planned by the U.S., involves treating used nuclear fuel as waste, with ultimate disposition of the material in a geologic repository (see Figure 1). In contrast, a closed (or recycle) fuel cycle, as currently planned by other countries (e.g., France, Russia, and Japan), involves treating used nuclear fuel as a resource whereby separations and actinide recycling in reactors work with geologic disposal (see Figure 2).

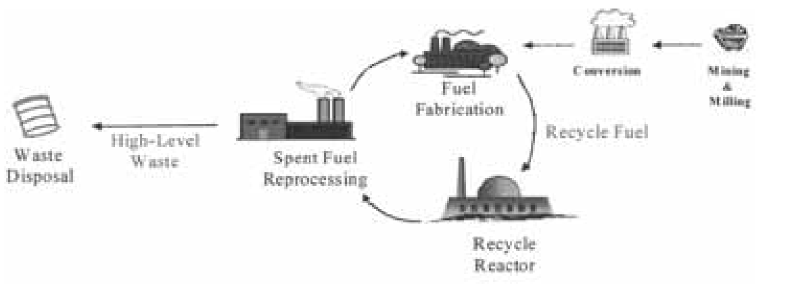

Figure 2. Closed nuclear fuel cycle (or reprocessing/recycling)

In the open nuclear fuel cycle, used nuclear fuel is sent to a geologic repository that must contain the constituents of the used nuclear fuel for hundreds of thousands of years. Several countries have programs to develop these repositories. This approach is considered safe, provided suitable repository locations and space can be found. It should be noted that other ultimate disposal options have been researched (e.g., deep sea disposal, boreholes, and disposal in the sun) and are not focused on currently. The challenges of long-term geologic disposal of used nuclear fuel are well recognized, and are related to the uncertainty about both the long-term behavior of used nuclear fuel and the geologic media in which it is placed.

For the closed nuclear fuel cycle, limited recycle options are commercially available in France, Japan, and the United Kingdom. They use the Plutonium and Uranium Recovery by Extraction (PUREX) process, which separates uranium and plutonium, and directs the remaining transuranics to vitrified waste, along with all the fission products. The uranium is stored for eventual reuse. The plutonium is used to fabricate mixed-oxide fuel that can be used in conventional reactors. Used mixed-oxide fuel is currently not reprocessed, though the feasibility of mixed-oxide fuel reprocessing has been demonstrated. It is typically stored for eventual disposal in a geologic repository. Note that a reactor partially loaded with mixed-oxide fuel can destroy as much plutonium as it creates, but this approach always results in increased production of americium, a key contributor to the heat generation in a repository. This limited recycle approach has two significant advantages:

- It can help manage the accumulation of plutonium.
- It can help significantly reduce the volume of used nuclear fuel and high-level waste destined for geologic disposal (the French experience indicates that volume reductions by a factor of 5 to 10 can be achieved).

Several disadvantages have been noted:

- It results in a small economic penalty by increasing the net cost of electricity a few percent.
- The separation of pure plutonium in the PUREX process is considered by some to be a proliferation risk.
- This process does not significantly improve the use of the repository space (the improvement is around 10%, as compared to many factors of 10 for closed fuel cycles).
- This process does not significantly improve the use of natural uranium (the improvement is around 15%, as compared to several factors of 10 for closed fuel cycles).

Full recycle approaches are being researched in France, Japan, and the U.S. These typically comprise three successive steps: an advanced separations technology that mitigates the perceived disadvantages of PUREX, partial recycle in conventional reactors, and closure of the fuel cycle in fast reactors. Note: the middle step can be eliminated and still attain the waste management benefits; inclusion of the middle step is a fuel cycle system-level consideration.

The first step, using advanced separations technologies, allows for the separations and subsequent management of highly pure product streams. These streams are:

- Uranium, which can be stored for future use or disposed of as low-level waste.
- A mixture of plutonium and neptunium, which is intended for partial recycle in conventional reactors, followed by recycle in fast reactors.

- Separated fission products intended for short-term storage, possibly for transmutation, and for long-term disposal in specialized waste forms.
- The minor actinides (americium and curium) for transmutation in fast reactors.

The advanced separations approach has several advantages:

- It produces minimal liquid waste forms, and eliminates the issue of the "waste tank farms."
- Through advanced monitoring, simulation, and modeling, it provides significant opportunities to detect misuse and diversion of weapons-usable materials.
- It provides the opportunity for significant cost reduction.
- Finally, and most importantly, it provides the critical first step in managing all hazardous elements present in the used nuclear fuel.

The second step—partial recycle in conventional reactors—can expand the opportunities offered by the conventional mixed-oxide approach. In particular, it is expected that with significant R&D effort, new fuel forms can be developed that burn up to 50% of the plutonium and neptunium present in used nuclear fuel. (Note that some studies also suggest that it might be possible to recycle fuel in these reactors many times—i.e., reprocess and recycle the irradiated advanced fuel—and further destroy plutonium and neptunium; other studies also suggest possibilities for transmuting americium in these reactors. Nevertheless, the practicality of these schemes is not yet established and requires additional scientific and engineering research.) The advantage of the second step is that it reduces the overall cost of the closed fuel cycle by consuming plutonium in conventional reactors, thereby reducing the number of fast reactors needed to complete the transmutation mission of minimizing hazardous waste. As mentioned above, this step can be entirely bypassed, and all transmutation performed in advanced fast reactors, if recycle in conventional reactors is judged to be undesirable.

The third step, closure of the fuel cycle using fast reactors to transmute the fuel constituents into much less hazardous elements, and advanced reprocessing technologies to recycle the fast reactor fuel, constitutes the ultimate step in realizing sustainable nuclear energy. This process will effectively destroy the transuranic elements, resulting in waste forms that contain only a very small fraction of the transuranics (less than 1%) and all fission products. These technologies are being developed in the U.S. at Argonne National Laboratory and Idaho National Laboratory, with parallel development internationally (e.g., Japan, France, and Russia).

Several disadvantages have been noted for a closed fuel cycle, including:

- The economics of closing the fuel cycle. (Note, in practice, closed fuel cycle processes would actually have limited economic impact; the increase in the cost of electricity would be less than 10%.)
- Management of potentially weapons-usable materials may be viewed as a proliferation risk.

These disadvantages can be addressed through a robust research, development, and demonstration program focused on advanced reactors and recycling options. In the end, the full recycle approach has significant benefits:

- It can effectively increase use of repository space.
- It can effectively increase the use of natural uranium.
- It eliminates the uncontrolled buildup of isotopes that are a proliferation risk.
- The advanced reactors and the processing plant can be deployed in small colocated facilities that minimize the risk of material diversion during transportation.
- A fast reactor does not require the use of very pure, weapons-usable materials, thus decreasing proliferation risk.
- Finally, it can usher the way towards full sustainability to prepare for a time when uranium supplies will become increasingly difficult to ensure.

In summary, the overarching challenge associated with the choice of any fuel cycle option is used nuclear fuel management. For example, current U.S. policy calls for the development of a geologic repository for the direct disposal of used nuclear fuel. The decision to take this path was made decades ago, when the initial growth in nuclear energy had stopped, and the expectation was that the existing nuclear power plants would operate until reaching the end of their design lifetime, at which point all of the plants would be decommissioned and no new reactors would be built.

While it may be argued that direct disposal is adequate for such a scenario, the recent domestic and international proposals for significant nuclear energy expansion call for a reevaluation of this option for future used fuel management (see Figure 3). While geologic repositories will be needed for any type of nuclear fuel cycle, the use of a repository would be quite different for closed fuel-cycle scenarios.

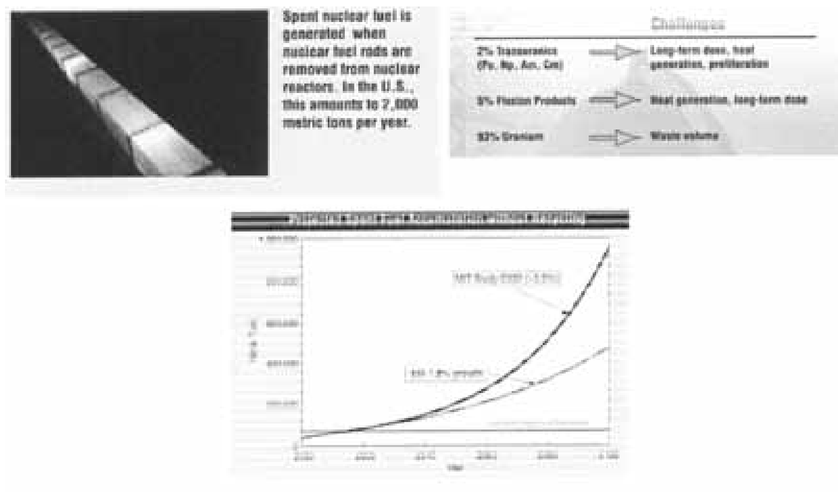

Figure 3. Used nuclear fuel generation and management

For reprocessing to be beneficial (as opposed to counterproductive), it must be followed by recycling, transmutation, and fission destruction of the long-lived radiotoxic constituents (i.e., plutonium, neptunium, americium). Reprocessing (with PUREX) followed by thermal-recycling (mixed-oxide [MOX] fuel in light water reactors [LWRs]) is well established, but is only a partial solution. It is not at all clear that the U.S. should embark on this path. especially since we have not made a massive investment in a PUREX/MOX infrastructure. (Although, the U.S. is proceeding with a plan to reduce excess-weapons plutonium inventory using MOX in LWRs.) In contrast, advancement of fast reactor technology for transuranic recycling and consumption would maximize the benefits of waste management and also allow essential progress toward the longer term goal of sustainable use of uranium (and subsequently thorium) with fast reactors.

There is no urgent need to deploy recycling today, but as nuclear energy expands, a once-through fuel cycle will not be sustainable. To maximize the benefits of nuclear energy in an expanding nuclear energy future, it will ultimately be necessary to close the fuel cycle. Fortuitously, it is conceivable that the decades-long hiatus in U.S. investment circumvents the need to rely on dated recycling technologies. Rather, we have the option to develop and build new technologies and develop business models using advanced systems.

Detailed Discussion

Argonne National Laboratory

Located 25 miles southwest of Chicago, Argonne National Laboratory was the country's first national laboratory—a direct descendant of the University of Chicago's Metallurgical Laboratory where Enrico Fermi and his colleagues created the world's first controlled nuclear chain reaction. Appropriately, Argonne's first mission 64 years ago was to develop nuclear reactors for peaceful purposes. Managed by the UChicago Argonne, LLC for the U.S. Department of Energy, Argonne has grown into a multidisciplinary laboratory with a unique mix of world-class scientists and engineers and leading-edge user facilities, working to create new technologies that address the most important scientific and societal needs of our nation.

Argonne's experience over many years of research in the advancement of nuclear energy positions it as a leader in the development of future generation reactors and fuel cycle technologies. A primary goal of the Laboratory's nuclear energy research program is to *advance the sustainable use of nuclear energy* through research and development of technologies that enable waste minimization, enhanced resource utilization, competitive economics, and increased assurance of reliability, safety, and security. Expertise in reactor physics, nuclear and chemical engineering, computational science and engineering, and fuel cycle analysis is applied in the assessment and conceptual development of advanced nuclear energy systems that meet these important goals.

In collaboration with other DOE laboratories and universities. Argonne is advancing a new science- and simulation-based approach for optimizing the design of advanced nuclear energy systems and assuring their safety and security. This approach seeks increased understanding of physical phenomena governing system behavior and incorporates this understanding in improved models for predicting system performance in operating and off-normal situations. Once validated, these models allow the simulation and optimization of system design and operation, to enhance safety assurance and cost competitiveness with alternative energy supply options. They also promise to accelerate the demonstration of commercially attractive systems in partnership with industry.

Argonne's waste management and reprocessing research and development activities are supported primarily by the DOE's Office of Nuclear Energy (DOE–NE) through its Fuel Cycle Research and Development program. The objective of Argonne's research in this area is to develop and evaluate separations and treatment processes for used nuclear fuel that will enable the transition from the current open fuel cycle practiced in the U.S. to a sustainable, environmentally acceptable, and economic closed fuel cycle. Our research focuses on the science and technology of chemical separations for the treatment of used fuel from both commercial and advanced nuclear reactors, used fuel characterization techniques, and waste form engineering and qualification. Ongoing projects related to reprocessing and waste management include:

- Using advanced modeling and simulation coupled with experiments to optimize the design and operation of separations equipment.
- Exploring an innovative one-step extraction process for americium and curium, radionuclides that are major contributors to nuclear waste toxicity, to reduce the cost of used-fuel treatment.
- Further developing pyrochemical processes for used fuel treatment. These processes enable the use of compact equipment and facilities, treatment of used fuel shortly after discharge from a reactor, and reduction of secondary waste generation.
- Developing highly durable and leach-resistant waste forms of metal, glass, and ceramic composition for safe, long-term disposal.

In addition, Argonne's nuclear science and engineering expertise utilizes theory, experiment, and modeling and simulation in the assessment and conceptual development of innovative, advanced reactors operating with a variety of coolants, fuel types, and fuel cycle schemes. Argonne also leads U.S. development of innovative technologies that promise to reduce the cost of fast-neutron reactors and increase their reliability. These technologies include high-performance fuels and materials; compact, low-cost components for the heat transport systems; advanced power conversion and refueling systems; and improved capabilities for in-service inspection and repair.

Argonne's research into the behavior of irradiated fuels and materials supports the U.S. Nuclear Regulatory Commission (NRC) in the regulation of industry initiatives to extend the operational lifetime and optimize the operation of existing and evolutionary nuclear reactors. Leading-edge systems analysis and modeling capabilities are used to assess the relative merits of different advanced nuclear energy systems and fuel cycles for various domestic and global scenarios of energy demand and supply consistent with environmental constraints and sustainability considerations. Argonne also has expertise in the components of nuclear technology that are critical for national security and nonproliferation, including the conversion of research reactors to low-enrichment fuels, technology export control, risk and vulnerability assessments, and national-security information systems.

Current Nuclear Waste Reprocessing Technologies

As discussed above, current commercial used nuclear fuel reprocessing technologies are based on the PUREX process, which is a solvent extraction process that separates uranium and plutonium and directs the remaining minor actinides (neptunium, americium, and curium) along with all of the fission products to vitrified waste. The PUREX process has over fifty years of operational experience. For example, the La Hague reprocessing facility in France treats used fuel from their domestic and foreign power reactors. Plutonium recovered is recycled as a mixed-oxide fuel to generate additional electricity. Other countries using this technology for commercial applications include the United Kingdom and Japan.

PUREX does not recover the minor actinides (neptunium, americium, curium, and heavier actinide elements), which compose a significant fraction of the long-term radiotoxicity of used fuel. Advanced reactors can transmute and consume minor actinides if separated from the fission product elements, but incorporation of minor actinide separations into existing PUREX facilities adds complexity and is outside commercial operating experience. Moreover, existing international facilities do not capture fission gases and tritium, but rather these are discharged to the environment within regulatory limits. Although plutonium is recycled as mixed oxide fuel, this practice actually increases the net discharge of minor actinides. Finally, the production of pure plutonium through PUREX raises concerns about materials security and proliferation of nuclear weapons-usable materials.

Pyroprocessing is presently being used at the Idaho National Laboratory to treat/stabilize used fuel from the decommissioned EBR–II reactor. The key separation step, electrorefining, recovers uranium (the bulk of the used fuel) in a single compact process operation. Ceramic and metallic waste forms, for active metal and noble metal fission products, respectively, are being produced and have been qualified for disposal in a geologic repository. However, the demonstration equipment used for this treatment campaign has limited scalability. Argonne has developed conceptual designs of scalable, high-throughput equipment as well as an integrated facility, but to date only a prototype advanced scalable electrorefiner has been fabricated and successfully tested.

Advanced Reprocessing Technologies

Research on advanced reprocessing technologies focuses on processes that meet U.S. non-proliferation objectives and enable the economic recycle of long-lived actinides in used fuel, while reducing the amount and radiotoxicity of high-level wastes that must be disposed. Main areas of research include:

- Aqueous-based Process Design—Current studies target the simplification of aqueous processes that can recover the long-lived actinides as a group in one or two steps.
- Pyrochemical-based Process Design—Present work is focused on development of scalable, high-throughput equipment and refining our understanding of the fundamental electrochemical process. We are targeting greater control of the composition of the recovered uranium/transuranic alloy, which will facilitate safeguards consistent with U.S. non-proliferation goals.
- Off-gas Treatment—Environmental regulations limiting the release of gaseous fission products require the development of materials that will efficiently capture and retain volatile fission products. Because these volatile fission products are generally difficult to retain, development of novel materials with strong affinities for particular fission products is essential.
- Product/Waste Fabrication—This development effort includes concentrating the product streams and recovery/recycle of process fluids, solidification of products for both waste form and fuel fabrication/recycle. The products must meet stringent requirements as nuclear fuel feedstocks or must be suitable for waste form fabrication.
- Process Monitoring and Control—Advanced computational techniques are being developed to assess and reduce uncertainties in processing operations within a plant. Such uncertainties in design, in processing, and in measurements significantly increase costs through increased needs for large design margins, material control and accounting, and product rework.
- Sampling Technologies—The tracking of materials is critical to the safeguarding and operational control of recycle processes. Improving the accuracy of real-time measurements is a major goal for material accountancy and control. Reducing the turnaround time for analysis by applying state-of-the-art sampling and analytical techniques will enable "on-line" material accountancy in real time. Advanced spectroscopic techniques are under study to reduce gaps in our ability to identify key species at key locations within a plant.

Impact on Future Nuclear Waste Management Policy

The Blue Ribbon Commission is evaluating options for the management of used nuclear fuel, which will result in recommendations for changes in U.S. nuclear waste policy. In parallel with these efforts, advances in used fuel processing and waste storage and disposal technologies will support the development of an integrated policy for nuclear waste management in the U.S., consistent with our energy security, nonproliferation, and environmental protection goals. In particular, advances in nuclear fuel processing and storage and disposal technologies would enable actinide recycle as fuel for advanced reactors, allowing for additional electricity generation while drastically reducing the amount of nuclear waste and the burden on future generations of ensuring its safe isolation.

Development and implementation of advanced reprocessing, recycle, and waste storage and disposal technologies should be done as part of an integrated waste management policy. Reprocessing and disposal options and long-term waste management policies should go hand in hand. Alternative technologies will have different economies of scale based on the type and number of wastes. In addition, waste packages may be retrievable or not and the waste form should be tailored to the site geology. This does not preclude the possibility of multiple disposal sites for selected wastes.

High-level waste disposal facilities are required for all fuel cycles, but the volumes and characteristics of the wastes will be different. Consequently, a waste classification system is needed to define the facilities needed to support waste disposal. The U.S. does not have a cohesive waste classification system, but rather an ad hoc system that addresses management of specific wastes. The current point of origin system requires a complex dual waste categorization system, one for defense wastes and another for civilian wastes. This approach has resulted in high disposition costs, wastes with no disposition pathways, limited disposition sites, and a system that will be difficult to align with any alternative fuel cycle that is adopted.

The International Atomic Energy Agency (IAEA) recommends a risk-based classification system that accounts for the intensity of the radiation and the time needed for decay to an acceptable level. The intensity of radiation is given by a range of radioactivity per unit of weight. Decay time is split into short lived (<30 years) and long lived (>30 years). There is no distinction in either categorization or disposition options based on the sources of nuclear waste. The result is a simple, consistent, standard system. Lacking a consistent waste classification system, it is not possible to compare waste management costs and risks for different fuel cycles without making arbitrary assumptions regarding theoretical disposition pathways.

DOE's Nuclear Energy Research and Development Roadmap

Observations

The DOE–NE "Nuclear Energy Research and Development Roadmap" (April 2010) provides a comprehensive vision for advancing nuclear energy as an essential energy source. Argonne strongly supports the R&D objectives described in the Roadmap, namely:

1. Sustaining and extending the operation of the current reactor fleet;
2. Improving the affordability of new reactors, for example, through development of small modular reactors;
3. Enhancing the sustainability of the nuclear fuel cycle through increased efficiency of uranium utilization and reduced discharge of actinides as waste; and
4. Quantifying, with the objective of minimizing nuclear proliferation and security risks.

Argonne also agrees with the R&D approach described in the Roadmap, in particular the synergistic use of experiment, theory, and modeling and simulation to achieve the foregoing objectives.

While all four objectives are clearly important, Argonne believes that the public sector has a proportionately larger role to play in the efforts supporting objectives 2, 3, and 4. Objective I will be met largely through industry-financed initiatives and will build on decades of developments achieved by industry. Objective 4 requires an integrated systems approach to safeguards and security in developing an advanced nuclear fuel cycle(s), and complementary assessment work by the National Nuclear Security Administration (NNSA); its achievement will depend substantially on implementation and enforcement of international nonproliferation agreements and security arrangements.

Concerning Objective 2, Argonne believes that deployment of small modular reactors (SMRs) is a potential game-changer to enable nuclear energy to be a significant contributor in addressing the world's climate and energy security challenges. SMRs may be financially competitive for countries and regions that cannot support commercial-sized units in the 800–1400 MWe range. Additionally, they offer flexibility, more broadly, by enabling smaller increments of capacity addition and may provide a route to competitive economics by shifting much of the plant assembly and construction work into factories from the plant site. For SMRs based on existing (light water) reactor technology, the domestic and international industry is best positioned to complete the development that is needed, so the Government's principal role may be to eliminate technical barriers to NRC licensing. Argonne, in collaboration with economists at the University of Chicago, is analyzing the economic competitiveness of SMRs. Two of the SMR attributes that the study is focusing on are: the increased flexibility for utilities to add appropriately-sized units as demand changes; and deployment of SMRs as on-site replacements of aging fossil-fueled power plants.

Concerning Objective 3, Argonne supports a greater emphasis on coupling the science-based approach for system development with an active design and technology demonstration effort that would guide and appropriately focus R&D, and enable assessment of programmatic benefits in a holistic manner. This would be accomplished by close cooperation of DOE, national laboratories, universities, and industry. The overall approach would seek to:

- Increase understanding of the diverse physical phenomena underlying reactor and fuel cycle system behavior;
- Improve ability to predict system behavior through validated modeling and simulation for design, licensing; and operation; and
- Develop advanced materials, processes, and designs for reactor and fuel cycle systems through application of scientific discoveries and advanced modeling and simulation capabilities, as well as the insights and lessons learned from past nuclear energy development programs.

These efforts would allow for fuel cycle demonstration in a timeframe that could influence the course of fuel cycle technology commercialization on a global basis. Moreover, the individual elements of the planned R&D (e.g., separations, waste forms, transmutation fuels) are each potentially vast in scope and can absorb substantial resources, without commensurate benefit, if the different areas are not sufficiently integrated for the results to fit together in a viable system.

An Effective Nuclear Energy R&D Strategy Going Forward

The objectives of the DOE–NE "Nuclear Energy Research and Development Roadmap" can be met in a reasonable time frame if the appropriate priorities are identified and sufficient funding is provided to allow acceleration of high priority areas. In particular, Argonne believes that advanced fast-neutron reactors (of small or large capacity), recycle processes, and waste management technologies should be developed and demonstrated at engineering scale during the next 20 years. Concurrently, support should be provided for facilitating the NRC review and certification of advanced reactors designed by commercial organizations, including small modular reactors.

To enable an effective nuclear energy research and development strategy, the development of advanced fuel treatment technologies and waste forms must be closely coordinated with R&D on:

- Advanced fuels and interim storage strategies for current light water reactors (LWRs), as these affect the requirements on reprocessing and waste technologies. Research on advanced fuels for light water reactors is one of the proposed thrusts of the DOE–NE Light Water Reactor Sustainability program (Objective 1 in the Roadmap).
- Advanced reactors such as liquid metal and gas cooled "Generation IV" reactors, which employ different fuel types and thus discharge used fuel that is very different from that of LWRs. In the administration's budget request for 2011, this research would be funded as part of the "Advanced Reactor Concepts" program. Advanced, fast spectrum reactors can efficiently consume the residual actinides in used nuclear fuel, effectively converting these actinides to electricity instead of discharging them as waste.

Overall, an effective research and development strategy for advanced fuel cycles must include:

- A fuel cycle system development activity to guide and appropriately focus the research.
- Improved systems analysis of nuclear energy deployment strategies.
- Science and discovery contributions to technology and design.
- Increased role of modeling and simulation in nuclear energy research, development, and system design.
- Advances in separations and fuel technologies to close the fuel cycle:

  - Develop and demonstrate aqueous-based technologies;
  - Develop and demonstrate pyroprocessing technologies; and
  - Develop and demonstrate transmutation fuels.
- Advances in nuclear reactor technology and design to generate electricity and close the fuel cycle:
  - Develop advanced reactor concepts; and
  - Develop advanced reactor component testing facilities.
- Advancement of safe and secure use of nuclear energy on an international basis:
  - Enhance safety assurance capabilities in countries newly adopting nuclear energy; and
  - Improve and deploy safeguard and security technologies and practices.
- Education and training of future nuclear energy professionals.
- University programs and partnering with institutions that have nuclear energy programs.
- Support for modernization of aging research facilities for conducting experimental work; such facilities should be regionally located in close proximity to universities in order to develop the human capital needed to sustain research advances in the future.
- Coordination and integration of R&D in separations and waste sponsored by different government agencies and offices (DOE–NE, DOE–EM, DOE–OCRWM, and DOE–SC).
- Close cooperation with industry in research and development, demonstration, and commercialization efforts as part of robust public-private partnerships.

Summary and Recommendations

The United States should conduct a science-based, advanced nuclear fuel cycle research, development, and demonstration program to evaluate recycling and transmutation technologies that minimize proliferation risks and environmental, public health, and safety impacts. This would provide a necessary option to reprocessing technologies deployed today, and supports evaluation of alternative national strategies for commercial used nuclear fuel disposition, effective utilization and deployment of advanced reactor concepts, and eventual development of a permanent geologic repository(s). This should be done as part of robust public-private partnerships involving the Department of Energy, its national laboratories, universities, and industry; and conducted with a sense of urgency and purpose consistent with the U.S. retaining its intellectual capital and leadership in the international nuclear energy community.

Over the next several years, the research, development, and demonstration program should:

- Complete the development and testing of a completely integrated process flow sheet for all steps involved in an advanced nuclear fuel recycling process.
- Characterize the byproducts and waste streams resulting from all steps in the advanced nuclear fuel recycling process.
- Conduct research and development on advanced reactor concepts and transmutation technologies that consume recycled byproducts resulting in improved resource utilization and reduced radiotoxicity of waste streams.
- Develop waste treatment processes, advanced waste forms, and designs for disposal facilities for the resultant byproducts and waste streams characterized.
- Develop and design integrated safeguards and security measures for advanced nuclear fuel recycling processes that enable the quantification and minimization of proliferation risks associated with deploying such processes and facilities.
- Evaluate and define the required test and experimental facilities needed to execute the program.
- On completion of sufficient technical progress in the program:
  - Develop a generic environmental impact statement for technologies to be further developed and demonstrated; and
  - Conduct design and engineering work sufficient to develop firm cost estimates with respect to development and deployment of advanced nuclear fuel recycling processes.

- Cooperate with the NRC in making DOE facilities available for carrying out independent, confirmatory research as part of the licensing process.

BIOGRAPHY FOR MARK T. PETERS

Dr. Mark Peters is the Deputy Laboratory Director for Programs at Argonne National Laboratory (ANL). Responsibilities of his position include management and integration of the Laboratory's science and technology portfolio, strategic planning, Laboratory Directed Research and Development (LDRD) program, and technology transfer. Duties also include technical support to the DOE Fuel Cycle R&D (FCR&D) Program and he also serves as FCR&D National Technical Director for Used Fuel Disposition.

Prior to his current position, Dr. Peters served as the Deputy Associate Laboratory Director for the Energy Sciences and Engineering Directorate. Responsibilities of this position included the management and integration of the Laboratory's energy R&D portfolio coupled with development of new program opportunities at the Laboratory, and management of the energy-related LDRD program. Duties also included technical support to the DOE Advanced Fuel Cycle Initiative (AFCI) and also served as the AFCI National Campaign Director for Waste Forms.

Selected to serve on a two-year detail to DOE Headquarters in Washington D.C., Dr. Peters worked as a senior technical advisor to the Director of the Office of Civilian Radioactive Waste Management. In a prior position, Dr. Peters was with Los Alamos National Laboratory, where he served as the Yucca Mountain Project (YMP) Science and Engineering Testing Project Manager. In that role, he was responsible for the technical management and integration of science and engineering testing in the laboratory and field on the YMP.

Before joining Los Alamos National Laboratory and the YMP in 1995, Dr. Peters had a research fellowship in geochemistry at the California Institute of Technology where his research focused on trace-element geochemistry. He has authored over 60 scientific publications, and has presented his findings at national and international meetings. Dr. Peters is a member of several professional organizations including the Geological Society of America, where he served as a member of the Committee on Geology and Public Policy. In addition, he is a member of the American Geophysical Union, the Geochemical Society, the Mineralogical Society of America, and the American Nuclear Society (ANS). He was elected recently to serve on the Executive Committee of the ANS Fuel Cycle and Waste Management Division. Dr. Peters' professional achievements have resulted in his election to Sigma Xi, the Scientific Research Society, as well as Sigma Gamma Epsilon, the Earth Sciences Honorary Society.

Dr. Peters received his Ph.D. in Geophysical Sciences from the University of Chicago and his B.S. in Geology from Auburn University.

Mr. BAIRD. To the minute or second, Dr. Peters.

Mr. Krellenstein.

STATEMENTS OF GARY M. KRELLENSTEIN, MANAGING DIRECTOR, TAX EXEMPT CAPITAL MARKETS, JP MORGAN CHASE & CO.

Mr. KRELLENSTEIN. Good morning, Mr. Baird, Members of the Committee. My name is Gary Krellenstein. I am a Managing Director in the Energy and Environmental Group at JP Morgan Chase. I appreciate the opportunity to testify today both on the Department of Energy's Nuclear Energy Research Roadmap.

At JP Morgan my areas of focus are utilities, energy technologies, and project financing. I have previous experience as a utility and energy analyst at Lehman Brothers and Merrill Lynch, and I have also worked as a nuclear engineer and systems analyst in private and governmental entities.

JP Morgan is the industry leader in underwriting, financing, and advising electric utilities and energy companies around the world.

This morning I am going to focus my testimony on the financial-related issues associated with small modular reactors and potential for the DOE roadmap to improve the investment fundamentals of nuclear power in the United States.

The smaller size and cost of SMRs gives them several distinct advantages over what I will call conventional nuclear reactors, but let me first provide a bit of context. For many people when they think of financing large industrial or entity facilities, they assume it will be done on a project finance basis, where the loan is ultimately repaid by the revenue generated from the asset being financed.

In practice, however, larger power projects, particularly conventional nuclear plants where the cost can be in the range of $15 billion for a twin nuclear project, usually have the financing backed by the full faith and credit of all the company's assets and net revenues, and they are not secured solely the project being financed.

So what does this mean for the investment fundamentals of SMRs? Well, three things. First, the construction of SMRs require less capital due to their size and other attributes compared to conventional nuclear plants.

Second, the smaller capital requirements would allow a single company to build an SMR as opposed to the large and diverse consortiums that greatly complicate investors' required diligence as well as their analysis of management structure in what is already a complex undertaking.

Third, the financing of large conventional nuclear plants requires utilities to bear a significant default risk such that construction of each plant is essentially a "bet the company" event. Many utilities are not willing to finance such a project.

Let me take a few moments to expand on these issues. As a practical matter, it is far easier to find buyers for $2 billion worth of securities than it is find buyers for $15 billion worth. While that's obvious, SMRs' substantially lower cost will make raising capital easier and one would expect to provide greater comfort that sufficient investors can be found at a reasonable price.

In addition, the low cost of SMRs has the potential to simplify investor analysis. The current enormous cost and very large capacity of conventional nuclear plants requires multiple partners to come together to finance a single project. Often these partners have different credit worthiness. Any financial consortium is only as strong as its weakest members, which can raise costs for the more credit-worthy participants, thus pushing up the costs of the entire project.

Furthermore, the interrelationship and ability of the group to work together without discord is a major credit factor for investors and was the cause of many of the difficulties encountered in the last round of nuclear plant construction in the '70, and '80.

Related to this consortium complexity I just discussed is the default risk posed to a particular company or entity and how that impacts the other participants and the project. The size of conventional reactors implies that if a project fails, so may the company. This bet-the-company reality persuades many private and public power generators to prefer other technologies that don't pose extinction risks to the company.

In theory, SMRs should substantially simplify potential investor analysis as well as reducing default risk to the power companies building them. There are also capacity attributes of SMRs that make them more attractive to utility and energy companies as cost-effective means of addressing small increases in energy demand and dealing with the uncertainties associated with forecasting local energy needs. SMRs scalable size and easier site-ability, particularly if located adjacent to or near an existing nuclear facility, make them a plausible alternative to building the gigawatt-sized nuclear power stations, which are currently the only option. If SMRs are validated, it should increase the ability of both utilities and investors to participate in nuclear projects.

I applaud the Department of Energy for acknowledging the potential of SMRs in the Nuclear Energy Research and Development Roadmap. Reduced capital requirements, expected improvements in quality control due to modular design, and potentially simpler issuer structure and therefore, one instead of multiple consortium members, will be major factors in the reduction of the financial risk profile, but will probably be insufficient to overcome investor concerns associated with a new commercial reactor design.

Consequently, a demonstration project will probably be needed to further mitigate investor concerns over the technological risks associated with SMRs, and I urge Congress to move forward on legislation that proposes such development.

That concludes my remarks, and I would be pleased to answer questions of the Committee. Thank you.

[The prepared statement of Mr. Krellenstein follows:]

PREPARED STATEMENT OF GARY KRELLENSTEIN

Good morning Chairman Gordon, Ranking Member Hall, and Members of the Committee. My name is Gary Krellenstein, and I am a Managing Director in the Energy and Environmental Group at JPMorgan Chase. I appreciate the opportunity to testify today on the Department of Energy (DOE)'s Nuclear Energy Research and Development Roadmap ("the Roadmap").

My areas of focus are utilities, energy technologies and project financing. I have previous experience as a utility and energy analyst at Lehman Brothers and Merrill Lynch, and as nuclear engineer and systems analyst at EnviroSphere Company (a subsidiary of EBASCO), the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission. I hold degrees in Nuclear Engineering, Computer Science and Business Administration. I have also been ranked multiple times as one of the top financial analysts in the Nation by *Institutional Investor Magazine* (1st team for 12 consecutive years), the *Bond Buyer*, *Global Guaranty*, and *Smith's Research and Rating Review*.

My firm, J.P. Morgan, is an industry leader in underwritings, financing and advisory work to electric utilities and energy companies in the United States. In 2009, J.P. Morgan underwrote more than $11 billion of debt just for electric utilities, and has been involved in hundreds of power-related projects over the past few years.

I will focus my testimony this morning on the cost and financing related issues of Small Modular Reactors (SMRs), and the potential for the DOE's Roadmap to improve the investment fundamentals of nuclear power in the United States.

The smaller size and cost of SMRs give them several distinct advantages over what I'll call conventional nuclear reactors. But first let me provide a bit of context. For many people, when they think of financing large industrial or energy facilities, they assume that it will be done on a "project" finance basis (i.e. where a loan is repaid from the revenue generated by the asset being financed). And for a limited number of power projects where the technology, capital costs and construction risks are relatively low—for example a simple cycle gas unit—this type of financing is often utilized.

But in practice, large power assets-particularly conventional nuclear plants where the costs can be in the range of $15 billion for a new twin unit project—usually have the financing backed by the full faith and credit of all the company assets' and net revenues (referred to as "system" financing)—and are not secured solely by the specific project being financed.

So what does this mean for the investment fundamentals of SMRs,—well, three things:

First, the construction of SMRs requires less capital, due to their size and other attributes, than conventional nuclear power plants. Second, the smaller capital requirements would allow a single company to build an SMR as opposed to the large and diverse consortium that can greatly complicate investors' required due diligence as well as their analysis of the management structure of what is already a complex undertaking. Third, the financing for large conventional nuclear plants require utilities to bear significant default risk such that the construction of each plant is essentially a 'bet the company' event. Many utilities are not willing to finance such a large project. Let me take a few moments expand on these issues.

As a practical matter, it is easier to find buyers for $2 billion worth of securities than it is to find buyers for $15 billion. While that's obvious, SMRs substantially lower cost will make raising capital easier and, one would expect it to provide greater issuer (utility) comfort that sufficient investors can be found at a reasonable price.

In addition, the lower cost of SMRs has the potential to simplify investor analysis. The current enormous cost and very large capacity (MWe) of new conventional nuclear plants has required multiple partners to come together to finance a single project. And often these partners have significantly different degrees of creditworthiness. Given the variability of credit ratings and differences in capital structures, performing due diligence on such a consortium is vastly more complex and, as a result, more expensive to finance because of the corresponding increase in uncertainty.

Moreover, any financial consortium is only as strong as its weakest member, which can raise costs for more creditworthy participants, thus pushing up costs of the entire project. Furthermore, the interrelationship and ability of the group to work together without discord is also a major credit factor for investors, and was the cause of many of the difficulties encountered in the last round of nuclear plant construction in the 70s and 80s.

And closely related to the consortium complexity I just discussed, is the default risk posed to a particular company or entity. The size of conventional nuclear reactors necessarily implies that if the project fails, so may the company. This "bet the company" reality persuades many private and public power generators to prefer other power technologies that don't pose an extinction risk to the company. In theory, SMRs should substantially simplify potential investors' analysis as well as reducing the default risk to the power companies building them.

Furthermore, there are capacity attributes of SMRs that make them more attractive to utility companies as a cost effective means of addressing smaller increases in energy demand and the uncertainties associated with forecasting of local energy needs. SMRs scalable size and easier sitability, particularly if located adjacent to or at an existing nuclear facility, makes them a plausible alternative to building gigawatt sized nuclear power stations, which is currently the only option. If SMRs are technically validated, and the procedural risks mitigated by Congress and the Administration, it should increase the ability of both utilities and investors to participate in nuclear projects.

I applaud the Department of Energy for their acknowledgment of the potential of SMRs in the Nuclear Energy Research and Development Roadmap. Reduced capital requirements, expected improvements in quality control due to modular design, and a potentially simpler issuer structure (one or two parties instead of a large consortium) will be major factors in the reduction of the financial risk profile, but will probably be insufficient to overcome investor concerns associated with a new commercial reactor design. A demonstration project will likely be needed to further mitigate investors concerns over the technological risks associated with SMRs and could help to catalyze a nuclear renaissance. In addition, clearly defined Federal financial support for SMRs is essential to mobilize private sector capital. New technology of any kind can sometimes struggle to raise capital and this challenge is accentuated in the nuclear context. I urge Congress to move forward on legislation that proposes cost-sharing programs for SMRs.

However, beyond these obstacles, there remain political and regulatory uncertainties that need to be addressed. The NRC's permitting processes is currently too long and unpredictable for many investors. It is unclear if the regulatory process can be streamlined for SMRs, but there should be some licensing synergy if they are located adjacent to existing nuclear power plants and/or constructed as identical modular units.

In conclusion, there are three major financial advantages for SMRs: lower capital requirements, the likelihood of sole-party financing, and a reduction of the significant default risk for utilities normally associated with traditional large nuclear facilities.

The Roadmap is laudable for its recognition of the potential for SMRs to overcome many of the obstacles that have previously hindered private financing for domestic nuclear facilities. However, while the Roadmap helps move the needle on addressing technology risk, both political and regulatory variables continue to give pause to investors in this space. Unless addressed, these risks will continue to undermine efforts to promote a domestic nuclear renaissance here in the United States. I appreciate the opportunity to testify before the Committee this morning.

Thank you.

BIOGRAPHY FOR GARY KRELLENSTEIN

Gary Krellenstein is an Investment Banker and Managing Director in JPMorgan's Energy and Environmental Group. His areas of focus are municipal utilities, Rural Electric Cooperatives, alternative energy technologies and project financing. He is also involved in JPMorgan's "carbon" policies. Prior to rejoining Morgan in 2000, Gary was the Director of Municipal Research at First Albany Corporation. He has also worked as a utility analyst (corporate and municipal) at Lehman Brothers, Merrill Lynch and Morgan Guaranty, and as a nuclear engineer and systems analyst for Envirosphere Inc., the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission.

Mr. Krellenstein is nationally recognized in his field and prior to becoming an investment banker in 2003, for 12 consecutive years took top honors in the annual polls of financial analysts by *Institutional Investor Magazine* (1st team 1991–2002 in the municipal utility category). He has also been elected to All-American Research Teams (first place in the Utilities, Industrial Development and Pollution Control categories) by the *Bond Buyer*, *Global Guaranty*, and *Smith's Research and Rating Review*. In addition, the National Federation of Municipal Analysts (NFMA) presented Mr. Krellenstein the "Award for Excellence." He is a frequent speaker on energy issues and has given presentations at Harvard University, Cornell University, Carnegie Mellon, the Electric Power Research Institute (EPRI), the National Governor's Association (NGA), and the American Public Power Association (APPA).

Mr. Krellenstein holds degrees in Nuclear Engineering and Computer Science, as well as an MBA from Cornell University. He is the former chairman of The Bond Marketing Association's (TBMA) Municipal Credit Committee and the NFMA's "Best Practices" committee for municipal utilities and also sat on the Advisory Committee for Public Utilities Fortnightly magazine. Gary is a member of the Institute of Electrical and Electronics Engineers, the American Nuclear Society, the Natural Resource Defense Council (NRDC), the National Federation of Municipal Analysts (NFMA), the IEEE Power Engineering Society, the NYC Partnership Energy Task Force, and the American Association for the Advancement of Science.

Mr. BAIRD. Thank you. Dr. Sanders.

STATEMENTS OF THOMAS L. SANDERS, PRESIDENT, AMERICAN NUCLEAR SOCIETY

Dr. SANDERS. Thank you, Mr. Lipinski, for that kind introduction. Chairman Baird, Mr. Rohrabacher, and other Members of the

Committee, I thank you for the opportunity to testify, and my written testimony is submitted for the record.

A lot of what I was going to say has been said by previous panelists and Members of the Committee so——

Mr. BAIRD. Okay. We will proceed to questioning then.

Dr. SANDERS. Let us say that American Nuclear Society applauds Assistant Secretary Miller and his team for developing a comprehensive R&D roadmap. I, too, will focus on small modular reactors, but I would like to take a little different approach to that.

Clearly small reactors have a potential to address nuclear energy's upfront costs as illustrated by several of the panelists. However, I would like to talk about the global environment and the opportunities associated with small modular reactors in that environment.

The world is embarking on a nuclear expansion with all the opportunities and risks associated with it. Unlike Iran and North Korea, most nations interested in nuclear energy are motivated by a sincere desire to improve the standard of living of their people. Indeed, the U.S. currently has very little say over whether this renaissance happens. If we are unable or unwilling to provide nuclear technology, these nations have plenty of other supplier options outside of the United States.

The choice we have today is clear. We can either commit ourselves to facilitating this renaissance as a major supplier of safe, proliferation-resistant nuclear technology, or we can stand on the sidelines and cross our fingers and hope that France and others will take care of us.

If we choose the path of engagement, the next step requires developed systems that are suited for the globally marketplace. More than 60 countries are actively seeking new nuclear generation capacity. At the same time nearly three-fourths of the world's power grids are not large enough to absorb large, 1 gigawatt-sized reactors.

This is where the small reactors come into the picture on the global marketplace. They comprise a diverse set of technologies. You have heard about mPower, a light water reactor design, metal-cooled reactors with extended refueling intervals could minimize waste. High temperature gas reactors were mentioned, to process heat and water desalination, and revolutionary concepts are on the table like traveling wave and nuclear batteries.

The common thread is their size, small enough to be shipped and exported to other nations. There are some that are not comfortable with the notion that the U.S. should actively promote and supply nuclear technology around the world. They believe that the risks of proliferation are too great.

However, there is an emerging consensus in my world and the U.S. nuclear community that, in fact, the opposite is true, that a revitalized domestic nuclear manufacturing sector is a critical and necessary component to sustaining our national interests around the world.

Our national security infrastructure provides us with a head start. We already make small reactors for submarines and aircraft carriers. We have modular manufacturing techniques, and we have the ability to make most of the fuels envisioned for these designs.

What we need is the collective will to make a long-term investment so that U.S. industry can, again, become a major supplier to the global marketplace.

NE's R&D Roadmap is a good start. Its areas of focus are appropriate to the task, but as always the key item of the debate is proper balance between fundamental R&D and initiatives specifically geared to accelerate deployment of real operating reactors. I can tell you that as ANS President I have traveled the country and met with thousands of ANS members. If there is one common theme in these conversations it is that the U.S. cannot afford to be overly cautious in developing advanced reactor systems.

We are in a race after all, and if we do not move forward with speed and purpose, we will forever be in the catch-up mode. Personally, I believe the DOE must make a revitalization of the U.S. nuclear supply industry one of its primary objectives. We need an industry capable of supplying cradle-to-grave technology and solutions that eliminate the incentives for nations outside of the United States and outside the current nuclear powers to develop sensitive enrichment and reprocessing capabilities.

If we could provide technology on the basis of cradle to grave, we could eliminate the reason for other countries to develop these technologies. I also believe we must ensure the U.S. industry is the primary beneficiary of taxpayer investments in nuclear technology so that we can maximize the economic job creation benefits of our investments.

So while I support the broad contours of the R&D Roadmap, I hope Congress will consider giving DOE additional tools to accelerate the deployment of the next generation reactor so that we may be better positioned to meet our environmental, national, and economic security objectives within the next 10 to 15 years.

This concludes my testimony, and I will be happy to answer any questions the Committee may have.

[The prepared statement of Dr. Sanders follows:]

PREPARED STATEMENT OF THOMAS L. SANDERS

Chairman Gordon, Ranking Member Hall, members of the Committee, thank you for the opportunity to testify. I am here in my capacity as President of the American Nuclear Society (ANS). ANS is dedicated to the peaceful use of nuclear science and technology and comprised of 11,000 men and women who work in the nuclear industry, our national labs, universities and government agencies.

In general, the ANS membership believes that nuclear energy can and should play a major role in supplying energy in a carbon-constrained environment. We applaud Assistant Secretary Miller and his team for developing a comprehensive R&D roadmap to guide the Office of Nuclear Energy's investments going forward. My testimony today focuses on the need for DOE to facilitate the development and deployment of a new generation of small modular reactors.

The nuclear debate in Washington these days focuses on the cost of nuclear versus other forms of energy—and specifically the large up-front costs of installing new nuclear generation capacity. Clearly, SMRs have great potential to address nuclear energy's upfront cost challenges by allowing the cash flow from initial reactor modules to help finance subsequent additions. However, to view the nuclear issue only through the lens of the U.S. market is to miss half the picture.

The world is embarking on a nuclear expansion with all the opportunities and risks associated with it. While we tend to hear about countries like Iran and North Korea, most nations interested in nuclear energy are motivated by a sincere desire to improve standards of living for their people. And in general, a world with plentiful clean energy will be more peaceful, more prosperous, and more environmentally sustainable over time.

Indeed, the U.S. actually has very little say over whether this renaissance happens. The Nuclear Nonproliferation Treaty guarantees that all signatories have the right to enjoy the peaceful benefits of nuclear energy technology. In addition, the nuclear energy supply infrastructure has become thoroughly globalized in the last three decades. Frankly, if the U.S. is unable or unwilling to provide nuclear technology, interested nations have plenty of other supplier options.

The choice we in the U.S. face today is clear. We can either commit ourselves to facilitating this renaissance as a major supplier of safe, proliferation-resistant nuclear technology, or we can stand on the sidelines and cross our fingers that other supplier nations will do it for us.

If we choose the path of engagement, the next step required is to develop nuclear power systems that are suited for the global marketplace. More than 60 countries are actively seeking or have expressed interest in developing new nuclear energy generation capacity. At the same time, over 80% of the world's power grids are not large enough to absorb a 1 GW class nuclear plant.

That is where SMRs come into the picture.

SMRs comprise a diverse set of technologies. The common thread is their size, generally from 10 to 300 MW electricity, small enough to be shipped on a flatbed or rail car and exported to other nations as a complete unit.

For purposes of this discussion, SMRs can be grouped into four different types.

1. Small light water reactors: these are based on well understood technology and the U.S. has an existing manufacturing capacity for supplying the Navy with propulsion reactors. These reactors would make an attractive option for existing nuclear plant operators to add capacity in a scalable fashion in the near term.
2. Sodium or lead cooled fast reactors: these are small pool type reactors that operate at low pressures. Their fast neutron spectrum could allow for extended refueling intervals of up to 20–30 years. They have desirable safety characteristics, and when combined with advancements in turbine technology, can be operated in an extremely safe manner for long periods of time.
3. High-temperature gas reactors: these proposed designs are generally optimized for process heat applications such as hydrogen production, water desalination, shale oil recovery. They could be located in industrial parks to offset the use of fossil fuels for process heat generation.
4. The fourth category is what I call exotic designs. While these innovative concepts will require longer-term research and development efforts, their simplicity of operation could provide "walk away safe" power to remote communities here in the U.S. and around the world.

There are some who are not comfortable with the notion that the U.S. should actively promote and supply nuclear technology around the world. They believe that the risks of proliferation are too great. However, there is an emerging consensus in the ANS membership and the U.S. nuclear community that in fact the opposite is true—that a revitalized domestic nuclear manufacturing sector is a *critical and necessary* component to sustaining U.S. nuclear influence around the world.

So, what would a revitalized, SMR-focused U.S. nuclear manufacturing industry look like?

Our national security infrastructure provides us with a head start. We already have a manufacturing infrastructure for small naval reactors. We have an operating geological repository in our defense infrastructure that could potentially accommodate transuranic waste from recycled SMR fuel. We have many years of operational data for water and sodium cooled systems. We already have modular manufacturing techniques. We have the ability to make the fuel envisioned in these designs. What we need is the collective will make long-term investments so that the U.S. can again be a major supplier to the global nuclear marketplace.

NE's R&D roadmap is a good start in that direction. It takes a crosscutting approach to identifying areas of R&D focus applicable to sustaining the current U.S. fleet of nuclear plants, developing new reactor designs and fuel cycles, ensuring a high level of operational safety, and minimizing the risks of proliferation. I believe these areas of focus are appropriate to the task and DOE should be applauded for sharpening its pencil.

As always, the key item of debate is the proper balance between fundamental R&D activities like modeling and simulation and initiatives specifically targeted at accelerated deployment of real, operating reactors. I can tell you that, as ANS president, I've traveled the country and met with hundreds of ANS members with nuclear engineering backgrounds. If there is one common theme in these conversations, it is that the U.S. cannot afford to be overly cautious in developing advanced reactor systems. We are in a race after all, and if we do not move forward with speed and purpose, we will forever be in catch-up mode.

Personally, I believe that DOE must make revitalization the U.S. nuclear industry one of its stated objectives. We need a U.S. industry capable of supplying "cradle-to-grave" technology solutions that eliminate the incentives for nations to develop sensitive enrichment and reprocessing capabilities. I also believe we must ensure that U.S. industry is the primary beneficiary of taxpayer investments in nuclear technology, so that we maximize the economic and job creation benefits of our investments.

So while I support the broad contours of the R&D roadmap, I hope Congress will consider giving DOE additional tools to accelerate deployment of next-generation reactors so that we may be better positioned to meet our environmental, national and economic security objectives in the next 10 to 20 years.

This concludes my testimony and I would be happy to answer any questions the committee may have.

BIOGRAPHY FOR THOMAS L. SANDERS

Dr. Sanders is currently serving as President of the American Nuclear Society. Recently appointed to be a member of the Civil Nuclear Trade Advisory Committee (CINTAC), which serves to advise Gary Locke, Chairman of the Trade Promotion Coordinating Committee on trade issues facing the U.S. civil nuclear industry. Recently elected to the International Nuclear Energy Academy (INEA). Co-founder and former Vice President of the American Council on Global Nuclear Competitiveness. Manager/integrator of Sandia National Laboratories Global Nuclear Materials Management and Global Nuclear Futures Initiatives since 1997. Organized numerous focus meetings with senior government policy officials on the need for a second nuclear era, from a national security perspective. As the leader of the Global Nuclear Futures vision, led the development of topical meetings, policy papers, news articles, partnership events with other countries and non-government organizations, and caucus events on Capitol Hill to articulate that a healthy and thriving U.S. nuclear energy infrastructure (from education to labs, suppliers, operators, and NGOs) is key to global proliferation risk management in the future. Developed a complementary partnership initiative between 7 U.S. and 9 Russian Lab Directors. This message has been delivered at Presidential summits, White House and Congressional briefings, and to numerous champions throughout government, industry, labor, and academia. Contributed to and managed several technical groups and programs at Sandia since joining in 1984. Authored over one-hundred journal articles, conference papers, magazine articles, and white papers covering all aspects of the nuclear fuel cycle, from fusion and fast fission breeder reactor systems to criticality safety of spent fuel transport, storage, and disposal systems. Completed Bachelor of Science, Master of Science, and Doctor of Philosophy Degrees in Mechanical/Nuclear Engineering at the University of Texas in Austin, Texas. While at UT, licensed as a Senior Reactor Operator at the University of Texas by the NRC. Also served as a nuclear operator and supervisor on U.S. Navy Nuclear Submarines for several years, completing several patrols on the USS Kamehameha and the USS Shark. Also qualified as a journeyman shipyard electrician. Member of ANS, ASME, ACGNC, and INMM.

DISCUSSION

Mr. BAIRD. Thank you, Dr. Sanders. I am glad I didn't cut you off. Excellent points added to the already other quality points made.

Mr. Lipinski, I recognize you for five minutes.

Mr. LIPINSKI. Thank you, Mr. Chairman.

Mr. BAIRD. Returning the favor when you are Chair.

U.S. MANUFACTURING NEEDS

Mr. LIPINSKI. Thank you, Chairman Baird. I thank all the witnesses for their testimony. I am especially interested in Dr. Sanders' testimony, because I know that for a lot of years the U.S. was the worldwide leader in nuclear technology, but we moved from an exporter of nuclear goods and services to an importer. Westinghouse is an American company and made many parts used in our current generation of reactors. They sold to the British company and then to Toshiba. They now do most of their manufacturing in Japan but plan to move to China in the near future.

So what is the best way for us to go about making sure that we have the ability, and not just for Dr. Sanders, but for the entire panel, have, first of all, the manufacturing capability to do the nuclear reactors? Especially if—I know Dr. Sanders talked about we do have the capability and we do build the nuclear reactors for the military, submarines, and ships. But besides the manufacturing, also to have the workforce that we need in order to be a leader in nuclear energy.

So I will start with Dr. Sanders. I am just looking for suggestions of what policies should we be pursuing in order to be able to maintain that or get back that leadership in nuclear energy across the board.

Dr. SANDERS. I would like to take us back a little bit in history and describe how it was done the first time around. President Eisenhower started Atoms for Peace for national security reasons. He recognized that the world was going to go nuclear, that nuclear energy was going to spread, and he established a vehicle called Atoms for Peace that enabled the U.S. industry to be a dominate player on the global marketplace for the next 40 years.

But the real enabler of that was that it had collateral defense applications. The Nuclear Navy was just starting out. We started out with a pressurized water reactor. The pressurized water reactor became the design component that ultimately led to civilian nuclear reactors, and basically Westinghouse and GE and B&W and others became the major suppliers around the globe.

We need to reinvent that series of actions basically. We need a market initiator. DOD could be a market initiator, and promotion and initiation within our own TVA and other utilities might be the way to do that.

We also need a technology leap. I don't believe personally that large scale light water reactor technology and manufacturers are going to come back to the U.S. because I don't believe that market is really that large in the United States. The market is outside the United States for the growth of nuclear energy, and most of that market is much more consistent with technology leaps and small modular reactors.

By the technology “leaps,” I mean, in all assets: manufacturing, proliferation resistance, the technologies of use, different coolants, gas, sodium, water, and technologies that minimized the waste burden, especially if these kinds of exports can promote our national interest relative to other countries developing fuel cycle technologies.

If we can offer solutions such that those countries don’t feel the need for enrichment and reprocessing technologies, then we have solved, or we have implemented a major opportunity to solve, most of the world’s proliferation issues.

Mr. LIPINSKI. Dr. Peters.

Dr. PETERS. Yes. I would comment on the science and engineering side of it at the labs and universities. I think this is where there is an inherent role for government-sponsored programs, and they exist, but I think we need to continue to bolster those. Over the last ten years as the DOE NE R&D Program has been revitalized, you start to see the workforce develop. You start to see young people coming into these problems, joining the national labs, and that is very, very exciting.

I am fortunate to be able to go to other countries on a scientist-to-scientist basis and talk to people, and they still look to the United States for leadership in areas around advanced fuel cycles for example, but they are investing heavily in their R&D in those countries. So we need to continue to do that here, both at the universities in terms of university programs, and also at the national laboratories. And that involves everything from people all the way to experimental facilities.

Mr. BAIRD. Mr. Mowry.

Mr. MOWRY. Yeah. I would just like to add a few comments to those already made by Dr. Sanders. First, the comment about the application of large reactors and the ability to bring that manufacturing back into the U.S., I think we would generally agree with that. One of the promises of SMRs is the ability to export a completed reactor to the developing country market that is actually in the long term the largest market access.

So SMRs, in addition to creating the potential for domestic jobs, also offers the promise of a new significant, high-technology export product that the U.S. could get into, and this in and of itself would create significant new opportunities for domestic jobs to support that export market.

I think it is our view that the workforce will follow a leadership role that government plays and industry plays in getting this SMR market off the ground. So if there is a demonstration project, if we enter into a cost-sharing partnership, young people will move into those fields that they see are being supported and endorsed by the Nation.

Mr. LIPINSKI. Anyone else?

Mr. BAIRD. Mr. Lipinski, I am going to go ahead and move——

Mr. LIPINSKI. Okay. Go ahead.

Mr. BAIRD. —because we may have a vote coming up at noon, and I want to make sure we get to——

Mr. LIPINSKI. Okay.

Mr. BAIRD. —have another chance.

Mr. LIPINSKI. Thank you.

Mr. BAIRD. Thank you. Mr. Rohrabacher or Mr. Smith.

Mr. ROHRABACHER. Mr. Chairman, I think Mr. Smith has an item on the floor he would like to go to, so why don't I——

Mr. BAIRD. Mr. Smith next.

NEW REACTOR PERMITTING

Mr. SMITH OF TEXAS. Thank you, Mr. Chairman, and I want to thank the Ranking Member, Mr. Rohrabacher, for letting me ask my questions. I do have a suspension bill coming up next, so I need to get to the floor.

Mr. Krellenstein, let me address my first question to you. You pointed out accurately that the permitting process slows down our efforts and makes the goals a little bit harder to achieve. In particular with regard to the small modular reactors, what do you specifically suggest that we do to expedite that permitting process?

Mr. KRELLENSTEIN. I am not sure that we can dramatically change the basic fundamental permitting required for a large or small nuclear plant, but I think something that we could do to expedite it would be to locate the SMRs at existing or adjacent to nuclear facilities, so we would be doing what is called brownfield citing versus greenfield citing. The burden would be to add a third or fourth unit, and because they are incremental in size, it would be far easier for many utilities that are uncertain about their future load gross or the financial commitment involved in building a large gigawatt-sized unit.

Mr. SMITH OF TEXAS. Okay. Thank you, and Dr. Sanders, you suggested that Congress give the Department of Energy some additional tools to accelerate the deployment of next generation reactors. Would you, too, be a little bit more specific as to what you would recommend?

Dr. SANDERS. I would recommend linking the R&D roadmap to what is going on in this chamber today, I believe, which is the competitiveness initiative.

Mr. SMITH OF TEXAS. COMPETES Act.

Dr. SANDERS. COMPETES Act. I think that is an opportunity to accelerate some of the deployment of some of these activities because, as said by other members of the panel, numerous jobs are going to be created to support an export market that is very significant in size.

HOW DOE CAN SUPPORT NEW DEVELOPMENTS

Mr. SMITH OF TEXAS. Okay. Thank you, Dr. Sanders, and Mr. Krellenstein, back to you for my last question. I would like to know what you might recommend beside the loan guarantees that have been proposed by the Administration. Do you think that the right posse approach, or do you think we ought to be looking at more direct subsidies? What is the best way, again, to get to the goal?

Mr. KRELLENSTEIN. I think depending on the individual issuer and the needs of the utility or power company. A portfolio approach would probably be better. Loan guarantees would be one way. There is a program available right now in the municipal market called BABS, or Build America Bonds. That might be another option to be considered. Favorable tax treatment would be another way, accelerated price depression.

Because there are so many different situations at various companies interested in building, I think there is no one single best option to do but a group of options would be available.

Mr. SMITH OF TEXAS. Do you think the Administration has done enough? Their loan guarantee program is relatively small. I don't know what we are going to do on tax credits that you just suggested.

Do you think we ought to be doing more than we are or more than the Administration has proposed?

Mr. KRELLENSTEIN. If we are serious about pursuing a nuclear renaissance, yes. I am afraid that what we have is a good start. It is probably not sufficient to provide the level that we need.

Mr. SMITH OF TEXAS. Okay. Thank you. Thank you, Mr. Chairman. I yield back.

Mr. BAIRD. Thank you, Mr. Smith.

FINANCING AND COST COMPETITIVENESS

I want to follow up with a financing question. Mr. Mowry, I noted with interest you specifically suggested even without carbon price that you felt that SMRs might be competitive. Walk us through that. And are there any government subsidies and is it the full cycle of fuel costs from mining to disposal or storage? How does that work out? Because that is somewhat different than what I have been reading.

Mr. MOWRY. Well, two things. First, yes, it would include the entire cost of ownership, the life cycle cost of electricity, ownership when we are looking at this. We believe that that has to be the goal of the SMR initiative. If you want to create a viable, market-based solution long term, it cannot require government subsidy in the long term.

So the technology approach that you select fundamentally needs to be competitive, and our goal at B&W is to make this solution competitive with $5 gas. That is the goal. In a brownfield application, that was discussed. When you apply this incrementally in a brownfield application, you want to have this competitive with $5 gas. There are——

Mr. BAIRD. Natural gas.

Mr. MOWRY. Yes.

Mr. BAIRD. Not with coal though?

Mr. MOWRY. Well, if it competes with $5 gas, it also competes in total, with our expected prices and goes forward in that area.

The other aspect of this thing is what innovations you are going to apply to this and what incremental infrastructure the SMR is going to require, and that is why we believe that in the near term SMRs need to be light water reactor based technologies that use what has been proven in industry over the past 30 years. The issue with the nuclear industry today is not fundamentally a technology issue. It is an affordability issue, and it has to do with how you finance the reactors and get the projects built with cost certainty and schedule certainty.

In the long term there is promise with fourth generation technologies, and therefore, R&D should be expended to develop these technologies, but in the near term that is not what the challenge is out there. We need to innovate on how light water reactors are made smaller and more cost effective so that they can compete with this.

Mr. BAIRD. I understand that the goal—and I want to refer to Mr. Krellenstein here, I understand the goal would be that. That would be an obvious goal with price competitiveness. I don't think we are even close to anything demonstrated in actual practice that has met that metric of actual producing at $5 gas level. And I am interested in how that relates—basically financing is making a bet here. They are betting how cost competitive will the electricity produced by this approach will be.

What are your analyses of this, Mr. Krellenstein?

Mr. KRELLENSTEIN. It is true that for a large number of investors, the expectation that there will be some type of restriction on emissions of carbon-based fuels is a factor, and they are viewing this as a viable economical alternative. There is the potential for modular units being manufactured partially in a factory and at a high rate to bring the cost down to a point where they may be able to compete directly.

The biggest challenge we see right now is actually that natural gas, which has far lower carbon emissions, is very plentiful, and seems to be becoming more plentiful with each passing day, and is a very strong competitor for any power generation technology where environmental considerations are paramount.

So nuclear really has to compete with gas rather than coal.

A SKILLED WORKFORCE AND DOMESTIC MANUFACTURING

Mr. BAIRD. Okay. Dr. Sanders, I was intrigued by your observation about the human resource and the technological resource. My understanding is that, first of all, I appreciate the shout out to America COMPETES. We hope to pass it this time through, and I think your point is well taken that we are going to have to have more engineers and scientists to—if we are going to bring this nuclear renaissance to reality, we have got to have the expertise.

What about domestic manufacturing? I understand that, for example, if you to build a large-scale nuclear plant, just getting the steel for the containment vessel is a challenge. How do we promote Buy America-type approaches for—and I think to some extent the modularity might help us there because we just assembly. How do we do that?

Dr. SANDERS. Well, like I stated, we do have a national security infrastructure that does that today, and I think what has to be recognized is that our international security interests require that we maintain certain infrastructures for competitive advantage on the global marketplace, particularly if that competitive advantage promotes our national security interests like liberation and risk management through a major position on the global marketplace as the supplier.

That never gets factored in the decisions relative to nuclear energy versus national security—at least they haven't been since the Atoms for Peace Initiative, for example. What has been factored into competitiveness of our nuclear industry is issues related to proliferation. We stopped reprocessing because of the belief that if we did, everybody else would, and that didn't happen. We have made other decisions relative to trade barriers and expert controls that have limited our ability. In fact, these decisions resulted in reasons for Westinghouse and others to move offshore.

Anybody on the panel can correct me if I am a little bit off base on some of this, but the reality is we have got to look at our nuclear industry like we look at our submarine manufacturing industry. We have got to look at it from the perspective of, it has got to promote our national interests relative to the national security parts that it plays. And in the past we have burdened commercial industry with basically promoting our national security interests, and we have either put barriers in place or removed the enablers that allowed them to do it in the beginning of the nuclear age, the first nuclear age.

And that is a difficult thing to get your arms around, but I think it is necessary in the future. I think the America COMPETES Act is probably a step forward in that area that at least recognizes there is certain areas of our domestic enterprise where we have to be able to compete. If we have to develop our aluminum, steel, and concrete resources. We have to recognize that in 2004, China imported half the world's cement in the world. We have got to be able to compete on that level also. We have got to be able to compete and start redeveloping some of our own resources.

Mr. BAIRD. Thank you, Dr. Sanders.

Mr. Rohrabacher.

SUBMARINE REACTORS AND MPOWER

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. Let me just note that after Three Mile Island the hysteria created by that incident caused huge regulatory costs and extra road blocks that were put in the way of this industry because our regulators were responding to the hysteria along with the population. So there was a huge cost, and it wasn't just penciled out in terms of what they—what it would do for economics because quite often these decisions are affected by things that are not just economics, not just what the bottom line is.

Let me ask about some of these various things. Now, why—we have submarines, we have ships, but submarines with nuclear reactors on it. How are those reactors different than the new reactor that you are suggesting, because that—are they light water reactors as well on the submarines?

Mr. MOWRY. Well, the mPower reactor that B&W is developing, its heritage comes from commercial nuclear ships because you are trying to solve a different problem here. You are trying to create an economically-viable product that can plug into the industry base, you know, that it—so it is a totally different——

Mr. ROHRABACHER. But we already are producing small nuclear reactors. Has to be if we have nuclear submarines. I mean, these are not——

Mr. MOWRY. Well, B&W has a distinct advantage that we have existing infrastructure in terms of facilities, manufacturing, infrastructure, engineers, manufacturing engineers that can be redeployed from the work we do with the government to this application.

Mr. ROHRABACHER. Yeah.

Mr. MOWRY. But, again, this gets back to the cost effectiveness. We need to focus on a cost-effective solution, and that is a different problem that you are trying to solve than the problem you are trying to solve when you do work for the government in these other areas that you mentioned.

Mr. ROHRABACHER. Do you have—with your small reactor, now, I have studied this—the one that General Atomics has put before me, and is the one that you are advocating—is your configuration, does it have leftover plutonium and reprocessing requirements? Or is that——

Mr. MOWRY. It uses the conventional fuel infrastructure and fuel supply chain that is out there today because that is a requirement of industry for any near-term deployment of SMRs.

FISSION VS. FUSION

Mr. ROHRABACHER. Got it. Now, yours is much further down the line obviously, and the General Atomics small reactor is supposedly not going to have the proliferation problems, left over plutonium, or require word processing, but they are not—you seem to be ready. They are a few years down the line.

It would be—if we permit the Chinese to become the nuclear, the builders of nuclear power reactors, we are going to have both safety problems but also major proliferation problems. So had better address these issues that are being raised right now, and let me ask, do any of you know—now, we are all talking about fission. All of these small reactors that we are talking about, whether it is a gas-cooled reactor or the reactor that you are talking about, are fission reactors. Is that right?

Well, how much—have we been putting the necessary research dollars or Department of Energy into fission as compared to fusion? What—do any of you know that answer?

Yes.

Dr. SANDERS. I am the non-technical one here, but I will try to answer. The best we can see is that fusion reactors from an economical point of view because of the inherently difficult technology are at least a generation away or further, and I am not sure that putting in dramatically more research dollars into right now would accelerate that dramatically.

Mr. ROHRABACHER. Oh, I agree with you, but as we are spending the money now, we are spending a lot of money on fusion research. Are we spending money on fission research as well?

Dr. PETERS. Maybe I can take a shot at that——

Mr. ROHRABACHER. Yes.

Dr. PETERS. —Congressman. So the fission-related research is what we have been talking about, what Dr. Miller talked about.

Mr. ROHRABACHER. Right.

Dr. PETERS. So in Department of Energy it is funded primarily by the Office of Nuclear Energy. There is fusion research going on in the Department of Energy that is primarily funded by the Office of Science.

Mr. ROHRABACHER. Okay.

Dr. PETERS. And so that includes participation in ITER.

Mr. ROHRABACHER. I am just thinking in terms of overall spending.

Dr. PETERS. Right.

Mr. ROHRABACHER. It seems to me that what we are talking about is something that has a potential, as we have a company here who has got a potential right now, and other companies that are stepping forward and saying we have got potential in a couple of years down the line as compared to fusion which I have never met a scientist who has told me that we are going to be able—we can guarantee you that we are going to be able to build one of these plants ten years from now, and we will have fusion.

So thus it would seem to me that it would be—we should be—research dollars should be focused on what we can actually accomplish rather than what potentially we can't accomplish.

Dr. PETERS. Certainly in the applied programs but I would argue there is fundamental science that one needs to do that the Department of Energy's Office of Science focuses——

Mr. ROHRABACHER. Uh-huh.

Dr. PETERS. —around fusion that is important. People still talk about the promise of fusion. There is a lot of barriers that involve materials and other barriers that we have to tackle and that requires science. So I would argue there is still need for investment, but the timelines for fusion versus fission are much different.

Mr. ROHRABACHER. Yes. That is correct. Well, I am going to look into that myself. In fact, I will be asking for the record to find out exactly how much money we are spending on fission research that would help the small modular reactors as compared to money that we are spending on fusion research that may never be put into practice.

EXPEDITING TECHNOLOGY DEVELOPMENT

We—one of the factors that seems to be coming up here and when we are talking about the activities, research activities, are we talking about research activities that is developing new technology or research activities that will permit us to set standards and have—and help along the permitting process? What are we talking about here?

Dr. PETERS. In fact, I would say the answer is probably yes. It is both. If you look at the roadmap, some components of it would include providing technical basis to the regulatory framework, for example, and the NRC themselves actually invest research dollars in this to do this as well.

But then a lot of what I was talking about with the fuel cycles really ultimately focused on technology development and commercialization.

Mr. ROHRABACHER. Well, isn't it time that we should be making up our mind and moving forward and I like this idea where we had some ideas about putting this on existing sites so we could move forward quicker without having to go through ten years of the regulatory process, perhaps on military bases as well could offer that, Mr. Sanders?

Dr. SANDERS. Well, in fact, I think you are exactly right. The issue here is the Valley of Death between good research and commercial applications in a lot of these activities. I would like to remind everybody we operated liquid metal cool fast reactors for 40 years in this country and never have taken the opportunity to transfer that technology to the commercial sector.

So there is this Valley of Death issue between good research and commercial applications, and our recommendation to DOE is to figure out how to do that. Basically it is a public-private partnership with the public side assuming more of the risk in the beginning of the phase, and the private side taking over the situation when the risk has been reduced through good technology development.

Mr. ROHRABACHER. Thank you very much. Thank you, Mr. Chairman.

Mr. BAIRD. Chairman Gordon has joined us. Mr. Chairman, did you have any questions you want to ask at this point?

Chairman GORDON. No. I think you should go ahead.

Mr. BAIRD. Okay. I will briefly make—we have had a chance to go through all the Members, but I will—I have one or two quick questions.

On the economic side, you know, in the realm of other alternative energies, one of the things we hear about is things like feed-in tariffs or guaranteed marketplace, et cetera. None of you have talked about that kind of approach as a methodology for stimulating the development of plants. We talk about loan guarantees, et cetera, but what about marketing, you know, some form of assurance that X—that maybe the government will buy X amount of energy produced by one of these plants.

Any thoughts on that?

Dr. SANDERS. Yes, if I could. I think the issue is nuclear is once the unit is up and running and the power produces on a variable basis, it is very competitive with energy sources and really doesn't require feed-in tariffs. That is not the case for some of the sustainable resources that we are looking at right now that require feed-in tariffs. Our principle objective is to get the capital together to build the nuclear plant. Once it is up and running, its variable cost is relatively low and very competitive. The initial capital cost is very high and has been a major detriment in its development.

Mr. BAIRD. And that is why the loan guarantees and things of that sort come in.

Dr. SANDERS. Correct.

MAINTAINING COMPETITION

Mr. BAIRD. One of the other questions is, you know, we have got a number of potential manufacturers. B&W is one, there are others, one actually, coincidentally, in Oregon, and several others. You know we are loathe to try to pick winners and losers, but at the same time stimulating competition can make sense.

How do we do that? How do we make sure that different models, both perhaps the technological model of how the plant functions, but also the competitive business model, how do we find a way to make sure that the taxpayer dollars that go out to try to promote the industry in general create a healthy competition so there are multiple approaches, each of which may win in some fashion?

Mr. Mowry, I would appreciate your thoughts on that.

Mr. MOWRY. Well, I think first of all, and I think you are right on in terms of what the ultimate goal is. You want to have an investment that ultimately yields success, and I think you need to let the marketplace vote. So we would advocate that this public, private partnership, a program that Dr. Miller talked about earlier today, the partnership on the industry side needs to be not just with a supplier like ourselves, but it needs to be with a group of utilities that will ultimately deploy that technology after the demonstration plant has been built, because unless you have that type of assurance that there is committed interest by ultimate users, you will never have assurance that the demonstration plant and the demonstration of that technology just won't end after the demonstration.

So a partnership has to include the ultimate users in the marketplace.

Mr. BAIRD. Does that then put the manufacturers of the SMRs in some relationship of—you are then trying to sell your partnership with the utility as would some of your competitors? In other words——

Mr. MOWRY. It would be incumbent upon each technology developer such as ourselves to convince the user marketplace that our technology, if demonstrated in a partnership, is something that they would want to deploy in a market-based environment. Otherwise you are spending money on something that may not ultimately help the Nation in terms of electric generation.

Mr. BAIRD. Other comments on that?

Dr. SANDERS. Yes. I would have to disagree with Mr. Mowry on this in that one of the major problems for investors in the '80s and '70s was the multiplicity of designs and their inability to determine what was better overall. We actually need some sort of a bake off done by the government and the standardization so that investors are not constantly trying to rediscover technologies that they are not comfortable with and invest in multiple different uses of small nuclear technologies, each one requiring a new learning curve, making it more difficult for them to invest their money into.

Mr. ROHRABACHER. Mark Twain—thank you, Mr. Chairman. Mark Twain once said, "Put all of your eggs in one basket and then watch that basket," and so there are several different approaches to that, and I am not sure Mark Twain really knew what he was talking about, but I do remember the quote.

Mr. BAIRD. Dr. Sanders.

Dr. SANDERS. Well, I would like to point out, though, that there are different goals and different markets. If you are promoting a particular technology in the national interest that wants to eliminate the need to refuel, you may go with a different technology, and that is driven by a different market. It is driven by a market that is looking out for national security interest for export, for example.

That is just one example. If it is for DOD applications for bases or, you know, to assure energy independence on a DOD base, either forward or local or in Guam, for example, there is different requirements that might drive you to a different type of technology.

So I don't like to close the package, the basket. I like more eggs in that basket because there is no single egg that can accomplish all of those objectives when you look at them across the board.

Mr. BAIRD. Would it make sense, though, I think these are excellent points. Would it make sense then, though, as we are looking at this—as we look at any form of government subsidy to in some way—and then perhaps I missed it. I don't know that this does address that that well.

But does it make sense to perhaps categorize some of the potential types of applications and then make the competition within those categories. Take the DOT. If you look at what it costs us to ship fuel into Afghanistan, it is a horrifying number. It is breaking our bank and dangerous as all heck.

A modular nuclear system that could somehow power the city and power our forced there might be one application. Export applications that don't have—does it make sense then as we look at subsidies to—maybe there is one group that is for domestics, augmentation of existing power supplies. Would that makes sense to categorize that in some fashion?

Dr. SANDERS. Absolutely. Absolutely, and you are categorizing according to different markets——

Mr. BAIRD. Right.

Dr. SANDERS. —basically.

Mr. BAIRD. And different applications.

Dr. SANDERS. Different applications. Applications—we spend a lot of money on summary and reactors. No doubt, but they have a different performance requirement. No doubt. They are a combat situation, and you would never put one of those in a domestic application then force civilian nuclear industry to pick that egg out of the basket. You could never compete, and we need to recognize that.

For exports to developing nations, we maybe want to something different, something we don't have to refuel but every 10 or 20 years. They can sit there for awhile. If we want to solve the solution and make energy out of Army garbage in Kabul or Baghdad, you are going to go to a high temperature system, very high temperature system able to convert that garbage at some price. It will never compete with gasoline at $4 but $150 a gallon, which is what I think a gallon of gas costs in Baghdad, you have got a different market situation.

Mr. BAIRD. I want to make sure we recognize the Chairman. The buzzers you heard, we are both being called. Before I recognize the Chairman, though, I just have to engage in a brief conversation with my friend, Mr. Rohrabacher, who is a dear friend, quite sincerely.

Mr. ROHRABACHER. I am about to be refuted again.

Mr. BAIRD. No, no. What I will just observe that several months ago on the Energy and Environment Subcommittee, we had a lengthy hearing about the role of social and behavioral sciences in our energy system, and just for the record I would observe that multiple occasions today Mr. Rohrabacher has talked about hysteria causing increased costs in our energy approach to nuclear power. Hysteria is a psychological diagnosis. So maybe Mr. Rohrabacher has become a convert to the importance of social and behavioral sciences in our energy picture.

I recognize the Chairman, Mr. Gordon.

Chairman GORDON. Thank you, Chairman Baird, for a good hearing today. I am looking forward to reviewing it on our website. I know that Mr. Rohrabacher wants to run over to the capitol and vote for the America COMPETES bill, so I don't want to take up much time.

I would like to ask the witnesses this in all seriousness. We are going to get out a reauthorization. We want to get out a good reauthorization. This record will remain open for a few days. I would hope that you would get back to us any recommendations concerning that reauthorization, areas that you think that should be covered and research concerning design, reprocessing, storage, or other areas. I hope you would do that.

The other area that I would be interested in knowing, this is expensive, and I know that we have got some international efforts going on with the G4 nuclear reactor. I would like to get your thoughts on how you think that is going, and anything that we might need to do to encourage it to go a different way. So, again, thank you for your time. Thanks for the good hearing, and I yield back the balance of my time.

Mr. BAIRD. Thank the Chairman and as soon as I find the appropriate closing remarks—essentially what I would like to say is thank you to the gentlemen for their testimony, and the record customarily will be open for I believe it is two weeks for additional comments, and with that the hearing stands adjourned and with gratitude to our witnesses.

[Whereupon, at 12:17 p.m., the Committee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Warren P. Miller, Assistant Secretary, Office of Nuclear Energy, U.S. Department of Energy

Questions submitted by Chairman Bart Gordon

Q1. One of the more exciting policy provisions in the Roadmap is the heavy emphasis on Small Modular Reactors (SMR) technology. Your testimony indicates that SMRs could achieve both lower capital costs and simplify the construction process.

a. Should the Federal government conduct a Federal demonstration program for SMR technology?

b. What is the appropriate scale for a demonstration program to prove small modular reactor technology, reduce the technology risk, and encourage mobilization of private capital?

A1a. The Office of Nuclear Energy (NE) is formulating an SMR program in FY 2011 that will be informed by a workshop that was held in June 2010. Light water reactor-based SMR technology is familiar and well characterized, and the safety systems and regulatory framework are well understood by the Nuclear Regulatory Commission (NRC); we see no need for a near-term federally-funded demonstration project.

As we evaluate opportunities and determine the most appropriate activities for the program in the context of the most effective and appropriate federal role, we will be considering the research and development needs, particularly of advanced SMR designs like metal and gas-cooled fast reactor technologies. Because these designs are less well characterized and have little or no domestic commercial history, there are a range of research and development activities that would likely be appropriate for NE to support. We will not be undertaking a demonstration project in the near-term for these advanced designs and future activities, if any, related to advanced SMRs will be evaluated and reviewed along with all other priorities in future budget development processes.

A1b. As noted above, proven and commercialized LWR technology does not require a demonstration program. Advanced, non-LWR technologies are still in the R&D phase and no demonstrations are planned.

Q2. Should the United States be reprocessing nuclear waste using current methods or should we focus on developing more advanced methods first? Is the Administration's Roadmap consistent with your recommendation?

A2. The Fuel Cycle Research and Development program is focusing on developing more advanced methods of reprocessing used nuclear fuel. Current methods, which are employed overseas, are expensive and have proliferation concerns, and it is likely that new technologies can reduce costs. It is also possible eventually to employ new technologies that would improve the environmental, safety, and nonproliferation impacts of current reprocessing methods. Since used nuclear fuel in the U.S. is currently being stored safely and can be for decades to come, we have ample time to conduct research and development on improved reprocessing technologies. We have no need to reprocess now using current methods.

The Administration's Nuclear Energy Research & Development Roadmap is consistent with this approach. Objective 3, "Develop Sustainable Nuclear Fuel Cycles," seeks to "develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors" (page 27). This approach will work to understand what can be accomplished and then to develop the most promising technologies (page 29).

Q3. There is indication that the non-Federal cost share has presented a high hurdle for private involvement in the Next Generation Nuclear Plant Project. Could you please give a brief overview of the issues currently complicating smooth development of this program and plant?

A3. The Department of Energy has actively engaged with industry from the inception of the Next Generation Nuclear Plant (NGNP) Project to ensure that this technology will be aligned with commercial needs. Our research and development activities as well as development of licensing requirements are progressing. Results are expected to be reviewed by the Nuclear Energy Advisory Committee, and the Committee will advise the Secretary on whether to proceed with Phase 2. Phase 2 challenges, as identified by various vendors and potential end-users, pertain to the high level of cost and economic risk associated with the deployment of gas reactor technology. Specific areas of concern that have been raised by industry include the value of constructing the reactor at the Idaho National Laboratory versus at an actual industrial location and the importance of having the design and licensing process result in a certified design for use at multiple locations. Industry also has stated that the government should fund the upfront demonstration costs. Their proposal is in conflict with cost-share requirements and does not reflect the proper federal role in this project.

Q4. How seamless is the integration between the Office of Nuclear Energy and the Office of Science on related issues? For example, what steps will be taken to coordinate efforts between programs on such issues as advanced nuclear materials and reactor design and simulation and what role will the Nuclear Energy Enabling Technologies program play in this coordination?

A4. There is a seamless integration of information between the Office of Nuclear Energy (NE) and the Office of Science (SC) in a variety of areas. Coordination efforts between the two programs in the areas of advanced nuclear materials, reactor design, and modeling and simulation include:

- *Advanced Nuclear Materials*: SC's three Energy Frontier Research Centers addressing materials performance under irradiation are directly connected to NE-funded materials research.
- *Reactor Design*: NE-funded researchers use the Argonne National Laboratory computer to simulate the neutronics of a full fast reactor core, making extensive use of SC and National Nuclear Security Administration (NNSA)-developed software.
- *Modeling and Simulation*: Strategically, NE's Modeling and Simulation Hub for Nuclear Reactors demonstrates the high level of cooperation between the two programs. The Department's Hubs are large, multidisciplinary, highly-collaborative teams of scientists and engineers working over a long time frame to achieve a specific high-priority goal, such as developing fuels from sunlight in an economical way and making buildings more energy efficient. SC provides capabilities that NE leverages within the NE Hub for R&D funded by other parts of the Department.
- The role of the Nuclear Energy Enabling Technologies (NEET) program, which is proposed for fiscal year 2011, would be to serve as a focal point for coordinating stakeholder input of commonly-themed R&D across the DOE complex. A core aspect of the NEET program would be successful collaboration with NNSA and SC through peer-to-peer discussions, joint meetings, review of research proposals, and sharing of scientific and engineering resources at the national laboratories. As the NEET program progressed, NE would expect to increase the opportunities for collaboration with the Office of Science and other DOE offices.

Q5. The Roadmap mentions thorium as a possible fuel source. Given our national stockpiles of depleted uranium and our limited thorium resources, why should we be examining thorium?

A5. Objective 3 of the Nuclear Energy Research and Development Roadmap, "Develop Sustainable Nuclear Fuel Cycles," seeks to "develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors" (page 27). The Fuel Cycle Research and Development program is examining thorium because it may prove to be part of a sustainable fuel cycle option in the long term. While we agree that there is a significant uranium resource available and there is no foreseeable need for thorium, we believe a limited review of thorium options would help provide a more complete examination of fuel cycle technologies and options. Thorium research will be a small portion of the overall portfolio.

Although depleted uranium stockpiles are abundant and more readily available, the United States also has large natural reserves of thorium. In addition to fuel resource availability considerations, advanced thorium fuels could provide improved fuel performance and increased resource utilization using thermal spectrum reactor systems. The benefits, along with the challenges, associated with the use of thorium will be taken into account as we evaluate particular technologies and integrated fuel cycle system options within our Fuel Cycle Research and Development program.

Questions submitted by Representative Ralph M. Hall

Q1. The Committee received written testimony from NuScale Power stating that a Federally-funded small, modular reactor (SMR) demonstration project was not necessary to advance SMR licensing and commercialization and Federal funds should instead be focused on assisting in support for first-of-a-kind applications for design certification, construction, and operating licenses.

a. Please provide DOE's position regarding the necessity of a Federally-supported SMR demonstration project. Is DOE planning to support such a demonstration project?

b. If so, what would it cost, and what does DOE propose should be the appropriate Federal/industry cost share?

A1a. For the SMR reactor technologies that are closest to commercialization, specifically the light water-based reactor technologies, the Department agrees with NuScale that a Federally funded demonstration project is not necessary for proving the technology. These designs are relatively mature and are well-characterized with respect to the existing NRC regulatory framework as the light water-based designs are very similar to the existing fleet of commercial reactors. The Department is not planning to support a demonstration project for these technologies. The more advanced reactor designs such as liquid metal, liquid salt, and gas-cooled fast reactor technologies are less well characterized and have little or no domestic commercial history and therefore more research and development is needed.

A1b. No demonstration projects are envisioned. All demonstrations would subject to the cost-share requirements in section 988 of the 2005 Energy Policy Act. Projects would be funded by DOE at no more than 50 percent of the total cost.

Q2. What is your reaction to concerns that an SMR demonstration could result in the Federal government "picking winners and losers" among competing technologies, resulting in reduced incentives for private sector investments in "losing" technologies and designs?

A2. In general, the future electricity needs will be met with a mix of technologies and this mix will be determined by industry based on a variety of factors. Any demonstration project inherently gives the chosen technology some type of advantage over its competitors. However, DOE's SMR efforts will be designed and executed in a manner that works within existing market mechanisms and there are no plans for SMR demonstration projects.

Q3. It was noted during the hearing that the cost-competitiveness of nuclear energy would suffer in the absence of regulations to increase the cost of carbon-based electricity and given expected sustained low prices for natural gas.

- *How might industry and Federal priorities—particularly with respect to research and development—change if both of these barriers remain in place over an extended period of time?*

A3. The absence of a carbon policy and the expectation of low natural gas prices could impact long-term R&D priorities for nuclear energy. However, the portfolio of nuclear R&D planned in the FY 2011 Budget strikes an appropriate balance to help provide the flexibility and information needed to inform future decisions and resource prioritization. Such future decisions will be made considering an array of factors, including economic and technical concerns as well as public benefit, federal role, and cost considerations.

Questions submitted by Representative Judy Biggert

Q1. How do SMRs compare to other types of advanced reactor designs being contemplated and pursued in the private sector, both in terms of economic potential as well as technical advantages and disadvantages?

A1. The near-term, light water reactor-based technologies being initially pursued by the industry and the Department are fundamentally the same as their larger counterparts in the current fleet of commercial reactors, and even closer in functional characteristics to the newly-designed Generation III+ reactors (*e.g.*, AP1000, ABWR and ESBWR). The primary difference is the scale, which may lead to several operational and economic advantages. Realization of these advantages is not a given and will be dependent on a variety of factors.

Compared with the Gen III reactors currently operating in the U.S., the SMR technologies being developed by industry today:

- Are smaller and, based on initial assumptions and modeling done by industry, may be safer with much lower predicted core damage frequency;
- May require no active response systems in post-accident conditions;
- May be less expensive to construct, operate and maintain;
- May be able to be transported to the deployment site by truck, rail or barge;
- Have the potential to supply remote areas with appropriate electrical capacity; depending on market needs and industry decisions; or
- Could be used to add new electrical capacity in smaller increments to match demand growth depending on ultimate cost, siting, market and other factors.

Projected benefits for SMRs have not been proven, such as whether smaller plants can overcome the benefits of economies of scale. They of course still generate used nuclear fuel the same as existing plants. Certain elements of the electric output and the economics of SMRs could be considered to be disadvantages, depending on a specific utility's needs. For example, SMRs may not be cost-competitive as a replacement for large baseload capacity. They provide the same greenhouse gas avoidance as existing nuclear technologies, so there is not a net advantage in that respect.

Some utilities and merchants have shown interest in SMRs, both domestically and internationally, as a potential solution for their energy requirements. Issues such as water limits and using nuclear as a low-carbon option for replacing aging fossil plants help make SMRs an increasingly attractive option.

The advanced metal, gas, and molten-salt cooled SMR designs are also similar to the advanced sodium and gas-cooled designs being pursued under Nuclear Energy programs such as the GEN IV and Next Generation Nuclear Plant (NGNP), and may offer some of the same technical and economic advantages discussed above.

These advanced SMR designs are, however, much farther from deployment readiness.

Q2. Given that the market and regulatory system can support only a limited number of reactor design types, is there any concern that going forward with SMR demonstration and licensing impact the viability of other advanced reactor types?

A2. Future electricity demand will be met by a mix of technologies. That mix will be determined by industry based on a variety of factors and nuclear, regardless of the design, will have to compete in that mix. Any demonstration project inherently gives the chosen technology some type of advantage over its competitors. There are no demonstration projects planned for LWR or advanced SMR designs.

In order to be successful SMRs would need to have their own commercial niche that would be borne out as customers emerge to partner with SMR vendors to meet specific technical, economic, and electrical load growth needs. For example, SMRs may allow the nuclear power option to be viable for customers or applications with power requirements or financial constraints that preclude the use of the larger plants. Larger nuclear plants are expected to maintain their market niche, particularly where there is a need for baseload power and where the grid and water resources can accommodate a large plant. We also recognize that, in the future, it could be possible to deploy several SMRs at a single site to create the equivalent output of a larger plant.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Christofer Mowry, President and CEO, Babcock & Wilcox Nuclear Energy, Inc.

Questions submitted by Chairman Bart Gordon

Q1. You indicated that your SMR design would be manufactured in the United States and supported by a "North American supply chain including all forgings."

How will SMR technology be able to keep the supply chain entirely domestic if we have been unable to do so with large reactors?

Could SMRs become a new American export?

A1. The B&W mPower™ reactor design is specifically designed to use a North American supply chain, and to be manufactured at existing B&W nuclear manufacturing facilities in Ohio, Indiana, Virginia, Tennessee, and Ontario, Canada. Large, gigawatt-sized reactors are unable to be 100% domestically sourced because they require ultra-heavy (>350 tons) forgings which are currently not available in the United States. Due to the size and modularity of the B&W mPower reactor, it does not require ultra-heavy forgings and can therefore be sourced from existing forging suppliers in the United States and manufactured at B&W facilities.

SMRs represent significant potential for American exports, once a first-of-a-kind plant is certified, licensed and deployed in the United States. The B&W mPower module is designed to be factory assembled and shipped to a plant site via rail as a finished unit. Due to this modularity and shippability, as well as the reactor's North American supply chain and air-cooled plant design, there is ongoing interest in international markets. This is particularly relevant in countries where cost, accessibility, water availability and grid capacity make larger reactors impractical.

Q2. NuScale Power in its testimony suggested that a federally funded "demonstration facility" is not necessary. Should the Federal Government conduct a Federal demonstration program for SMR technology? What is the appropriate scale for a demonstration program to prove small reactor technology, reduce the technology risk, and encourage mobilization of private capital? Could you please provide comment on private interest you are aware of in a demonstration plant?

A2. B&W supports a demonstration program to support near-term development and deployment of SMR technology through public-private partnership to share the costs of design, design certification, site licensing and final engineering. However, Federal Government funding of construction of a facility is not expected or necessary. While light water SMRs take advantage of proven technology and decades of operational experience, unique risks are inherent in being a technology "first-mover". Government cooperation through cost-sharing is essential to realistically address the licensing and schedule risks inherent in such first-of-a-kind projects. A public-private partnership between government and industry would share the risks and benefits of deploying a "first-of-class" practical SMR before the end of this decade. It would provide a realistic mechanism to accomplish the following broader set of National objectives for the U.S. energy infrastructure:

- Regain U.S. leadership position in the global commercial nuclear power industry,
- Create significant high-quality U.S. manufacturing, construction and engineering jobs,
- Provide carbon-free power generation, and
- Provide a practical baseload clean-power option for DOD applications, aging fossil plant sites, and remote or isolated locations.

In 1957, the first commercial nuclear power plant at Shippingport, PA achieved full power operation, the result of a partnership between the Atomic Energy Commission and Duquesne Light Company. This cooperation between industry and government set in motion the development of the U.S. commercial nuclear industry. Our government's investment in this first-of-a-kind technology more than 50 years ago provided lasting and significant value to the Nation. A new public-private partnership to share the costs of design, design certification, site licensing and final engineering will enable the U.S. to demonstrate the promise which SMR technology holds for our energy industry by the end of this decade.

To this end, the estimated total funding requirements for a *single* SMR reactor are:

- To complete design work and obtain design certification—$320M
- To obtain a combined operating license—$80M
- To complete detailed final design to prepare an Engineering, Procurement, and Construction contract for the initial SMR deployment—$325M

We believe the appropriate Federal/industry cost-share for these activities would be 50%/50%.

It is essential that the utility industry be fully engaged in such a program to ensure that the result is an SMR plant that utilities are likely to construct and operate in quantity, and that can achieve commercial financial viability without long-term Federal support. This first-of-a-kind plant should therefore be developed in partnership with the Federal Government and constructed, owned and operated by a U.S. utility, with construction costs borne by the utility customer, rather than by the U.S. government. In this way, government and industry can share the risks and benefits of developing the first SMR plants for deployment by the end of this decade.

We have developed a B&W mPower Consortium made up of B&W and leading U.S. utilities, including the Tennessee Valley Authority, First Energy and Oglethorpe Power Corporation. The Consortium is dedicated to addressing the proper regulatory framework, design requirements, and licensing infrastructure necessary to support the commercialization of the B&W mPower reactor. The ultimate goal of the Consortium is to deploy one or more demonstration plants in the U.S. by 2020, if not earlier.

Questions submitted by Representative Ralph M. Hall

Q1. You recommend in your testimony that DOE increase its support for design certification and long-term R&D from $39 million to $55 million in fiscal year 2011. What specific activities do you believe the additional $16 million should support?

A1. The DOE's Fiscal Year (FY) 2011 budget request includes $39 million for the SMR program, of which approximately half is expected to be dedicated to a cost-sharing program for design certification of up to two light water SMR designs, with the remaining half used for R&D activities for longer-term, non-light water technologies. While this budget request is on the right track, it is not aggressive enough to support the deployment of SMRs by the end of the decade. To meet this goal, we recommend that the funding for the SMR program be increased to $55 million in FY 2011, with $35 million dedicated to the cost-sharing program for up to 2 light water SMR designs. This funding would be used for cost-sharing of development and design activities leading to design certification no later that 2016, to help support deployment by 2020.

Q2. The Committee received written testimony from NuScale Power stating that a federally funded small, modular reactor (SMR) demonstration project was not necessary to advance SMR licensing and commercialization and Federal funds should instead be focused on assisting in support for first of a kind applications for design certification, construction and operating licenses.

Please provide B& W's reaction to this position regarding the necessity of a federally-supported SMR demonstration project.

If such a demonstration project were to go forward, what would it cost, and what would be the appropriate Federal/industry cost-share?

A2. B&W supports a demonstration program to support near-term development and deployment of SMR technology through public-private partnership to share the costs of design, design certification, site licensing and final engineering. However, Federal Government funding of construction of a facility is not expected or necessary. While light water SMRs take advantage of proven technology and decades of operational experience, unique risks are inherent in being a technology "first-mover". Government cooperation through cost-sharing is essential to realistically address the licensing and schedule risks inherent in such first-of-a-kind projects. A public-private partnership between government and industry would share the risks and benefits of deploying a "first-of-class" practical SMR before the end of this decade. It would provide a realistic mechanism to accomplish the following broader set of National objectives for the U.S. energy infrastructure:

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We believe the appropriate Federal/industry cost-share for these activities would be 50%/50%.

It is essential that the utility industry be fully engaged in such a program to ensure that the result is an SMR plant that utilities are likely to construct and operate in quantity, and that can achieve commercial financial viability without long-term Federal support. This first-of-a-kind plant should therefore be developed in partnership with the Federal Government and constructed, owned and operated by a U.S. utility, with construction costs borne by the utility customer, rather than by the U.S. government. In this way, government and industry can share the risks and benefits of developing the first SMR plants for deployment by the end of this decade.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Charles Ferguson, President, Federation of American Scientists

Questions submitted by Chairman Bart Gordon

Q1. Dr. Ferguson, your testimony notes the advantage that India and China currently have in the Small Modular Reactor market and that they are preparing to sell reactors to foreign nations and into developing markets. You also mention the technology that those nations seek to export may be more prone to proliferation and use for a weapons program.

a. Would you suggest this is a reason to develop SMR technology in the U.S.?

A1a. I think the United States should encourage further international competition in SMR technology, including development within the United States. While China is moving ahead with selling two more medium power reactors to Pakistan, it is important to recognize that this action likely stems from China trying to support its traditional ally Pakistan and bring back into balance the relationship Pakistan has with India in response to the U.S.-India civilian nuclear deal. The proliferation concern is that China is rewarding Pakistan, a country that has a history of not being able to control of nuclear technologies, in particular, A. Q. Khan's nuclear black market. The Chinese reactors themselves are not necessarily proliferation-prone as long as adequate safeguards are in place. Aside from China's deal with Pakistan, it remains uncertain that China will sell more small or medium sized reactors. Similarly, while India's nuclear industry has expressed some interest in selling small pressurized heavy water reactors, which are proliferation prone, India may not be ready to make such sells in the near term because it is focused on its domestic nuclear power development. Thus, the United States and other potential suppliers of more proliferation-resistant SMRs may have the opportunity to compete successfully with China and India.

b. Would U.S. development of SMR technology set a safety standard by which all others competitors are measured or would cheaper options likely be developed and deployed internationally?

A1b. Setting a safety and security (including proliferation-resistance) standard for SMR technology would appear to require: (1) demonstration of one or more SMR designs with enhanced safety and security features, (2) U.S. leadership within the International Atomic Energy Agency for an assessment of all small and medium power reactor designs on the basis of safety and security, and (3) U.S. leadership within the Nuclear Suppliers Group to encourage suppliers to only supply reactors with enhanced safety and security features. Under the theme of leadership by example, the United States can and should take the lead in demonstrating SMR technology. Concerning the cost of safe and secure SMRs versus competitors' designs, many factors determine cost. While a less safe and secure reactor may appear cheaper in terms of initial capital costs, a safer and more secure reactor may in the long term offer advantages in that (1) the much lower probability of an accident would lower costs related to the consequences of an accident, (2) more proliferation-resistant fuels would likely be more fuel efficient and thus save money, and (3) more proliferation-resistant SMRS would likely require fewer refueling or provide a lifetime core and thus likely result in lower costs in terms of transportation of fuel and reactor downtime.

Q2. Should the Federal Government conduct a Federal demonstration program for SMR technology? What is the appropriate scale for a demonstration program to prove small modular reactor technology, reduce the technology risk, and encourage mobilization of private capital?

A2. Yes, I think the time is ripe for the Federal Government to conduct a demonstration program. Utilities may be reluctant to purchase an SMR without seeing one demonstrated because the dominant paradigm is for large reactors. One demo option is for the Defense Department to purchase an SMR. While that would show the reactor in operation, such a plan may not satisfy the need to encourage mobilization of private capital. Another option is to demonstrate one or more SMRs in a location where the Federal Government has authority but also where the states and the commercial sectors have jurisdiction. One location that comes to mind is the Tennessee Valley Authority, which has a defense mission in its charter. The Oak Ridge National Laboratory with expertise in nuclear energy technologies may be the natural partner with TVA to demonstrate SMRs. The SMRs could provide electrical power to ORNL as well as the local communities. ORNL and the communities could share costs in paying for the electricity generated.

Q3. You mention that small markets like Alaska and Hawaii may benefit most from SMRs and that this technology would be attractive to small markets with weak grids. But other panelists here suggest that SMRs and their ability to be "stacked" or used in tandem would make them a logical choice for scaled deployment of nuclear generation across the board. What is your response?

A3. I think this is not an either/or choice. As indicated in my written testimony, there may be considerable merit in stacking or building sequentially several SMRs at one location as long as there are economic advantages. The International Atomic Energy Agency study that I cited in the testimony suggests that four SMRs at one location could be stacked in such a way to be very cost competitive with one large power reactor with the equivalent amount of power of the four SMRs.

Concerning communities in Alaska and Hawaii, the electricity markets at those locations are relatively small and thus may not be able to handle a large power reactor or several SMRs in a stacked configuration. Nonetheless, as long as one SMR is cost competitive with alternative energy choices, then those communities may find value in purchasing an SMR. Both Alaska and Hawaii rely significantly on fossil fuels for electricity generation. So, nuclear power could serve to reduce reliance on these greenhouse gas generating sources. Concerning reliance on oil for electricity generation, Hawaii has the highest dependency in the United States. Consequently, alternative electricity generation sources would help alleviate this dependency. In addition to considering nuclear power in the form of SMRs, Hawaii should examine increased use of geothermal and solar sources, which are ideal in Hawaii's location. A systems analysis would be useful for Hawaii in determining what combination of geothermal, nuclear, and solar sources are environmentally sound and cost competitive with fossil fuels.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Mark Peters, Deputy Director for Programs, Argonne National Lab

Questions submitted by Chairman Bart Gordon

Q1. Dr. Peters, you have indicated that there are problems with the PUREX process of recycling currently available today, such as proliferation risks and an inability to perform multiple cycles and fully use nuclear fuel.

Does the Roadmap as presented provide the resources necessary to research and develop the advanced reprocessing methods you list and potentially mitigate many of the problems with nuclear waste?

A1. The DOE Nuclear Energy R&D Roadmap provides a comprehensive vision for the research and development needed for advanced reprocessing and recycling technology development that will ultimately mitigate many of the challenges of nuclear waste management. The research and development approach described in the Roadmap, in particular the synergistic use of experiment, theory, and modeling and simulation, is a sound approach to enabling the required technologies.

This said, the Roadmap needs a greater emphasis on coupling the science-based approach for system development with an active design and technology demonstration effort that would guide and appropriately focus research and development in this next decade to allow for advanced reprocessing and recycling technology demonstrations at engineering scale beginning circa 2020. These efforts would allow for fuel cycle demonstration in a timeframe that could influence the course of fuel cycle technology commercialization on a global basis.

With an additional emphasis on timely demonstration of advanced technologies, the objectives of the Roadmap can be met in a reasonable time frame if the appropriate priorities are identified and sufficient funding is provided to allow acceleration of high priority areas. Current resources are not adequate to implement the required program through robust public-private partnerships involving the Department of Energy, its national laboratories, universities, and industry. The R&D and demonstration program needs sufficient resources and should be conducted with a sense of urgency and purpose consistent with the U.S. retaining its intellectual capital and leadership in the international nuclear energy community.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Gary M. Krellenstein, Managing Director, Tax Exempt Capital Markets, JP Morgan Chase & Co.

Questions submitted by Chairman Bart Gordon

Q1. One of the concerns raised about SMR technology is that building out the necessary infrastructure will be too costly to justify deployment of an SMR. For instance, if a customer were to want to use a single 100 MW reactor and then slowly scale up to ten 100 MW reactors, they would still be required to build all of the surrounding infrastructure for the full complement of SMRs from the outset.

Could you comment on this argument?

When we build combustion turbine unit plants, which typically come in 50–150 MWe sizes, we usually start with one or two units and then add additional units as needed. If planned and sited correctly for potential additional generating expansion, only incremental improvements are likely to be needed for the remaining units since most of the infrastructure is needed for the first unit constructed. The capital costs for the first unit or two are often higher since items such as the road, switchyard, transmission and piping are often allocated to those units. The incremental units added to the site do not require these facilities or "right-of-ways," and usually just require upgrades of relatively low cost.

Q2. Are there any other technology or research pathways that you think should be explored by this Committee that could reduce the capital costs for nuclear power?

A2. Yes. Most likely we would use a water moderated nuclear reactor for the SMR. However, several other technologies are suitable for that size and should be reviewed before a decision is made to proceed with a scale model. That would include gas-cooled, pebble bed, liquid sodium moderated, and several other designs. Investors would probably be most comfortable with water-moderated reactors because they are an extension of the existing nuclear technology in use today. However, if significant cost and/or safety advantages could be demonstrated using alternative reactor designs, it would definitely garner investor interest.

Q3. Should the Federal Government conduct a Federal demonstration program for SMR technology? What is the appropriate scale for a demonstration program to prove small modular reactor technology, reduce the technology risk, and encourage mobilization of private capital?

A3. If sufficient types of Federal or other types of guarantees could be provided, it might not be necessary, but investors have become skeptical and confused by many the "subsidies" and guarantees that have been provided to other energy technologies. In my opinion, the construction of a full (150 MWe) scale SMR would probably be the most effective way to mitigate investor (and safety) concerns over a new reactor technology.

Questions submitted by Representative Ralph M. Hall

Q1. The Committee received written testimony from Nuscale Power stating that a federally-funded small, modular reactor (SMR) demonstration project was not necessary to advance SMR licensing and commercialization and Federal funds should instead be focused on assisting in support for first of a kind applications for design certification, construction, and operating licenses.

Do you agree or disagree, and why? If such a project were to go forward, what would be the approximate overall cost and appropriate Federal/industry cost-share?

A1. See response to question 3 above.

Q2. What is your reaction to concerns that an SMR demonstration project could result in the Federal Government "picking winners and losers" among competing technologies, resulting in reduced incentives for private sector investment in "losing" nuclear technologies and designs?

A2. This is a legitimate concern with no easy answer. To minimize the risk of picking the "wrong" technology, extensive analysis by an independent group of the various designs should be conducted to determine which reactor configuration looks most promising from both a technological and economical (including financing) perspective before selecting a potential "winning" design. The relatively small number of SMRs that would most likely be built in the first few years is unlikely to justify multiple prototypes being constructed. Clearly, the multiplicity of different reactor designs that were used in the 1960s–1980s was a detriment to the industry and a standard design, while not a perfect solution, would represent a significant improvement of the experience of the 1960s–1980s.

Q3. It was noted during the hearing that the cost competitiveness of nuclear energy would suffer in the absence of regulations to increase the cost of carbon-based electricity and given expected sustained low prices for natural gas.

How might industry and Federal priorities—particularly with respect to research and development—change if both of these barriers remain in place over an extended period of time?

A3. If no carbon tax is imposed and/or natural gas prices remain low, the Federal Government will have to increase subsidies and incentives to the nuclear industry for it to remain competitive. Clearly, there are significant externalities associated with carbon based fuels that are not reflected in their current "market" prices and the need for energy diversification using a domestic, non-carbon emitting source is compelling.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Thomas L. Sanders, President, American Nuclear Society

Questions submitted by Chairman Bart Gordon

Q1. Is our workforce prepared to operate, manufacture and evaluate SMR technology?

A1. The short answer is yes and no. The U.S. retains significant core experience in the manufacture, operation, and evaluation of SMR technology through its involvement with the U.S. Naval nuclear propulsion program, including fuel fabrication, reactor design, reactor operation, modular fabrication techniques and transportation of used nuclear fuel. Furthermore, graduate and undergraduate enrollments in nuclear engineering and related disciplines have increased sharply in the last few years. (Total enrollments are now approaching 3000 students from a low of roughly 200 students in the 1990s.) Many of these students have chosen to focus on SMR related technology as part of their educational programs. However, I remain concerned that the U.S. will experience significant knowledge gaps in certain technical areas, especially as they relate to fast and liquid metal reactors, which many in the field expect to play a significant role in SMR development in the medium term. While we have nearly 40 years of operating experience with sodium cooled fast reactors, many of the scientists and engineers that were involved in its development and implementation are reaching retirement age. It is critically important that we capture and preserve their collective knowledge of sodium cooled/fast reactor technology so that we may employ it in the design and implementation of SMR's in the future.

Q2. Should the Federal Government conduct a Federal demonstration program for SMR technology? What is the appropriate scale for a demonstration program to prove small modular reactor technology, reduce the technology risk, and encourage mobilization of private capital?

A2. Given the significant political and financial uncertainties surrounding the development and deployment of SMR technology by U.S. vendors, it is critical that the Federal Government take an active role in SMR technology incubation, demonstration, and implementation both in the U.S. and worldwide. As I suspect you are aware, you can divide SMR technology into three broad buckets:

advanced light water, high temperature gas cooled, and liquid metal cooled fast designs. Each of these technologies differs in their needs for Federal support and partnership. We have a fairly advanced understanding of the major technical issues related to light water SMRs, given our experience in Naval nuclear propulsion program and their big cousins in the U.S. commercial nuclear fleet. As such, Federal support should focus on the acceleration of design certification and licensing for first of a kind systems combined with financial support perhaps to be provided through a DOE loan guarantee. Congress should also consider the notion of having the Federal Government become a "lead customer" perhaps on a military base or some other Federal facility.

For high temperature gas reactors, I'm reasonably confident that the current legislative mandate and regulatory plans for the Next Generation Nuclear Plant (NGNP) provide a reasonable implementation pathway, assuming it is aggressively funded by the Federal Government. Liquid metal cooled SMR designs require additional research and development activities, including perhaps one or more small engineering demonstrations to address key technical issues, for which the Federal Government should take an active role in partnership with U.S. industry. While these reactors will certainly take longer to implement them their light water counterparts, they have certain safety, waste minimization and nonproliferation characteristics that would make them uniquely attractive.

Questions submitted by Representative Ralph M. Hall

Q1. The Committee received written testimony from Nuscale Power stating that a federally funded small modular reactor demonstration project was not necessary to advance SMR licensing and commercialization and Federal funds should instead be focused on assisting in support for first of a kind applications for design certification, construction, and operating licenses. Do you agree or disagree, and why? If such a project were to go forward, what would be the appropriate Federal/industry cost share?

A1. It is difficult to say for certain whether a particular SMR demonstration project would be appropriate for Federal investment, without understanding the detailed mechanics of the proposal. Furthermore, it is important to recognize that at least two companies are developing light water SMRs technologies which are, in my understanding, generally similar in design although they vary in power output. The Federal Government should be extremely careful that in developing and implementing its mechanisms for SMR support, so that it does not inadvertently favor one vendor over the other.

That said however, my personal opinion is that the Federal Government should consider all avenues it has at its disposal, including the possibility of a technology demonstration program, to ensure the deployment of this technology, so critical to both our energy security and national security objectives, is implemented in an expeditious manner. As for the specific percentages of a Federal/industry cost share, I would hope that the government share would be less than 50% of the total project cost.

Q2. It was noted during the hearing that the cost competitiveness of nuclear energy would suffer in the absence of regulations to increase the cost of carbon-based electricity and given expected sustained low prices for natural gas. How might industry and Federal policies—particularly with respect to research and development—change if both of these barriers remain in place over an extended period of time?

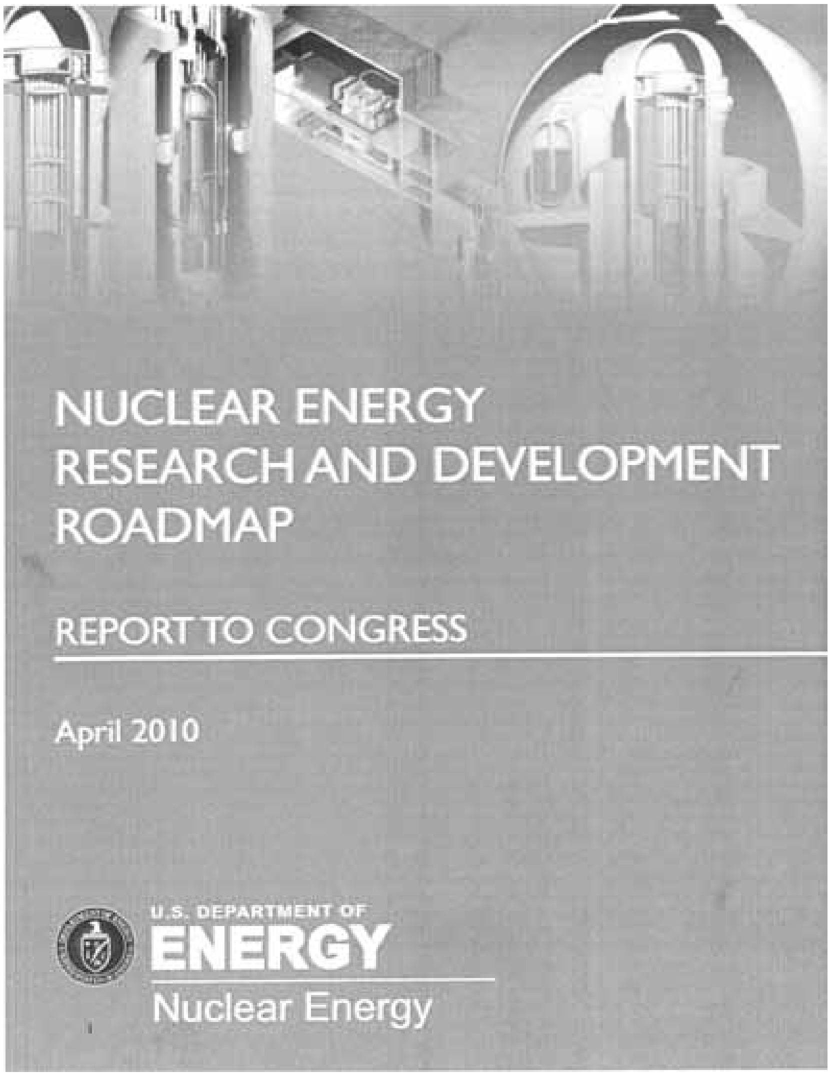
A2. There is no doubt that the combination of low natural gas prices and the absence of binding carbon constraints will reduce the financial incentives for private industry to invest in the development and appointment of SMR technology. However, Federal investment in SMR technology should not be judged solely on the basis of its role in U.S. energy supplies. Around the world, over 60 countries are constructing or actively exploring adding nuclear generation capacity to their energy portfolios. Many of these countries, approaching 80%, do not have an electrical grid large enough to absorb the power generated by a 1 GW nuclear plant, and therefore SMR technology is there only reasonable option. Other nations such as Russia and China are moving forward aggressively to develop export—oriented SMR technology to serve these markets. Clearly, the profit and job creation possibilities are compelling to these nations. If the U.S. is not actively involved in developing and exporting SMR technologies, other countries will reap the benefits of the global nuclear renaissance, while the U.S. watches from the sidelines with little role in influencing global safety and nonproliferation norms.

In short, this is a U.S. national security issue, therefore, the Federal role in developing and deploying SMR technologies should be strong and consistent regardless of the U.S. domestic market.

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD

SUMMARY AND TABLE OF CONTENTS, DEPARTMENT OF ENERGY NUCLEAR RESEARCH AND DEVELOPMENT ROADMAP, APRIL 2010



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Executive Summary

To achieve energy security and greenhouse gas (GHG) emission reduction objectives, the United States must develop and deploy clean, affordable, domestic energy sources as quickly as possible. Nuclear power will continue to be a key component of a portfolio of technologies that meets our energy goals. This document provides a roadmap for the Department of Energy's (DOE's) Office of Nuclear Energy (NE) research, development, and demonstration activities that will ensure nuclear energy remains viable energy option for the United States.

Today, the key challenges to the increased use of nuclear energy, both domestically and internationally, include:

- The capital cost of new large plants is high and can challenge the ability of electric utilities to deploy new nuclear power plants.
- The exemplary safety performance of the U.S. nuclear industry over the past thirty years must be maintained by an expanding reactor fleet.
- There is currently no integrated and permanent solution to high-level nuclear waste management.
- International expansion of the use of nuclear energy raises concerns about the proliferation of nuclear weapons stemming from potential access to special nuclear materials and technologies.

In some cases, there is a necessary and appropriate federal role in overcoming these challenges, consistent with the primary mission of NE to advance nuclear power as a resource capable of making major contributions to meeting the nation's energy supply, environmental, and energy security needs. This is accomplished by resolving technical, cost, safety, security and proliferation resistance barriers, through research, development, and demonstration, as appropriate. NE's research and development (R&D) activities will help address challenges and thereby enable the deployment of new reactor technologies that will support the current fleet of reactors and facilitate the construction of new ones.

Research and Development Objectives

NE organizes its R&D activities along four main R&D objectives that address challenges to expanding the use of nuclear power: (1) develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors; (2) develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals; (3) develop sustainable nuclear fuel cycles; and (4) understanding and minimization of risks of nuclear proliferation and terrorism.

R&D OBJECTIVE 1: Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors

The existing U.S. nuclear fleet has a remarkable safety and performance record, and today these reactors account for 70 percent of the low greenhouse gas (GHG)-emitting domestic electricity production. Extending the operating lifetimes of current plants beyond sixty years and, where possible, making further improvements in their productivity will generate near-term benefits. Industry has a significant financial incentive to extend the life of existing plants, and as such, activities will be cost shared. Federal R&D investments are appropriate to answer fundamental scientific questions and, where private investment is insufficient, to help make progress on broadly applicable technology issues that can generate public benefits. The DOE role in this R&D objective is to work in conjunction with industry and where appropriate the Nuclear Regulatory Commission (NRC) to support and conduct the long-term research needed to inform major component refurbishment and replacement strategies, performance enhancements, plant license extensions, and age-related regulatory oversight decisions. DOE will focus on aging phenomena and issues that require long-term research and are generic to reactor type.

R&D OBJECTIVE 2: Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals

If nuclear energy is to be a strong component of the nation's future energy portfolio, barriers to the deployment of new nuclear plants must be overcome. Impediments to new plant deployment, even for those designs based on familiar light-water reactor (LWR) technology, include the substantial capital cost of new plants and the uncertainties in the time required to license and construct those plants. Although subject to their own barriers for deployment, more advanced plant designs, such as small modular reactors (SMRs) and high-temperature reactors (HTRs), have characteristics that could make them more desirable than today's technology. SMRs, for example, have the potential to achieve lower proliferation risks and more simplified construction than other designs. The development of next-generation reactors could present lower capital costs and improved efficiencies. These reactors may be based upon new designs that take advantage of the advances in high performance computing while leveraging capabilities afforded by improved structural materials. Industry plays a substantial role in overcoming the barriers in this area. DOE provides support through R&D ranging from fundamental nuclear phenomena to the development of advanced fuels that could improve the economic and safety performance of these advanced reactors. Nuclear power can reduce GHG emissions from electricity production and possibly in co-generation by displacing fossil fuels in the generation of process heat for applications including refining and the production of fertilizers and other chemical products.

R&D OBJECTIVE 3: Develop Sustainable Nuclear Fuel Cycles

Sustainable fuel cycle options are those that improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and limit proliferation risk. The key challenge is to develop a suite of options that will enable future decision makers to make informed choices about how best to manage the used fuel from reactors. The Administration has established the Blue Ribbon Commission on America's Nuclear Future to inform this waste-management decision-making process. DOE will conduct R&D in this area to investigate technical challenges involved with three potential strategies for used fuel management:

- *Once-Through* – Develop fuels for use in reactors that would increase the efficient use of uranium resources and reduce the amount of used fuel requiring direct disposal for each megawatt-hour (MWh) of electricity produced. Additionally, evaluate the inclusion of non-uranium materials (*e.g.*, thorium) as reactor fuel options that may reduce the long-lived radiotoxic elements in the used fuel that would go into a repository.
- *Modified Open Cycle* – Investigate fuel forms and reactors that would increase fuel resource utilization and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per MWh), with limited separations steps using technologies that substantially lower proliferation risk.
- *Full Recycling* – Develop techniques that will enable the long-lived actinide elements to be repeatedly recycled rather than disposed. The ultimate goal is to develop a cost-effective and low proliferation risk approach that would dramatically decrease the long-term danger posed by the waste, reducing uncertainties associated with its disposal.

DOE will work to develop the best approaches within each of these tracks to inform waste management strategies and decision making.

R&D OBJECTIVE 4: Understand and minimize the risks of nuclear proliferation and terrorism

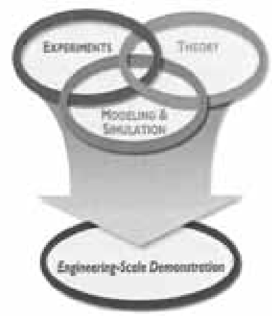
It is important to assure that the benefits of nuclear power can be obtained in a manner that limits nuclear proliferation and security risks. These risks include the related but distinctly separate possibilities that nations may attempt to use nuclear technologies in pursuit of a nuclear weapon and that terrorists might seek to steal material that could be used in a nuclear explosive device. Addressing these concerns requires an integrated approach that incorporates the simultaneous development of nuclear technologies, including safeguards and security technologies and systems, and the maintenance and strengthening of non-proliferation frameworks and protocols. Technological advances can only provide part of an effective response to proliferation risks, as institutional measures such as export controls and safeguards are also essential to addressing proliferation concerns. These activities must be informed by robust assessments developed for understanding, limiting, and managing the risks of nation-state proliferation and physical security for nuclear technologies. NE will focus on assessments required to inform domestic fuel cycle technology and system option development. These analyses would complement those assessments performed by the National Nuclear Security Administration (NNSA) to evaluate nation state proliferation and the international nonproliferation regime. NE will work with other organizations including the NNSA, the Department of State, the NRC, and others in further defining, implementing and executing this integrated approach.

R&D Areas

The Department expects to undertake R&D in a variety of areas to support its role in the objectives outlined above. Examples include:

- Structural materials
- Nuclear fuels
- Reactor systems
- Instrumentation and controls
- Power conversion systems
- Process heat transport systems
- Dry heat rejection
- Separations processes
- Waste forms
- Risk assessment methods
- Computational modeling and simulation

Figure 1. Major Elements of a Science-Based Approach



R&D Approach

A goal-driven, science-based approach is essential to achieving the stated objectives while exploring new technologies and seeking transformational advances. This science-based approach, depicted in Figure 1, combines theory, experimentation, and high-performance modeling and simulation to develop the fundamental understanding that will lead to new technologies. Advanced modeling and simulation tools will be used in conjunction with smaller-scale, phenomenon-specific experiments informed by theory to reduce the need for large, expensive integrated experiments. Insights gained by advanced modeling and simulation can lead to new theoretical understanding and, in turn, can improve models and experimental design. This R&D must be informed by the basic research capabilities in the DOE Office of Science (SC).

NE maintains access to a broad range of facilities to support its research activities. Hot cells and test reactors are at the top of the hierarchy, followed by smaller-scale radiological facilities, specialty engineering facilities, and small non-radiological laboratories. NE employs a multi-pronged approach to having these capabilities available when needed. The core capabilities rely on DOE-owned irradiation, examination, chemical processing and waste form development facilities. These are supplemented by university capabilities ranging from research reactors to materials science laboratories. In the course of conducting this science-based R&D,

infrastructure needs will be evaluated and considered through the established planning and budget development processes.

There is potential to leverage and amplify effective U.S. R&D through collaboration with other nations via multilateral and bilateral agreements, including the Generation IV International Forum. DOE is also a participant in Organization of Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and International Atomic Energy Agency (IAEA) initiatives that bear directly on the development and deployment of new reactor systems. In addition to these R&D activities, international interaction supported by NE and other government agencies will be essential in establishment of international norms and control regimes to address and mitigate proliferation concerns.

A Sustainable Energy Future: The Essential Role of Nuclear Energy, from DOE Directors of National Laboratories

A Sustainable Energy Future: The Essential Role of Nuclear Energy

August 2008

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A Sustainable Energy Future: The Essential Role of Nuclear Energy

The Directors of the Department of Energy (DOE) national laboratories strongly believe that nuclear energy must play a significant and growing role in our nation's — and the world's — energy portfolio. This conclusion is based on an analysis of national and international energy needs in the context of broader global energy, environmental, and security issues. This paper provides details regarding our position in relation to nuclear energy. It is intended to be used as a basis for further discussion with stakeholders to help in developing specific near-term actions as well as a coherent long-term strategy incorporating the items listed below:

- Make maximum use of the current 'fleet' of operating light-water reactors, including plant life extensions, extended fuel burnup, and power uprates.
- Establish a national priority to immediately deploy advanced light-water reactors to meet our nation's increasing energy demand, while limiting greenhouse gas emissions and continuing to provide critical support to the Nuclear Regulatory Commission (NRC).
- Employ an integrated approach to manage used nuclear fuel and high-level waste, including interim storage, licensing of the Yucca Mountain Repository as a long-term resource, and exploration of optimal future waste management options.
- Implement an aggressive research and development (R&D) program on advanced reactors, reprocessing, waste management, and fuel fabrication concepts to enable timely identification of the technological options for a sustainable closed fuel cycle.
- Pursue partnering with other countries and implementation of an international regime that discourages the spread of enrichment and reprocessing capabilities and promotes the assurance of worldwide fuel supply and effective waste management.
- Strengthen international safeguards through aggressive R&D, thereby revitalizing U.S. safeguards technology and human capital and providing for U.S. leadership to help in assuring achievement of international security objectives and nonproliferation goals.
- Form a robust public-private partnership to ensure that (1) nuclear energy plays a more significant role in energy independence and environmental health, and (2) human infrastructure is rebuilt across industry, government, and academia.
- Incorporate independent and authoritative guidance and peer review from government and nongovernment entities to ensure that the U.S. nuclear energy agenda is responsive to current and future national needs and international conditions.

BROAD ENERGY CONTEXT

Energy is vital to human civilization and underpins national security, economic prosperity, and global stability. Worldwide demand for energy is rapidly increasing and could double by 2050. At the same time, the evidence is clear that CO_2 emissions must be reduced globally. Abundant, affordable, and environmentally responsible energy must be developed, both domestically and internationally, to meet that demand.

Reducing U.S. dependence on foreign oil will provide economic and national security benefits, including both industrial competitiveness and international trade. Crude oil expenditures represent the largest deficit item to our balance of trade. To reverse the trend on energy imports, while at the same time meeting required reductions in CO_2 emissions, the United States must use energy more efficiently. Furthermore, our nation must develop and deploy multiple energy sources in the context of a strategic and comprehensive energy plan. A broad mix of energy technologies is essential to meet the growing demand.

BENEFITS OF NUCLEAR ENERGY

Today, nuclear energy provides 16 percent of the world's electricity and offers unique benefits. It is the only existing technology with capability for major expansion that can simultaneously provide stability for base-load electricity, security through reliable fuel supply, and environmental stewardship by avoiding emissions of greenhouse gases and other pollutants. Furthermore, it has proven reliability (greater than 90 percent capacity factor), exemplary safety, and operational economy through improved performance.

We believe that nuclear energy must play a significant role in our nation's — and the world's — electricity portfolio for the next 100+ years. Nuclear energy has great potential for contributing more to our broader energy needs, however. For example, nuclear energy could supplement or even supplant fossil fuels by providing the electricity for electric-powered vehicles, or it could be used to generate hydrogen for vehicles that utilize hydrogen fuel cells. Nuclear energy could also help to generate high-temperature process heat, provide a valuable input for feedstock to chemical production and aid in the production of freshwater from seawater and contaminated surface and groundwater sources.

FOCUS EFFORTS AND INVESTMENTS: WHY NOW?

There are many reasons to focus on and invest in the expansion of nuclear energy. First, time-critical clean energy needs can be met through reactor life-time extensions, higher fuel burnup, power uprates, and additional deployment of existing light-water reactor technology. Second, to maximize the benefits of nuclear energy domestically, advanced fuel cycles that cost-effectively optimize energy utilization and waste management are needed; however, there is a long lead time for developing the required technologies. Third, the United States now has a window of opportunity to influence global directions in safety, security, and nonproliferation throughout the nuclear fuel cycle. A strong, sustained, integrated effort across all three areas must begin now.

SUCCESSFUL PATH FORWARD

The directors of the DOE national laboratories remain committed to U.S. energy security and the important role that an increased nuclear energy component can and should play in strengthening our energy security. Essentials for success are a strategy that integrates across DOE as well as other federal agencies; a concentrated effort to rebuild the necessary nuclear enterprise, including a broad-based R&D effort; and engagement with industry and the international community. Key to ensuring a successful effort is decisive leadership and a strong public-private sector partnership.

Strategy and Policy Development

To facilitate that leadership, all stakeholders must work together to develop a comprehensive strategic plan that has broad, bipartisan support and clear, consistent communications among government, researchers, the international community, industrial stakeholders, and the public. The development and implementation of a strategic plan should include:

- A clear statement of national energy policies. The full range of benefits and risks involved in nuclear energy create an inextricable link between government and industry. Furthermore, government policies and programs should be harmonized with those of the private sector. This relationship must be a partnership.

- A clear differentiation between short- and long-term goals. Private sector providers of nuclear power have expressed their priorities, but they are inevitably short term in nature and may not necessarily include long-term, national priorities.

- A sustainable approach to used fuel disposition and waste management. Confidence must exist in the ability to manage nuclear fuel and to dispose of nuclear waste safely so as to enable the sustainable expansion of nuclear energy.

- A clear focus on strengthening the nonproliferation regime. Enhanced safeguards and physical security, international fuel service arrangements, and new nuclear fuel cycle technologies can advance our nonproliferation objectives.

- A mechanism for review by the stakeholders to ensure that the strategy remains relevant to current and future national needs and international conditions.

Rebuilding of the Nuclear Enterprise

The nuclear sector stakeholders must address three key areas: manufacturing base, science and technology infrastructure, and human capital. Expansion of nuclear energy will create stresses on the industrial resources needed to build and operate nuclear power plants. Nuclear power plants require a large forged pressure vessel and head, huge civil works, a myriad of pumps and valves, miles of piping and wiring, and robust process and system controls that must be "N-stamp qualified." To have substantial growth in nuclear energy, more suppliers are needed. The worldwide forging capacity is very limited, and none of it resides in the United States. This example illustrates one of the many choke points in the supply chain. Transport of material, support for construction, and enrichment of uranium for the fuel supply all must be considered. Moreover, financial institutions need to have confidence that a reliable supply chain exists before they will invest in new plant construction.

The science and technology infrastructure must include modern capabilities such as irradiation systems for testing new fuels and structural materials; chemical separations and characterization capabilities; and physics facilities for radiation transport, thermo-hydraulics, cross-sections, and criticality science. These and other capabilities require modern facilities; however, our current R&D infrastructure, which was built during the Cold War, has atrophied and is obsolete. Modeling and simulation technologies have made tremendous advances since the design of the existing facilities. The design of the next-generation facilities must incorporate state-of-the-art testing and diagnostics tools and be guided by the data requirements for advancing the realism and accuracy of high-performance simulation tools and approaches.

In addition, training the next generation of engineers and scientists must be an integral part of a robust nuclear program. A recent industry study pointed out that over the next five years, half of the nation's nuclear utility workforce will need to be replaced. To satisfy the need for both professional and crafts workers, government and industry must both play important roles to stimulate workforce development for construction, operations, and R&D by providing an environment that is exciting and thriving. Industrial and federal government commitment will be required to invigorate university and trade school programs. For example, the government should establish and fund a nuclear energy workforce development program at universities and colleges to meet the expected need.

Research and Development

To reduce cost, ensure sustainability, and improve efficiency, safety, and security, investments in a sustained nuclear science and technology R&D program are needed. Such a program must effectively support and integrate both basic and applied research and use, to the extent possible, modeling and simulation capabilities to address both near-term, evolutionary activities (e.g., life extensions of the current fleet) and long-term solutions (e.g., advanced reactors and fuel-cycle facilities). Industry will pursue evolutionary R&D to further improve efficiencies along each step of the current fuel cycle. It is incumbent upon the government, however, to implement long-term R&D programs for developing transformational technologies and options for advanced nuclear fuel cycles. Including regulators in the research and evaluation of results will facilitate the development of licensing and regulation of future nuclear facilities and technologies. Review of research plans and results by expert peer reviewers and open availability of the results will strengthen these efforts.

International Engagement

Thirty countries currently operate nuclear power reactors, and approximately thirty-five reactors are under construction outside the U.S. An additional two dozen countries that have never used nuclear power to generate electricity (e.g., Egypt, Indonesia, Turkey, Vietnam) are now expressing serious interest in the technology, citing stability, security, sustainability, and environmental stewardship as key drivers. As a result, the amount and types of nuclear material in the world will grow, commerce in nuclear technology and materials will increase, and there will be interest in assuring a reliable supply of nuclear fuel. Ongoing bilateral and multilateral engagement will provide opportunities for improving our understanding of the needs, plans, and initiatives of other countries; the potential benefits and risks of these initiatives; and ways to positively impact technological development and choices. The R&D of viable technical options for the United States will also maximize our ability to influence the expanding global commercial enterprise.

CHALLENGES AND OPPORTUNITIES

Important challenges and opportunities are on the horizon: near-term expansion, used nuclear fuel disposition, a sustainable "closed" fuel cycle, and nonproliferation and security. These are discussed below.

Near-term Expansion

An urgent need exists to extend the life of our existing nuclear plants; to begin building new plants, including addressing the financial constraints; and to implement further cost improvements. Relicensing for 60 years has already occurred for many existing reactors and is being aggressively sought for the remaining plants. In parallel, R&D activities that explore the technical feasibility and path forward for long-term operations to 80 years should also be pursued.

Capital investments required for construction of nuclear plants are substantial, and private sector investment decisions must seriously consider risks over a long planning horizon, including the ability to recover capital costs through the rate base. Since new nuclear power deployments are in the national interest, the private sector and government share the responsibility for undertaking the activities needed to ensure that the investment risk associated with constructing, licensing, and operating new light-water reactors is reduced sufficiently to enable commercial investment and deployment. The Energy Policy Act of 2005 provides important loan guarantees, standby support, and tax credits to mitigate financial and regulatory risks that need to be implemented: the financial community and rate regulators must be engaged to enable nuclear energy expansion. Finally, critical support of the NRC for license review and approval also needs to continue to ensure timely review of new license applications.

Further cost-effective technical improvements to light-water reactors are feasible. In addition to simplified reactor and ancillary systems, areas of emphasis include the development of sensing capabilities, robust communication systems, and development of advanced approaches to safeguards and physical protection. The achievement of a simplified safe and secure plant will also require systematic consideration of human factors as a major contributor to a plant's economics, safety, security, and operational performance. Many of these advances can also provide cost-efficient operations and maintenance of existing plants.

Used Nuclear Fuel Disposition

The disposition of used nuclear fuel must be considered from both a short- and long-term perspective. Confidence regarding the disposal of waste is needed before the NRC will grant a license for a new plant and before private investors will accept the financial risk of ordering new nuclear plants. In the short term, this confidence can be achieved by continuing the licensing of a geologic repository at Yucca Mountain and enabling the continued interim storage of used nuclear fuel in dry casks and fuel pools.

Dry cask storage is a safe and secure interim solution, either at existing reactor sites or consolidated regionally if future circumstances dictate. Through policy and investment actions, government can make it clear that interim storage is not intended to push the burden of an ultimate solution to a future generation, but rather to keep waste management options open, pending the results of continued R&D investments. The use of dry casks incorporates proven technologies and regulatory regimes to protect the public from hazards during handling, transport, and storage.

The design and operation of the repository may evolve as knowledge advances. Yucca Mountain Repository was envisioned at a time when the country did not have plans for significant nuclear energy expansion. At that time, used reactor fuel was considered "waste"; thus, direct disposal was chosen as the approach. In the long term, given the envisioned expanded use of nuclear energy, it is both appropriate and timely to reconsider the sustainability of the fuel cycle and to recognize that even with recycling, a geologic repository will be required. In our opinion, R&D must be conducted, and a comprehensive evaluation of disposition pathways must be performed.

Sustainable "Closed" Fuel Cycle

As nuclear energy expands, the traditional once-through fuel cycle will not be sustainable. To maximize the benefits of nuclear energy in an expanding *nuclear energy future*, "closing" the fuel cycle will ultimately be necessary. Simultaneously addressing such issues as the full utilization of the fuel's stored energy content, waste minimization, and strengthening of the nonproliferation regime is essential and will require systems and economic analysis; and investigation of new technologies. Thus, the immediate urgency of our efforts should be directed toward conducting broad-based R&D to support an informed decision on how to proceed. The results of these investments will yield a deeper understanding of the above issues, and will provide the basis and timing for closing the fuel cycle. We believe that the decades-long hiatus in U.S. investment provides an opportunity and an advantage to avoid reliance on a dated recycling infrastructure. As a result, our nation has the opportunity, through new technologies and business models, to determine the best path forward.

An evaluation for light-water reactor recycling in the near-term must consider the increased efficiency in the use of fissile resources, the alteration of waste forms and reductions in overall waste burden, the anticipated need for plutonium/actinides to fuel fast reactors for burning or breeding, and U.S. nonproliferation objectives. Other considerations include establishing a credible U.S. role in an international fuel supply regime, getting our nation back into industrial-scale reprocessing, and demonstrating U.S.

leadership in providing nuclear safety, safeguards and other essential disciplines in the global nuclear renaissance. Integrated analyses of the factors above have not provided sufficient direct evidence to date to support substantial Federal Government investments to deploy existing technology for commercial scale recycling in light-water reactors. It is incumbent upon the Federal Government to establish the policy framework and working with industry ensure that technologies are available for deployment that satisfy that framework, including the non-proliferation and waste management considerations discussed in this paper, while the marketplace will ultimately determine the need for implementation within that framework.

Nonproliferation and Security

Strengthening the nuclear nonproliferation regime in the context of the global expansion of nuclear energy will require a multipronged approach. While the nonproliferation regime and other institutional measures will continue to provide the primary framework to ensure that the growth of nuclear power does not increase proliferation and terrorism risks, there should be a strong emphasis on limiting the spread of enrichment and reprocessing capabilities and enhancing our ability to track, control, and protect nuclear materials.

Three key areas will help to accomplish this focus: an assured fuel cycle service system with incentives for foregoing enrichment and reprocessing capability, improved safeguards technologies and transparency, and "safeguards by design" (i.e., designing safeguards technologies and methodologies into new facilities or systems). These key areas should be tightly integrated with other nuclear fuel cycle R&D and be informed by a risk assessment methodology. This methodology will enhance our ability to understand the benefits and risks of fuel cycle choices in the context of the overall fuel cycle system. These choices include technology options, framework options, and policy options. As an example, formulating international frameworks that support U.S. nonproliferation policy objectives will require understanding the energy goals and objectives of other countries, options for meeting these objectives, and a clear understanding of any specific trade-offs.

COMMITMENT OF THE NATIONAL LABORATORIES

Our nation is facing urgent problems in energy, environment, and national security. Nuclear energy can play a vital role in meeting our future energy needs, reducing our dependence on foreign oil, and protecting our environment. However, a clear national strategy with bipartisan support and strong U.S. leadership is necessary. The national laboratories, working in collaboration with industry, academia, and the international community, are committed to leading and providing the research and technologies required to support the global expansion of nuclear energy.

ADDITIONAL TESTIMONY FROM MARVIN S. FERTEL, PRESIDENT AND CHIEF EXECUTIVE OFFICER, NUCLEAR ENERGY INSTITUTE

June 3, 2010

The Nuclear Energy Institute is the industry's policy organization, whose broad mission is to foster the beneficial use of commercial nuclear technology. NEI has more than 350 corporate members representing 17 countries include every U.S. electric utility that operates a nuclear power plant; international electric utilities; nuclear plant designers; architect and engineering firms; uranium mining and milling companies; nuclear service providers; universities; manufacturers of radiopharmaceuticals; labor unions; and law firms. NEI is responsible for establishing unified nuclear industry policy on technical, regulatory and legislative policy issues affecting the industry.

My testimony will address four areas:

1. nuclear energy industry interest in the Department of Energy's research and development roadmap
2. the DOE R&D roadmap as a guidance document for reactor research
3. how the DOE R&D roadmap will impact used nuclear fuel management and nonproliferation
4. additional elements needed for an effective R&D strategy for commercial nuclear technologies

The U.S. nuclear energy industry's top priority is, and always will be, the safe and reliable operation of our facilities. America's nuclear power plants have sustained exemplary levels of safety and operational performance, and this safe, reliable operation drives public and policymaker confidence in the industry. Nuclear energy has had an electric sector-leading average capacity factor of 90 percent or higher over the last decade. In 2009, the nation's 104 reactors produced nearly 800 billion kilowatt-hours of electricity—enough for about 80 million homes—at production costs lower than coal and natural gas-fired power plants. Nuclear power plants in 31 states generate 72 percent of electricity that comes from carbon-free sources.

Why Is NEI Interested in the Nuclear Energy R&D Roadmap?

NEI appreciates this committee's recognition of the strategic importance of increased Federal funding for nuclear energy research and development. Increases in nuclear energy R&D investment will be necessary in the years ahead to help create a sustainable, reliable and low-carbon electric supply infrastructure. Unfortunately, recent trends are in the opposite direction. In a 2007 analysis, the Government Accountability Office found that DOE's budget authority for renewable, fossil and nuclear energy R&D declined by more than 85 percent (in inflation-adjusted terms) between 1978 and 2005. Over that period, the need for new technologies to address critical energy needs has not diminished; rather, it has increased with the advent of climate change concerns.

A robust research and development program is necessary if nuclear energy is to realize its full potential in the nation's low-carbon energy portfolio. In 2008, directors of the 10 DOE national laboratories, including now-Secretary of Energy Steven Chu, published a report recognizing that "nuclear energy must play a significant and growing role in our nation's . . . energy portfolio . . . in the context of broader global energy, environmental, and security issues. The national laboratories, working in collaboration with industry, academia and the international community, are committed to leading and providing the research and technologies required to support the global expansion of nuclear energy."

The national laboratory directors pointed out that the U.S. leadership position in the global nuclear enterprise is at stake. Participation in the development of advanced nuclear energy technologies will allow the United States to influence energy technology choices around the world. This participation also could help assure that objective and viable nonproliferation controls are in place as other countries develop commercial nuclear capabilities. Therefore, technical leadership and increased R&D funding should be a strategic and economic imperative of the administration, Congress and the industry.

The 2008 report identified areas of research that have been incorporated into a comprehensive strategy for nuclear energy R&D developed by the Electric Power Research Institute and the Idaho National Laboratory. NEI supports the R&D priorities listed in that strategy:

- Maintaining the high performance of existing light water reactors and extending potential operation of these facilities from 60 years to 80 years. Research and development programs are needed to develop improved advanced diagnostic and maintenance techniques, extend component life, introduce new technologies, and enhance uranium fuel reliability and performance.

- Significantly expand the number of light water reactors, including small reactor designs. Building new U.S.-designed reactors internationally will provide global leadership in safe nuclear plant operation while meeting stringent nonproliferation objectives.
- Developing fast reactor designs and more proliferation-resistant reprocessing technologies will enable a higher percentage of the uranium fuel to be used before reprocessing or disposal. Reprocessing also could reduce the volume and toxicity of the uranium fuel byproduct that requires safe permanent disposal in a geologic repository.
- Developing high-temperature reactors for electricity generation and use in other applications, such as a heat source for industrial processes. High-temperature reactors can reduce greenhouse gas emissions from large-scale process heat operations in the petroleum and chemical industries. This technology could economically produce hydrogen for fuel-cells and other industrial applications.

In February, NEI convened the 7th Nuclear Energy R&D Summit, bringing together industry, academia and DOE national laboratory officials to discuss the industry's R&D portfolio. Nearly 400 participants developed a statement of principles (attached), which recommends seven focus areas for nuclear energy R&D:

1. Maintain a consistent long-term plan for nuclear energy programs, including an integrated R&D strategy that supports basic research that is goal-oriented.
2. Select a limited number of cost-shared projects for development of reactor and fuel management technologies.
3. Support development of reactor technologies that qualify for DOE's Loan Guarantee Program.
4. Encourage the restoration and expansion of the domestic manufacturing supply chain to build new nuclear facilities.
5. Research, demonstrate and deploy technology innovations for continued safe operation of current reactors.
6. Support work force education and training through congressional appropriations for university programs, investment in the industry-endorsed uniform curriculum at community colleges and tax credits for worker training.
7. Fund the development of reactors to ensure a domestic supply of medical and industrial isotopes.

NEI believes the DOE R&D roadmap can bring these recommendations to fruition as it engages industry in implementation of the objectives outlined in the document.

NEI's Impression of the Nuclear Energy R&D Roadmap

Overall, the roadmap makes a strong case for a continued robust DOE nuclear energy program to help meet the nation's energy and environmental goals. Existing and new nuclear plants will help the United States meet its future electricity demand and climate change objectives. Various independent assessments of how to reduce electric sector CO_2 emissions—including those by the International Energy Agency, McKinsey and Company, National Academy of Sciences, Cambridge Energy Research Associates, Pacific Northwest National Laboratory, the Energy Information Administration and the Environmental Protection Agency—show that there is no single technology that can slow and reverse increases in CO_2 emissions. A portfolio of technologies and approaches will be required, and that portfolio must include more nuclear energy as well as an aggressive pursuit of energy efficiency and expansion of renewable energy, advanced coal-based technologies, plug-in hybrid electric vehicles and distributed energy resources. Removing any technology from the portfolio places untenable pressure on those options that remain.

NEI estimates that approximately 28,000 megawatts of new nuclear energy capacity (22 new reactors) must be built by 2030 to maintain nuclear energy's 20 percent share of the U.S. electricity supply. To increase nuclear energy's contribution to achieve greenhouse gas reduction goals, the amount of new nuclear energy capacity must be substantially higher. EPRI's PRISM analysis, a study of potential low-carbon emission energy deployment over the next 20 years, shows that to provide a high degree of confidence that America's long-term climate change goals can be achieved, 45 new reactors must be operational by 2030, with others under construction or in the licensing process.

The DOE roadmap achieves this goal by creating a sustained program for license extension for current reactors to 80 years and enabling new standardized reactor designs to be licensed and built more efficiently. Any program that is developed under the auspices of the roadmap must adhere to the DOE's principle described on page 16 of the roadmap: "In laying out the activities in each of the R&D objectives described below, we must remain goal-oriented to avoid falling into the trap of doing a great deal of work that, while interesting, fails to address the challenges to the deployment of nuclear energy."

NEI supports the proposed Light Water Reactor Sustainability program and the Nuclear Energy Modeling and Simulation Hub. Both programs will contribute significantly to maintaining safe operation of existing reactors and improving the efficiency of new reactor development. The modeling and simulation hub also will help to reduce the time to market for innovative reactor designs. The industry supports an expedited program plan over what DOE includes in the key activities table on page 21 of the roadmap. The industry also encourages DOE to continue its efforts to bring advanced light water reactors and small modular reactors to the market place in an expedited manner.

NEI strongly encourages DOE to continue the funding of advanced fuel cycle programs that will improve uranium fuel resource use, maximize generation, reduce the volume of used fuel that has to be disposed of in a deep geologic repository and limit proliferation risk.

Domestic facilities are expanding the capacity for uranium fuel supply. This week, LES opened the first U.S. centrifuge uranium enrichment plant in Lea County, New Mexico. The plant is currently awaiting final NRC approval to commence commercial operations, which is expected shortly. At full capacity, the facility can produce enriched uranium for nuclear fuel to provide as much as ten percent of America's electricity needs. Last month, the Energy Department offered a $2 billion conditional loan guarantee commitment to AREVA for its planned uranium enrichment facility in Idaho. The project will use advanced centrifuge technology and could create as many as 4,800 direct and indirect jobs. USEC and the Department of Energy announced an agreement in March to provide $45 million in funding to USEC to fund ongoing American Centrifuge enrichment technology demonstration and manufacturing activities. USEC will match the DOE funding on a 50-50 cost-share basis. Other companies also are investigating advanced facilities for uranium enrichment, including GE Hitachi Nuclear Energy, which is developing the Global Laser Enrichment. This is a new method for enriching uranium that could benefit from DOE support.

How the R&D Roadmap Will Impact Waste Management and Nonproliferation Programs

Used nuclear fuel is managed safely and securely at nuclear plant sites and can be done so for an extended period of time. Used nuclear fuel does not represent an impediment to new reactor development in the near term. It is, however, an issue that must be addressed for the long term.

The nuclear industry's position on used fuel management is clear:

- The Nuclear Waste Policy Act establishes an unequivocal Federal legal obligation to manage used nuclear fuel. Until that law is changed, the nuclear industry believes the NRC's review of the Yucca Mountain repository license application should continue.
- A credible and effective program to manage used nuclear fuel must include three integrated components: storage of used nuclear fuel at nuclear plant sites and at centralized locations; technology development necessary to demonstrate the technical and business case for advanced fuel treatment, including recycling; and, ultimately, operation of a permanent disposal facility.

DOE's activities in Objective 3 of the roadmap are limited to fuel cycle research until the Blue Ribbon Commission on America's Nuclear Future reports its findings to the secretary of energy. NEI supports the inclusion of a modified open fuel cycle to determine if there is an opportunity for new waste forms that could reduce the costs of a national repository program. Here too, the DOE principle stated on page 16 of the roadmap is relevant: "In laying out the activities in each of the R&D objectives described below, we must remain goal-oriented to avoid falling into the trap of doing a great deal of work that, while interesting, fails to address the challenges to the deployment of nuclear energy." Any program that expends taxpayer funds to pursue research must be directly linked to an R&D goal.

Nonproliferation issues impact the commercial nuclear industry worldwide. The U.S. industry works closely with Federal, state and local governments to ensure safe operation and security at commercial reactors and fuel facilities. In addition, the nuclear industry complies with current export control laws and protocols. NEI recently hosted a Nuclear Security Conference that brought together more than 200 industry leaders from 29 countries to discuss the appropriate role for industry in securing nuclear materials. Subsequently, the industry formed a task force of industry executives to develop recommendations for taking additional steps in securing nuclear materials used in commercial nuclear applications. As the DOE Office of Nuclear Energy works to minimize the risk of nuclear proliferation, the industry looks forward to continued constructive engagement in this area.

NEI supports the inclusion of $3 million for international nuclear energy cooperation in the FY 2011 budget that will allow DOE's Office of Nuclear Energy to participate more fully in discussions and negotiations on a range of international nuclear energy concerns. The Institute encourages DOE to engage with the nuclear energy industry as it pursues international nuclear energy cooperation to leverage these interactions and support the export of U.S. products and services.

What Are the Missing Elements of an Effective R&D Strategy for Nuclear Technologies?

Supply Chain

The domestic commercial nuclear manufacturing industry has immense prospects for growth and job creation, yet R&D on manufacturing is essential to achieve the objective of supplying components for new and existing U.S. nuclear plants. Failure to conduct targeted R&D in this area may inhibit American workers from fully realizing the benefits of global growth in commercial nuclear energy, estimated to be in excess of $1.6 trillion over the next 20 years.

Research and development for nuclear manufacturing falls into three categories: fabrication technology; education and training; and codes and standards. An integrated approach that focuses on each of these areas will enable the industry to better leverage development in these areas and more effectively meet the industry's objective—supplying new nuclear projects from domestic manufacturers.

The industry, with the help of organizations such as the Nuclear Fabrication Consortium, has started to focus on education and training as well as the development of new or updated codes and standards for manufacturing and materials. A specific R&D focus on fabrication technologies would dramatically expand the North American manufacturing base for nuclear energy components. A targeted emphasis on high-cost, high-benefit manufacturing should be in the area of technology investment. Areas of immediate need and opportunity include:

- *Real-time Quality Monitoring and Control*. This would enable manufacturers to find fabrication-related defects in the manufacturing process sooner or eliminate them altogether. The technology would offer the unique benefit of being deployable across virtually all fabricated component systems and being incorporated directly into the fabrication equipment (machining centers, inspection systems and welding equipment). When standardized, these improved processes, practices and technologies would enable a more rapid use throughout the American fabrication industry.
- *Thick Section Welding Technology*. Many nuclear facility components are large and have heavy section thicknesses. Even when forgings are used, numerous thick section welds are required. By further developing and validating technologies that other industries are using (such as laser welding, Laser-Gas Metal Arc Hybrid Welding, Tandem Gas Metal Arc Welding, and inertia-based welding processes), production costs could be reduced while improving quality and lowering the residual welding stress.
- *Machining Technology*. Apart from advances in computer-aided machinery, machining techniques and equipment have remained relatively unchanged for the last half century. The development of new technologies, such as enhanced ultrasonic machining, will enable substantial increases in productivity while maintaining product and machine tool quality.
- *Forming*. Improved forming technologies, beyond those associated with ultra-large forgings, could have a dramatic impact on the nuclear manufacturing industry. Improved techniques and technologies could reduce or eliminate welds; produce formed components that have an initial geometry that could be machined to a final design instead of welding multiple pieces together; and

enable multi-material components and systems to be formed together as a unit rather than formed individually, then combined.

- *Materials Development*. The nuclear industry uses a cadre of specialized materials ranging from polymers to high-alloy metallics. Much of what is known about these materials is the result of research to maintain safety at existing reactors. The development of new materials or assessment of materials being used in other industries, along with the associated manufacturing techniques, could reduce manufacturing and component costs while improving reliability and component life-cycle estimates.

Isotope Production

Nuclear medicine offers procedures that are essential in many medical specialties, from pediatrics to cardiology to psychiatry. New and innovative nuclear medicine treatments that target and pinpoint molecular levels within the body are revolutionizing our understanding of, and approach to, a range of diseases and conditions. However, the domestic supply of medical isotopes has virtually disappeared. Leading companies that provide products for medical diagnostic and therapeutic applications obtain supplies from Canada and other nations. This year, supplies of essential medical isotopes and equipment from Canada and Europe were interrupted, leading to disruption of critical health services for patients. Despite warnings from industry and the medical community, DOE has not supported U.S. reactor development in time to forestall this shortage. Similarly, the DOE laboratory facilities providing isotopes for industrial purposes cut production, without warning, for Californium-252, which is a key element in starting new reactors. Prompt government action is required to develop U.S. reactors for the production of medical isotopes.

The fact that there is no mention of isotope production in the roadmap indicates that the government continues to ignore this vital part of the nation's health care infrastructure. NEI supports continued funding of isotope production reactors by NNSA but believes that the Office of Nuclear Energy is responsible for establishing a roadmap objective ensuring the availability of isotopes for nuclear medicine. Equally, the Office of Nuclear Energy roadmap is incomplete without objectives for uranium supply and enrichment.

Work Force

A highly educated and well-qualified work force is a critical element in the development of nuclear technologies. The nuclear industry commends DOE's Office of Nuclear Energy for its longstanding commitment to nuclear work force development for both the government and commercial sectors. This commitment, in conjunction with the support of other Federal agencies, has resulted in growing enrollments in nuclear engineering programs and the development of nuclear technician programs.

Based upon this success, NEI encourages the continued support of universities to carry out R&D. These programs support the R&D objectives of the Energy Department and provide support for the development of future nuclear scientists and engineers as they pursue advanced degrees. Further, NEI encourages the continued support of the integrated university program and additional funding of community college and other programs that will support the development and training of technicians and skilled craft, the most critical area in regard to work force development for the commercial nuclear industry. Finally, NEI encourages greater coordination of existing DOE energy education and workforce development programs through initiatives such as Re-Energyse.

Attachment: Statement of Principles offered by the NEI Nuclear Energy R&D Summit

NEI NUCLEAR ENERGY R&D SUMMIT

Statement of Principles on Nuclear Energy Research & Development

Participants at the 2010 Nuclear Energy R&D Summit developed the following principles to guide policymakers on decisions regarding resources to support the continued safe and reliable operation of the existing fleet of 104 nuclear plants, deployment of new reactors and commercial nuclear technologies and progress toward an economically viable closed fuel cycle.

We believe:

1. The federal government needs to maintain a consistent long-term plan for nuclear energy programs, including an integrated R&D funding strategy that supports basic research at the same time as development and deployment. Such a strategy includes support from Administration officials to engage the public on the benefits of nuclear technology through partnerships with state/local public officials, professional societies and associations.

2. DOE nuclear energy R&D programs must establish competitive processes that incent the commercial sector to co-select and co-fund a limited number of reactor technologies for financial cost-share assistance. This will enable DOE to allocate program dollars in research and advanced technology of value to the country.

3. The private sector and DOE should establish requirements for cost-sharing with the federal government, especially for high-risk, long lead-time projects using innovative technologies. While the overall goal of such an agreement may be to maintain a 50/50 cost share over the lifetime of the project, advanced nuclear technologies may require a higher government share in initial years and then phase in a higher industry share in later years. The agreement should explain not only the cost to the taxpayer but also detail the benefits accrued through the partnership in job creation, energy security and educational opportunities.

4. DOE should continue its support for deployment of nuclear technologies that meet the qualifications of the Title 17 Innovative Technology Loan Guarantee Program and seek support other federal agencies to encourage the restoration of a U.S. domestic manufacturing supply chain to build new nuclear plants.

5. Federal government support for sustaining the existing fleet of nuclear plants must include programs to research, demonstrate and deploy technology innovations for continued safe operation.

6. DOE support for work force education and training is critical to ensuring a competent cadre of commercial and government worker force in the decades ahead. It includes the following elements: fully-funded integrated university programs, with appropriations to DOE NE, DOE NNSA and NRC; substantial stewardship of university reactors, without which the nuclear engineering discipline suffers; investment in the Nuclear Uniform Curriculum Program at community colleges; and funds to improve craft training and apprentice programs with labor and support for a worker training tax credit to enable employers to hire and then train new employees for specific skilled jobs at plant sites and manufacturing facilities.

7. Supply chain problems have adversely affected the distribution of isotopes for nuclear medicine diagnosis and therapy. Therefore, passage of legislation to fund the development of reactors to ensure a domestic supply of medical isotopes is needed in the 111th Congress.

ADDITIONAL TESTIMONY FROM PAUL LORENZINI, CHIEF EXECUTIVE OFFICER, NUSCALE POWER

NuScale Power

Paul Lorenzini
Chief Executive Officer

June 1, 2010

The Honorable Bart Gordon
Chairman, Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

The Honorable Ralph Hall
Ranking Member, Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

RE: Written Testimony for the Record – May 19, 2010 Hearing on "Charting the Course For American Nuclear Technology"

NuScale Power appreciates the opportunity to submit its views on questions that have been raised with regard to the future of nuclear power in this country. Incorporated in 2007 with private venture capital funding, NuScale Power in many ways exemplifies the evolution of the nuclear power industry, which is the topic of your hearing. NuScale Power's modular, scalable reactor design is receiving accolades from government and industry for its safety, economics and market-readiness.

I would like to focus our comments on the following questions: Why are small, modular reactors important for the future of the nuclear industry, and more broadly, national energy policies? What is the proper federal role in their market deployment? How can the federal government assist market penetration of new technology and leverage market competition at the same time?

As Secretary of Energy Dr. Stephen Chu acknowledged in his confirmation hearings, nuclear power provides over 70% of the nation's carbon free electricity and it is baseload. Any serious, sustainable climate change policy must not only include expanded uses of nuclear power, it must seek ways to assure its uses are maximized so as to reach its full market potential. Small, modular nuclear reactors, specifically light-water pressurized technology which can be market ready by 2018 – 2020, achieve that goal. They reach markets that current large nuclear plants do not reach and will provide utilities with another tool for meeting growing energy demands in a carbon constrained economy. NuScale's passively safe 45 MWe power module is based on current light water technology; can be made entirely in the U.S. using our existing domestic manufacturing base; is transported by rail, truck or barge to the reactor site; can be scaled to 540 MWe power plant; and provides an approach to deploying nuclear power that minimizes the financial constraints associated with larger plants.

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The federal government can play a critically important role in helping the potential for small, modular reactors become a reality. The principal barriers to the full deployment of small light water reactors such as NuScale are not related to technology development; they are associated with first of a kind risks and costs. The costs of preparing a license application for design certification, the costs of NRC fees during the certification process, and the costs associated with customer preparation, approval and payment of NRC fees for Early Site Permits and Construction and Operating License Applications pose the most significant constraints to the expansion of this market. First costs will necessarily be greater than "nth of a kind" costs and customers making the investment in first plants need help in overcoming these front-end financial barriers to fully assure the early expansion of this market.

While Federal support in these areas is needed, NuScale does not believe that a federally-funded "demonstration" facility for light-water reactor based SMR technology is necessary. The implication of building a "demonstration plant" is that technologies are new and require confirmation in a first plan before the technology can be licensed and introduced to the market. For advanced SMR technologies that involve new technologies, generally relying on coolants more exotic than light water, this may be appropriate. However, for light water-cooled SMR technologies, such a program is not required and will likely slow the introduction of these plants into the commercial market.

When GEN III nuclear plants such as the Westinghouse AP-1000 were deployed, what was required was an integral test facility sufficient to provide the R&D data necessary to support licensing. As long as the necessary experimental data from such a facility can provide the information to satisfy regulatory requirements, a "prototype" or "demonstration plant" is not needed. A test facility was built at Oregon State University and it was on this foundation that NRC certification of both the AP600 and AP1000 was accomplished. No one expected or required a "demonstration plant" because the underlying technology was well-established. NuScale Power similarly relies on proven underlying technologies and intends to follow an identical approach, utilizing its own integral test facility, also built and operated by Oregon State University, to support licensing and certification of its plant design. Given the large body of R&D for light water reactor technologies, and the existing licensing framework that now exists within the NRC, NuScale does not believe a taxpayer-funded demonstration plant is necessary to further this technology.

Indeed, it is our view that a "demonstration plant" approach could actually impede the market. In essence, this approach would signal that the technology is not ready for commercial deployment, a position we would strongly challenge. As a result, potential customers – and potential manufacturers – would likely withhold decisions to commit to SMR light water technologies until the "demonstration plant" is built and operating. The long-term timeline for full deployment would thus be unnecessarily delayed for years.

What is appropriate and needed is federal assistance to minimize the barriers to entry; specifically, the substantial costs associated with first of kind applications for both the design certification and construction and operating licensing at the NRC. Encouragement also could be provided to first customers in more directed and specific ways, none of which need to carry the costs or policy implications of a "demonstration plant" while still assisting them with first of a kind costs. This is an area where the federal government can continue the key role it has played in the past.

Apart from these concerns, the federal government should continue its critical role in funding research and development for more advanced fuel types, reactor designs and process applications that at this junction show technical merit but are further from commercialization.

President Obama's proposed budget for FY2011 includes $38.8 million for a small, modular reactor program, a portion of which would be used to undertake a competitive selection of two light-water reactor designs that would be eligible for a 50/50 sharing of costs associated with submission of a design certification document to the NRC. To leverage the full benefit of private sector competition, the cost-sharing program should not have arbitrary conditions placed on the use of funds, like limiting expenses to NRC fees only. Instead, they should be applicable to all costs associated with submission of a DCD throughout the licensing process. The selection criteria should be based on maturity of the design and readiness to meet the rigors of the NRC licensing process, among other factors.

On behalf of NuScale Power, our investors and our business partners, I want to thank you and the Committee for your interest in small, modular reactors and their future role in the industry.

Sincerely,

Paul G. Lorenzini
Chief Executive Officer
NuScale Power

ADDITIONAL TESTIMONY FROM DR. TRAVIS W. KNIGHT, ASSISTANT PROFESSOR AND DIRECTOR, NUCLEAR ENGINEERING PROGRAM, UNIVERSITY OF SOUTH CAROLINA, SUBMITTED BY REPRESENTATIVE BOB INGLIS

Statement by Representative Bob Inglis on Dr. Travis W. Knight and Testimony

I am pleased to be able to offer the Committee additional testimony by Dr. Travis W. Knight of the University of South Carolina. Dr. Knight received his training in nuclear engineering at the University of Florida, and joined USC on the faculty of the Nuclear Engineering Program in the Mechanical Engineering Department in the fall of 2004. He is currently serving as the Acting Director of the program, and recently added a new research laboratory for the study of advanced nuclear fuels. He has more than ten years of experience in the research field, and focuses on advanced fuels, fuel cycle analysis, and nuclear safeguards.

Dr. Knight is a young and promising professor, offering promise of a successful nuclear renaissance in the United States lead by homegrown talent and intellect. He is a great asset to USC and to the State, and Dr. Knight is one of the reasons I believe that the road to energy independence runs through South Carolina.

I would like to offer his written testimony for the record and encourage the Committee to rely on Dr. Knight's expertise into the future.

Comments on DOE Nuclear Energy Research and Development Roadmap

Travis W. Knight

26 May 2010

I should begin by saying that I applaud the DOE in its effort to layout a roadmap for the development of advances in nuclear energy. I believe it very carefully outlines the range of technological concerns and areas for development. It should prove important in giving direction to academia and industry for making investments in personnel and infrastructure to be able to be responsive and partner with DOE. This partnership should advance the technology to make our nation more secure both economically and strategically and at the same time protect our environment and promote the health and welfare of our people by reducing pollution and GHG.

However, no plan is perfect. So I should focus my comments on areas where I observe a need/gap exists to advance the aforementioned goals and enable nuclear power to play a larger role.

My chief concern is over what may be a sense of timidity for pursuing larger demonstration facilities to advance the technology as evidenced in the language that is repeated several times in the roadmap:

> "Although some smaller component or process "demonstration" activities are mentioned, these are largely field tests and other actions to provide proof or validation of system elements. They are not costly, large-scale demonstrations like NGNP [Next Generation Nuclear Plant]. Any consideration to embark on such large-scale demonstrations will be the result of decision-making and budget development processes."

My concern is that this could represent a belief that government has limited or no role in advanced demonstration facilities. I submit that public investment and government leadership is needed to recapture the U.S. position in this critical technology area that impacts both our energy and national security. The truth is that there is a dearth of infrastructure and advanced demonstration facilities to support the advances needed. In particular, the U.S. has

- no fast reactor to study the destruction of high-level waste,
- no high temperature reactor to study the production of other energy products such as synthetic fuels or hydrogen to reduce our dependence on foreign energy sources and cut GHG emissions,
- and no recycling plant to address the long-term sustainability of nuclear power and waste minimization.

This is true while such facilities exist at either the demonstration or commercial scale in places like China, India, Russia, France, Japan, etc.

We should not down play the significance of larger demonstration facilities to provide the critical understanding of the problems that can exist in larger facilities and issues that arise in bringing to commercialization technologies developed earlier at the laboratory scale. Additionally, some demonstration facilities provide useful research tools in and of themselves such as a fast reactor which is necessary to study the transmutation (destruction) of high-level waste. In other instances, government leadership and investment may be needed to allay concerns over stability of regulation and national policy. This is perhaps best evidenced in the history of reprocessing/recycling where changes in U.S. policy in the 1970s led to the abandonment of commercial facilities constructed for this purpose and worth several hundred million dollars. These changes in policy did not achieve their purpose of encouraging other nations to not pursue recycling but did result in the loss of U.S. leadership in this technology. By originally abandoning this technology earlier, we are now licensing a more advanced form developed in subsequent years by the French for our recycling of excess nuclear warheads, which I may add is a very worthwhile and important effort.

Without a doubt, there is great need to conduct research at a laboratory scale to develop the most advanced and robust technologies. However, resisting the need to develop demonstration facilities threatens significant delay in implementing these advanced technologies due to the practical knowledge gained in operating a production facility and understanding the issues involved in scale up. Timeliness is further complicated by the long lead times involved in designing and constructing such facilities where none exist today. If the urgency is real to address GHG emissions for climate change and reduce dependence on fossil fuels, then time is of a greater issue. Only by building the necessary pilot or demonstration facilities in the next decade can we reliably progress down a path of larger implementation to meet our needs on a commercial scale. Only follow on commercial-scale implementation can truly provide the impact to the larger economy and provide the necessary energy security and independence.

Still, these first steps are not only necessary to provide incentive and assurance to the commercial sector to pursue investments but these larger efforts are also needed to provide assurance to educational institutions to invest in new hires, new programs, and new curricula and to provide assurances to students that jobs will exist in these areas upon graduation. Here I can relate my own experience as a student. In 1994, I was in route to a summer internship at what is now part of the Idaho National Laboratory when the order came down to cancel the EBR–II reactor. When I arrived after driving for four days and having leased an apartment, I was told that I could turn around and go home or I could stay and work on the paperwork to close out the Fuel Cycle Facility. I decided to stay and now I can say that I am glad that I did. Our nation faces a shortage of scientists and engineers and the situation will only get worse as the current generation that developed this technology moves to retirement. We cannot expect to inspire and educate a new generation of engineers and scientists without an accelerated investment in infrastructure and partnering with industry to ramp up the development of advanced technologies to meet targets in waste reduction, GHG reductions, and sustainability.

In my humble opinion, the U.S. should aggressively pursue the NGNP project to demonstrate the planned improvements in the high temperature reactor technology. The DOE should implement the major components of the DOE Global Nuclear Energy Partnership including the Consolidated Fuel Treatment Center (CFTC) based on the most advanced, proven technology for the recycling of used nuclear fuel. The Advanced Recycling Reactor (ARR) should be constructed to demonstrate the closed fuel cycle through the recycle of used fuel and to ensure the long-term sustainability of nuclear power and our nation's energy security. Here research should be focused on ways to make these fast reactors cost competitive with current technology to enable their larger implementation in coming decades.

The construction of these larger, demonstration facilities carries the added stimulus of many good jobs at all levels from skilled craft to the most advanced research positions. By proving the advances in technology through these demonstration facilities, a lasting stimulus is provided leading to the commercialization and deployment on a large enough scale for sustainable, secure energy production.

All of these investments should not come at the expense of current and planned efforts to provide loan guarantees to commercial entities for the construction of new light-water reactor (LWR) plants and fuel cycle facilities. These guarantees are needed to jump start the U.S. industry to prevent even longer delays in starting construction. Indeed, the currently proposed new reactors are only sufficient for the U.S. to maintain the current nuclear power contribution of about 20% to our electricity generation. If we are to make serious cuts in GHG emissions and contribute to energy independence through the use of nuclear electricity in the transportation sector (i.e. plug-in hybrids), we must do all we can to encourage even larger numbers of new plants.

So in summary, the benefits one should derive from investments in larger scale research and demonstration facilities should be:

- The recapture U.S. leadership in this critical area,

- Training and education of a new generation of engineers and scientists,
- Lay the foundation in R&D for commercialization of technologies that will provide energy security/independence, environmental stewardship, and sustainability,
- Provide a lasting stimulus in well paying jobs at all levels from skilled craft to advanced research positions.

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