ASSESSING THE GOALS, SCHEDULE, AND COSTS OF THE GLOBAL NUCLEAR ENERGY PARTNERSHIP

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

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ASSESSING THE GOALS, SCHEDULE, AND COSTS OF THE GLOBAL NUCLEAR ENERGY PARTNERSHIP

THURSDAY, APRIL 6, 2006

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Judy L. Biggert [Chairwoman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Assessing the Goals, Schedule and Costs of the Global Nuclear Energy Partnership

Thursday, April 6, 2006

10:00 AM – 12:00 PM
2318 Rayburn House Office Building

Witness List

Mr. Shane Johnson
Deputy Director for Technology, Office of Nuclear Energy Science and Technology, Department of Energy

Dr. Neil Todreas
Kepco Professor of Nuclear Engineering and Professor of Mechanical Engineering, Massachusetts Institute of Technology

Dr. Richard Garwin
IBM Fellow Emeritus, Thomas J. Watson Research Center, Yorktown Heights, NY

Mr. David Modeen
Vice President, Nuclear Power and Chief Nuclear Officer, Electric Power Research Institute

HEARING CHARTER

SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Assessing the Goals, Schedule, and Costs of the Global Nuclear Energy Partnership

THURSDAY, APRIL 6, 2006
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, April 6, 2006, the Energy Subcommittee of the House Committee on Science will hold a hearing to examine the goals, schedules and costs of the advanced fuel cycle technologies research and development (R&D) program in the Administration's Global Nuclear Energy Partnership (GNEP) proposal.

2. Witnesses

Mr. Shane Johnson, Deputy Director for Technology, Office of Nuclear Energy Science and Technology, Department of Energy

Dr. Neil Todreas, Kepco Professor of Nuclear Engineering and Professor of Mechanical Engineering, Massachusetts Institute of Technology

Dr. Richard Garwin, IBM Fellow Emeritus, Thomas J. Watson Research Center, Yorktown Heights, NY

Mr. David Modeen, Vice President, Nuclear Power and Chief Nuclear Officer, Electric Power Research Institute

3. Overarching Questions

- Is the R&D program envisioned by GNEP likely to be an effective approach to get us to an advanced nuclear fuel cycle that minimizes waste and ensures the long-term sustainability of nuclear power?
- Are the proposed timelines for technology demonstration and deployment realistic? Do we know enough to build three major demonstration facilities in the next ten years?
- What are the cost estimates for GNEP and are they realistic?
- If GNEP were successful, how would the domestic nuclear energy landscape change?

4. Brief Overview

- Nuclear reactors generate about 20 percent of the electricity used in the U.S. No new nuclear plants have been ordered in the U.S. since 1973, but there is renewed interest in nuclear energy both because it could reduce U.S. dependence on foreign oil and because it produces no greenhouse gas emissions.
- One of the barriers to increased use of nuclear energy is concern about nuclear waste. Every nuclear power reactor produces approximately 20 tons of highly radioactive nuclear waste every year. Today, that waste is stored onsite at the nuclear reactors in water-filled cooling pools or, at some sites, after sufficient cooling, in dry casks above ground. About 50,000 metric tons of commercial spent fuel is being stored at 73 sites in 33 states. A recent report issued by the National Academy of Sciences concluded that this stored waste could be vulnerable to terrorist attacks.
- Under the current plan for long-term disposal of nuclear waste, the waste from around the country would be moved to a permanent repository at Yucca Mountain in Nevada, which is now scheduled to open around 2012. The Yucca

Mountain facility continues to be a subject of controversy. But even if it opened and functioned as planned, it would have only enough space to store the nuclear waste the U.S. is expected to generate by about 2010.

- Consequently, there is growing interest in finding ways to reduce the quantity of nuclear waste. A number of other nations, most notably France and Japan, "reprocess" their nuclear waste. Reprocessing involves separating out the various components of nuclear waste so that a portion of the waste can be recycled and used again as nuclear fuel (instead of disposing of all of it). In addition to reducing the quantity of high-level nuclear waste, reprocessing makes it possible to use nuclear fuel more efficiently. With reprocessing, the same amount of nuclear fuel can generate more electricity because some components of it can be used as fuel more than once.
- Experts on nuclear energy have suggested that if the United States is to expand the use of nuclear power, it will have to develop an advanced fuel cycle that involves reprocessing spent fuel and "transmutation" of some of the most radioactive waste components in special reactors called "burner" or "fast"[1] reactors that change, or "transmute," some of the most radioactive elements into less radioactive elements.
- During last year's appropriations process, the House Appropriations Subcommittee on Energy and Water expressed the view,[2,3] that DOE must accelerate the development and demonstration of reprocessing technology to enable the development and deployment of an advanced fuel cycle for nuclear power reactors in the U.S.
- On February 6, the Administration announced the Global Nuclear Energy Partnership as part of its fiscal year 2007 (FY07) budget request. According to the Administration, the vision for GNEP is to provide for the safe and extensive expansion of nuclear power worldwide, while addressing nuclear weapons proliferation and waste management concerns. GNEP has two main components:
    1. the development of a domestic advanced nuclear fuel cycle that includes reprocessing and "transmutation" of the most highly radioactive waste components into less radioactive elements; and
    2. the establishment of an international framework for the selling and leasing of nuclear fuel and reactor technologies.
- The component of GNEP that is the subject of this hearing, the development of an advanced nuclear fuel cycle for use by the domestic commercial nuclear power industry, has the potential to significantly reduce both the volume and the radioactivity of nuclear waste produced by commercial power reactors. Successful deployment of an advanced fuel cycle could reduce nuclear waste from electricity generation to the extent that the Yucca Mountain geological waste repository would be sufficient to store most, if not all, of the waste expected to be produced by commercial power reactors during the next 100 years. Without an advanced fuel cycle, continued use of nuclear power would require the construction and licensing of several more geological waste repositories like Yucca Mountain.

[1] "burner" refers to the fact that these reactors consume (or "burn") highly radioactive spent fuel components and "fast" refers to the fact that these reactors involve high temperature (and, therefore, fast moving) neutrons. Fast neutrons can produce nuclear reactions that change, or "transmute," some highly radioactive elements into less radioactive elements.

[2] The report accompanying H.R. 2419, the *Energy and Water Development Appropriations Act for Fiscal Year 2006,* which the House passed in May 2005, directed DOE to focus research in its Advanced Fuel Cycle Initiative program on improving nuclear reprocessing technologies. The report went on to state, "The Department shall accelerate this research in order to make a specific technology recommendation, not later than the end of fiscal year 2007, to the President and Congress on a particular reprocessing technology that should be implemented in the United States. In addition, the Department shall prepare an integrated spent fuel recycling plan for implementation beginning in fiscal year 2007, including recommendation of an advanced reprocessing technology and a competitive process to select one or more sites to develop integrated spent fuel recycling facilities."

[3] During Floor debate on H.R. 2419, the House defeated an amendment that would have cut funding for research on reprocessing. In arguing for the amendment, its sponsor, Mr. Markey, explicitly raised the risks of weapons proliferation. Specifically, the amendment would have cut funding for reprocessing activities and interim storage programs by $15.5 million and shifted the funds to energy efficiency activities, effectively repudiating the report language. The amendment was defeated by a vote of 110–312.

- Under the GNEP, the Administration is proposing to build and operate three major new advanced fuel cycle technology demonstration facilities within ten years—
  1. a UREX+ nuclear fuel reprocessing facility (UREX+ is an advanced nuclear fuel reprocessing technology that works in the laboratory but that has not yet been tested on a sufficient scale to demonstrate its feasibility);
  2. an Advanced Burner Reactor (ABR), a specialized nuclear reactor (in this case, a sodium-cooled fast reactor) designed to "transmute" highly radioactive nuclear waste components into to less radioactive elements; and
  3. an Advanced Fuel Cycle Facility (AFCF), a specialized R&D and test facility to develop and test reprocessed nuclear fuels produced by the UREX+ process to be used in the ABR.
- Questions remain as to the scale and cost of these facilities (current estimate of construction costs alone is $4 billion over ten years to build all three demonstration facilities), the reasonableness of the proposed timeline, and the fundamental R&D that still must be carried out to make these demonstrations successful.
- In particular, Energy Subcommittee Chairman Judy Biggert, in a conversation with Deputy Secretary of Energy Clay Sell last year, asked DOE to conduct a complete systems analysis the of the anticipated fuel cycle, and the R&D steps necessary to implement it. (A systems analysis involves an integrated analysis and modeling of all the components of a an advanced fuel cycle—commercial power reactors, reprocessing technologies and facilities, Advanced Burner Reactors, and waste disposal technologies and facilities—, how all of the components would interact as a system, and how technology choices related to any one component would affect other elements of the system.) In addition, Section 955 of the *Energy Policy Act of 2005* requires DOE to do a survey of the civilian nuclear infrastructure and facilities in the national laboratory system. Neither of these efforts has been completed.

5. Issues

Do we know enough to build each of these three major demonstration facilities?

Science and engineering related to advanced fuel cycle technologies have not advanced much in the last 30 years because, until quite recently, it has been U.S. policy not to pursue reprocessing of spent nuclear fuel. Consequently, many fundamental questions remain in the areas of chemistry, materials and physics related to fuel recycling (reprocessing and "transmutation") and advanced waste management.

These questions can be addressed, in part, through the development of sophisticated molecular-scale computer models, but all models have to be validated empirically (both in the lab and through engineering scale demonstrations) to be useful. According to some experts, neither the computer models, nor the experiments required to validate them, have been developed to an extent sufficient to address the outstanding science and engineering questions related to advanced fuel cycle technologies. The Basic Energy Sciences (BES) of the DOE Office of Science is planning the second in a series of workshops[4] on the advanced fuel cycle this coming summer. The second workshop will focus specifically on the R&D required to support GNEP. To what extent will or should the results of this workshop influence the timeline for technology demonstrations?

Are the proposed timelines for technology demonstration and deployment realistic?

The proposed timeline calls for all three demonstration facilities—the UREX+ reprocessing facility, the Advanced Burner Reactor (ABR), and the Advanced Fuel Cycle Facility (AFCF)—to be built and operational in approximately the next ten years, at a total estimated construction cost of at least $4 billion. The current budget request for these activities is $250 million, meaning construction costs alone would require the budget to almost double over the next decade. There are also R&D activities that will need to be done to feed into the design and construction activities. In addition, there is another large demonstration elsewhere in the nuclear

[4] In September 2005, the Basic Energy Sciences Office (BES) of the DOE Office of Science hosted a workshop entitled *The Path to Sustainable Nuclear Energy: Basic and Applied Research Opportunities for Advanced Fuel Cycles.* Workshop participants identified several science and engineering challenges that must be overcome in the course of developing advanced fuel cycle technologies.

energy R&D program, the Next Generation Nuclear Plant, that is legally required to be operational by 2021 and is likely to compete for funding.

If resources are constrained, is there a logical way to sequence these activities? If an advanced fuel cycle were in commercial operation, reprocessing would precede fuel fabrication and its use in special reactors ("burner" or "fast" reactors, such as the ABR) that are necessary to recycle the fuel. But experts say that the benefits of the advanced fuel cycle are dependent on the success of the ABR, which, in turn, may first require the construction and operation of the AFCF.

Are the cost estimates for GNEP realistic?

Many of the parameters of the research program and the demonstration facilities have not yet been determined, making current cost estimates unreliable. According to testimony given by Deputy Secretary of Energy Clay Sell before the Senate Appropriations Committee on March 2, the Department "will be looking for a sizeable portion of GNEP costs to be shared by [their] partners and industry starting in FY 2008." How interested is industry in cost-sharing and what level of commitment is DOE counting on?

How does the nuclear industry view GNEP?

Key players in the nuclear future, most notably industry and the Nuclear Regulatory Commission (NRC) were not at the table during the development of GNEP. Some in industry and in Congress are concerned that GNEP will distract from licensing and building new nuclear power plants and the Yucca Mountain repository in the next 5–10 years. The Electric Power Research Institute (EPRI), representing all of the nuclear-owning utilities, issued a draft "Consensus Strategy for U.S. Government and Industry" (Appendix A). In short, EPRI identifies industry priorities and R&D goals that do not seem entirely aligned or complementary to the R&D goals outlined in GNEP.

If GNEP were successful, how would the domestic nuclear energy landscape change?

The U.S. Government heavily subsidized the nuclear industry to get it to where it is today. Utilities building new nuclear power plants over the next several years will also have access to federal subsidies and risk insurance, but they will own, operate and safeguard the plants. There is little disagreement that an advanced fuel cycle will be much more expensive than the once-through fuel cycle currently in use. What happens if industry isn't willing to build, buy or operate any of the technologies of the advanced fuel cycle? Is the public benefit large enough that the government should pay the entire bill?

Workforce needs.

One issue that several experts have brought up is that of the scientific and engineering workforce necessary for the future of nuclear power. The Administration has proposed zeroing its University support program (housed in the Nuclear Energy Office) in FY07, claiming that the goals of the program have been met in terms of the number of undergraduate students enrolled in nuclear engineering programs. There is some disagreement over which numbers are relevant. The number of students graduating from these programs, in addition to the number of masters and doctoral students, has actually declined in recent years. This does not appear to bode well for an expanded domestic nuclear industry.

6. Background

Current U.S. Practice: The open fuel cycle

Current U.S. nuclear technology uses what is called an "open fuel cycle," also known as a "once-through cycle" because the nuclear fuel only goes through the reactor one time before disposal, leaving most of the potential energy content of the fuel unused. In an open cycle, the uranium is mined and processed, enriched,[5] and packaged into fuel rods, which are then loaded into the reactor. In the reactor, some of the uranium atoms in the fuel undergo fission, or splitting, releasing energy in the form of heat, which in turn is used to generate electricity. Once the fission efficiency of the uranium fuel drops below a certain level, the fuel rods are removed from the reactor as spent fuel.

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[5] The enrichment process increases the ratio of the ^{235}U isotope relative to the ^{238}U isotope. Uranium ore contains less than one percent ^{235}U by weight and only ^{235}U is fissionable. Low-enriched uranium for light-water reactors typically contains 3–4 percent ^{235}U.

Spent fuel contains approximately 95 percent uranium by weight.[6] The remaining five percent consists of other radioactive elements, including plutonium, which accounts for one percent of the total spent fuel.[7] The radioactivity of the spent fuel means that it still generates a lot of heat, so after removal, the spent fuel rods are cooled in deep, water-filled pools. After sufficient cooling (typically 3–5 years), the fuel rods may be transferred to dry cask storage pending ultimate disposal at a geologic waste repository such as Yucca Mountain. Often they are just left in the cooling pools while awaiting disposal.

The repository at Yucca Mountain will effectively be full by the year 2010 with the spent fuel from the current fleet of reactors. As the industry looks to extend the operational lifetime of existing nuclear power plants while beginning the process of getting new plants designed and built, current waste management policies and statutes deserve to be reexamined. The options are:

- increase the statutory storage capacity of Yucca Mountain to its technical limit (approximately double the statutory limit);
- build a second repository;
- establish a plan for indefinite above-ground dry storage until another solution is found; or
- develop an advanced fuel cycle that minimizes nuclear waste such that only a single repository will be needed for the next century.

In fact, some suggest that selecting one of these options is a necessary prerequisite to any expansion of the nuclear industry in this country because the public needs to be convinced that the U.S. has a long-term strategy for waste disposal. In addition, by law, the Nuclear Regulatory Commission must make a "waste confidence determination"—that the waste created can be safely disposed of—in order to continue issuing facility licenses. The political hurdle to increasing the statutory capacity of Yucca or building a second repository seems insurmountable for the time being. A National Academy of Sciences panel determined that dry storage is a valid option from a technical and safety standpoint.[8] But the Administration is taking the position that interim storage is insufficient, and that the U.S. must lead the world toward a long-term solution. GNEP would put the U.S. on a path toward developing an advanced fuel cycle.

The advanced fuel cycle as envisioned in GNEP

The advanced fuel cycle requires the same mining, processing and fuel fabrication as the open cycle, at least for the current generation of nuclear reactors. However, in the advanced fuel cycle, the cooled spent fuel is reprocessed, or chemically separated into various combinations of its many components. In this approach, some components of the spent fuel, known as the "transuranics," can be used to fabricate fuel for a "burner" or "fast" reactor, such as the ABR. The transuranics are elements listed after uranium in the period table of the elements. Plutonium is included in this group. In theory, the transuranics could be recycled several times in fast reactors until most of the energy content is converted into electricity and the remaining material is sent to Yucca Mountain. However, there is still a waste stream associated with each of these recycles, and utilization of fast reactors, such as the ABR, as part of an advanced fuel cycle may require the development of additional reprocessing technology. Recycling the transuranics in fast reactors involves a physical process called "transmutation," which, in addition to producing electricity, reduces the radioactivity and associated heat output of the remaining spent fuel. This is significant because the repository at Yucca Mountain is technically limited by the heat content of the stored waste rather than simply the volume. If the United States is able to develop and deploy an advanced fuel cycle for commercial power reactors that includes "transmutation" of highly radioactive waste in fast reactors, such as

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[6] The percentage of ^{235}U in spent fuel is only slightly higher than the naturally occurring level; however, other isotopes of uranium in the spent fuel must be removed before the uranium can be re-enriched into usable fuel.

[7] Four percent of the spent fuel consists of fission products (elements that result from splitting the Uranium—primarily Strontium, Cesium, Iodine, Technetium and elements in a series known as the Lanthanides) and transuranics (elements greater than Uranium that result from the capture of neutrons, including Plutonium, Neptunium, Americium and Curium). The fission products and transuranics have half-lives ranging from a few days to millions of years. The "half-life" of a radioactive substance is the period of time required for one-half of a given quantity of that substance (e.g., plutonium) to decay either to another isotope of the same element, or to another element altogether. The substances with shorter half-lives tend to generate more heat.

[8] *Safety and Security of Commercial Spent Nuclear Fuel Storage,* Board on Radioactive Waste Management, National Academy Press, 2005.

the ABR, it may be possible to store all future commercially-generated nuclear waste in Yucca Mountain.[9,10,11,12] Without an advanced fuel cycle capability, several more geological waste repositories like Yucca Mountain will be required.

Near-term GNEP technology demonstration plans

The Administration is requesting $250 million in the FY07 Nuclear Energy, Science and Technology (NE) budget to accelerate R&D and begin design work on three major advanced fuel cycle demonstration facilities: a UREX+ reprocessing facility, an advanced burner (fast) reactor, and an advanced fuel cycle facility. According to DOE, $155 million of that sum, if appropriated, will go toward design work for an engineering scale demonstration of UREX+. A preliminary timeline calls for all three facilities to be built over the next ten years or so, in anticipation of advanced fuel cycle technology initial deployment in twenty years. Much of the cost of these facilities will depend upon the scale of the facilities and the scope of the R&D. The three facilities combined are currently estimated to cost at least $4 billion just to build.

1. UREX+

UREX+ is based on the PUREX technology originally developed in the U.S. and in use today in other countries as mentioned above. In both processes, spent fuel rods are chopped up and dissolved in an acidic bath before constituent elements are chemically separated. The main differences are: 1) UREX+ does not separate a pure plutonium stream—instead it always leaves plutonium mixed with some combination of other highly radioactive elements and 2) UREX+ is a continuous rather than batch process. These differences mean that UREX+ is more proliferation-resistant than PUREX, and could have significantly less liquid radioactive waste associated with the process. In fact, DOE's conceptual goal is to recycle the liquid solvent in the process multiple times, then purify the liquid before disposal by removing the remaining radioactive elements. If this proves successful at the engineering scale, DOE would be able to mitigate concerns about a repeat of the type of environmental problems experienced at the DOE Hanford site.

Different versions of UREX+ have been demonstrated at the bench scale in batch processes—processing approximately one kilogram of spent fuel per year. DOE officials have been inconsistent in predictions of the scale of the demonstration plant, with scales under discussion ranging from hundreds of kilograms to 200 metric tons. For comparison, an industrial scale reprocessing facility might be on the order of 2,000 metric tons total input capacity per year, approximately the output of the current fleet of light water reactors. Scale-up of chemical processes can involve numer-

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[9] The separated uranium is considered low-level waste and can be stored as such—that is, it does not need to be stored in a geologic repository like Yucca Mountain. While the uranium, which makes up 95 percent of the spent fuel by weight, theoretically can be treated to make it usable reactor fuel again, the technology to do so in practice does not exist and is not considered practical in the near-term.

[10] Under the most likely U.S. reprocessing scenario, some of the most problematic but short-lived radioactive waste could be stored above ground in dry casks for 100 years until it decayed significantly, at which point it could either be moved to Yucca Mountain or perhaps treated further using some other technology. Some of the longer-lived material could go directly to Yucca Mountain following the separations process. Some of the shorter-lived highly radioactive material would be left in with the fuel materials, at least temporarily, to make the fuel materials more difficult to divert for weapons purposes. However, this same "protective" material may have to be separated out before a usable fuel can be fabricated.

[11] One point of controversy regarding Yucca Mountain is whether the radiation standard should be for 10,000 years or more than a million years. According the DOE's calculations, the advanced fuel cycle scenario described above could result in a hundred-fold increase in the technical capacity of the Yucca Mountain repository, as well as a reduction in the radiotoxicity of the repository waste to below the level of natural uranium ore in less than 1,000 years. A radiation level this low would eliminate that particular debate over Yucca Mountain.

[12] Several countries around the world, including Japan, Russia and France, currently reprocess their spent fuel with a process known as PUREX, short for plutonium-uranium extraction, in which plutonium and uranium streams are isolated from the remaining elements in the spent fuel. (PUREX was developed as part of the U.S. weapons program explicitly to make plutonium for nuclear weapons.) In the current commercial application of PUREX, most of the highly radioactive components are cooled and then vitrified, or encased in glass, for long-term disposal. The uranium separated through PUREX is disposed of as low-level waste. The pure plutonium can be mixed with freshly mined and enriched uranium to fabricate a mixed-oxide fuel known as MOX, which is recycled into thermal reactors to generate more power. Current practice in these countries is to reuse the plutonium only once and then dispose of the remaining spent fuel. This approach is known as partial recycle, and is far different from the advanced fuel cycle envisioned under GNEP. Fast reactors needed to consume other long-lived radioactive elements (in particular the transuranics) are not currently part of this fuel cycle, but there are plans to incorporate fast reactors in France several decades from now.

ous chemical engineering challenges that do not exist at the bench scale. Chemistry involving nuclear materials presents additional and unique challenges. Discovering and addressing all of these challenges is the main purpose of an engineering scale demonstration.

2. Advanced Burner Reactor

The advanced burner reactor (ABR) being proposed by DOE is, to be more precise, a sodium-cooled fast reactor. This particular design selection was made from the six technologies that were considered under DOE's Generation IV (GenIV) reactor program. The other designs are being pursued by other countries in the GenIV partnership, and domestic R&D on those designs has been all but eliminated in the FY07 budget request (with the exception of the very high temperature reactor selected under the Next Generation Nuclear Plant program). In general, GenIV reactors are designed to be more energy efficient, proliferation-resistant and safer than the current fleet of reactors. In particular, the sodium-cooled reactor design chosen for the ABR is considered by the technical community to be one of the best choices for efficient transmutation of the transuranics. Notably, not a single fast reactor has been successfully commercialized anywhere in the world. However, the U.S. and several other countries do have a long history of research on fast reactor technologies, including sodium-cooled fast reactors.

3. Advanced Fuel Cycle Facility

The advanced fuel cycle facility (AFCF) would serve the fuel design and testing needs for the ABR. The fast reactor fuels made possible by the UREX+ separations process currently exist only in concept. AFCF would be a dedicated facility for the R&D necessary to make these fuels a reality, assuming there are no as-yet-unknown technical showstoppers. Once fuels were designed and tested in the demonstration ABR, tests to characterize and understand the new spent fuel, and tests using that information to optimize the fuel, would also be done at AFCF.[13]

7. Witness Questions

Mr. Johnson

- Please describe the timelines for major Global Nuclear Energy Partnership (GNEP) demonstration projects as currently envisioned. What are the anticipated costs of each component? What is the life cycle cost of the program and what does that encompass? How and when will the Department of Energy (DOE) determine how to distribute the $250 million requested for fiscal year 2007?
- Please describe the fuel cycle systems analysis that is currently underway by DOE. What questions will this analysis answer? What is its status? To what extent will the results from this analysis influence GNEP program planning?
- What other research will be performed under GNEP?

Dr. Todreas and Dr. Garwin

- How realistic are the goals, timelines and budgets being proposed under the Global Nuclear Energy Partnership (GNEP)?
- What does the Department of Energy (DOE) need to do to develop a robust program to meet its goal of an advanced nuclear fuel cycle—one that includes both recycling and transmutation—while sufficiently addressing non-proliferation and waste management needs?
- What significant research and development (R&D) questions, both science and engineering, exist for UREX+? Sodium-cooled fast reactors? Mixed-actinide fuels? In your view, how well do the GNEP R&D priorities coincide with these research needs?

[13] A possible future GNEP technology is pyroprocessing, or electro-metallurgical reprocessing, a dry process in which fuel rods are mechanically chopped and fuel is electrically separated into constituent products. At this time, pyroprocessing appears to be the best candidate for reprocessing the spent fuel coming out of the ABR, assuming that the ABR is operated with metal fuel rather than metal-oxide fuel (e.g., uranium rather than uranium oxide). The U.S. has experience operating a small-scale pyroprocessing facility in Idaho, to reprocess the stockpiled spent fuel from the EBR–II, an experimental fast reactor shut down ten years ago. However, the nature of that stockpile is quite different from the spent fuel that the ABR would produce in the advanced fuel cycle, so much research still needs to be done on the pyroprocessing technology itself.

- DOE is in the process of developing the tools to carry out a cradle-to-grave systems analysis of the advanced fuel cycle. What questions should that systems analysis be able to answer?

Mr. Modeen

- Please summarize the draft report, *"The Nuclear Energy Development Agenda: A Consensus Strategy for U.S. Government and Industry,"* presented by the Electric Power Research Institute at a nuclear energy research and development summit in February. Who was involved in the development of this report and what is its status?
- What are the utility industry's nuclear research and development (R&D) priorities? How do they compare to the R&D priorities in Global Nuclear Energy Partnership (GNEP)?
- How realistic are the goals, timelines and budgets being proposed under GNEP?
- DOE officials have stated that they expect industry to cost-share in the demonstration of GNEP technologies, including reprocessing, fuel fabrication and fast reactor technologies. What does industry see as its role in GNEP technology demonstrations?

Appendix A

The Nuclear Energy Development Agenda: A Consensus Strategy for U.S. Government and Industry

Executive Summary

Nuclear energy in the U.S. is entering a renaissance. With strong interest and support for new plant construction, there is a sense of a bright future not only for nuclear energy's increasing role in U.S. electricity generation and reliability, but also in helping meet the challenges of (1) revolutionizing the transportation sector's dependence on foreign oil, (2) reducing the need to use natural gas for electric power generation and for the production of hydrogen for industrial applications, (3) fostering safe and proliferation-resistant use of nuclear energy throughout the world, and (4) achieving these in an environmentally responsible manner.

Meeting these challenges with nuclear energy requires consensus, and a coordinated effort on what needs to be done. Achieving this *nuclear energy agenda* will require the combined efforts of industry and government, supported by the innovation of the research community. The Department of Energy and Congress will play a critical role in this consensus, facilitating nuclear energy's expanding role in a sustainable national energy policy.

The Electric Power Research Institute has developed a technically-based, market-relevant, and nationally-oriented assessment of the nuclear systems needed in the United States over the next half century. This assessment was supported by the technical resources of the Idaho National Laboratory. The assessment is founded on the assumption that nuclear energy will be challenged to expand dramatically in the world over the coming decades: It must provide safe, reliable and environmentally responsible electricity and process heat to meet the needs of the industrial and residential sectors. U.S. nuclear energy technology, along with realistic plans, resources and a renewed infrastructure must all be ready for this expansion. Government and industry must share and coordinate their responsibilities with a *consensus strategy* for nuclear energy.

To forecast the U.S. nuclear technology needs, moderately aggressive planning assumptions were developed to guide the types and timing of the technology needed in seven *major goals:*

1. Ensure the continued effectiveness of the operating fleet of nuclear plants.
2. Establish an integrated spent fuel management system consisting of centralized interim storage, the Yucca Mountain repository, and, when necessary, a closed nuclear fuel cycle.
3. Build a new fleet of nuclear plants for electricity generation.
4. Produce hydrogen at large-scale for transportation and industry, and eventually for a hydrogen economy.
5. Apply nuclear systems to desalination and other process heat applications.
6. Greatly expand nuclear fuel resources for long-term sustainability, commercializing advanced fuel cycles when market conditions demand them in the long-term.
7. Strengthen the proliferation resistance and physical protection of closed nuclear fuel cycles both in the U.S. and internationally.

With these goals, a matrix of technology options to address each goal was developed with an assessment of the technology capabilities and challenges of each option. From this matrix, a technology development agenda was derived, with timing and cost estimates. The evolving role of government and industry in the agenda was also considered. Finally, current nuclear R&D programs were reviewed in relation to this assessment, and three areas were identified for action:

1. **Significant light water reactor research is needed.** Many significant needs exist for the current fleet and the new fleet, especially in areas of age-related materials degradation, fuel reliability, equipment reliability and obsolescence, plant security, cyber security, and low-level waste minimization. Also, developing a new generation of LWR fuel with much higher burnup will better utilize uranium resources, improve operating flexibility, and significantly reduce spent fuel accumulations, resulting in additional improvements in nuclear energy economics. A number of these are mid-term R&D needs whose impact would be considerable, if accelerated with government investment.

2. **Nuclear energy's role in a future hydrogen economy can begin now.** An essential consideration in reducing dependence on foreign sources of oil and natural gas is found in the fact that hydrogen is necessary today in upgrading heating oil and gasoline, and in making ammonia for fertilizers. In fact, making hydrogen today consumes five percent of all natural gas in the U.S. and demand for hydrogen is growing rapidly. This situation can be improved with a nuclear system having hydrogen production capability as soon as it can be developed. In the mid-term, nuclear-produced hydrogen can be used to exploit heavy crude from large reserves in Canada and Venezuela. Of course, in the long-term, many believe that a hydrogen economy is essential for revolutionizing transportation, in which case the demand for competitive and environmentally responsible hydrogen will greatly increase. A large-scale, economical nuclear source would hasten that future.

3. **A proliferation-resistant closed fuel cycle for the U.S. should be ready for deployment by mid-century.** Establishing a closed fuel cycle with the demonstrated ability to handle much more nuclear waste will bring added confidence in a stable fuel supply and long-term spent fuel management in the U.S. in support of greatly expanding the use of nuclear energy. It will also bring the potential for establishing a nuclear fuel lease/take-back regime internationally. This would reduce the number of countries that need to develop enrichment and reprocessing technology, a goal of the President's nuclear nonproliferation initiatives. Importantly, various advanced fuel cycle technology options provide the ability to supply sufficient nuclear fuel in the future to ensure long-term energy and environmental sustainability for the U.S. and globally.

   Necessary technologies include cost-effective and proliferation resistant reprocessing to separate and manage wastes, and alternate reactor concepts (e.g., fast reactors) to generate electricity as they generate additional fuel and burn the long-lived minor actinides and other constituents that are recycled. These are both critical to assuring an adequate and economic supply of fuel, reducing the spent fuel backlog, and increasing the effective capacity of Yucca Mountain many-fold in the long-term. While the technology challenges and market uncertainties are many, large-scale deployment of a closed fuel cycle by government and industry could begin by mid-century.

Introduction: A New Paradigm for Public-Private Cooperation on Nuclear R&D

For many years, disagreement over the future direction of nuclear energy technology in the United States has existed, hindering progress toward the full potential of this energy source. There is general agreement among experts in government and industry that nuclear energy must expand as a major component of national energy policy. In fact, the 2001 National Energy Policy included a recommendation supporting this expansion for reasons of national security, energy security and environmental quality. The disagreements have been over how to achieve this expansion safely and economically, with differing views on goals, direction, timing, R&D priorities, and the respective roles of public and private sectors.

A recent step toward forging a consensus on the future direction of nuclear energy was undertaken by the Idaho National Laboratory in July 2004, when it assembled a "Decision-Makers Forum" in Washington, DC. That forum attracted a broad spectrum of key stakeholders in the nuclear technology enterprise. Although the Forum was successful at engaging industry, national laboratories and academia, significant differences among key sectors still remain.

Using the results of this forum as a starting point, the Electric Power Research Institute (EPRI), technically supported by the Idaho National Laboratory (INL), has developed this assessment of the nuclear systems R&D needed in the United States over the next half century. The assessment is founded on the assumption that nuclear energy will be challenged to expand dramatically in the world over the coming decades. An important focus is on improved coordination and prioritization of government and industry nuclear energy R&D programs.

A series of strategic planning sessions was held to map out a common set of high-level goals and time-based planning assumptions for nuclear energy, and to then identify the R&D needed to prepare for deployment consistent with those assumptions. These assumptions were formulated to be aggressive yet achievable, and were grounded upon open market principles. Following this, R&D challenges were identified. Finally, an assessment of current nuclear R&D programs was made to identify opportunities for action.

A benefit of this joint approach is its potential to build a framework for cooperation between public and private sectors for completing the needed R&D. This framework would be based on an *80–20 paradigm,* to replace the current paradigm that, "Government only works on long-term research, and industry only works on short-term research." Instead, having government dedicate about 20 percent of its efforts to short-to-medium-term R&D, and having industry dedicate about 20 percent of its efforts to medium-to-longer-term R&D was seen as a new way to encourage collaboration in areas of common interest, and to bridge the gaps and sustain the alignment on overall goals for nuclear energy.

Vision, Principles and Methods

The purpose of this consensus strategy is to develop an aggressive, success-oriented, yet credible and defensible R&D strategy for nuclear energy in the U.S. over the next 50+ years. The long time horizon is necessary to include the development of a closed fuel cycle. Emphasis was placed on global nuclear issues only to the extent they directly impact development in the U.S. Research programs and advances internationally were not specifically incorporated.

Recent works on nuclear energy planning were reviewed (a summary is found in Appendix A), and the session leaders agreed that the primary focus of the effort should be on national energy and security missions and imperatives, and especially on the vision and goals nuclear energy must strive toward in meeting those imperatives. While these goals have been prepared by EPRI and INL, it is important for the Department of Energy (for the government) and the Nuclear Energy Institute (for the industry) to consider the merits and credibility of these planning assumptions and goals to base new actions. National goals and priorities for nuclear energy, if supported by both industry and government, will have a substantial impact on the development of new nuclear technology. New technologies with great potential to the Nation will not be brought to market if government and industry do not jointly make them a priority.

The session leaders reviewed a number of existing high level vision and mission statements for nuclear energy, and arrived at a *vision* deemed appropriate for the planning exercise:

> *Expand the use of safe and economical nuclear energy in the United States to meet future electricity demand and industrial process heat needs, foster economic growth and energy diversity, provide security and proliferation resistance, and enhance environmental stewardship.*

The session leaders also provided three *guiding principles* for the consensus strategy:

1. **Strive for a moderately aggressive yet credible technology portfolio.**
2. **Understand the importance of market forces to long-term planning.** It is recognized that each future Administration and Congress will make federal investments in nuclear R&D only to the extent necessary to achieve national goals. However, each values the private sector's participation in that investment, and ultimately in its deployment. Thus, long-term market demand is a key factor in long-term nuclear energy investments and deployment.
3. **Align the technology portfolio with evolving nuclear energy policies and priorities.** There has been a general perception that widely divergent views on nuclear energy policy exist in the U.S. Yet a surprisingly close consensus exists on the basic priorities for technology development, as shown by a review of five key government and independent studies on the future of nuclear energy in Appendix A.

The *process* was to lay out a high level set of success-oriented planning assumptions for 2015, 2030, and 2050, covering reactor technologies, fuel cycle technologies, spent fuel management, infrastructure needs, etc. These planning assumptions were then weighed against the three guiding principles above, in terms of broad national energy, economic, safety and environmental goals, considering achievability, timing and sequencing.

Next, the minimum set of nuclear technologies that would satisfy the planning assumptions were determined. Where multiple nuclear technologies could meet the goal, factors were identified that determine which ones should be pursued and/or what the appropriate "mix" in effort or investment should be. These factors included budgetary limits on R&D, technology risk, commercial cost-competitiveness, NRC licensing risk (i.e., cost and duration of review; likelihood of success), implications to overall waste management strategies and costs, etc. Also considered were market-demand issues. For example, "Will demand for hydrogen lead or lag technology development?," and "When will uranium prices justify reprocessing?"

Finally, the length of time that each of these technologies will need to become commercially competitive to support the planning assumptions was estimated; and the R&D timeline needed for each technology was set to assure in-time licensing, demonstration, and commercialization. It is important to be realistic and objective about the time and resources needed to commercialize new technologies, factoring in technological, licensing, and funding uncertainties. In particular, the time required to prepare for and successfully complete the regulatory process was included.

Planning Assumptions

The planning assumptions proposed below are intentionally challenging, but also realistic and achievable. The predicted rapid growth is enabled by competitive economics, but is also accelerated in response to the growing societal demand to reduce the environments impacts of fossil fuels, including the risk of global climate change (by imposing limits on CO_2), which will increase demands for low- or zero-emitting sources. All three categories of low or zero-emitting technologies—nuclear energy, renewable energy, and fossil energy with carbon capture and sequestration—will face formidable challenges. Specific planning assumptions are presented in Appendix B, and are summarized below:

Currently Operating Nuclear Plants:

- All existing plants remain operational in 2015, and all have applied for and have been granted a 20-year life extension. Despite continued high safety performance and record-setting reliability, materials aging and equipment obsolescence have moderated their former profitability. Continued high performance is maintained in part by strategic, safety-focused plant management, and in part by new technology solutions, e.g., advanced monitoring and repair techniques, improved fuel performance, remedial coolant chemistry, greater reliance on advanced materials and digital controls.
- In the 2020–2030 timeframe, some plants are granted an *additional* 20-year life extension (i.e., to 80 years). Advanced fuel designs with higher burnup limits enable longer fuel cycles, significantly increase fuel economy, and significantly reduce the rate of spent fuel generation.

New Plants for Electricity Generation:

- Six to twelve new nuclear plants are in commercial operation by 2015, with many more under construction. 30 GWe of new nuclear electric generating capacity is on line or under construction by 2020. A cumulative total of 100 GWe of new nuclear capacity has been added by 2030. By 2050, nuclear energy is providing 35 percent of U.S. electricity generation by adding a cumulative total of about 400 GWe of new nuclear capacity. This number includes electricity generation from all reactor types. It also includes replacement power for a large segment of the current fleet of reactors, most of which have been retired or are close to retirement by 2050. This build-rate severely challenges U.S. industrial infrastructure.

New Plants for Process Heat:

- Based on a prototype Very High Temperature Reactor (VHTR) built and operating by 2020, about twelve VHTRs are in commercial operation by 2030, with about twelve more under construction. VHTRs are assumed to be commercially successful at 600 MWth per module (nominally four modules per plant), and with an outlet temperature around 850–900C. The VHTRs are initially dedicated to producing hydrogen for commercial and industrial use, focused primarily on rapidly expanding hydrogen demand by the oil, gas and chemical industries. They expand to a fleet of roughly 200 by 2050, still focused primarily on industrial applications, but also serving a growing market for hydrogen to power fuel cells in hybrid and plug-in hybrid vehicles. U.S.-built commercial VHTRs are also serving hydrogen demand for U.S. companies at some petrochemical facilities operating overseas.
- Commercial versions of the VHTR, without hydrogen production equipment, also begin to serve process heat needs in the petrochemical and other industries. High value-added applications above 800C are found in recovery of petroleum from oil shale and tar sands, coal gasification, and various petrochemical processes (e.g., ethylene and styrene).
- Nuclear energy begins to assume a significant role, starting in the 2020 timeframe, in support of the desalination mission for arid coastal regions of the U.S. with acute shortages of potable water. Some 16 trillion additional gallons

per year will be required in the United States by 2020 for municipal and light industrial uses. This is equivalent to one quarter of the combined outflow from the Great Lakes. If desalination is viable with nuclear energy, it will likely be accomplished by equipment designed for new light water reactors, or by new reactors dedicated to desalination as are being pursued in other countries.

Spent Fuel Management and Expanding Nuclear Fuel Resources:

- Licensing of a spent fuel repository at Yucca Mountain Nevada is completed by 2015, with construction and waste acceptance into the repository and into nearby above-ground storage underway by that date. Interim storage away from reactor sites is also established at two other locations in the U.S., one east and one west of the Mississippi River.
- With a rapidly expanding nuclear energy industry and a growing inventory of spent fuel, an integrated spent fuel management plan for the U.S. emerges by 2015 that obtains bipartisan support for implementation. Key elements of the plan include expansion of the capacity of the Yucca Mountain repository, and a decision to maintain continued monitoring of the repository well in excess of 50 years (e.g., 300 years) prior to closure. The plan also includes a commitment to begin reprocessing spent fuel in a demonstration plant by about 2030, based on an active R&D program aimed at identifying cost-effective and proliferation-resistant means to recover usable reactor fuel. These technologies will also demonstrate the reduction of radiotoxicity and heat output of spent fuel, and the potential to greatly extend repository capacity. The reprocessing plan is integrated with both reactor technology and repository strategies, and offers a least-cost path for safe, long-term management of spent nuclear fuel.
- The reactor technology part of this integrated strategy develops means (e.g., fast reactors) to recycle light water reactor spent fuel in order to burn minor actinides as well as produce electricity, and later to breed additional fuel. Following a demonstration plant, built and operated with government funding in 2035, new fast reactors are deployed commercially, with government subsidy as needed for the waste burning mission. In the long-term, the price of uranium increases to a level that supports breeding.

R&D Technology Matrix

A matrix was created to detail the specific technology agendas and programs. Goal areas were mapped against specific technology options, missions and capabilities. Estimates were made for when each capability is needed, how many years are needed to develop, license, and demonstrate each, and from these estimates, when R&D must start or ramp up. Key R&D needs for each technical capability were identified, along with specific challenges that needed to be addressed. Next, the matrix was used to compare the relative R&D challenges, and to consider the likelihood of success. The full R&D matrix is found in Appendix C, and is summarized below.

Goal	Technology Option	Technical Capability
1. Ensure the continued effectiveness of the operating fleet of nuclear plants	Current LWRs	1A. Managing age-related degradation
		1B. Equipment reliability and system obsolescence
		1C. Power uprates
		1D. Plant security
		1E. Grid reliability
		1G. Fuel reliability
		1H. New generation LWR fuel
2. Establish an integrated spent fuel management system consisting of centralized interim storage, the Yucca Mountain repository, and, when necessary, a closed nuclear fuel cycle	Interim Storage	2A. Acceptance criteria for transportation of spent HBU fuel
	YM repository	2B. Transportation and storage of multi-purpose canisters
	Economic closed nuclear fuel cycle	2C. Proliferation-resistant reprocessing
		2D. Reactors that can burn minor actinides
3. Build a new fleet of nuclear plants for electricity generation	ALWRs	3A. Demonstration licensing process
		3B. Reduce capital costs (FOAKE)
		3C. Reduce construction time
		3D. Address shortfall in infrastructure
		3E. Reduce operating costs
4. Produce hydrogen at large scale for transportation and industry, and eventually for a hydrogen economy	LWRs	4A. Conventional electrolysis
	Commercialized VHTR – H2 only	4B. High temperature electrolysis (HTE)
		4C. Sulfur-iodine (S-I) or other chemical processes
	VHTR – cogen	4D. Cogeneration with 4B or 4C
	VHTR – all	4E. Codes and Standards development
5. Apply nuclear systems to desalination or other process heat applications	ALWRs (low T)	5A. Desalination, wood pulp, urea
	VHTR (high T)	5B. Petrochemical, coal gasification, iron reduction
6. Expand nuclear fuel resources for long term sustainability	Alternate fuel cycles and reactor concepts	6A. Closed fuel cycle with breeding (e.g., fast reactors)
7. Strengthen the proliferation-resistance and physical protection technologies of closed nuclear fuel cycles., both in the U.S. and internationally	Institutional needs	7A. Real-time materials accountability
		7B. Proliferation issues and policies
		7C. Framework for int'l fuel supply/take-back regime
	Reprocessing	7D. Closed fuel cycle with supply/take-back
		7E. Assessment methodologies and technology
		7F. Physical protection technology

Timing and Costs of the Nuclear Energy Development Agenda

The timing and costs associated with addressing the R&D challenges were roughly estimated. The timelines in Appendix B are moderately optimistic estimates of how long it will take to meet the challenges. Costs were estimated based on both U.S. and international experience.

The near-term deployment goals for electricity generation, including a renewed commitment to LWR research, are the least expensive. The bulk of federal investments are envisioned to occur over the next ten years, with continued modest funding after that as necessary. Costs of federal spending on electricity generation are based on continued funding on a cost-shared basis of the NP2010 program, and projections that the private sector will deploy ALWRs for electricity generation by 2015, based on limited federal incentives, with no federal funding requirements for NP2010 after that date. Total federal costs are roughly $500M through 2015, with equal or greater cost share by industry. This does not include costs of completing Yucca Mountain, which are uncertain; nor does it include the costs of revitalizing nuclear industrial infrastructure.

Federal spending for nuclear generated hydrogen and other process heat applications are based on projections that the commercial VHTR technology can be demonstrated and will become competitive in the 2020 timeframe for industrial applications. This timeline assumes that conservative technology choices are made to maximize near-term licensing and commercial deployment. Total federal costs for the nuclear hydrogen mission (exclusive of hydrogen economy infrastructure, which come later and are not projected here) are estimated at $2B through about 2020, after which VHTRs will go forward as commercial units.

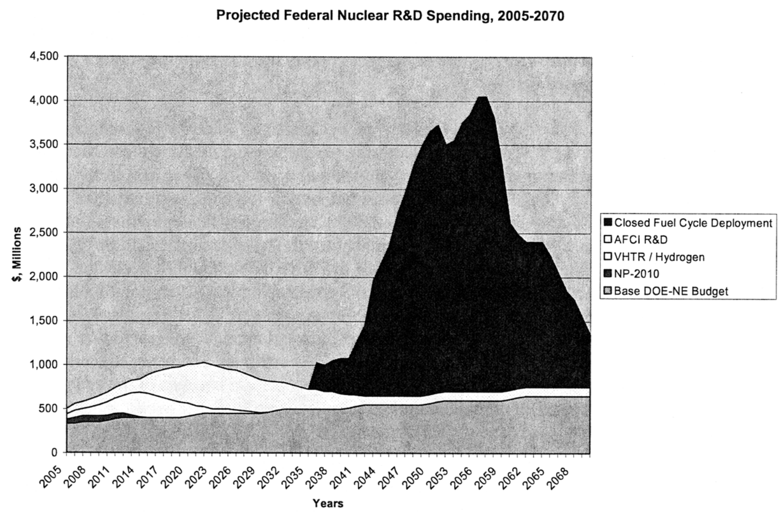
The costs of establishing centralized interim storage and of completing Yucca Mountain are covered by the Nuclear Waste fund (funded by a fee paid by nuclear generating plants). Eventually, after these requirements are met, and as uranium fuel prices justify a shift from an open to a closed nuclear fuel cycle, Nuclear Waste Fund revenues, at the current fee rate of one mil/KWH), are assumed to defray the costs of closed fuel cycle facilities, as discussed below.

The costs of establishing a closed nuclear fuel cycle are considerably higher than reestablishing the ALWR option for electricity generation and creating a commercial VHTR option for hydrogen generation. There are a number of significant technical, cost, and institutional challenges facing reprocessing that will force the postponement of the start of prototype demonstration until about 2030, and large scale deployment until mid century. Rough costs to the Federal Government for the least-cost path will probably exceed $35B by 2050 and could exceed $60B by 2070, including both R&D and government-funded subsidy for a portion of the construction and operation of a large number of fast reactors and nuclear fuel reprocessing plants. These costs assume significant reliance on the private sector to construct and operate fast reactors as commercial power plants (after the technology is demonstrated and licensed, and the learning curve is ascended). These costs are highly uncertain because of the speculative nature of estimating when nominal commercial viability can be achieved for these facilities.

- Federally funded research for a closed nuclear fuel cycle includes major R&D to develop new separations technologies that are more proliferation resistant and less expensive than current separations processes (i.e., PUREX). R&D is also required to develop alternate fuel cycles and reactor applications (e.g., fast reactors) to generate electricity with reprocessed fuel that includes plutonium and minor actinides from ALWRs. Total RD&D costs to 2050 are estimated at roughly $15B comprising $5B for fast reactor development and demonstration and $10B for advanced separations technology.
- Federal spending to deploy closed fuel cycle technologies is estimated at roughly $20B by 2050. This estimate includes $15B for the first reprocessing plant and initial costs for a second plant beginning construction, and $5B in cumulative subsidies to construct and operate the initial modular fast reactor plants. Fast reactor subsidies would continue until cost parity with ALWRs opens the commercial market for closed cycle systems.
- Full deployment, including conversion of the nuclear generation base in the U.S. to fast reactors will take well over a century to complete.

Rough costs to the Federal Government through mid-century depend primarily on whether the reprocessing plan has been structured to be the least-cost path for safe, long-term management of spent nuclear fuel (per above planning assumptions), or whether an accelerated plan is chosen that does not wait for the market price for uranium to drive the shift from the once-through fuel cycle to a closed fuel cycle, and from LWRs to a mix of LWRs and fast reactors.

A rough estimate of federal investments in future nuclear R&D is shown in the figure.



There are fundamental differences between the deployment of nuclear energy generation with ALWRs and commercial VHTRs, and technologies to close the nuclear fuel cycle. First, there are commercial markets for electricity and hydrogen that enable near-term deployment of ALWRs, and a transition of VHTRs to the private sector as soon as the technology is ready. There is no comparable commercial market for reprocessing. A market could evolve for the fast reactor component of closed fuel cycle systems because fast reactors can produce electricity. However, based on today's technology and uranium ore costs, fast reactors are not expected to compete with ALWRs in power generation until about mid-century. Economic parity could be achieved when new fuel for ALWRs based on enriched U–235 becomes sufficiently more expensive than fast reactor fuel using recycled components. In the long-term, as uranium prices rise, the alternate fuel cycles will advance to breeding and the need for subsidy will end.

In addition, reprocessing plants are expensive and not attractive to commercial financing in the context of the U.S. economy. Thus, the cost increment for reprocessing (i.e., the incremental cost above the cost of repository disposal) will be subsidized initially by the Federal Government. Although the estimate above does not include repository costs, it is expected that reprocessing will remain more expensive than storage (centralized above-ground plus geologic repository) for the foreseeable future. Projections of major savings in Yucca Mountain repository costs as a result of reprocessing are highly speculative at best. On the other hand, the increased revenues to the Nuclear Waste Fund from an expanding fleet of new reactors will eventually help defray the costs of operating closed fuel cycle facilities.

It is important to note that despite the extended timetable for introducing reprocessing in the U.S. (due to R&D prerequisites to satisfy cost and nonproliferation objectives, policy considerations, etc.), that a single expanded-capacity spent fuel repository at Yucca Mountain is adequate to meet U.S. needs, and that construction of a second repository is not required under this timetable.

If, however, reprocessing is implemented on an accelerated schedule before it is economic to do so based on fuel costs, then the Federal Government will need to bear a much larger cost. As discussed in Appendices B and D, the optimum scenarios for transitioning nuclear energy to a closed fuel cycle in the U.S. context requires us to focus the R&D on those technologies that would enable a transition to cost-effective and proliferation resistant "full actinide recycle" mode with fast reactors that would eventually replace light water reactors. This path is preferred over one that maintains for decades a "thermal recycle" mode using MOX fuel in light water reactors, because the high costs and extra waste streams associated with this latter path do not provide commensurate benefits in terms of either non-proliferation or spent fuel management costs.

Assessment of Current Programs

Current federal programs in three major nuclear energy R&D areas were reviewed in relation to the development agenda.

Light Water Reactor R&D

Many significant needs exist for the current fleet and the new fleet, especially in areas of age-related materials degradation, fuel reliability, equipment reliability and obsolescence, plant security, cyber security, and low-level waste minimization. Also, developing a new generation of high reliability LWR fuel with much higher burnup will better utilize uranium resources, improve operating flexibility, and significantly reduce spent fuel accumulations, resulting in additional improvements in nuclear energy economics. A number of these are mid-term R&D needs whose impact would be considerable if accelerated with government investment.

Process Heat R&D

An essential consideration in reducing dependence on foreign sources of oil and natural gas is found in the fact that hydrogen is necessary today in upgrading heating oil and gasoline, and in making ammonia for fertilizers. In fact, making hydrogen today consumes five percent of all natural gas in the U.S. and demand for hydrogen is growing rapidly. This situation can be improved with a nuclear system having hydrogen production capability as soon as it can be developed. In the mid-term, nuclear-produced hydrogen can be used to exploit heavy crude from large reserves in Canada and Venezuela. Of course, in the long-term, many believe that a hydrogen economy is essential for revolutionizing transportation, in which case the demand for competitive and environmentally responsible hydrogen will greatly increase. A large-scale, economical nuclear source would hasten that future.

Closed Fuel Cycle R&D

Establishing a closed fuel cycle with the demonstrated ability to handle much more nuclear waste will bring added confidence in a stable fuel supply and long-term spent fuel management in the U.S. in support of greatly expanding the use of nuclear energy. It will also bring the potential for establishing a nuclear fuel lease/take-back regime internationally. This would reduce the number of countries that need to develop enrichment and reprocessing technology, a goal of the President's nuclear nonproliferation initiatives. Importantly, various advanced fuel cycle technology options provide the ability to supply sufficient nuclear fuel in the future to ensure long-term energy and environmental sustainability for the U.S. and globally.

Necessary technologies include cost-effective and proliferation resistant reprocessing to separate and manage wastes, and alternate reactor concepts (e.g., fast reactors) to generate electricity as they generate additional fuel and burn the long-lived minor actinides and other constituents that are recycled. These are both critical to assuring an adequate and economic supply of fuel, reducing the spent fuel backlog, and increasing the effective capacity of Yucca Mountain many-fold in the long-term. While the technology challenges and market uncertainties are many, large-scale deployment of a closed fuel cycle by government and industry could begin by mid-century.

Conclusions

- The strategy for nuclear energy development and implementation in the United States requires a consensus of industry and government.
- The overall strategy should be determined by a combination of market needs and long-term nationally established energy goals for energy security, national security, and environmental quality.
- The priorities in the consensus nuclear energy strategy should address near-term, medium-term, and long-term priorities. R&D needs to proceed now on all fronts, but priorities for implementation and deployment are as follows:
  - Near-term: license renewal for the current fleet, and licensing and deployment of new, standardized ALWRs within the next decade. Near-term deployment of ALWRs will require demonstration of a workable licensing process, and completion of first-of-a-kind engineering for at least two standardized designs. Industry and DOE should cost share these R&D programs.

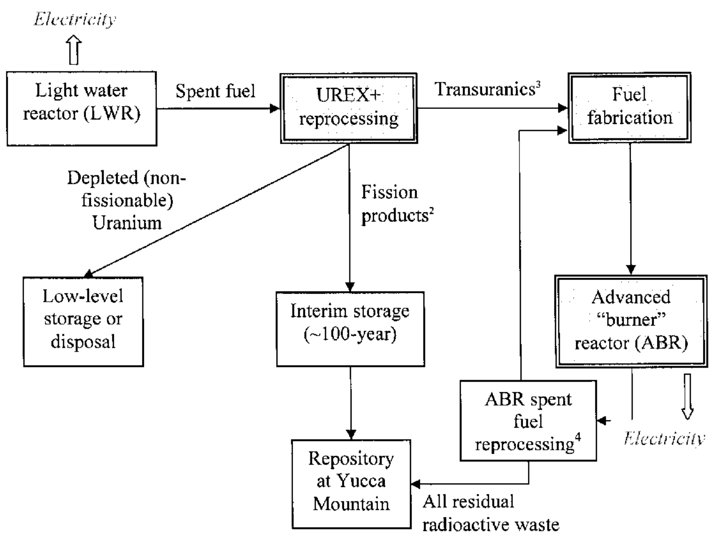
    To enable the resurgence of nuclear energy, the near-term elements of an integrated spent fuel management plan must proceed with bipartisan support from both the Administration and Congress. These near-term elements include completion of the repository at Yucca Mountain, deployment of multi-purpose canisters approved by the NRC, implementation of an effective spent fuel transportation system, and provision for centralized interim storage. This effort should be funded by the Nuclear Waste Fund, established by Congress and paid for by nuclear energy ratepayers and nuclear plant licensees for these purposes, in accordance with the Fund provisions in the *Nuclear Waste Policy Act.*

- Medium-term: development of a high temperature commercial VHTR capable of generating hydrogen and electricity at competitive costs, for initial use by the petroleum and chemical industries. Deployment will require concept development, defining end-user requirements and interfaces, engineering, resolution of design and licensing issues and prototype demonstration. This effort should be funded by government, but targeted for rapid commercialization.
- Long-term: development of new closed fuel cycle technologies supporting an integrated, cost-effective spent fuel management plan. Key elements of the plan include expansion of the capacity of the Yucca Mountain repository, and a decision to maintain continued monitoring of the repository well in excess of 50 years prior to closure. The plan also includes provisions for centralized interim storage of spent fuel, and a commitment to begin reprocessing spent fuel in a demonstration plant by about 2030, based on an active R&D program aimed at identifying more cost-effective and proliferation-resistant means to recover usable reactor fuel. It also includes development of safe and cost-effective fast-spectrum reactor technology for "burning" the long-lived actinides in spent fuel, and "recycling" the usable uranium and plutonium recovered from spent fuel. These capabilities, along with other advanced fuel cycle options, should be used to achieve long-term energy supply sustainability—long after fossil fuel supplies are exhausted. These facilities should be funded by government. They are not authorized expenses to be recovered from the Nuclear Waste Fund, but eventually, as uranium fuel prices justify a shift from an open to a closed nuclear fuel cycle, Nuclear Waste Fund revenues are assumed to defray the costs of closed fuel cycle facilities.

• A strategy for rebuilding the nuclear industrial infrastructure in the U.S. is necessary. Currently, major equipment must be procured offshore. Long-term energy security requires that the U.S. industry have the capability of supplying and supporting U.S. energy producers, and better integrating energy supplier and end-user needs. These infrastructure needs include large numbers of new skilled construction workers, engineers, nuclear plant operators and other key personnel needed for construction, operation and maintenance of new facilities.

Appendix B

APPENDIX B
SIMPLIFIED[1] MATERIALS PATHWAYS IN THE ADVANCED FUEL CYCLE



1 – A complete flow diagram would have a few more boxes and arrows, but this simplified version shows the major elements of an advanced fuel cycle under discussion in this hearing ((in double-bordered boxes)): a UREX+ reprocessing facility, a fuel fabrication facility (the "advanced fuel cycle facility" in the GNEP R&D proposal), and a fast, or "burner" reactor (ABR) for the transuranics-based fuel. In any fuel cycle, a permanent repository is required.

2 – The fission products, which result from the splitting of uranium into smaller elements, include cesium (Cs), strontium (Sr), iodine (I) and technetium (Tc), as well as a group of elements known as the Lanthanides. The Cs and Sr are short-lived and would be placed in interim above-ground storage until they are sufficiently "cool" to move into Yucca Mountain. Iodine would be removed as an off-gas during the UREX process, and Tc and the Lanthanides would likely go straight to Yucca Mountain in appropriate storage form.

3 – The transuranics are a group of elements listed after uranium in the period table of the elements and result from the capture of neutrons by uranium. They include plutonium (Pu), which accounts for one percent of the total spent fuel, as well as americium (Am), curium (Cm) and neptunium (Np).

4 – The technology for ABR spent fuel reprocessing will be dictated by the fuel choice for the ABR – a longer-term decision based on R&D carried out in the advanced fuel cycle facility.

Prepared by Science Committee staff based on materials provided by DOE.

Chairwoman BIGGERT. The Subcommittee on Energy of the Science Committee will come to order.

I will now recognize myself for an opening statement.

I want to welcome everyone to this hearing on the President's Global Nuclear Energy Partnership, commonly referred to as GNEP. The purpose of this partnership is to clear the way for the safe expansion of nuclear energy worldwide. How do we do this? By using technology to address growing inventories of spent nuclear fuel, and today we intend to take a look at the goals, schedules, and costs associated with this innovative research and development program.

In 20 years, electricity demand in the United States is expected to increase by 50 percent. We must meet that demand and do so in an environmentally responsible way. Carefree increases in greenhouse gas emissions are not an option. We need a diverse supply of clean electricity, and nuclear power must be part of that mix. It is the only reliable, carbon-free, emissions-free source of electricity currently available that could provide the baseload capacity to meet this demand. If we cannot supply our nation's need for clean energy, we run the risk of unacceptable environmental and economic consequences.

However, for the United States and the world to benefit from the expanded use of nuclear energy, there is one vitally important issue that must be resolved: What do we do with the inventory of spent nuclear fuel? Yucca Mountain was to be the solution. Unfortunately, its intended opening slipped from 1998 to 2010, and it slipped again to 2012 or 2014, or even possibly later. And we all know by now that the statutory limit of Yucca Mountain is such that the repository effectively will be full from the waste generated by 2010.

Yesterday, President Bush sent to Capitol Hill draft legislation intended to speed construction of the nuclear waste repository at Yucca Mountain. As part of this proposal, President Bush would lift the statutory limit on the capacity of Yucca Mountain, which is set at 70,000 metric tons under the current law. Lifting this limit would allow for storage of up to 120,000 metric tons of spent fuel, which is still less than the repository's technical capacity.

This proposal certainly buys us some time, but it would not obviate the need for additional repositories this century. At one of this subcommittee's previous hearings on the future of nuclear energy, a witness testified that the United States would need up to nine additional repositories, nine additional Yucca Mountains, to accommodate the waste generated in the 21st century alone.

The good news is that we can achieve the vision of a single repository for the next century. And how do we do this? By transitioning to a closed, or some prefer the word advanced, fuel cycle now. The advanced fuel cycle that I envision involves a lot more than just the reprocessing of spent nuclear fuel. Reprocessing alone won't help, it won't really help. It would only reduce the heat load of waste destined for Yucca Mountain by 10 percent. We also need to recycle and reduce spent fuel using fast reactors for transmutation, which could reduce the heat load by a factor of 10 or more.

To ensure a sustainable future for nuclear power in the United States, we must develop an advanced fuel cycle with all three components. We must take bold action now to realize the benefits of the advanced fuel cycle to our energy security, our economic security, and our national security. And I believe that the Administration has stepped up to the challenge with the announcement of the Global Nuclear Energy Partnership.

GNEP supports the comprehensive development of an advanced fuel cycle, including all three of the important elements that I just mentioned: reprocessing, recycling, and the use of advanced burner reactors to reduce the waste. And it puts their development on a very aggressive timetable. We need to start now, because these technologies won't be developed overnight.

We are eager to learn more about the details of this important initiative, especially details about the comprehensive systems analysis. It is essential that DOE understands how every component of the advanced fuel cycle interacts as the fuel moves through the system from cradle to grave. This will ensure the success of the program and raise the confidence of Congress and the public that we are making smart choices. Through modeling that incorporates the relevant technical, economic, and policy considerations, this "systems approach" will allow us to optimize the fuel cycle and make informed decisions about how to proceed.

I understand that this effort is already underway, and I applaud DOE for requesting a separate funding line in the fiscal year 2007 budget request to support this systems analysis. I believe such an analysis is the linchpin of the GNEP.

Whether we are motivated by climate change, our addiction to foreign sources of energy, or skyrocketing energy costs, all of which have national security implications, nuclear power is a necessary and significant part of the solution. However, nuclear energy, as we know it today, won't be sustainable without an advanced fuel cycle.

I realize that some of the witnesses on the panel today are concerned about the timeliness and research and development priorities proposed by the DOE. I think it is important that we allow smart, informed nuclear scientists and engineers from outside the Administration to weigh in. It is also important that we hear from members of the energy industry, who, in the long-term, will be an important player in the development of an advanced fuel cycle.

Without hesitation, I support the vision of GNEP. We owe our children and grandchildren our best efforts to secure a clean, safe, reliable future—fuel for the future.

With that, I want to thank our witnesses for agreeing to share their knowledge and insight with us today, and I look forward to an open and spirited discussion on this very important subject.

[The prepared statement of Chairman Biggert follows:]

PREPARED STATEMENT OF CHAIRMAN JUDY BIGGERT

I want to welcome everyone to this hearing on the President's Global Nuclear Energy Partnership, commonly referred to as GNEP. The purpose of this partnership is to clear the way for the safe expansion of nuclear energy worldwide. How do we do this? By using technology to address growing inventories of spent nuclear fuel, including the risk of proliferation. Today we intend to take a look at the goals, schedules and costs associated with this innovative research and development (R&D) program.

In twenty years, electricity demand in the United States is expected to increase by 50 percent. We must meet that demand and do so in an environmentally responsible way. Carefree increases in greenhouse gas emissions are not an option. We need a diverse supply of clean electricity, and nuclear power *must* be part of that mix. It is the only reliable, carbon-free emissions-free source of electricity currently available that could provide the base-load capacity to meet this demand. If we cannot supply our nation's need for clean energy, we run the risk of unacceptable environmental and economic consequences.

However, for the United States and the world to benefit from the expanded use of nuclear energy, there is one vitally important issue that must be resolved—what we do with growing inventories of spent nuclear fuel. Yucca Mountain was to be *the* solution. Unfortunately, its intended opening slipped from 1998 to 2010. Then it slipped again to 2012 or 2014, or possibly even later. And we all know by now that the statutory limit of Yucca Mountain is such that the repository effectively will be full from the waste generated by 2010.

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The good news is that we can achieve the vision of a *single* repository for the next century. How do we do this? By transitioning to a closed—or some prefer the term advanced—fuel cycle now.

The advanced fuel cycle that I envision involves a lot more than just the reprocessing of spent nuclear fuel. Reprocessing alone won't really help. It would only reduce the heat load of waste destined for Yucca Mountain by 10 percent. We also need to recycle and reduce spent fuel using fast reactors for transmutation, which could reduce the heat load by a factor of 10 or more.

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Without hesitation, I support the vision of GNEP. We owe our children and grandchildren our best effort to secure a clean, safe, reliable fuel for the future.

With that, I want to thank our witnesses for agreeing to share their knowledge and insight with us today. I look forward to an open and spirited discussion on this very important subject.

Chairwoman BIGGERT. I will now recognize the Ranking Member, Mr. Honda, for his opening statement.

Mr. HONDA. Thank you. And I thank the Chairwoman Biggert for holding this hearing today so we can learn more about the Global Nuclear Energy Partnership, which President Bush announced without providing much detail in February in his budget request.

As we all know, currently, the United States does not reprocess nuclear spent fuel because of concerns about the proliferation of nuclear weapons material.

In addition, reprocessing is not cost-effective since uranium supplies around the world are plentiful and can be fabricated into fuel at far less cost than reprocessing spent fuel. The economics of the situation have not changed and are not going to change for a long time.

Which brings us to the real reason that the Bush Administration is putting forward a nuclear fuel reprocessing program, the problem of dealing with nuclear waste.

The politics of Yucca Mountain have made it clear that siting and licensing a second waste repository is highly unlikely. At this point, it still isn't clear how things are going to proceed with Yucca Mountain.

The Bush Administration has seized upon this political situation to justify reprocessing of spent fuel to reduce the heat of the material that would potentially be put in Yucca Mountain in order to expand the capacity of the proposed repository.

Yesterday, the Administration sent a legislative proposal to Congress to expedite the repository, which would lift the current statutory limit on the amount of waste that could be stored there. Such a move is essential to justify developing a reprocessing program.

What troubles me about this whole Global Nuclear Energy Partnership proposal is the haste with which it seems to have been developed and the fact that a very small number of people seem to have made all of the key decisions without much input from the industry or scientific community.

For example, it appears that the technology for reprocessing spent fuel, UREX+, has already been selected by the advocates for the program. While the final decision hasn't been made, it seems that the decision has essentially been made to use metal fuel, which would require the construction of a pyroprocessing plant for each fast reactor that will be used to convert reprocessed fuel into electricity.

What isn't clear to me is who made these decisions, what process was used to make those decisions, or even why they have been already made, given the premature stage of the technologies and huge uncertainty as to whether they will be successful and cost effective.

The spent nuclear fuel we have now can safely be stored in dry casks for 50 years or more, giving us plenty of time to do more research, more fully evaluate technology alternatives, and have a greater engagement from all interested parties in the decision-making process.

Now for a program that may cost as much as hundreds of billions of dollars in taxpayer money, it seems that such a study and scrutiny is at—the least we can do to ensure that the best policy is what is pursued.

From where I sit, the way that the Global Nuclear Energy Partnership has been put together and then proposed looks a lot like the way in which the President took the Nation to war in Iraq.

The policy decisions have already been made by a small isolated group within the Administration without all of the facts and without input from the experts from outside the group. Once that decision was made then a justification for it was developed and sold to Congress.

A story posted on the website of the scientific journal *Nature* yesterday about the disbanding of the Secretary of Energy's advisory board, which was chartered to provide the Secretary with timely, balanced external advice on issues of importance only reinforces the impression that outside input is not welcome on major programs such as GNEP.

But as with Iraq, there seems to be major uncertainties in GNEP, uncertainties in the technical feasibility, the cost, and uncertainty in the ability of the agency in charge to successfully carry out such a large effort. I don't believe that it is wise for us to rush to judgment on GNEP, as we rushed the war, and I certainly don't want to see the kind of outcome that a rushed decision and incomplete plan are sure to deliver.

This decision doesn't need to be made today. We have other means for storing nuclear waste temporarily while we wait for all of the facts.

In closing, Madame Chairwoman, I thank you again for holding this hearing so that we can try to get some answers on how these decisions were made, we can hear some outside thoughts on this proposal, and perhaps hear some alternative options for dealing with the problem.

Thank you.

[The prepared statement of Mr. Honda follows:]

PREPARED STATEMENT OF REPRESENTATIVE MICHAEL M. HONDA

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In addition, reprocessing is not cost effective, since uranium supplies around the world are plentiful and can be fabricated into fuel at far lest cost than reprocessing spent fuel. The economics of this situation have not changed and are not going to change for a long time.

Which brings us to the real reason that the Bush Administration is putting forward a nuclear fuel reprocessing program—the problem of dealing with nuclear waste.

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For example, it appears that the technology for reprocessing spent fuel, UREX+, has already been selected by the advocates for the program. While the final decision hasn't been made, it seems that the decision has essentially been made to use metal fuel, which would require the construction of a pyroprocessing plant for each fast reactor that will be used to convert reprocessed fuel into electricity.

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For a program that may cost as much as hundreds of billions of dollars in taxpayer money, it seems that such study and scrutiny is the least we can do to ensure that the best policy is what is pursued.

From where I sit, the way that the Global Nuclear Energy Partnership has been put together and then proposed looks a lot like the way in which the President took the Nation to war in Iraq.

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But as with Iraq, there seem to be major uncertainties in GNEP, uncertainties in the technical feasibility, the cost, and uncertainty in the ability of the agency in charge to successfully carry out such a large effort.

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In closing, Madame Chairwoman, I thank you again for holding this hearing so that we can try to get some answers on how these decisions were made, we can hear some outside thoughts on this proposal, and perhaps hear some alternative options for dealing with the problem.

Chairwoman BIGGERT. Thank you, Mr. Honda.

With that, any additional opening statements submitted by Members may be added to the record.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

According to the Energy Information Administration, Texas ranked 7th among the 31 states with nuclear capacity.

In 2004, the Nation set a new record for electricity generation at nuclear power plants.

During 2004, the larger of Texas' two nuclear power plants was up-rated in capacity, contributing to a new State record for nuclear output. For the first time, Texas generated more than 40 billion kilowatt hours. Of Texas energy, ten percent comes from nuclear plants.

Together, the Comanche Peak plant near Dallas and South Texas plant near Houston produce 100 percent of the nuclear energy in Texas.

As Texas makes great strides with nuclear energy, the state continues to struggle to modernize its overall energy economy.

Texas regrettably still relies heavily on fossil fuels to the detriment of the environment. Texas ranks first in the Nation in carbon dioxide emissions, third in nitrogen oxide, and fourth in sulfur dioxide. These chemicals contribute toward Texas' poor air quality.

I am concerned for my constituents in Dallas as well as residents in Houston, two major Texas cities with some of the poorest air quality in the Nation. Bad air leads to cancer, asthma, and a host of other diseases.

For these reasons I strongly advocate for clean, efficient and alternative fuel sources. Development of these technologies and support of a national infrastructure will require great investment.

But Mr. Chairman, if one has a toothache, does it not make sense that one would pay the dollars to have the issue addressed?

I look at federal investment in clean energy that way. It may cost money, but it is an investment we cannot afford not to make.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Mr. Davis follows:]

PREPARED STATEMENT OF REPRESENTATIVE LINCOLN DAVIS

Good morning. Thank you, Madame Chairwoman and Ranking Member, for the opportunity for us to discuss the Global Nuclear Energy Partnership (GNEP) Proposal. I would also like to thank all the witnesses for their presence today.

Before I get into the issue at hand, I would like to express my support for nuclear energy in this country. As America has become more addicted to fossil fuels that pollute our air and our water, I believe nuclear energy can play a major role in our country's energy future. Opponents of nuclear energy argue that it is unsafe.

With that mind set America has not ordered a new nuclear plant in over 25 years. However, over the same time the Navy has acquired over 80 vessels that contain nuclear reactors. To date, there have been no incidents reported on any of these 80 vessels and none of the crew on these ships has become ill from serving on them. So, clearly the technology exists that can make nuclear power safe. It is my hope once we solve the nuclear waste question we can add more nuclear power to the Nation's power grid.

While I believe that nuclear energy needs to play a major role in our energy future, I also have serious reservations about the GNEP proposal. My main concerns stem from the fact that it appears a majority of important decisions about this program have already been made—such as site locations and specific technologies to be used for GNEP. These possible actions concern me because they exclude the expertise of industry leaders and scientists who are at the forefront of nuclear energy. I believe for this program to be successful we must include all the experts and not just a selective few.

As you may know, Oak Ridge National Lab is near my district and employs some of the brightest and most experienced scientists on nuclear technology. For years Oak Ridge has been at the forefront of developing and maintaining nuclear programs for DOE and DOD. However, to my knowledge no one from Oak Ridge was involved in the development of GNEP. To me it makes sense to have people involved that have a clear and long history of working within this field to help plan the future of the technology.

I hope today's hearing will ease some of my concerns as I believe we must act now to deal with nuclear waste and the successful expansion of nuclear energy in America.

Madame Chairwoman, thank you and I yield back the balance of my time.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Chairwoman Biggert, Ranking Member Honda, I want to thank you for organizing this very important Energy Subcommittee hearing on the Global Nuclear Energy Partnership (GNEP). While energy policy may not captivate the attention of most Americans right now, it is one of the most important and complex issues that the Nation must face in the coming years. And we will need hearings such as this to discuss our future energy policies.

In the news these days, most of what we see are stories from Iraq and Afghanistan, or the latest political scandal. The energy policies of the United States are complex and multi-faceted, and many Americans simply do not understand the gravity of the issues. I hope that the witnesses testifying today will shed some light on a very difficult issue that often falls through the cracks.

Madam Chairwoman, I have a number of concerns regarding the policies put forth in the GNEP. Not the least of my concerns is the cost of the program. Over the next decade, the Bush Administration wants to build three new uranium reprocessing facilities that will cost the taxpayers an estimated $20 to $40 billion dollars.

In this age of skyrocketing record deficits, this is not the time to take on massive new projects when we cannot get our fiscal house in order. Until we have scientific data to prove that this alternative is feasible, now may not be the time to increase the deficit even more.

Nuclear energy is a large part of our nation's energy structure. 20 percent of all the electricity generated in the U.S. comes from nuclear sources. And with nuclear energy comes a large amount of nuclear waste. With every single nuclear power plant generating about 20 tons of highly radioactive nuclear waste every year, we must find a way to deal with the waste. The Yucca Mountain waste storage facility was supposed to have been the solution 20 years ago, so we do need to plan our next steps. The GNEP program has good ideas for a starting place. But the simple fact is that the budget may not currently allow it.

Madam Chairwoman, President Bush recently announced that he will run a $423 billion deficit this year. The Congress was just forced to raise the debt ceiling once again. It now stands at $9 trillion. That means that every child born in the United States is immediately saddled with over $28,000 in debt. We are essentially giving the child a birth certificate and a credit card bill. Our energy policy is not perfect. However, until we can afford to build new facilities, we should not be spending over $20 billion without specific, clear, and informed plans.

In addition, even if we did build the small-scale reprocessing facilities, and even if they did work as they are supposed to work, there are indications that they would only process a small fraction of our nuclear waste output. In order to reduce the waste output to the level that GNEP envisions, it could easily end up costing US taxpayers over $100 billion.

The current nuclear energy policies are not sustainable. Over the next two decades, we are going to need to change the way that waste is handled, or build new storage facilities. I look forward to today's hearing to shed some light on how we can effectively move forward.

Thank you, Madam Chairwoman, and I yield the remainder of my time.

Chairwoman BIGGERT. And at this time, I would like to introduce our witnesses and thank you all for coming this morning. And going from left to right—or my left to right, Mr. Shane Johnson is the Deputy Director for Technology in the Office of Nuclear Energy, Science, and Technology at the Department of Energy, though just a few days ago, Mr. Johnson served as the Acting Director of the Office. So thank you, Shane, for agreeing to appear before us today. We do understand that three days on the job probably wasn't enough for your new Assistant Secretary, Dennis Spurgeon, to catch up on everything, but I do want to take this opportunity to congratulate Mr. Spurgeon and to brag a little. Mr. Spurgeon would be a Director rather than an Assistant Secretary if I hadn't fought hard for the elevation of that position in the Energy Bill last summer, and I think that is a—that was a much-needed change in title.

Dr. Neil Todreas is the Kepco Professor of Nuclear Engineering at the Massachusetts Institute of Technology. He is also a member of the distinguished MIT panel that wrote the 2003 report on the future of nuclear power. Welcome.

Dr. Richard Garwin is an IBM Fellow Emeritus at the Thomas J. Watson Research Center in New York and has a—has had a long and distinguished career in research, teaching, writing, and government policy on nuclear issues. Welcome.

And then Mr. David Modeen is the Vice President for Nuclear Power and the Chief Nuclear Officer of the Electric Power Research Institute and is also a nuclear engineer by training.

As the witnesses know, spoken testimony will be limited to five minutes each, after which the Members will have five minutes each to ask questions.

So we will start with Mr. Johnson. You are recognized for five minutes.

STATEMENT OF MR. R. SHANE JOHNSON, DEPUTY DIRECTOR FOR TECHNOLOGY, OFFICE OF NUCLEAR ENERGY SCIENCE AND TECHNOLOGY, DEPARTMENT OF ENERGY

Mr. JOHNSON. Chairman Biggert, Ranking Member Honda, and Members of the Subcommittee, I would like to express my thanks for the opportunity to discuss the Administration's proposed Global Nuclear Energy Partnership, or GNEP, with you this morning. I have submitted a written statement for the record but would like to provide a few summary remarks.

The Global Nuclear Energy Partnership is the nuclear energy component of the President's Advanced Energy Initiative, and it addresses the global issues of energy security, the environment, and nuclear proliferation. To support the Global Nuclear Energy Partnership, the Department has proposed $250 million in fiscal year 2007 to accelerate efforts already underway under our Advance Fuel Cycle Initiative to demonstrate technologies associated with spent nuclear fuel recycling. My testimony today focuses on the goals, schedule, and anticipated cost of the technology development component of the Global Nuclear Energy Partnership.

The President has stated a policy goal that includes worldwide expansion of nuclear energy. The reasons for this are obvious: nuclear power is the only mature technology of significant potential to provide large amounts of emission-free baseload power, resulting in cleaner air, reduced global greenhouse gas intensities, pollution abatement, and energy diversity.

To accomplish the objectives of the Global Nuclear Energy Partnership, the Department proposes to accelerate the development, demonstration, and deployment of new technologies to recycle spent fuel through the Office of Nuclear Energy's Advanced Fuel Cycle Initiative. As an initial step, the Department has requested $250 million in our fiscal year 2007 budget request.

As part of this initial step, the Department proposes to accelerate the demonstration of more proliferation-resistant recycling technologies. In concert with this, the Department will work with international partners to incorporate advanced safeguard technologies into the design and potential construction of advanced facilities. In broad outline, the technology demonstration phase consists of developing, designing, constructing, and operating an integrated set of demonstration facilities: an advanced separations technology, called Uranium Extraction Plus, or UREX+, which features a group transuranic separations process; an advanced fast burner reactor that could consume the transuranics from the spent fuel, significantly reducing the amount of nuclear waste requiring disposal; and a new fuel cycle laboratory for developing the transuranic fuels needed for the advanced reactor.

By proceeding with the demonstrations of these technologies, we will learn the practicality of closing the fuel cycle in the United States. We have had considerable success demonstrating the advanced separations technology at the laboratory scale. However, by demonstrating the closure of the fuel cycle at an engineering scale, we will be able to optimize the design of a future full-scale facility and reduce the cost and time to deploy such a facility.

The Department has established a target range of 2011 to 2015 for initial operation of the advanced separations facility, 2014 to 2019 for initial operation of the advanced test burner reactor using conventional fuels, and 2016 to 2019 for the first modules of the advanced fuel cycle laboratory.

Early preconceptual estimates of the cost to bring these facilities to the point of operation range from $4 billion to $10 billion. As the project matures, we will develop more detailed and accurate baselines of cost and schedule.

Presently, the Department's efforts are aimed at conducting the applied research, engineering, and environmental studies needed over the next two years to inform a decision in 2008 on whether to proceed to detailed design and construction of these facilities.

In fiscal year 2007, the Department would continue the applied research to refine the UREX+ technology, begin work on the conceptual design, functions, and operational requirements and other analyses leading to the development of baseline costs and schedules for these three facilities.

The Department would also propose to invest in the development of the advanced burner reactor technology, initiate conceptual design studies, and start a series of extensive studies again, to establish cost and schedule baselines for the advanced burner reactor.

To guide this effort, the Office of Nuclear Energy has instituted a multi-laboratory process to develop the detailed program plan that will lay out the scope of work for the next five years. This plan will establish the milestones and work to be accomplished and establish the research priorities for the next five years, subject to appropriations. This plan is expected to be completed in May 2006.

The integration of basic research and simulation in the Global Nuclear Energy Partnership is a key priority for the Department. The Department organized a workshop on simulation for the nuclear industry at our Lawrence Livermore National Lab, and the Office of Science will lead a program of basic science workshops this summer. The results from these workshops will help guide our long-term R&D agenda for closing the fuel cycle.

We are in a much stronger position to shape the future if we are part of it.

In closing, this is an ambitious plan, and the technology demonstrations will be a key challenge for the United States and our partner countries. But it is an endeavor, if successful, that can ensure that nuclear energy is available, safe, and secure for generations to come. We seek the advice and support of this Committee and of the Congress, and I look forward to answering your questions.

[The prepared statement of Mr. Johnson follows:]

PREPARED STATEMENT OF R. SHANE JOHNSON

Chairman Biggert, Ranking Member Honda, and Members of the Committee, it is an honor for me to be here today before the House Science Subcommittee on Energy to discuss the Administration's proposed Global Nuclear Energy Partnership or GNEP. GNEP is the nuclear energy component of the President's Advanced Energy

Initiative and it addresses the global issues of energy security, the environment, and nuclear proliferation. To support GNEP, the Department has proposed $250 million in fiscal year 2007 to accelerate efforts under the Advanced Fuel Cycle Initiative (AFCI) to demonstrate technologies associated with spent nuclear fuel recycling. My testimony today focuses on the goals, schedule and anticipated costs of the technology development component of GNEP.

As you know, the President has stated a policy goal of promoting a significant expansion of nuclear power here in the United States and around the world. The reasons for this are clear—total world energy demand will double by 2050 and over the next twenty years, electricity demand alone will increase 75 percent over current levels. The safety and performance record of nuclear energy in the U.S. has been outstanding. It is a proven technology that can deliver large quantities of electricity that will be needed in the future, reliably, predictably, affordably and without producing harmful air emissions.

Building on the efforts of the Administration and because of Congress efforts in passing the *Energy Policy Act of 2005,* we are confident that there will be new plants built in the U.S. over the next 10 years. With more than 130 new nuclear plants under construction, planned or under consideration world-wide, many countries around the world are clearly moving forward with new nuclear plants.

As such, it is important for our own future that nuclear energy expands in a way that is safe and secure, in a way that will not result in nuclear materials or technologies used for non-peaceful purposes. But significant growth will not be possible unless we effectively address the fuel cycle and spent fuel management.

The U.S. operates a once-through fuel cycle, meaning that the fuel is used once and then disposed of without further processing. In the 1970's, the U.S. stopped the old form of reprocessing, principally because it could be used to produce separated quantities of plutonium, a nuclear proliferation concern. But the rest of the nuclear economies—France, Japan, Great Britain, Russia and others operate closed fuel cycles, in which spent fuel is processed and the plutonium and uranium are recovered from the spent fuel to be recycled back through reactors. As a result, the world today has a buildup of nearly 250 metric tons of separated civilian plutonium. The world also has vast amounts of spent fuel and we risk the continued spread of fuel cycle technologies. Furthermore, recent years have seen the unchecked spread of enrichment technology around the world.

Opening Yucca Mountain remains a key priority of the Administration and is a necessity. We are committed to beginning operations at Yucca Mountain as soon as possible so we can begin to fulfill our obligation to dispose of the approximate 55,000 metric tons already generated and approximate 2,000 metric tons being generated annually. Whether we recycle or not we must have Yucca Mountain open as soon as possible. However, the statutory capacity of Yucca Mountain will be oversubscribed by 2010 and without GNEP simply maintaining existing nuclear generating capacity would require additional repositories in the U.S.

GNEP seeks to address the challenges of the expansion of nuclear power and limiting proliferation risk by developing technologies that can recycle the spent nuclear fuel from light water reactors in a more proliferation-resistant manner. In addition, GNEP supports a reordering of the global nuclear enterprise to encourage leasing of fuel from what we call fuel cycle states in a way that presents strong commercial incentives against new states building their own enrichment and reprocessing capabilities. For the U.S., transition to a closed fuel cycle would enable more efficient use of our nuclear fuel resources, would significantly reduce the nuclear waste that requires disposal in a geologic repository and would assure sufficient repository capacity through the end of the century.

To accomplish these objectives, the Department proposes to accelerate the development, demonstration, and deployment of new technologies to recycle spent fuel through the Office of Nuclear Energy's AFCI program. These are technologies that would not result in separated plutonium—a key proliferation concern presented by current generation reprocessing technologies. Moreover, these technologies would be deployed in partnership with other fuel supplier nations. As an initial step, the Department has requested $250 million in FY 2007.

By proceeding with the demonstrations of the separations, fuels and reactor technologies, we will learn the practicality of closing the fuel cycle in the U.S. We have had considerable success demonstrating the advanced separations technology, in particular, at the "laboratory scale." However, by demonstrating a closed fuel cycle at an "engineering scale," will enable us to optimize the design of a full-scale facility and reduce costs and time to deploy a full-scale facility. This will give us the information we need to design and deploy full-scale recycling facilities by the time they are needed decades from now.

The U.S. would propose to work with international partners to conduct an engineering-scale demonstration of advanced separations technologies (e.g., a process called Uranium Extraction Plus or UREX+) that would separate the usable components in used commercial fuel from its waste components, without separating pure plutonium from other transuranic elements.

In addition, the Department would propose to demonstrate the ability to consume transuranic elements separated from the spent nuclear fuel in a fast reactor called the Advanced Burner Test Reactor (ABTR). In conjunction with this, DOE would propose an Advanced Fuel Cycle Facility (AFCF) to fabricate and test the actinide based fuels for the demonstration test reactor.

The Department has established a target of 2011 for initial operation of the advanced separations demonstration facility, 2014 for initial operation of the Advanced Burner Test Reactor using conventional fuels, and 2016 for the first modules of an AFCF. The first mission of the AFCF would be to produce actinide-based fuels for the ABTR.

Early, pre-conceptual estimates of the ten-year cost to bring the engineering scale facilities to the point of initial operation range from $4 billion to $9 billion. As the project matures, we will develop more detailed and accurate baseline of cost and schedule estimates. The experience with the engineering scale demonstrations will inform the design, cost estimates and schedule for building full-scale recycling facilities. More accurate estimates of the demonstration phase will be available as the conceptual and preliminary design phases are completed.

The GNEP technology demonstration program is a phased program. Each phase would begin after a well defined decision on the results of the previous phase and an assessment of the risks associated with proceeding to the next phase. DOE would only proceed to detailed design and construction of these engineering scale demonstrations after the Department is confident that the cost and schedules are understood and after we have put in place the project management framework that will allow these projects to succeed. Presently, the Department's efforts are aimed at conducting the applied research, engineering and environmental studies needed over the next two years to inform a decision in 2008 on whether to proceed to detailed design and construction of the engineering scale demonstration facilities. The $250 million requested in FY 2007 is the Department's best assessment of the funding required for GNEP program technical development priorities and sequencing toward demonstration facilities.

This week, the Department approved the mission need for the demonstration facilities. The Department also issued an advance notice of intent, announcing plans to prepare an environmental impact statement for the GNEP technology demonstration program. The EIS effort is anticipated to be completed over the next two years. Also last month, the Department announced that it is seeking expressions of interest from the public and private sectors for hosting advanced recycling demonstration facilities and related activities. The Department anticipates issuing a Request for Proposals after consideration of the comments received and would anticipate contract awards for site evaluation studies later this year.

In FY 2006 and FY 2007, the Department would continue the applied research to refine the UREX+ technology, begin work on a conceptual design, acquisition strategy, functions and operating requirements and other analyses leading to the development of baseline costs and schedules for the UREX+ demonstration, the advanced burner test reactor, and the advanced fuel cycle facility by 2008. The Department would also propose to invest $25 million in FY 2007 on the advanced burner reactor technology, to initiate conceptual design studies and a series of extensive studies to establish cost and schedule baselines and determine the scope, safety, and health risks associated with fuel design, siting and acquisition options.

To guide this effort, the Office of Nuclear Energy has instituted a multi-lab process to develop a program plan and a five-year technology plan. The effort involves nine national laboratories. The overall effort also involves several program secretarial offices, including the National Nuclear Security Administration. For example, NNSA will provide key assistance in assuring that safeguards approaches and technologies are incorporated into the demonstration facilities early in the planning for the facilities.

The five-year technology plan will establish the milestones, the work to be accomplished and establish applied research priorities over the next five years, subject to appropriations. The technology plan is anticipated to be completed by the end of May 2006. Execution would extend from the Department down to the multi-lab teams.

In addition, while DOE currently sponsors university research grants through the Nuclear Energy Research Initiative, universities will be engaged through an embedded research and development program. Industry will also be engaged as the program progresses through the design process to provide specific expertise.

Demonstration of the key technologies demands that DOE carry out a variety of research; ranging from technology development for those processes initially identified (equipment, waste forms) to longer-term research and development on alternatives (equipment, processes) for risk reduction. In addition, the Office of Science is initiating a program of basic science in support of nuclear technology with three technical workshops in July 2006. Although not specific to GNEP, the results of this activity will help guide the long-term R&D agenda for closing the fuel cycle.

Furthermore, simulation is expected to play an important role in the development of this program. DOE organized a workshop on simulation for the nuclear industry at Lawrence Livermore National Laboratory which was chaired by Argonne's Lab Director, Dr. Robert Rosner, and Dr. William Martin from the University of Michigan. We expect to see a greater role for simulation as a result, supported by both the Office of Science and the Office of Nuclear Energy.

Systems analysis forms an important part of the ongoing AFCI program and will have an increased role during the next two years. The systems analysis will investigate several key issues. One such issue is the required rate of introduction of burner reactors and separations facilities to avoid a second repository this century. Another would be a detailed study of the technical requirements for the facilities and how they relate to the top level goals of the program. The results of these analyses are essential to establishing the basis for each key decision in the accelerated AFCI program and will have a profound effect on GNEP program planning.

In closing, the U.S. can continue down the same path that we have been on for the last thirty years or we can lead a transformation to a new, safer, and more secure approach to nuclear energy, an approach that brings the benefits of nuclear energy to the world while reducing vulnerabilities from proliferation and nuclear waste. We are in a much stronger position to shape the nuclear future if we are part of it. This is an ambitious plan and the technology demonstrations will be a key challenge for U.S. and our partner nations. But it is an endeavor, which if successful, can ensure that nuclear energy is available, safe and secure for generations to come. We seek the advice and support of this committee and of Congress and I look forward to answering your questions.

BIOGRAPHY FOR R. SHANE JOHNSON

Shane Johnson is the Deputy Director for Technology within DOE's Office of Nuclear Energy. Since 2004, Mr. Johnson as served as Deputy Director for Technology, responsible for the Department's nuclear energy research and support to U.S. nuclear engineering programs. Mr. Johnson served as Acting Director for the Office of Nuclear Energy, Science and Technology between May 2005 and March 2006.

For the last six years, Mr. Johnson has led the Office's nuclear technology initiatives, serving a key leadership role in the initiation and management of all of the Office's major research and development initiatives, including the Generation IV nuclear systems initiative, the Advanced Fuel Cycle Initiative, and the Nuclear Hydrogen Initiative.

Mr. Johnson serves a central role in the Department's efforts to reassert U.S. leadership in nuclear technology development. He is the senior principal in NE responsible for the recently announced Global Nuclear Energy Partnership. He also led the formation of the Generation IV International Forum (GIF), an international collective of ten leading nations and the European Union's Euratom, dedicated to developing advanced reactor and fuel cycle technologies. He leads the Office's international cooperation activities, including establishment of cooperative research agreements with other countries and the development by the GIF of the Generation IV technology roadmap, which resulted in the selection of six promising reactor and fuel cycle technologies by the GIF for future development efforts. Mr. Johnson currently serves as the U.S. representative to the GIF policy committee.

Mr. Johnson has over twenty years of relevant management and engineering experience within the Government and industry. During his career with NE, he has had direct management responsibility for all of the NE programs, including nuclear and research facilities. Prior to joining DOE, Mr. Johnson was employed for five years by Duke Power Company and Stoner Associates, Inc. where he was responsible for performing engineering studies for nuclear, natural gas, and water utilities.

Mr. Johnson received his B.S. degree in Nuclear Engineering from North Carolina State University and his M.S. degree in Mechanical Engineering from Pennsylvania State University. He is a licensed professional engineer.

Chairwoman BIGGERT. Thank you very much.

I would just like to interrupt a moment to extend a warm welcome to our colleague from California, Mr. Rohrabacher, who I know is very interested in this issue. And I would ask unanimous consent that he would be allowed to sit with the Subcommittee and participate in today's hearing. Without objection, so ordered.

Dr. Todreas, you are recognized for five minutes.

STATEMENT OF DR. NEIL E. TODREAS, KEPCO PROFESSOR OF NUCLEAR ENGINEERING; PROFESSOR OF MECHANICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. TODREAS. Thank you, Madame Chairwoman and Members of the Committee.

It is an honor to appear before you to discuss GNEP. The program offers a strategic vision for expanded use of nuclear energy in the world and in the United States. Its achievement of its goals, as a long-term objective, is highly desirable.

However, my concerns deal with the apparent schedule of rapid implementation of GNEP program elements, a schedule which implies near-term choice and deployment. And here, I am not speaking of R&D. I am making a distinction of R&D with choices on reprocessing technologies, fast reactor fuel, fast reactor design characteristics, and associated reactor demonstration facilities. These near-term choices are not necessary since alternate approaches are sufficient for spent fuel and proliferation management over the time period before GNEP could provide an effect. Rapid implementation of choices is unwise since it threatens the successful execution of a GNEP program. By successful program execution, I mean effective integration and coordination of program elements, expenditures which are both reasonable and sustainable, protection of the public as well as worker health and safety, facilities with adequate and demonstrable physical protection, and an expanding nuclear deployment with adequate proliferation safeguards.

My focus this morning, and in my written statement, was on the formulation and timing of the R&D program. I speak on GNEP from limited literature materials. I must say the depth of detail provided by DOE on GNEP through these sources is technically very meager.

I framed my views in the written statement and this morning, as I talk, on the key facilities for GNEP, particularly their missions and their time scales. It is these deployment schedules which shape the allowed depth and breadth of the R&D associated with each facility.

First is the simulation and visualization lab.

Simulation and visualization are properly the initial step underlying all subsequent selections among process, fabrication, and reactor design choices. It is here the R&D data are used to formulate and/or validate predictive models for such selections. Our MIT study highlighted the lack of such a capability in the Nation's nuclear program and recommended that among 11 program elements we proposed, it received the largest R&D expenditure, that of $100 million per year over 10 years. I applaud the launching and the plan for this.

The Engineering Scale Demonstration is next to be operable in 2011. It is here the process for separation of uranium and short-lived fission products from the transuranics and the long-lived fission products is to be demonstrated. The selection of the separation process is the first critical step. As has been mentioned, UREX+1, or perhaps UREX+1A, I haven't been able to figure that out yet, has been selected at a capacity of 100 to 200 tons per year. The important question is whether there is a satisfactory basis for this selection for scale-up from the laboratory to pilot plant since it is an important and large expenditure. The criteria against which these questions must be answered are process economics, safety, materials accountability, and physical protection. Some demonstration above the laboratory scale must be made, but it shouldn't be premature, because it locks GNEP into a critical, likely irreversible, plan.

I have comments on each of the facilities. We can discuss these, if you want. I will move toward a conclusion.

By the facilities, I mean the test reactor, the advanced burner reactor, and the fuel cycle—advanced fuel cycle facility, as well as, actually, small-scale reactors. Those four are additional critical facilities.

I wanted to close, though, with pointing out to you that while the partnership is very technically-intensive and long-term, its execution and the probability of the success will depend heavily on the technical strengths of the new generation of nuclear professionals recruited to its ranks.

The U.S. academic community today lacks depth in its faculty in reprocessing technology and in reactor design. So it is unfortunate in two aspects that the existing AFCI fellowship program in the new budget proposed has been cut in half and also that the Department terminated the broader, all-encompassing university research fuel and assistance support program, which is the primary vehicle for supporting the infrastructure of the nuclear engineering academic community.

In summary, GNEP is worthy of pursuit, however, there are serious decisions about its possible and optimum pace to be resolved, which involve technical readiness, facility processes and scale selection, and the consequences of redirecting most of the available funding for nuclear energy to this program.

Thank you.

[The prepared statement of Dr. Todreas follows:]

PREPARED STATEMENT OF NEIL E. TODREAS

Madam Chairwoman and Members of the Committee:

It is an honor to be called before you to discuss the subject of the Global Nuclear Energy Partnership, a matter of considerable importance to the future of nuclear energy as well as to the effort to prevent the further spread of nuclear weapons.[1]

The GNEP program offers a strategic vision for the expanded use of nuclear energy in the U.S. and the world. Its goals are to ease the long-term management of spent fuel by destroying the transuranic (TRU) elements that contribute most to the long-term radiological risk and to reduce proliferation risk by creating a fuel cycle supplier and user state regime. This will enable other nations, including developing nations, to acquire/expand nuclear energy while minimizing proliferation risk. Achievement of these goals as a long-term objective is highly desirable.

[1] Previous hearings of this subcommittee reviewed the security and economic aspects of reprocessing, a key element of the GNEP vision.

However, my concerns deal with the apparent schedule of rapid implementation of the GNEP program elements—a schedule which implies near-term choice and deployment of reprocessing technologies, fast reactor fuel, fast reactor design characteristics as well as associated reactor demonstration facilities. These near-term choices are not necessary since alternate approaches are sufficient for spent fuel and proliferation management over the time period before GNEP could provide an effect. Rapid implementation of choices is unwise since it threatens the successful execution of a GNEP program. By successful program execution I mean effective integration and coordination of the program elements, expenditures which are both reasonable and sustainable considering program benefits, protection of public as well as worker health and safety, facilities with adequate and demonstrable physical protection and an expanding nuclear deployment with adequate proliferation safeguards.

My focus this morning will be on the formulation and timing of the R&D program underlying such a successful GNEP program execution. The broader questions of the alternate approaches to deal with GNEP goals in the next several decades as well as GNEP's potential detrimental effect on nearer-term nuclear priorities such as achievement of the Nuclear Power 2010 program I'll set aside for industry representatives and your later questions.

I speak on the GNEP program based on the limited open literature materials I have found (Appendix A). As a member of the general nuclear community, I have not been briefed on GNEP; as a member of NERAC, I have had access to only a very general DOE briefing and the recent report of our relevant Subcommittee. In sum, I must say the depth of detail on GNEP provided by DOE through these sources is technically very meager.

I will frame my views through comment on the key facilities of GNEP and particularly their missions and timelines. (Appendix B) It is these deployment schedules which shape the allowed breadth and depth of the R&D associated with each facility. I have found no information on the projected costs of these facilities. This is not unreasonable since the process selection and designs of these facilities are likely in their infancy—a situation I respect but which reflects the significant R&D challenge ahead.

From the GNEP website, the first facility to be operational is the Simulation & Visualization Laboratory. Simulation and Visualization are properly the initial step underlying all subsequent selections among process, fabrication and reactor design choices. It is here that R&D data are used to formulate and/or validate predictive models for such selections. Our MIT Study on the Future of Nuclear Power (7/03) highlighted the lack of such capability in our nuclear program and recommended that it receive the largest sustained R&D expenditure ($100M/year over 10 years) among the eleven program elements we proposed.

The Engineering Scale Demonstration (ESD) is the next facility to be operational, in 2011. Here the process for separating uranium and short-lived fission products from the transuranics and longer-lived fission products is to be demonstrated at an engineering significant scale. The transuranics are to be supplied to the next facility, the Advanced Fuel Cycle Facility (AFCF), for conversion and fabrication into fast reactor fuel.[2] The selection of the ESD separation process is the first critical fuel cycle step of GNEP. The UREX+1 process and its capacity at 100–200 tons per year have been selected. This capacity is about four to eight percent of the anticipated full-scale need for our LWR fleet. The important question is whether there exists satisfactory basis for this selection process for scale-up from the laboratory to a pilot plant. The criteria against which these questions must be answered are process economics, safety, materials accountability and physical protection. I have not been privy to the evidence which supports the current GNEP selections. Some demonstration above laboratory scale must be made—it must not be made prematurely because it locks GNEP into a critical, likely irreversible path.

The Advanced Burner Test Reactor (ABTR) is next operational in 2014. Nuclear fuel, because of the long lead time needed for irradiation testing, is always the critical path item in reactor development. For transmutation in TRU fueled elements such testing is essential, hence the need for a test reactor. Limited testing capability exists in Japanese, Russian, Indian and—for a very limited future period—French reactors, which I presume is being arranged. The U.S. facility, the FFTF, is now unavailable—is it irretrievably lost to us? I support the need for a U.S. fast spectrum test reactor as part of a robust R&D program. Timing dictates it be sodium cooled and, likely at least initially, oxide fueled. Since Advanced Burner Reactors of similar design may follow, the construction and safety standards as well as the regulatory review process developed for this test reactor can be tailored to set prece-

[2] Lanthanide fission products are likely extracted in the TAL SPEAK process before TRU conversion and fabrication into fuel elements.

dent and practice for this follow-on fleet. This was the practice followed in the execution of the FFTF project. While costly to the test reactor schedule, such a practice significantly enhances the progress of deployment of any follow-on power reactor fleet. A 2014 operational target date is most aggressive but the goal can be reached in the 2010s decade.

The Advanced Fuel Cycle Facility (AFCF) is envisioned as a multi module facility first operational in 2016. It will have modules to perform production scale

1) separations operations on spent LWR fuel,
2) remote fabrication of TRU-bearing fuel for Advanced Burner Reactors,
3) spent fast reactor fuel processing,
4) waste and storage form development,
5) advanced separations process development.

This is the mainstay facility for execution of the closed fuel cycle. It is critical that the fast reactor fuel selected allow achievement of both the desired fast reactor performance characteristics and the needed processing and fabrication characteristics. The economics, safety, materials accountability and physical protection of the GNEP closed cycle must be reasonably assured through simulation and visualization based on firm R&D results before construction of such a facility is undertaken. The announced schedule of achievement of operational modules for these three functions between 2016 and 2019 is highly optimistic.

The deployment of Advanced Burner Reactors (ABR) for TRU management then follows beginning in 2023. These fast reactors are likely to be sodium cooled, although gas and liquid lead cooled designs are possible. This selection was one of the goals of the Generation IV down-select process which the current level of research activity does not support. ABRs will be electricity producers owned and operated by industry along with the thermal LWRs needed to achieve expected nuclear power demand. Significant deployment of ABRs will be needed to measurably impact TRU management. It is therefore essential that these ABRs produce electricity at cost competitive with the LWRs. Given that the fuel cycle is likely to be more expensive than the existing once-through cycle and when last built in the 1990s sodium fast reactors were 1.2 to 1.5 times the capital cost of LWRs, this prospect is daunting. To achieve cost competitiveness a major R&D effort on cost efficient fast reactor innovations is essential. Its success is far from assured. The proposed timeframe of ABR deployment in 2023 is most unlikely considering the time needed to select and test its fuel, develop its reprocessing technology, make its design cost effective and, importantly, effectively engage industry as the owners and operators of the subsequent ABR fleet.

It is also not obvious why, at least for a transition period of multiple decades, a two-tier strategy is not envisioned to allow a fast reactor concept to be designed and tested. One such strategy would recycle the plutonium plus the other actinides in fertile free pins which comprise a fraction of a LWR core. Although final passes in a fast spectrum are likely needed because of curium buildup in a thermal spectrum, thermal recycling has been determined to destroy significant quantities of TRU. The benefit of this scheme is the existing availability of operating LWRs to do this transmutation function.

The final facilities in GNEP are Small-Scale Reactors for developing economies for which fresh fuel would be provided and spent fuel returned to the supplier states. The small scale is not necessitated by the fuel cycle but rather the electrical grid and capital structure of the developing economy. Such a supply and spent fuel return arrangement would provide adequate proliferation safeguards in an era of worldwide expansion of nuclear technology. It is, however, by no means certain that the capital and fuel cycle costs of these small-scale reactors would yield an attractive cost of electricity (COE) for these economies. Considerable R&D needs to be supported by DOE to refine such designs to a level where realistic COE can be projected and proliferation resistant effectiveness assessed especially if fast spectrum design options are to be considered. There are, however, some innovative LWR designs already existing and pebble bed reactors being developed in South Africa and China that offer considerable advances in reactor safety features which bode well for introduction of nuclear power into technically unsophisticated nuclear economies, if competitive COE can be achieved.

Two important topics remain—first, the proliferation dangers of diffusion of reprocessing technology and second, the readiness of the U.S. educational infrastructure to sustain the GNEP. The first involves the proposition that these dangers are so serious that all work should be avoided, especially since the practical need for deployment of reprocessing is so distant. The alternate view is that U.S. R&D is necessary to maintain U.S. credibility and influence in international affairs.

Quoting from a working paper of the MIT Study (Deutch, 2/03), "There are basically three costs of the U.S. not supporting separation technology going forward. First, and most importantly, we will lack the technical knowledge to be credible and influential in the evolution of commercial nuclear power. Second, we will not acquire the knowledge necessary to develop effective safeguards for operating reprocessing facilities in other nations. Third, we will not acquire the knowledge to permit us to make timely and informed judgments about long-term options for closed nuclear fuel cycles that may be of importance in future generations." These costs dictate that we pursue such R&D.

In closing, let me remind you that this Partnership is a very technically intensive and long-term undertaking. Its execution and certainly its probability of success will depend heavily on the technical strength of the new generation of nuclear professionals recruited to its ranks. The U.S. nuclear academic community today lacks depth in faculty skilled in recycling and particularly reprocessing as well as fast reactor analysis and design technology. Consequently, the stream of graduates in these areas is very small. The Department's AFCI program has started an education assistance initiative which I presume will be subsumed by a GNEP program although it has been proposed to be halved by DOE for FY 2007. However, these very limited actions need the existence of the broader program of Department nuclear education support to build and sustain the infrastructure necessary for the success of these limited, targeted AFCI/GNEP fellowship programs. University administrators look to government and industry support of such programs for indication that the nuclear renaissance is real. It is ironic and self-defeating that, coincident with the launching of GNEP, the Department has proposed termination of its University Reactor Fuel Assistance and Support Program, which is a primary vehicle for supporting nuclear engineering graduate students and university faculty research.

In summary, GNEP is worthy of pursuit; however, there are serious decisions about its possible and optimum pace to be resolved which involve technical readiness, facility processes and scale, and the consequences of redirecting essentially most of the available funding for nuclear energy to this effort.

Appendix A

Sources Consulted

1. DOE websites
   www.gnep.gov or
   www.gnep.energy.gov
2. Advanced Fuel Cycle Initiative, FY 2007 Congressional Budget Request
3. Statement of Clay Sell to FY 2007 Appropriations Hearing on the Global Nuclear Energy Partnership, March 2006
4. GNEP Presentation to Nuclear Energy Research Advisory Committee (NERAC) on February 22, 2006 by R. Shane Johnson, Acting Director, Office of Nuclear Energy, Science and Technology, U.S. DOE
5. Presentation on March 10, 2006 by Phillip Finck, Argonne National Laboratory, "The Benefits of the Closed Nuclear Fuel Cycle"
6. EPRI–INL, Nuclear Energy Development Agenda, January 4, 2006
7. Report of NERAC's ANTT Subcommittee of March 22, 2006 transmitted to NERAC for review.

Appendix B

GNEP Facilities*

Facility	Mission	Schedule
Advanced Simulation Laboratory	Computer simulations and visualizations in support of the design of facilities and processes	Operational by 2008
Engineering Scale Demonstration (ESD)	• "Large scale" demonstration of UREX+1 separation process (100 to 500 MT/yr) sized to provide insights for designing a 2500 MT per year facility in the next 15-20 years • Provide "required" TRU* for ABR fuel (assumes deployment of commercial-scale ABRs will start in 2022 – 4 module units with each module 840 MWt (320 MWe)	Operational by 2011.
Advanced Burner Test Reactor (ABTR)	Burner demonstration reactor for: • TRU-bearing fuel multi-cycle demonstration • ABR licensing • ABR TRU-bearing fuel qualification.	Operational by 2014.
Advanced Fuel Cycle Facility (AFCF)	Four-module facility to develop and demonstrate advanced fuel cycle technologies at engineering scale • Remote TRU-bearing transmutation fuel fabrication (rod and subassembly scale; ≤8 LTA/yr) • Integrated aqueous separation process development and demonstration using LWR spent nuclear fuel (≤25 MT/yr) • Integrated dry process development and demonstration using fast reactor spent fuel (≤1 MT/yr) • Advanced safeguards instrumentation for materials protection, control, and accountability, and advanced control and monitoring systems.	Facility operational by 2016 (first module) Fuel fabrication module: 2016 Aqueous separation processing module: 2017 Pyroprocessing module: 2019
Advanced Burner Reactors (ABR)	Reactors for actinide treatment and Pu burn up.	Wide-scale deployment of 4-module plants (each module 840 MWt/320 MWe) beginning in 2023.
Small-Scale Reactors	To be made available to emerging economies for safely expanding nuclear energy without increasing proliferation concerns.	Deploy demonstration plants in parallel with advanced fuel cycle demonstrations.

*Adapted from NERAC ANTT Subcommittee report and GNEP website

BIOGRAPHY FOR NEIL E. TODREAS

Dr. Neil Todreas is the Korea Electric Power Corp. Professor of Nuclear Engineering and a Professor of Mechanical Engineering at the Massachusetts Institute of Technology. He has served at MIT for 34 years, including an eight-year period from 1981–1989 as the Nuclear Engineering Department Head. From 1975 to 2003, was a co-director of the MIT Nuclear Power Reactor Safety summer course,. He holds Bachelor and Master of Mechanical Engineering degrees from Cornell and the Sc.D. in Nuclear Engineering from MIT. His area of technical expertise is thermal and hydraulic aspects of nuclear reactor engineering and safety analysis.

He has an extensive record of service for government (Department of Energy—DOE, U.S. Nuclear Regulatory Commission—USNRC, and national laboratories), utility industry review committees, and international scientific review groups. Dr. Todreas started his professional career with nine years of service with the U.S. Atomic Energy Commission, four years initially with Naval Reactors and a subsequent five years with Civilian Reactor Development. He is a member of the National Academy of Engineering and a fellow of the American Nuclear Society (ANS) and the American Society of Mechanical Engineers (ASME).

His current service is as a member of the National Accreditation Board of INPO, the DOE Nuclear Energy Research Advisory Committee, and the CEA Nuclear Energy Division Scientific Committee.

HONOR & AWARDS

Effective Teaching Award, MIT Graduate Student Council—1975

Outstanding Professor Award, Nuclear Engineering Department—1976, 1980

Fellow, American Nuclear Society—1981

Fellow, American Society of Mechanical Engineers—1983

American Nuclear Society Best Paper Award, Thermal-Hydraulic Div.—1987

National Heat Transfer Conference Best Paper Award—1987

Member, National Academy of Engineering—1988

Chair, Korea Electric Power Corp. Professor of Nuclear Engineering—1992

American Nuclear Society Technical Achievement Award, Thermal-Hydraulic Division—1994

MIT School of Engineering Ruth & Joel Spira Award for Distinguished Teaching—1995

American Nuclear Society Arthur Holly Compton Award—1995

Inaugural Lecture, Distinguished Lecture Series of the Department of Mechanical & Nuclear Engineering, Pennsylvania State University—2001

Inaugural Lecture, O'Hanian Engineering Lecture Series, University of Florida—2002

Henry DeWolf Smyth Nuclear Statesman Award—2005

PUBLICATIONS

Professor Todreas has made important contributions in the areas of reactor heat transfer and fluid flow. He has written or been co-author of more than 190 publications, a two-volume textbook published in 1990, which is widely used internationally for the study of reactor thermal analysis and a reference book on safety features of light water reactors.

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April 3, 2006

Representative Judy Biggert
Chairwoman, Energy Subcommittee
House Committee on Science
Suite 2320, Rayburn House Office Building
Washington DC, 20515-6301

Dear Representative Biggert:

I am to testify at your invitation at the April 6, 2006 hearing on *R&D Priorities in the Global Nuclear Energy Partnership*. This letter provides you with a record of financial disclosure according to the Rules of the House of Representatives for testimony at your Subcommittee's hearing.

My current federal funding contracts and obligation are provided in the following list. These awards are the result of peer-reviewed Nuclear Energy Research Initiative (NERI) competition. They deal respectively with Small-Scale Reactors and Fast Reactors, which are elements in the GNEP program plan:

Federal Sponsor	**Period**	**Amount**	**Remarks**
Department of Energy – Office of Nuclear Energy	8/20/99-1/15/03	$290,000	DE-FG03-99SF21954*
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*"The Secure Transportable Autonomous Light Water Reactor-Star-LW"
**"Flexible Conversion Ratio Fast Reactor Systems Evaluation"

Please let me know if you require any further information regarding these federally funded contracts.

Sincerely yours,

Neil E. Todreas
KEPCO Professor of Nuclear Science and Engineering
and Professor of Mechanical Engineering (emeritus)

NET:rs

Chairwoman BIGGERT. Thank you, Doctor.

And now, Dr. Garwin, you are recognized for five minutes. Could you make sure your mike is on?

STATEMENT OF DR. RICHARD L. GARWIN, IBM FELLOW EMERITUS, THOMAS J. WATSON RESEARCH CENTER, YORKTOWN HEIGHTS, NY

Dr. GARWIN. Thank you. I have provided some visual aids to help me keep on track.

So I am speaking on my own. Affiliation is given for identification only.

The U.S. nuclear power plants, 103 of them, provide almost 20 percent of U.S. electricity, and we want to see that expanded in the future. So first, the requirement for GNEP is that it do no harm to this industrial base and its future expansion.

Now GNEP includes the provision of reactor fuel to international partners and take-back of spent fuel for disposal. This is a policy matter, not so much a technical matter. We need to create an international system. This is not just going to be bilateral.

Reprocessing can extend uranium resource for light water reactors by 20 percent at most and at a cost that is very high, $130 to $1,000 per kilogram of uranium saved. The DOE purpose in reprocessing is primarily to save the repository resource. But at what cost and risk? How much does it cost to save compared with expanding the repository, as we will see?

Yucca Mountain can be extended and replicated. Dry cask storage is cheap and safe for 50 to 100 years, so there is really no hurry to move on reprocessing, if we do it at all.

GNEP doesn't propose reprocessing and recycle into light water reactors, and for good reason. This was really a failed bet on the part of the Japanese, French, and British. The price of uranium did not rise, so it has cost them a lot of money and immobilized a lot of radioactivity that would otherwise be sitting pretty harmlessly in spent fuel.

The once-through U.S. fuel cycle is far more proliferation resistant than is the proposed UREX+ reprocessing. For example, to obtain 10 kilograms of plutonium to make a bomb, you must steal and reprocess 1,000 kilograms of self-protecting spent fuel. With UREX+, you steal 11 kilograms of separated plutonium plus some other transuranics.

GNEP's proposed UREX+ separation for LWR fuel and burning in fast neutron advanced burner reactors is far more costly than enhancing repository space. Yucca Mountain is estimated at 200,000 tons technically, and there is a proposal to expand it halfway there. The cost that—the charge from DOE is 1 mil per kilowatt hour. Eminently affordable, reprocessing and burning is going to be at least five times that much.

Refining the GNEP program without the promised systems analysis tool is like driving without a map. Such a tool would show that the $155 million first year UREX+ program is misguided. UREX is not significantly better than PUREX when conducted in the United States or other nuclear weapon state.

The advanced burner reactor fuel reprocessing needs to be 99-plus percent efficient, not the LWR reprocessing that is done just once. So the goals for UREX+ for reprocessing light water reactor fuel are set technically too high. We don't need them. We could approach them gradually.

The ABRs, at least 30 percent of the light water reactors, will need to be government-operated or heavily subsidized. With this heavy subsidy, it is important to know how much it is going to be and for how long. It is very important to have the ABR, its fuel form, its fuel reprocessing all decided together with an extended design competition that should justifiably take decades in order to minimize the subsidy that would be required and to find out how much it is.

Well, what should we do? Lift the arbitrary cap on Yucca Mountain, commit to dry cask interim storage, take the lead in creating an international system for a short supply of LEU reactor fuel and assured disposal, lead in the institutional design to encourage commercial competitive mined geologic repositories that would be certified by the IAEA to accept IAEA certified spent fuel and waste forms, and we should outsource to repositories elsewhere, not just in the United States.

And finally, the United States Government should fund worldwide evaluation of resource versus cost of currently uneconomic terrestrial and seawater uranium resources. Are there 170 million tons of terrestrial uranium up to $260 per kilogram? Can we obtain 2,000 million tons of uranium from seawater at $300 or $1,000 per kilogram? If we are talking about reprocessing and saving uranium at $1,000 per kilogram, we ought to know the alternatives. And we need, urgently, to complete and use the systems analysis tool to guide decisions, not to justify them after the fact.

Thank you. My prepared testimony, I hope, justifies these comments.

[The prepared statement of Dr. Garwin follows:]

PREPARED STATEMENT OF RICHARD L. GARWIN

I provide here a narrative form of discussion of elements of the proposed GNEP, in order that the Committee should understand better my recommendations.

Most important is to understand that 103 reactors in the United States provide some 17 percent of U.S. electricity needs now with high reliability and that dry cask storage of spent nuclear fuel from these reactors is a safe, low-cost approach to covering any further delays in the availability of the mined geologic repository at Yucca Mountain.

I begin by answering the four questions in the invitation from the Chairman.

1. How realistic are the goals, timelines and budgets being proposed under the Global Nuclear Energy Partnership (GNEP)?

Garwin Reply: The goals and timelines advanced under the major portion of GNEP are unrealistic. Such a long-term program should not be considered without consideration of the long-term budgets rather than the near-year expenditures.

2. What does the Department of Energy (DOE) need to do to develop a robust program to meet its goal of an advanced nuclear fuel cycle—one that includes both recycling and transmutation—while sufficiently addressing non-proliferation and waste management needs?

Garwin reply: DOE needs to step back from its dirigiste/gigantesque (in English, government-directed) approach in GNEP to one that more modestly and realistically addresses the primary goal—a reduction in repository requirement, while highlighting the cost of alternative approaches that include expanding Yucca Mountain, taking the initiative toward international commercial competitive mined geologic repositories, and greatly expanding the spectrum of reactors to be considered for burning the TRU waste.

3. What significant research and development (R&D) questions, both science and engineering, exist for UREX+? Sodium-cooled fast reactors? Mixed-actinide fuels? In your view, how well do the GNEP R&D priorities coincide with these research needs?

Garwin reply: GNEP R&D priorities hardly match the needs for decision—whether the burner reactors will be sodium or lead cooled, or whether they will indeed be thermal high-temperature encapsulated fuel reactors. Whether the fuel for the fast-neutron reactor will be metallic, carbide, nitride, or based on an inert matrix for one of these forms. GNEP assumes the answer and would launch us into a costly program that would surely cost more to do the job less well than would a program at a more measured pace guided by a more open process.

4. DOE is in the process of developing the tools to carry out a cradle-to-grave systems analysis of the advanced fuel cycle. What questions should that systems analysis be able to answer?

Garwin reply: The GNEP program must await either good human leadership or the promised cradle-to-grave systems analysis of the advanced fuel cycle. In particular, the questions should include:

a. Cost and availability of competitive commercial mined geologic repositories for the direct disposal option.

b. Costs and performance (including safety and nonproliferation measures) for reactors suitable for burning TRUs separated from LWR fuel.

c. The spectrum of fuels for such burner reactors, understanding that reactor type, fuel choice, and reprocessing approach are coupled, and that not only fast-neutron reactors but some thermal reactors can achieve reductions in transuranics that would expand capacity of a given repository at least several fold.

d. The benefit associated with government-funded resource estimation for amount of uranium available as a function of price. This needs to include research and demonstration on obtaining uranium from seawater, where there is at least 2000 million tons readily available, but at a price that is very uncertain. Yet the exploration of seawater uranium at costs up to $1000/kg is vital for decision-making in this field and is long overdue.

There are important points to be made beyond the answers to these specific questions.

There is wide agreement that the ABRs cannot operate economically as power producers in competition with LWRs. Yet there is no estimate of the government subsidy that would be required for private operation or the cost of government operation of these plants. All the more reason for a combined technical and economic effort to provide the least-cost solution for this vision, in competition with evaluating the straightforward approach of commissioning more mined geologic repositories.

As emphasized in my book with Georges Charpak[1] and in the September 2005 book with Charpak and Venance Journé,[2] we believe that the expansion of nuclear power can best be helped now by the United States and other nuclear states taking the lead in changing the rules to permit and encourage competitive, commercial, mined geologic repositories. These would be approved by the IAEA, and would accept only spent fuel forms and packages (and vitrified fission-product forms and packages) approved by IAEA.

Commercial firms operating the repositories would provide employment and benefits to the local communities, and rather than seeing a repository as a burden, it would be seen by many as a commercial opportunity. Russia, China, the United States, Australia, and even Sweden might be locations for such repositories.

The other urgent matter for the U.S. and other governments is to determine the cost to obtain vastly more uranium. It is essential to know whether half of the 4000 million tons of uranium in seawater can be extracted at a cost of $300/kg, as is tentatively suggested by the Redbook. Or whether the GEN–IV working group approach that leads to an estimate of 170 million tons of uranium from terrestrial deposits at an extraction price less than $260/kg is valid.

[1] Book by R.L. Garwin and G. Charpak, *"Megawatts and Megatons: The Future of Nuclear Power and Nuclear Weapons,"* University of Chicago Press, January 2003.

[2] French publication of book by G. Charpak, R.L. Garwin, and V. Journé, *"De Tchernobyl en tchernobyls,"* Odile Jacob, September 2005.

So in general I admire the goal of GNEP, but visions that ignore technical reality have often led to disasters, since they preclude more conventional and incremental approaches.

Aside from important elements such as the assured fuel supply—provision of enriched fuel and take back of spent fuel—and the supply of cartridge reactors (in competition with other nuclear supplier countries, no doubt) GNEP embodies a major vision for the United States and for the world.

THE GNEP VISION

This is to handle in the intermediate term (on the order of 100 years) the spent fuel from existing nuclear reactors by separating the plutonium and other actinides so that they can be burned in fast-neutron reactors. This is quite different from the reprocessing and recycle that has been practiced in France and that is going to take place in Japan as well, where the plutonium is fabricated into MOX fuel and burned in LWRs. This recycle in LWRs does not in any way solve the actinide problem, nor does it help with repository space, because the spent MOX fuel element has at least four times the long-term heat output of a spent UOX fuel element, and so does not diminish the repository space required. Reprocessing as practiced in France, Britain, and about to begin in Japan has been a costly way to delay putting spent fuel into the repository that all agree is necessary; far cheaper would have been the straightforward approach of dry cask storage for whatever delay was desired.

The GNEP vision, however, would have most of the fission products extracted from the spent LWR fuel, together with most of the uranium, so that a fuel form that might be 15–20 percent actinides mixed with some of the initial uranium would provide fuel for a generation of fast-neutron Advanced Burner Reactors—ABRs, which are essentially breeder reactors without the uranium "blanket." All of the actinides can be fissioned with fast neutrons, so they do not accumulate to the extent that curium does, for instance, in multiple recycle into LWRs. However, since one obtains only about 25 percent burnup of fuel in a fast reactor, that fuel needs to be reprocessed and recycled many times before the LWR actinides are substantially destroyed. In addition, if the actinides are mixed with uranium, the ABR is likely to have a "conversion ratio" on the order of at least 0.50, so that half of the actinides destroyed are replaced by Pu-239 that will need to be burned in the ABR and thus reduce the rate at which LWR actinides are destroyed, for a given thermal output power of the ABR. The question for the GNEP vision is how big a repository is needed for U.S. commercial fuel (and for possible U.S. reprocessing of foreign fuel) and at what cost for the repository and for the measures to reduce the necessary size. All indications are that the cost of direct disposal of spent LWR fuel is much less than the cost of the reprocessing and ABRs that are intended to reduce repository size.

There are major questions as to the fuel form for the generation of ABRs. Will it be metallic fuel, carbide fuel, nitride fuel, or oxide fuel? Will it be normal "mixed fuel" with uranium, that gives rise to more Pu-239, or will it be a "sterile fuel"—so-called inert matrix fuel (IMF)—rather than uranium-based. What will be the delayed neutron fraction in that reactor, and how will a safe operating margin be achieved?

Will the ABRs be cooled with liquid sodium or with molten lead? There are good arguments on both sides, but GNEP and its supporters appear to assume that the cooling will be liquid sodium, in order to be able to build the first "demonstration" ABR rapidly. This haste and ill-defined purpose recall the Clinch River sodium-cooled reactor project, terminated in 1977 and against which I testified, which would simply have demonstrated the high cost of fast-reactor power in comparison with LWRs. If the purpose is to have a "demonstration/test reactor which would be used to effect qualification of advanced burner reactor fuel to consume transuranic elements (TRU) from spent light water reactor fuel and spent fast reactor fuel," why not use existing fast reactors in Russia and France for this purpose, thus saving years of delay? Simply building another sodium-cooled fast reactor to show that it can be done in the U.S. is not likely to advance the acquisition of knowledge necessary to the coupled choice of reactor type, fuel, and approach for the really difficult job of reprocessing ABR fuel with process losses of 0.1 percent or less.

The reprocessing for the ABR is a more important choice than the reprocessing for the LWR, since it needs to be done multiple times, and will also set the basis for a later breeder economy. So why is $155M of the $250M first-year budget sought for GNEP to go to the demonstration of UREX+ reprocessing for LWR fuel? Contrary to the 99.9 percent efficiency (0.1 percent loss) sought for each of the many reprocessing cycles for ABR fuel, 90 percent efficiency for the one-time reprocessing of PWR fuel would obtain most of the benefit. The proposed UREX+ ESD plant for

PWR fuel is excessively large and has technical goals totally unnecessary for this task.

That fuel for the ABR will need to be available only when we have the first-generation ABR coming on-line, and it is an economic waste to reprocess the LWR fuel prematurely. The discounted present value (cost) of reprocessing is much less if reprocessing is delayed by a further 20 years, for instance.

It seems that one ought to have multiple design competitions for fast-neutron ABRs, and when the best two ABR designs have been chosen after the detailed technical evaluation that such a momentous step warrants, two separate engineering designs should be commissioned for each, in order to have some confidence of being able to choose the better.

One of the chief concerns with the ABR, as indicated, is its fuel composition, and the ABR reprocessing choice needs to be made in conjunction with the choice of fuel composition.

My major concern with the GNEP program as it has been presented is that it has the priorities all wrong—with premature initiation of an engineering scale demonstration—ESD—of UREX+ for LWR fuel, when what we need is to move rapidly to see whether it is technically and economically feasible at all to deploy the vast numbers of ABRs that are required. This is an old dream, and if it is not feasible, the reprocessed LWR fuel will be a security and economic nightmare and an impediment to the expansion of nuclear energy supply. Furthermore, the technical goals of the program are set far higher than is needed to obtain the benefits of reprocessing of PWR fuel.

The goal of "proliferation resistance" is not met in any case, because the UREX process itself separates essentially all of the uranium. To obtain 10 kg of plutonium from ordinary PWR spent fuel containing one percent Pu, a terrorist would need to acquire and reprocess 1000 kg of highly radioactive material. Once the uranium and the fission products have been removed in any of the UREX processes, the plutonium will be contaminated only with a modest amount of transuranics (TRU) so that the terrorist would need to reprocess a mere 11 kg of material, and according to recent DOE studies, this would have only about 1/2000 of the penetrating radiation that would count as "self protecting." In fact, Pu metal contaminated with minor actinides could perfectly well be used in an implosion bomb. So UREX really offers no significant benefit over PUREX so far as resistance to proliferation or terrorist acquisition of weapon-usable materials. Of course, radioactivity could be left with or the Pu (actinide) fraction and removed after shipment from the PWR reprocessing plant to the ABR complex, but the likely contaminant, lanthanides, offer relatively little protection and, in any case, does not change the fact that only one percent as much material needs to be diverted and processed as in the case of spent LWR fuel itself.

The relatively minor goal of reducing uranium requirement comes at an extremely high price. Recycle of all of the TRU can reduce uranium requirements by about 20 percent (unless one has a breeder reactor that then does not eliminate the plutonium but preserves or expands its supply). Sound, recent studies show that this uranium saved comes at an equivalent cost of $130–1000/kg of natural uranium that would otherwise need to be bought. At a time when two million tons of uranium can be mined at costs below $40/kg, this is far from a good investment!

The main benefit claimed for the UREX+ teamed with the deployment of large numbers of ABRs is the reduced requirement for space in a mined geologic repository. Here we are greatly aided by an April 2006 paper from the Argonne National Laboratory.[3] The authors refer, and appropriately so, to a "recent review by the National Academy of Sciences, where the potential benefits regarding dose rate, decay heat load, and nonproliferation were discussed and estimated, at least qualitatively."[4] Strangely, the 1996 report is hardly referenced in the DOE literature on GNEP, but it is a monumental study that should be understood by all involved. It concluded:

> "The excess cost for an S&T disposal system over once-through disposal for the 62,000 tons of LWR spent fuel is uncertain but is likely to be no less than $50 billion and easily could be over $100 billion if adopted by the United States."

[3] "Separations and Transmutation Criteria to Improve Utilization of a Geologic Repository," by R.A. Wigeland, T.H. Bauer, T.H. Fanning, and E.E. Morris, *Nuclear Technology,* Vol. 154, pp. 95–106, (April 2006).

[4] "Nuclear Wastes: Technologies for Separations and Transmutation," by the Committee on Separations Technology and Transmutation Systems, ("STATS" for short), National Research Council, National Academy Press, Washington, DC (1996).

This is equivalent to $800–1600/kg of fuel (undiscounted), or roughly 2–4 mill/kWh.

A current EPRI–INL paper provides a sobering assessment both of the prospects for the reprocessing approach and of its necessity:[5]

> "In addition, reprocessing plants are expensive and not attractive to commercial financing in the context of the U.S. economy. Thus, the cost increment for reprocessing (i.e., the incremental cost above the cost of repository disposal) will be subsidized initially by the Federal Government. Although the estimate above does not include repository costs, it is expected that reprocessing will remain more expensive than storage (centralized above-ground plus geologic repository) for the foreseeable future. Projections of major savings in Yucca Mountain repository costs as a result of reprocessing are highly speculative at best. On the other hand, the increased revenues to the Nuclear Waste Fund from an expanding fleet of new reactors will eventually help defray the costs of operating closed fuel cycle facilities.
>
> "It is important to note that despite the extended timetable for introducing reprocessing in the U.S. (due to R&D prerequisites to satisfy cost and nonproliferation objectives, policy considerations, etc.), that a single expanded-capacity spent fuel repository at Yucca Mountain is adequate to meet U.S. needs, and that construction of a second repository is not required under this timetable.
>
> "If, however, reprocessing is implemented on an accelerated schedule before it is economic to do so based on fuel costs, then the Federal Government will need to bear a much larger cost. As discussed in Appendices B and D, the optimum scenarios for transitioning nuclear energy to a closed fuel cycle in the U.S. context requires us to focus the R&D on those technologies that would enable a transition to cost-effective and proliferation resistant "full actinide recycle" mode with fast reactors that would eventually replace light water reactors. This path is preferred over one that maintains for decades a "thermal recycle" mode using MOX fuel in light water reactors, because the high costs and extra waste streams associated with this latter path do not provide commensurate benefits in terms of either non-proliferation or spent fuel management costs."

The Wigeland, et al., paper arrives at conclusions that are summarized, for instance, in its Fig. 7, which I reproduce here.

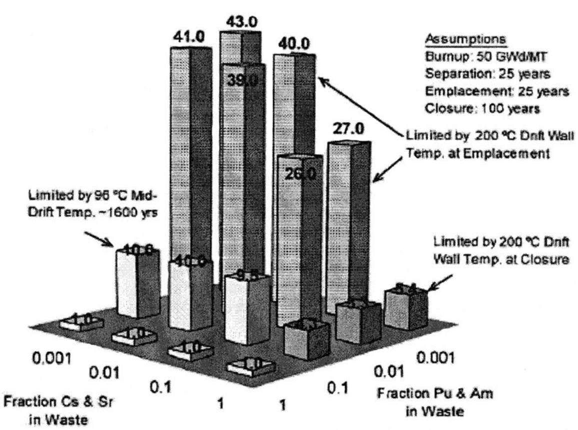

Fig. 7. Potential repository drift loading increase as a function of separation efficiency for plutonium, americium, cesium, and strontium.

This bar chart shows the increase in repository capacity that can be achieved by separating out plutonium, americium, cesium, and strontium, for various assumed fractions remaining in the waste. Note that the removal of the uranium does nothing to increase the capacity of the repository, which is limited by the decay heat

[5] "The Nuclear Energy Development Agenda: A Consensus Strategy for U.S. Government and Industry."

of the radioactive materials. With no removal of these materials, the repository is planned for a reference value of initial 1.1 metric ton of heavy metal of spent PWR fuel per meter of “drift” space—1.1 MTIHM/m of the mined drift. If 90 percent of the Pu and Am are removed from the PWR waste, while all the Cs and Sr are retained, the repository capacity would be increased by a factor 4.3. But repository space is also required for the reprocessing waste from the ABR recycle process.

The paper notes that separation and recycle of Pu into LWRs cannot achieve this increase in repository performance, because the spent fuel from this recycle has as much TRU heat in a single fuel element as in the four or five UOX fuel elements that were reprocessed to make it. The fast-neutron ABR, however, is able to fission the minor actinides so that they do not contribute to the decay heat, thus enabling the increase in repository capacity shown in Fig. 7.

Removing 90 percent of the Cs and Sr results in the bar labeled “9.5” for the factor by which the spent fuel loading in the repository could be increased. Note that this could be achieved either by chemical separation or by holding the waste for an additional 100 years, which gives a further factor 10 decay of the amount of Cs and Sr in the waste.

The 1996 STATS report used a 0.1 percent process loss estimate, and the Wigeland paper begins with a one percent process loss, as illustrated in its Fig. 6.

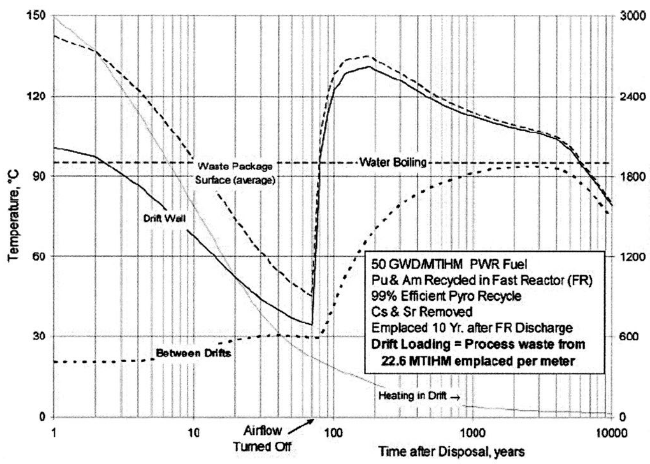

Fig. 6. Transient thermal response of a repository at Yucca Mountain with removal of plutonium, americium, cesium, and strontium from spent PWR fuel, recycling plutonium and americium in a fast reactor, with increased drift loading.

In Fig. 6 of Wigeland, et al., the FR fuel was burned to 80 GWD/MTHM, with about four tons of fuel in the FR. Assumed separation efficiency for the PWR fuel was 99.9 percent.[6]

The arguments for GNEP assert that 99.9 percent might be achieved, and a big part of the UREX+ ESD demonstration is to go from demonstrated 99 percent removal efficiency to 99.9 percent in the case of LWR fuel! But this effort is misguided; it is the ABR reprocessing that would benefit from efficiencies above 99 percent—not the PWR UREX+ process.

No rational business person or economist looking at Fig. 7 would want to do the UREX+ ESD program at the level requested.

What is happening here is that one has a cost structure that includes the cost of separation and transmutation (the “chemical plant” and the ABRs) and also the cost of the repository, presumably reduced by a factor comparable with the increased loading that can be achieved. A factor 10 improvement in repository capacity is sufficient to reduce the already low cost of the repository (estimated at 0.1 cents per kWh) to a much lower value. One could perfectly well leave further reduction in repository costs and increase in permitted loading to the much longer-term future rather than expending vast sums and time up front to demonstrate on a large scale unnecessarily efficient processes.

[6] Personal communication from R. Wigeland, April 5, 2006.

Therefore, a reasonable goal for the performance of the chemical plant on PWR (or, more generally, LWR) fuel is 90 percent removal of Pu and Am, and similar 90 percent removal of Cs and Sr, if that is economically achievable. Note that even substantially less removal of Cs and Sr would not much diminish the factor 9.5 increase in repository capacity. Performance already demonstrated far exceeds that required for PWR spent fuel separations. This minimal requirement for separation efficiency for the one-time PWR fuel separation contrasts strikingly with the 99+ percent that is needed for repeated separation and recycle in the ABR, just because of the multiple recycles required in the case of the ABR fuel.

These specific points reinforce my global point that the uncertainty is what kind of burner reactor can be built to operate 30 or 50 years hence, that will be safe and as close as possible to economically competitive with the LWR or other thermal reactor for the production of electrical power. This is the critical question and is linked to the type of fuel to be burned and hence to the separations technology that must be achieved in ABR fuel recycle.

Since a major element of cost and performance in this "waste reduction" program is the subsidy that would be required for the ABRs, it is of interest to note that there is a very different technology under development that would also modestly reduce repository needs. This is the thermal neutron reactor championed and developed by General Atomics that had deployed two plants—one at Peach Bottom and the other at Fort St. Vrain, that relies on millimeter-size pressure vessels of carbon and silicon carbide to contain the fissile fuel and the resulting fission products. In the form of a modular high temperature gas turbine reactor—(MHTGTR)—such systems could be deployed in a "deep burn" mode, without reprocessing of this fuel, so as to achieve the modest benefits to the repository that could compete with or supplement expanding the repository capacity.

The American Physical Society Nuclear Energy Study Group[7] in its May 2005 report concluded,

> "Any decision to reprocess spent fuel in the United States must balance the potential benefits against the proliferation risks. Fortunately, there is no near-term urgency to make a decision on implementing reprocessing in the United States. No foreseeable expansion of nuclear power in the U.S. will make a qualitative change in the need for spent fuel storage over the next few decades. Even though Yucca Mountain may be delayed considerably, interim storage of spent fuel in dry casks, either at current reactor sites, or a few regional facilities, or at a single national facility, is safe and affordable for a period of at least 50 years."

The "GNEP Program" needs to be disaggregated and the technical priorities set appropriately—the design of the ABR or other waste-burning reactor to be as safe and inexpensive as possible, and the choice of the nature of that reactor together with its fuel. As for the role of GNEP in assured supply of enriched uranium and take back of fuel from much of the world, those policy problems must be addressed, as to whether the United States wishes alone to dispose of radioactive wastes from the rest of the world, or whether it wishes to take the lead in a process that is commercially viable and environmentally acceptable to have internationally approved repositories storing internationally approved waste forms in appropriate areas of the world.

As noted, the other urgent matter for the U.S. and other governments is to determine the cost to obtain vastly more uranium. It is essential to know whether half of the 4,000 million tons of uranium in seawater can be extracted at a cost of $300/kg, as is tentatively suggested by the Redbook. Or whether the GEN–IV working group approach that leads to an estimate of 170 million tons of uranium from terrestrial deposits at an extraction price less than $260/kg is valid.

So in general I admire the goal of GNEP, but visions that ignore technical reality have often led to disasters, since they preclude more conventional and incremental approaches. The reprocessing and transmutation aspect of GNEP must be seen as a gamble, and an optional—not a necessary—gamble. It is presented as an alternative to expansion of the approved repository capacity, but is linked to the momentous decision to deploy highly subsidized fast reactors in numbers that would generate about 77 percent as much power[8] as the light-water reactors with which they

[7] Its membership included the Chairman of the Advanced Nuclear Transformation Technology Subcommittee of DOE's Nuclear Energy Research Advisory Committee.

[8] The number "1/3" is often quoted by advocates of Separation and Transmutation, but the fast-neutron reactor of Footnote 3 (Wigeland, et al., of April 2006) has a conversion ratio (CR) of 0.64 for TRU. For each TRU atom burned by fission, 0.64 is regenerated (R.A. Wigeland, per-

Continued

would co-exist. And it blithely assumes above-ground storage for hundreds of years of separated cesium and strontium waste, as well as the operation of reprocessing plants, all a high-cost, technically risky, and proliferation-prone approach to saving a low-cost resource—space in a mined geological repository and the auxiliary interim dry-cask storage.

Note added by R.L. Garwin 06/25/06:

On 06/19/061 received via R.A. Wigeland an analysis by Robert N. Hill of ANL indicating that in the AFCI program by 2004, fast-neutron reactors were analyzed with a conversion ratio of 0.25 (TRU atoms produced per TRU atom destroyed). These ABRs use fuel that is as much as 50 percent TRU. Under these circumstances, the ABR electrical power would be 0.23/(0.75–0.83) = 37 percent of the LWR reactor power. No such reactor has yet been built; nor has an engineering design been accomplished.

I add here also material from the EPRI report: of May 2006 "Program on Technology Innovation: Room at the Mountain—Analysis of the Maximum Disposal Capacity for Commercial Spent Nuclear Fuel in a Yucca Mountain Repository. EPRI, Palo Alto CA: 2006. 1013523." There we read, "EPRI is confident that at least four times this legislative limit (~260,000 MTU) can be emplaced in the Yucca Mountain system..." And EPRI believes that with additional site characterization this minimum factor of four could well be a factor nine."

I restate my principal conclusions and recommendations:

1. The Engineering Scale Demonstration of UREX+ for the reprocessing of LWR fuel to 99.9 percent efficiency at a scale of 100 to 200 tons of fuel per year is highly premature, for the reasons given above.
2. The big technical uncertainty in the program is the design of an affordable and safe fast-neutron burner reactor, with its associated fuel form and reprocessing. To the extent that reprocessing of LWR fuel is considered, all the effort under GNEP should be associated with competitive designs for the ABR, its fuel, and its reprocessing.
3. There is no necessity to reprocess fuel in implementing a fuel leasing and take back program, if the United States would take the lead in encouraging the creation of commercial, competitive, mined geologic repositories open to the deposit of spent fuel and reprocessed spent fuel. The repositories and the spent fuel should be subject to IAEA regulation. Unreprocessed spent fuel can be kept in interim storage casks for at least 100 years, thus easing the ultimate burden on the repositories and providing more time for their construction or for the possible development of economical burner reactors and associated reprocessing industry.
4. GNEP, as formulated and presented at the hearing of April 6, 2006, is not necessary to achieve the stated goals of nonproliferation and is more likely to hinder the achievement of those goals. A proposal to lease fresh fuel and take back the spent fuel was published by Harold M. Agnew, then Director of the Los Alamos Scientific Laboratory in the *Bulletin of the Atomic Scientists* (May 1976, page 23), as "Atoms for lease: An alternative to assured nuclear proliferation."

sonal communication to the author, 04/18/06) so that only 0.36 TRU atom is consumed per fission. Since a LWR produces 0.23 TRU per fission, fast-neutron reactors consuming LWR waste would have an electric power 0.23/0.36 = 64 percent as large as the LWR complex, if the thermal efficiency were the same. Because of the higher operating temperature of the liquid-metal fast-neutron reactors only about 0.83 as many heat-producing fissions are required in an ABR to produce the same electrical power as a set of LWRs; the power output of a set of such ABRs consuming LWR waste is then 0.64/0.83 = 77 percent that of the LWR reactors.

R&D Priorities
For the
Global Nuclear Energy Partnership

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Comments on GNEP

- US nuclear power plants (103 of them) provide almost 20% of US electricity. First, do no harm.
- GNEP includes provision of reactor fuel to international partners and take back of spent fuel for disposal. Need to create an international system.
- Reprocessing can extend uranium resource for light-water reactors (LWR) by 20% at most, at a cost per kg of $130-1000. DOE purpose is primarily to save repository resource; at what cost and risk?
- Yucca Mountain can be extended and replicated; dry cask storage is cheap and safe for 50-100 years.

Comments on GNEP (2)

- GNEP does not propose reprocessing and recycle into LWRs, and for good reason.
- Once-through US fuel cycle is far more proliferation resistant than is the proposed UREX+ reprocessing
  - To obtain 10 kg of Pu, must steal and reprocess 1000 kg of self-protecting spent fuel; vs.
  - UREX+: must steal 11 kg of separated Pu
- GNEP's proposed UREX+ separation for LWR fuel and burning in fast-neutron Advanced Burner Reactors—ABR—is far more costly than enhancing the repository space. YM estimated at 200,000 tons.

Comments on GNEP (3)
(Reprocessing and Burning of Transuranics)

- Defining the GNEP program without the promised systems analysis tool is like driving without a map
- The $155 M first-year UREX+ program is misguided
  - UREX not significantly better than PUREX
  - It is ABR-fuel reprocessing that needs 99+% efficiency, not the LWR that is done just once
- The ABRs (at least 30% of the LWR population) will need to be government operated or heavily subsidized.
- Big gamble is the ABR, fuel form, fuel reprocessing; needs extended design competition (decades).

What to do?

- Lift arbitrary 62,000 ton cap on Yucca Mountain
- Commit to dry-cask interim storage for up to 100 yr
- USG take the lead in creating an international system for assured supply of LEU reactor fuel, and assured disposal
- USG lead in institutional design to encourage commercial, competitive mined geologic repositories, certified by IAEA, to accept IAEA-certified spent fuel forms and IAEA-certified high-level waste packs such as vitrified fission products. Outsource to repositories elsewhere, not just in the U.S..

What to do? (2)

- USG fund worldwide evaluation of resource vs. cost of currently uneconomic terrestrial and seawater uranium resources, e.g.,
  - 170 million tons terrestrial at $260/kg?
  - 2,000 million tons from seawater at $??/kg
- Complete and use the systems analysis tool to guide decisions—not to justify them after the fact

BIOGRAPHY FOR RICHARD L. GARWIN

Richard L. Garwin was born in Cleveland, Ohio, in 1928. He received the B.S. in Physics from Case Institute of Technology, Cleveland, in 1947, and the Ph.D. in Physics from the University of Chicago in 1949.

He is IBM Fellow Emeritus at the Thomas J. Watson Research Center, Yorktown Heights, New York. After three years on the faculty of the University of Chicago, he joined IBM Corporation in 1952, and was until June 1993 IBM Fellow at the Thomas J. Watson Research Center, Yorktown Heights, New York; Adjunct Research Fellow in the Kennedy School of Government, Harvard University; and Adjunct Professor of Physics at Columbia University. In addition, he is a consultant to the U.S. Government on matters of military technology, arms control, etc. He has been Director of the IBM Watson Laboratory, Director of Applied Research at the IBM Thomas J. Watson Research Center, and a member of the IBM Corporate Technical Committee. He has also been Professor of Public Policy in the Kennedy School of Government, Harvard University. From 1994 to 2004 he was Philip D. Reed Senior Fellow for Science and Technology at the Council on Foreign Relations, New York.

He has made contributions in the design of nuclear weapons, in instruments and electronics for research in nuclear and low-temperature physics, in the establishment of the nonconservation of parity and the demonstration of some of its striking consequences, in computer elements and systems, including superconducting devices, in communication systems, in the behavior of solid helium, in the detection of gravitational radiation, and in military technology. He has published more than 500 papers and been granted 45 U.S. patents. He has testified to many Congressional committees on matters involving national security, transportation, energy policy and technology, and the like. He is co-author of many books, among them *Nuclear Weapons and World Politics* (1977), *Nuclear Power Issues and Choices* (1977), *Energy: The Next Twenty Years* (1979), *Science Advice to the President* (1980), *Managing the Plutonium Surplus: Applications and Technical Options* (1994), *Feux Follets et Champignons Nucleaires* (1997) (in French with Georges Charpak), and *Megawatts and Megatons: A Turning Point in the Nuclear Age?* (2001) (with Georges Charpak).

He was a member of the President's Science Advisory Committee 1962–65 and 1969–72, and of the Defense Science Board 1966–69. He is a Fellow of the American Physical Society, of the IEEE, and of the American Academy of Arts and Sciences; and a member of the National Academy of Sciences, the Institute of Medicine, the National Academy of Engineering, the Council on Foreign Relations, and the American Philosophical Society. In 2002 he was elected again to the Council of the National Academy of Sciences.

The citation accompanying his 1978 election to the U.S. National Academy of Engineering reads "Contributions applying the latest scientific discoveries to innovative practical engineering applications contributing to national security and economic growth." He received the 1983 Wright Prize for interdisciplinary scientific achievement, the 1988 AAAS Scientific Freedom and Responsibility Award, the 1991 Erice "Science for Peace" Prize, and from the U.S. Government the 1996 R.V. Jones Foreign Intelligence Award and the 1996 Enrico Fermi Award. In 2003 he received from the President the National Medal of Science.

From 1977 to 1985 he was on the Council of the Institute for Strategic Studies (London), and during 1978 was Chairman of the Panel on Public Affairs of the American Physical Society. He is a long-time member of Pugwash and has served on the Pugwash Council.

His work for the government has included studies on anti-submarine warfare, new technologies in health care, sensor systems, military and civil aircraft, and satellite and strategic systems, from the point of view of improving such systems as well as assessing existing capabilities. For example, he contributed to the first U.S. photographic reconnaissance satellite program, CORONA, that returned three million feet of film from almost 100 successful flights 1960–1972.

He has been a member of the Scientific Advisory Group to the Joint Strategic Target Planning Staff and was in 1998 a Commissioner on the nine-person "Rumsfeld" Commission to Assess the Ballistic Missile Threat to the United States. From 1993 to August 2001, he chaired the Arms Control and Nonproliferation Advisory Board of the Department of State. On the 40th anniversary of the founding of the National Reconnaissance Office (NRO) he was recognized as one of the ten Founders of National Reconnaissance. In June, 2002, he was awarded la Grande Medaille de l'Academie des Sciences (France)–2002.

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March 29, 2006

Rep. Judy Biggert
Chairman
Subcommittee on Energy
Committee on Science
U.S. House of Representatives
2320 Rayburn House Office Building
Washington, DC 20515-6301

Dear Chairman Biggert,

As a witness at the hearing of April 6, 2006, I am required to provide for you the identification of any sources of federal funding "which directly supports the subject matter" on which I will be testifying.

I have no federal funding of any kind in conjunction with my analysis or testimony on the Global Nuclear Energy Partnership.

Sincerely yours,

/R.L. Garwin/

Richard L. Garwin

RLG:jah:6088JB:032906..JB

Chairwoman BIGGERT. Thank you very much, Dr. Garwin.

Mr. Modeen, you are recognized for five minutes.

STATEMENT OF MR. DAVID J. MODEEN, VICE PRESIDENT, NUCLEAR POWER; CHIEF NUCLEAR OFFICER, ELECTRIC POWER RESEARCH INSTITUTE

Mr. MODEEN. Okay. Thank you very much.

On behalf of the Electric Power Research Institute and its nuclear utility members, I would like to express our appreciation for this opportunity to address your Committee, Chairman Biggert, on the matter of nuclear energy and the research and development we need to expand its use, not only nationally, but globally.

EPRI, working with the Idaho National Laboratory, recently completed a document entitled *"The Nuclear Energy Development Agenda: A Consensus Strategy for the U.S. Government and Industry."* I was glad to see that the Committee Members were given a copy of that, and I also appreciated, of course, listening to your remarks at the most recent NEI R&D summit where we had, really, our first public unveiling of that strategy.

The agenda that I refer to is included in my written testimony in more detail, but I will focus here on three main points.

The first point, for nuclear energy to expand and prosper as a key element of our national energy strategy, industry and government must work together more. Specifically, industry and government need to reach a consensus on the strategy and work together on both the planning and the execution.

The second point, the longer-term future of nuclear energy must be built on a solid foundation that is grounded in the current, ongoing nuclear energy initiatives, which, we believe, must be successful in order for the longer-term elements, those included in GNEP, I believe, that really have any relevance.

And those three initiatives that form that foundation are: first, the continued safe and effective operation of our current fleet of reactors; the second, the near-term licensing and deployment of advanced light water reactors; and third, the licensing and construction of a geologic repository of Yucca Mountain.

And the third point, enabled by success in these three nearer-term areas, longer-term goals for nuclear energy become possible through advances in technology. And here again, there are three initiatives required: expanding the application of nuclear energy into process heat applications, including production of hydrogen for industrial and transportation uses as well as desalination; and the second is greatly expanding the nuclear fuel resources for long-term energy and environmental sustainability through spent fuel recycling; and then third, strengthening the proliferation resistance and physical protection of any nuclear fuel cycle.

And what I would like to do now is expand on each of those three areas that I just mentioned.

First, on the need for industry and government to work together. To a large degree, the paradigm, at least in nuclear R&D the past 10 years or more, has been that government only works on the long-term research and industry works on only the relatively short-term. We believe that paradigm has been an obstacle to really achieving alignment on goals and priorities. And in fact, trying to achieve alignment in forming the basis for a consensus strategy is why we developed the paper that we did. It was our motivation and really agreed upon by my CEO as well as the Director of the Idaho National Lab. And so, consequently, we agreed that the government should dedicate more of its efforts to the short, medium-term and tried to outline what those might be, and then vice-versa, industry needs to step up to some of those longer-term.

And this really has three objectives. The first is to leverage the government R&D investment. The second is to introduce mission focus and market relevance in the R&D decision making. And third, to accelerate that research and development process and the transfer of results into the economy in the marketplace. And consequently, again, I can reinforce that I believe the industry and government, by working synergistically in planning and execution, will achieve more.

And adding to a point that Dr. Todreas mentioned, I would like to refer that the industry that I am talking about is more than utilities. It includes the vendors, the architect engineers, the manufacturers, academia, and craft labor: entities that are absolutely necessary to achieve our goals. And we certainly recognize that we need a more comprehensive plan to restore the nuclear-industrial infrastructure in this country. And I share Dr. Todreas' concern about the loss of funding to the nuclear university education programs.

The renaissance in nuclear energy that is beginning to take shape poses challenges for both industry and government, and challenges, I believe, are probably the greatest of our professional careers in the nuclear industry. The expectations are high, the schedules are aggressive, and the resources will be limited. Planning must be realistic and address commercial deployment in a competitive marketplace, not just the cost of completing the R&D. And we believe the utility industry has much to offer the Department of Energy as it embarks on major new technology development programs. We want to be part of that planning as well as the execution, and we are looking forward to working with the new leadership.

The second area that I talked about was the near-term priorities for nuclear energy, because they do have some insights relevant to the GNEP activity.

First, we commend the Congress for its insight and support for creating a new program authorized in the *Energy Policy Act of 2005* focused on the current plants, entitled "The Nuclear Energy Systems Support Program." EPRI has long argued that there is an important federal role in certain aspects of current plant R&D, particularly in areas where there is either a strong federal interest in the success, and I will give an example in a moment, or where the technology challenges are just too high or the risk is too high for the private sector to fund on its own.

A good example is high-performance nuclear fuel, both for the current fleet and the advanced light water reactors. This high-performance fuel, we believe, can achieve burn-up levels, and that is really energy production, twice as high as the current fleet, and this would reduce the volume of spent fuel generated by a factor of two. And if, in fact, that the stated goal of GNEP—one of the stated goals is to reduce the volume of waste that would be required in a disposal in a repository by 80 percent, it certainly stands to reason that this type of technology is in the federal interest and should be a priority.

The second piece is that near-term—or second element is the near-term licensing and deployment of advanced light water reactors, which is critical to the industry's ability to provide safe, economic, and reliable electric generation for decades to come. We were pleased to see that GNEP recognized this strategic importance of the NP–2010 program and believe this cost-shared program requires acceleration to support the new plant project schedule. The recent Nuclear Regulatory Commission called for a design-centered approach for combined license applications will require more extensive work upfront in standardizing these submittals.

And finally, the EPRI–INL strategy paper calls for an integrated and cost-effective spent fuel management plan. The lynchpin of this strategy is the repository at Yucca Mountain. Not only is the geologic repository needed under all strategies and scenarios for the future, but near-term progress on licensing of Yucca Mountain is essential to expanding nuclear energy in this country. The other key elements of that integrated strategy include allowing expansion of the Yucca Mountain site to its whole technical capacity, as Dr. Garwin mentioned, reducing the rate of spent fuel generation via deployment of high-performance light water reactor fuel, maintaining engineered cooling of the repository well in excess of 50 years prior to closure, providing for interim centralized storage where aging pads for dry canister passive cooling, deploying multipurpose canisters, and implementing an effective spent fuel transportation system, and eventually the recycling of spent fuel to reduce volume and heat grade, thus making more effective use of the repository space.

These steps, if taken together and coordinated, provide ample time for long-term R&D that I will discuss next, to be completed before concerns arise as to the need for a second repository.

And a final perspective, then, on the longer-term goals regarding process heat and hydrogen generation. There is a market today, and we believe that we support the plan laid out in the *Energy Policy Act of 2005.*

Regarding GNEP specifically, our paper was developed with no knowledge of GNEP and before it was issued and that we do support the vision and the goals. It is really just a matter of, I think, the timing. And consequently, we support the funding for it, such that we can really get in and explore the types of issues that Dr. Todreas and Dr. Garwin had cited.

And I think I am out of time, Chairman.

Thank you for the opportunity to address your committee.

[The prepared statement of Mr. Modeen follows:]

PREPARED STATEMENT OF DAVID J. MODEEN

On behalf of EPRI and its nuclear utility membership, I'd like to express our appreciation for this opportunity to address your committee. Most of my remarks today are based on a document prepared jointly by EPRI and the Idaho National Laboratory (INL), entitled, *"Nuclear Energy Development Agenda: A Consensus Strategy for U.S. Government and Industry."*

I will focus initially on the rationale and desired outcome of this strategy paper, as it relates to achieving closer alignment between industry and government on research & development (R&D) priorities, and its value. Second, I will review key content and recommendations from our paper. Finally, I will offer a few observations relative to the Global Nuclear Energy Partnership.

To a large degree, the paradigm for nuclear R&D has become, "Government only works on long-term research, and industry only works on short-term research." The EPRI–INL paper attempts to address this situation, which has become an obstacle to alignment on goals and priorities.

Steve Specker, our EPRI CEO, and John Grossenbacher, the Director of INL, met in May 2005 and committed to a joint effort to articulate a vision for nuclear energy and a supporting R&D agenda that could form the basis for a consensus between industry and government. The framework they agreed to pursue was based on an *80–20 paradigm,* to mend the long-term—short-term chasm: government should dedicate about 20 percent of its efforts to short-to-medium-term R&D, and industry should dedicate about 20 percent of its efforts to medium-to-longer-term R&D.

EPRI and INL were well positioned to undertake this effort. EPRI is a nonprofit organization that manages a broad collaborative energy R&D program for the Nation's electric utility industry, with significant international utility participation. Its R&D programs cover all technologies for electricity generation, transmission, distribution, and end-use. Specifically with respect to generation, EPRI advocates a diverse portfolio where nuclear plays a key role, along with clean coal, natural gas and renewables, wind, biomass and solar. My remarks today will only focus on the nuclear portfolio. All U.S. nuclear utilities are members of EPRI's nuclear power sector, along with many international utilities representing about 50 percent of the world's nuclear electric generation capacity. Together, they sponsor about $100M/year in R&D.

INL was identified by DOE in 2004 as its lead laboratory for nuclear energy research, development, demonstration, and education, with the goal of becoming the premier laboratory for nuclear energy within a decade. INL has extensive experience and supporting research facilities in all facets of nuclear energy research, including advanced reactor design, advanced fuel cycle design, nuclear materials and fuel design and testing, and advanced digital controls.

The renaissance in nuclear energy in the U.S. that is beginning to take shape poses challenges for both industry and government. Expectations will be high for safe, high quality, high performance technologies, delivered on aggressive schedules. The technology thrusts are highly interdependent. There will be significant resource limitations to goal achievement, requiring careful planning and prioritization. Planning must be realistic and address the commercial deployment in a competitive marketplace, not just the cost of completing the R&D. In short, we support industry and government working synergistically in pursuit of the technologies that will enable a major expansion of nuclear energy to improve energy security and environmental quality. For industry and government to achieve common objectives, we need alignment around a consensus strategy, as well as collaboration in both planning and execution.

EPRI and INL sought to align the technology portfolio with evolving nuclear energy policies and priorities. We reviewed five key government and independent studies on the future of nuclear energy, and found among them a consensus on the basic priorities for technology development:

1. "National Energy Policy: Report of the National Energy Policy Development Group," May 2001. Augmented by Presidential Initiatives supporting the National Energy Policy.
2. "The Future of Nuclear Power," Massachusetts Institute of Technology (MIT), July 2003.
3. "U.S. Department of Energy/Nuclear Power Industry Strategic Plan for Light Water Reactor Research and Development," February 2004.
4. "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges," The National Commission on Energy Policy (NCEP), December 2004.
5. "Moving Forward with Nuclear Power: Issues and Key Factors: Final Report of the Secretary of Energy Advisory Board Nuclear Energy Task Force," January 2005.

Starting with consensus goals that were based on these well-recognized government and independent strategic plans, EPRI and INL assessed the nuclear energy R&D needed in the U.S. over the next half century.

A team of EPRI and INL staff mapped out a common set of high-level goals and time-based planning assumptions for nuclear energy, and then identified the R&D needed to prepare for deployment. These assumptions were formulated to be aggressive yet achievable, and were grounded upon open market principles. R&D challenges were identified, after which an assessment of current nuclear R&D programs was made to identify opportunities for action. The resulting strategy paper is currently undergoing industry review. We have shared the paper with DOE and are looking forward to discussing its merits and implications with DOE in detail.

These goals, paraphrased, are:

1. Ensure continued effectiveness of the operating fleet of nuclear power plants.
2. Establish an integrated spent fuel management system consisting of centralized interim storage, the Yucca Mountain repository, and, when necessary, a closed nuclear fuel cycle.
3. Build a new fleet of nuclear power plants for electricity generation.
4. Produce hydrogen for transportation and industry, and eventually for a hydrogen economy.
5. Apply nuclear systems to other process heat applications, including desalination.
6. Greatly expand nuclear fuel resources for long-term sustainability, commercializing advanced fuel cycles when market conditions demand them in the long-term.
7. Strengthen proliferation resistance and physical protection of nuclear fuel cycles.

The end result of the process that EPRI and INL followed was something we like to call "the R&D continuum." The fifty-plus year strategy for nuclear energy expansion and enhanced spent fuel management starts with a prioritized set of technology goals that flow logically and function in an integrated manner to achieve national objectives. This long time horizon is necessary to assess the R&D and demonstrations required to deploy nuclear fuel recycle systems, which will eventually be needed to assure sustainability as fuel resources are diminished through expanded use of the present once-through systems. With these "continuum" goals and supporting planning assumptions, a matrix of technology options was developed to address each goal, with an assessment of the technology capabilities and challenges of each option. From this matrix, a technology development agenda was derived, with timing and budgets aimed as much as practical to lead to private sector investment and deployment. The strategy paper assumed that each future Administration and Congress will expect Federal investments in nuclear R&D to be based on market demand as a key driver for long-term energy investments and deployment.

Planning Assumptions

The planning assumptions are *intentionally challenging* in order to help identify potential technology gaps, but also realistic and achievable. The predicted rapid growth is enabled by economic competitiveness and is also accelerated by the growing societal demand to increase non-emitting sources of generation. The planning assumptions are summarized below:

Currently Operating Nuclear Plants:

- All existing plants remain operational in 2015, and all have applied for and have been granted a 20-year life extension. Despite continued high safety performance and reliability, materials aging and equipment obsolescence demand rigorous monitoring, maintenance and modification with enhanced technology. Continued high performance is maintained in part by strategic, safety-focused plant management, and in part by new technology solutions, e.g., advanced monitoring and repair techniques, improved fuel performance, remedial coolant chemistry, greater reliance on advanced materials and digital controls.
- In the 2020–2030 timeframe, some plants are granted an *additional* 20-year license renewal (i.e., to 80 years). Advanced high performance fuel designs are introduced to enable longer fuel cycles, increase fuel economy, and significantly reduce the spent fuel generation rate.

New Plants for Electricity Generation:

- Many new nuclear plants are in commercial operation by 2015, with many more under construction. About 30 GWe of new nuclear electric generating capacity is on line or under construction by 2020. A cumulative total of about 100 GWe of new nuclear capacity has been added by 2030. By 2050, nuclear energy is providing roughly 35 percent of U.S. electricity generation, by reaching a cumulative total of about 400 GWe of new nuclear capacity. These numbers include electricity generation from all reactor types. They also include replacement power for a large segment of the current fleet of reactors, most of which have been retired or are close to retirement by 2050. This assumed build-rate severely challenges the existing U.S. industrial infrastructure.

New Plants for Process Heat:

- Based on a prototype Very High Temperature Reactor (VHTR) built and operating by 2020, a few VHTRs are in commercial operation by 2030, with more under construction. The VHTRs are initially dedicated to producing hydrogen for commercial and industrial use, focused primarily on rapidly expanding hydrogen demand by the oil, gas and chemical industries. They expand to a sizable fleet by 2050, still focused primarily on industrial applications, but also serving a growing market for hydrogen to power fuel cells in hybrid and plug-in hybrid vehicles. U.S.-built commercial VHTRs are also serving hydrogen demand for U.S. companies at some petrochemical facilities operating overseas.
- Commercial versions of the VHTR, without hydrogen production equipment, also begin to serve process heat needs in the petrochemical and other industries. High value-added applications above 800 C are found in recovery of petroleum from oil shale and tar sands, coal gasification, and various petrochemical processes (e.g., ethylene and styrene).

Spent Fuel Management and Expanding Nuclear Fuel Resources:

- Licensing of a spent fuel repository at Yucca Mountain Nevada is completed by 2015, with construction and waste acceptance into the repository and into a co-located used fuel aging facility by that date. Interim storage away from reactor sites is established at two locations in the U.S., one east and one west of the Mississippi River (per NCEP recommendation).
- With a rapidly expanding nuclear energy industry and a growing inventory of spent fuel, an integrated spent fuel management plan for the U.S. emerges by 2015 that obtains bipartisan support for implementation. Key elements of this plan include expansion of the capacity of the Yucca Mountain repository; engineered cooling of the repository well in excess of 50 years (e.g., up to 300 years) prior to closure, in combination with centralized interim storage of spent fuel. Reprocessing of spent fuel is expected to begin in a demonstration plant by about 2030. The integrated plan addresses reprocessing, reactor and repository strategies, and offers a least-cost path for safe, long-term management of spent nuclear fuel.
    - The reprocessing part of this integrated strategy is based on an aggressive R&D program aimed at identifying cost-effective and diversion-resistant means to recover usable reactor fuel. These technologies will also demonstrate the ability to separate isotopes that contribute the most to heat output from spent fuel, thereby increasing repository storage capacity.
    - The reactor technology part of this integrated strategy develops fast reactors to recycle light water reactor spent fuel in order to transmute minor actinides as well as produce electricity. Following a demonstration plant, built and operated with government funding by about 2035, new fast reactors are deployed commercially, with government subsidy as needed for the waste-consuming mission. In the long-term, the price of uranium increases to a level that supports recycle and eventually breeding.

Timing and Costs of the Nuclear Energy Development Agenda

The length of time that each technology will need to become commercially competitive to support the planning assumptions was estimated; and the R&D timeline needed for each technology was set to assure in-time licensing, demonstration, and commercialization. It is important to be realistic and objective about the time and resources needed to commercialize new technologies, factoring in technological, licensing, and funding uncertainties. The time required to prepare for and successfully complete regulatory approval was included.

The near-term deployment goals for Advanced Light Water Reactors (ALWRs) for electricity generation, and a renewed commitment to R&D applicable to all LWRs (including current plants), are the least expensive. The bulk of federal investments are envisioned to occur over the next ten years, with continued modest funding after that as necessary, particularly on strategic areas such as advanced LWR fuels and materials. Costs of federal spending on electricity generation are based on continued funding of the NP2010 program on a cost-shared basis, and projections that the private sector will deploy ALWRs for electricity generation by 2015, based on limited federal incentives. No federal funding is expected for NP2010 after initial deployment of the first six plants. Total federal costs are roughly $500M, with equal or greater cost share by industry. This does not include costs of completing Yucca Mountain, which are uncertain; nor does it include the costs of revitalizing the nuclear industrial infrastructure.

Federal spending for nuclear generated hydrogen and other process heat applications are based on projections that the commercial VHTR technology can be demonstrated and will become competitive in the 2020 timeframe for industrial applications. This timeline assumes that conservative technology choices are made to maximize near-term licensing and commercial deployment potential. Total federal RD&D costs for the nuclear hydrogen mission are estimated at $2B through about 2020, after which VHTRs will go forward as commercial units.

The costs of establishing nuclear fuel recycle are considerably higher than reestablishing the ALWR option for electricity generation and creating a commercial VHTR option for hydrogen generation. There are a number of significant technical, cost, and institutional challenges facing reprocessing that likely will delay the start of prototype demonstration until about 2030, and large scale deployment until about mid century. Rough costs to the Federal Government may reach $35B by 2050 and $60B by 2070. These estimates include both the RD&D costs and government-funded subsidies for a portion of the construction and operation of fast reactors and nuclear fuel reprocessing plants. These costs assume significant reliance on the private sector to construct and operate fast reactors as commercial power plants (after the technology is demonstrated and licensed, and the learning curve is ascended). These costs are highly uncertain because of the speculative nature of estimating when nominal commercial viability can be achieved for these facilities.

Rough costs to the Federal Government through mid-century depend primarily on whether the reprocessing plan has been structured to be the least-cost path for safe, long-term management of spent nuclear fuel (per above planning assumptions), or whether an accelerated plan is chosen for deployment that does not wait for the market price for uranium to drive the shift from the once-through fuel cycle to a closed fuel cycle, and from LWRs to a mix of LWRs and fast reactors.

There are fundamental differences between the deployment of nuclear energy generation with ALWRs and commercial VHTRs, and technologies to close the nuclear fuel cycle. There are commercial markets for electricity and hydrogen that enable near-term deployment of ALWRs and a transition of VHTRs to the private sector as soon as the technology is ready. There is no comparable existing commercial market for fuel recycle.

A market will evolve for the fast reactor component of closed fuel cycle systems because fast reactors can produce electricity. However, based on today's technology and uranium ore/enrichment costs, fast reactors are not expected to compete with ALWRs in power generation until about mid-century. Economic parity could be achieved when ALWR fuel based on enriched U–235 becomes sufficiently more expensive than fast reactor fuel using recycled components. In the long-term, as uranium prices rise, the alternate fuel cycles will advance to breeding and the need for subsidy will end.

Even with the extended timetable for introducing fuel recycle in the U.S., a single expanded-capacity spent fuel repository at Yucca Mountain is still adequate to meet U.S. needs. Construction of a second repository is not required under this timetable. If, however, reprocessing is implemented on an accelerated schedule before it is economic to do so based on fuel costs, then the Federal Government will need to bear a much larger cost.

In the U.S. context, the optimum scenarios for transitioning to fuel recycling require an R&D focus on those technologies that enable "full actinide recycle," and fast reactors. This path is preferred over one that maintains a "thermal recycle" mode using MOX fuel in light water reactors, because the high costs and extra waste streams associated with this latter path do not provide the desired benefits in terms of either non-proliferation or spent fuel management costs.

Priorities for R&D Programs

Light Water Reactor R&D

Significant R&D needs exist for the current fleet and the new fleet, especially in areas of age-related materials degradation, fuel reliability, equipment reliability and obsolescence, plant security, cyber security, and low-level waste minimization. Also, developing a new generation of high reliability LWR fuel with much higher burnup will better utilize uranium resources, improve operating flexibility, and significantly reduce spent fuel volume and transportation needs, resulting in additional improvements in nuclear energy economics. These are mid-term R&D needs whose impact would be considerable if accelerated with government investment.

Process Heat R&D

An essential consideration in reducing dependence on foreign sources of oil and natural gas is that hydrogen is necessary today in upgrading heating oil and gasoline, and in making ammonia for fertilizers. Making hydrogen today consumes five percent of all natural gas in the U.S. and demand for hydrogen is growing rapidly. This situation can be improved with a nuclear system having hydrogen production capability as soon as it can be developed. In the long-term, many believe that a hydrogen economy is essential for revolutionizing transportation, in which case the demand for competitive and environmentally responsible hydrogen production will greatly increase. A large-scale, economical nuclear source would hasten that future.

Fuel Recycle R&D

Establishing a fuel recycle with the demonstrated ability to improve the management of nuclear wastes will bring added confidence in greatly expanding the use of nuclear energy. More importantly, advanced fuel cycle technology options provide the ability to supply sufficient nuclear fuel in the future to ensure long-term energy and environmental sustainability.

Necessary technologies include cost-effective and diversion-resistant reprocessing to extract fuel and separate and manage wastes, as well as alternate reactor concepts (e.g., fast reactors) to generate electricity as they generate additional fuel and consume the long-lived actinides and other constituents. These increase confidence in achieving a sustainable economic fuel supply, reducing the spent fuel backlog, and increasing the effective capacity of Yucca Mountain many-fold in the long-term. While there are significant technology challenges and market uncertainties, large-scale deployment of fuel recycle by government and industry could begin by mid-century.

Conclusions

- The strategy for nuclear energy development and implementation in the United States requires a consensus of industry and government.
- The overall strategy should be determined by considering a combination of market needs and national goals for energy security, national security, and environmental quality.
- The strategy should integrate near-term, medium-term, and long-term priorities. *R&D needs to proceed now on all fronts,* but priorities for deployment are as follows:
  - **Near-term:** License renewal for the current fleet, and licensing and deployment of new, standardized ALWRs are high priorities within the next decade. Timely near-term deployment of ALWRs will require demonstration of a workable licensing process, and completion of first-of-a-kind engineering for at least two standardized designs. Industry and DOE should cost share these R&D programs at a level to achieve deployment by 2015. In addition, DOE and industry should cost share certain LWR technology thrusts with significant national benefits, e.g., a new generation of LWR fuel. The newly authorized Nuclear Energy Systems Support Program is key to this objective.

    To enable the resurgence of nuclear energy, the near-term elements of an integrated spent fuel management plan must proceed. These near-term elements include completion of the repository at Yucca Mountain, deployment of multi-purpose canisters approved by the NRC, implementation of an effective spent fuel transportation system, and provision for "aging pads" to allow cooling prior to placement in the repository.
  - **Medium-term:** Development of a high temperature commercial VHTR is needed, capable of generating hydrogen at competitive costs, for initial use by the petroleum and chemical industries. Deployment will require concept development, defining end-user requirements and interfaces, resolution of design and licensing issues and prototype demonstration. This effort should be funded primarily by government, but targeted for expanding industry cost-sharing as commercialization becomes more promising.
  - **Long-term:** Development of fuel recycling technologies will eventually be needed for a sustainable nuclear energy future. These technologies will also support an integrated and more cost-effective spent fuel management plan. Key elements of this integrated plan include expansion of the capacity of the Yucca Mountain repository; provisions for engineered cooling of the repository well in excess of 50 years prior to closure, in combination with co-located "aging pads" for spent fuel. Reprocessing of spent fuel is expected to begin in a demonstration plant by about 2030, based on an aggressive R&D program aimed at identifying cost-effective and diversion-resistant means to recover usable reactor fuel. Successful development of fast-spectrum reactors will be required for "recycling" the usable uranium and plutonium recovered from spent fuel, while consuming the long-lived actinides. These facilities should be funded by government.
- The strategy should address rebuilding the nuclear industry infrastructure in the U.S. Currently, major equipment for nuclear plants must be procured offshore. Long-term energy security requires that the U.S. industry have the capability of supplying and supporting U.S. energy producers, and better integrating energy supplier and end-user needs. These infrastructure needs include large numbers of new skilled construction workers, engineers, nuclear plant operators and other key personnel needed for construction, operation and maintenance of new facilities.

Initial Observations Relative to GNEP:

The above Consensus Nuclear Energy R&D Strategy for U.S. Government and Industry was drafted prior to DOE announcing its Global Nuclear Energy Partnership. Nevertheless, there is significant agreement and alignment between these independent planning efforts.

EPRI supports the vision and goals of the GNEP. We look forward to the opportunity to work with DOE on this important initiative.

The consensus strategy paper was intended to address the continuum of nuclear energy R&D needs. In contrast, GNEP has a somewhat more focused scope, so there are understandable differences between the two approaches.

Important areas of substantial agreement include:

- *Near-term deployment of ALWRs and the licensing of Yucca Mountain.* The NP2010 program is critical to the future expansion of nuclear power and ultimately to moving the Nation to a more sustainable and secure energy future. Further, we agree with GNEP that under all strategies and scenarios for the future of nuclear power, the U.S. will need a permanent geologic repository.
- *Creating a nuclear fuel leasing and used fuel take-back regime for "user" nations in return for their commitment to refrain from developing and deploying enrichment and reprocessing technologies.* This central foundation for GNEP was supported by the EPRI–INL paper, based primarily on the recommendation in the Dec. 2004 report of the National Commission on Energy Policy, as a vital non-proliferation initiative.
- *Improving the cost and diversion resistance of reprocessing technologies before deployment.* Advanced separation technologies that are more proliferation resistant and more cost effective than currently available technologies are essential objectives. Today's recycling technology has significant limitations that effectively eliminate it as an option to accomplish the GNEP non proliferation and spent fuel management objectives.
- *Developing advanced fast spectrum reactors for reducing the long-lived, heat producing isotopes present in spent fuel.* This is an essential step for improving spent fuel management, since single-pass recycling in LWRs provides little or no reduction in long-lived waste volume and heat output. The alternative, "full actinide recycle" will reduce heat output, and may also contribute to diversion resistance by relying on processing schemes that keep minor actinides and plutonium together.
- *Advanced reactors will need to be certified by the Nuclear Regulatory Commission.*
- Perhaps most important to Congressional deliberations, our work and the GNEP agree that *well-crafted, deliberate, and rigorous R&D is needed now to advance both reprocessing and fast reactor technologies.*

As discussed above, our estimate is that reprocessing in a large scale demonstration plant would begin operation by about 2030, with fast reactor technology demonstration in the same timeframe. Smaller scale pilot demonstrations may be feasible earlier than 2030. Full scale commercial deployment would occur in the 2050 timeframe. These timelines are more conservative than corresponding deployment estimates provided in GNEP documents. We believe that the significant technical, resource, and licensing challenges facing these advanced technologies will drive deployment dates.

It is important to note the origin and implications of these timing projections. As previously stated, we believe that starting the R&D now is a high priority. In short, our longer timelines should not be interpreted as a recommendation to "go slow," but rather as a belief that the technical challenges to moving from laboratory to commercial scale are daunting, and that achieving end results that are cost effective is equally challenging. Hence we encourage adequate funding for GNEP, with a program timeline and challenging yet achievable milestones. We also encourage adequate funding for other priority nuclear energy programs such as NP2010, Nuclear Energy Systems Support Program, and the nuclear hydrogen mission. We believe that an aggressive nuclear fuel recycling technology development program, even if it takes longer than currently envisioned, will still be beneficial.

On the subject of repository deployment, we found that "a single expanded-capacity spent fuel repository at Yucca Mountain is adequate to meet U.S. needs, and that construction of a second repository is not required under this timetable." This is due to a number of factors, including:

- Modifying the legislative limit on the Yucca Mountain repository capacity to permit utilization of its full technical capacity.

- Developing a new generation of high performance LWR fuel in the 2010–2020 timeframe, which will reduce the rate of spent fuel generation in the U.S. by up to a factor of two.
- Maintaining engineered cooling of the repository before final closure for periods of time in excess of 50 years to allow for decay of the shorter-term fission products.
- Alternatively or in combination with in-repository cooling, temporary centralized storage or aging pad sites can be provided where spent fuel is cooled for an appropriate length of time before repository emplacement.
- Deployment of reprocessing and fast reactors can be initiated in time to adequately manage used fuel within a single expanded-capacity geological repository.

The EPRI–INL paper identifies energy and environmental sustainability as the primary justification for fuel recycling. Recycling nuclear fuel may also enable breeding of new fuel, which will extend nuclear power's contribution to future energy supplies for many centuries to come. We believe that improved spent fuel management is a potential inherent benefit of recycling, with the degree of improvement dependent upon technology advances. Based on its extensive work, EPRI believes that the current repository design poses a small and acceptable risk to society. This will remain so, whether or not the long lived actinides are reduced by recycling. So the advantages of recycling to the repository primarily relate to the efficient use of repository space, and having the flexibility to recover and recycle prior-emplaced used fuel, if and when technical and economic conditions so dictate.

We support the assured fuel supply and used fuel take-back regime proposed by the Administration. For this regime to gain acceptance among user nations, the U.S. and other fuel supplier nations must provide assurance of their ability to meet commitments for both fuel supply and take-back, in order to obtain early commitments from the user nations to forgo enrichment and reprocessing. This is an important reason why completion of centralized interim storage facilities and a permanent repository are urgent to success of the fuel supply and take-back regime, even before recycling is ready.

Finally, we support development of a comprehensive plan and joint efforts to rebuild our national nuclear infrastructure. Currently, major equipment must be procured offshore, and aging workforce issues point to the need for aggressive training and recruiting initiatives. Long-term energy security requires that the U.S. industry have the capability of supplying and supporting U.S. energy system vendors, architect-engineers, and better integrating energy supplier and end-user needs. Workforce infrastructure needs include large numbers of new skilled construction workers, engineers, nuclear plant operators and other key personnel needed for construction, operation and maintenance of new facilities. I share with other industry spokesmen the current concern for lost funding to nuclear university education programs.

In summary, EPRI would like to work with DOE on creating a consensus nuclear R&D strategy for the future. U.S. utilities accept the DOE premise that GNEP is primarily a federal initiative for governmental purposes, and thus should be funded by federal appropriations. Our members are presently focused on maintaining excellent performance of current plants and preparing for near-term deployment of ALWRs. These are the areas that utilities believe justify cost-sharing with DOE at the present time. EPRI and its members are interested in helping inform the R&D agenda for long-term programs. If the R&D is successful, they will be ready to cost share advanced reactor deployment in a manner consistent with the EPRI–INL Nuclear Energy R&D Strategy paper and the "80–20 paradigm" discussed earlier.

Biography for David J. Modeen

David J. Modeen has over 29 years of operational, technical and policy experience in the nuclear field. Dave joined EPRI in March 2003 as the Vice President, Nuclear Sector & Chief Nuclear Officer. In this capacity, he leads the team responsible for development of EPRI's Nuclear Power technology research and development program and business development, in close concert with its advisors, both domestic and international. The technology development plans and outcomes are reflected in annual, three-year, and longer-term nuclear strategic planning documents aligned with EPRI's overarching Electricity Technology Roadmap.

Previously, Dave was a Director at the Nuclear Energy Institute (NEI) located in Washington, DC, with responsibilities in a variety of areas, including engineering, security/access authorization, training and risk assessment. During his 14 years at

NEI and its predecessor organization, he managed the development and ultimate approval of a number of formal industry positions requiring collaboration among EPRI staff, INPO, vendor and utility advisors. His leadership resulted in industry executives endorsing industry guidance from NEI that effectively mandated implementation.

Prior to his Washington experience, Dave spent seven years with the Portland General Electric Company as a Senior Engineer, and obtained a Senior Reactor Operator certificate and stood watch as a Shift Technical Advisor at the Trojan Nuclear Plant. He had broad technical responsibilities at Trojan including upgrade of the Emergency Operating Procedures, development of Safety Parameter Display System, Control Room Design Review, and fire protection safe shutdown analysis and alternative shutdown procedures.

An honors graduate of Iowa State University, Modeen holds a B.S. degree in industrial engineering. He served five years in the U.S. Navy as a submarine warfare officer, qualifying as Engineer while serving on board the USS Patrick Henry. He serves on the Institute of Nuclear Power Operations Advisory Council, is a registered nuclear and mechanical professional engineer in the state of Oregon, and is a member of ANS.

ELECTRIC POWER RESEARCH INSTITUTE

Representative Judy Biggert
Chairwoman, Energy Subcommittee
House Committee on Science
Suite 2320, Rayburn House Office Building
Washington DC, 20515-6301

Dear Representative Biggert:

This is to provide a record of financial disclosure according to the Rules of the House of Representatives for testimony at your Subcommittee's Hearing, *"Assessing the Goals, Schedule and Costs of the Global Nuclear Energy Partnership"* on April 6, 2006.

My current federal funding contracts and obligation are provided in the following list:

Federal Sponsor	Period	Amount	Remarks
DOE-NE	FY2006	$272K	NP2010

This funding is DOE's FY06 portion of a three year cost-shared Cooperative Agreement between EPRI and DOE to support Combined License guideline development.

Please let me know if you require any further information regarding these federally funded contracts.

Sincerely,

David J. Modeen
Vice President and Chief Nuclear Officer

Together . . . Shaping the Future of Electricity

1300 West W.T. Harris Boulevard, Charlotte, NC 28262-8550 USA • 704.595.2173 • Fax 704.595.2860 • dmodeen@epri.com

DISCUSSION

Chairwoman BIGGERT. Thank you very much.

And we will now have—Members will ask questions. Again, we have a time limit for us, for five minutes. And I will begin with the first question.

Mr. Johnson, Dr. Garwin supports the vision of GNEP, but he asserts in his testimony that technical goals of the program are more ambitious than is really needed. Achieving GNEP's technical goals could increase the effective storage capacity of Yucca Mountain's repository by a factor of 100 whereas a 10-fold increase in capacity, which could be achieved at lower cost, would enable Yucca Mountain to store the waste produced by commercial power reactors operating for the next century. Do you agree with this?

Mr. JOHNSON. Based on simply hearing the statement this morning, I can't say that I hear anything I disagree with, but I would prefer to read a little bit more in detail and understand the basis for the conclusions.

Chairwoman BIGGERT. Well, then would you think that DOE would consider scaling back the technical requirements for separation efficiency in the—in your systems analysis?

Mr. JOHNSON. If, upon further study and investigation, that is the correct course of action; yes.

Chairwoman BIGGERT. Okay. Thank you.

Then this is for Dr. Garwin, Mr. Johnson, and Dr. Todreas. I cannot say that. Todreas. Is that right?

Dr. TODREAS. Todreas.

Chairwoman BIGGERT. Todreas. I am putting an extra syllable in there. Thank you. Todreas.

Again, Dr. Garwin asserts in his testimony that the ordering of R&D priorities in GNEP is all wrong, and he suggested any near-term demonstration of UREX is premature and wasteful and we should instead focus on the advanced burner reactors and the fuels for the ABRs and the reprocessing technology necessary for the ABRs. So do you agree with that, Dr. Todreas?

Dr. TODREAS. Yes, let me start.

The other thing Dr. Garwin said is that the fuel reprocessing and the reactor design have to be done together and in coordination. This is new in reactor technology. We always used to design the reactor with the fuel then throw the fuel over the fence and let people take care of it from a waste management point of view. In this new activity, particularly with reprocessing, you have to do them all together in terms of coordination. And so the bottleneck here is the reactor design and its fuel selection, as well as successful reprocessing. So my answer would be you have got to pursue UREX, or whatever comes out of it, and in parallel, design a fast reactor, select the fuel, and most importantly, which hasn't been mentioned, is you have got to get the capital cost of the fast reactors down so they can be cost-competitive so that industry will take over the operation of these, which will make electricity on the competitive market.

Chairwoman BIGGERT. If there were to be built, then, a new reactor, the light water reactor, wouldn't that show how to cut the cost on that? We haven't built a reactor, you know, in this country, in so long. Would that help to start with that and then determine how to build the other?

Dr. TODREAS. Yes. First, getting a light water reactor order to get the industry going to rejuvenate people, that is critical. But if you are implying that there is not significant difference between the design and the objectives of a fast reactor for——

Chairwoman BIGGERT. No, I am not suggesting that.

Dr. TODREAS. Okay. So you have to start with the light water reactor, but then the challenges of a fast spectrum reactor for transmutation with its fuel, with its reprocessing, are a factor above a light water reactor design. And you have got to get after that, too.

Chairwoman BIGGERT. Well, I think we need to start that process right away, but—and some of you are saying we should wait, but I think that—also with the industry to start.

Mr. Johnson, do you have anything to add to that?

Mr. JOHNSON. What we have tried to do is lay out a development program where we are scaling up to an appropriate size of demonstration facilities to better inform the question and the cost of any further commercialization of the technology. We are trying to walk through this in a step-wise fashion, better understand the technology, better understand the ultimate cost and schedule requirements.

Chairwoman BIGGERT. Thank you.

Dr. Garwin, how would we obtain enough material to fabricate and test new fuels without a sizable UREX demonstration plant?

Dr. GARWIN. You know, there is plenty of separated fuel available abroad. There is MOX fuel, if you wanted to go to mixed oxide fuel, 40 tons of it that was prepared for the Superphenix in France. So it is no problem, and what you want is test fuel. That is, you want small amounts of fuel, not a full reactor load. The advanced burner test reactor is to be a neutron source, a fast spectrum source, for testing small amounts.

Chairwoman BIGGERT. And if we don't want to use MOX, then what——

Dr. GARWIN. Well, it is very much up in the air as to whether one uses metal fuel or oxide fuel or carbide fuel or a nitride fuel. And there are advantages to both of them. As Dr. Todreas says, it has never really been considered altogether, the reactor design, its safety, its margins, the fuel form, and the reprocessing. And that is exactly what needs to be done here in order to get the capital cost of this fast reactor down.

So this is a big gamble, and the question is can we increase the odds of winning it. But I do emphasize that the engineering scale demonstration for UREX+ is far too big, whatever its technical requirements. It assumes that there will be a single 2,000 ton per year plant, and one percent is a typical demonstration scale. That would be 20 tons per year, not 200 tons per year. Much too big, much too soon, much too high requirements are set on it.

Chairwoman BIGGERT. I think we have wasted 25 years since we have stopped this process. I hope that we will move ahead.

Mr. Modeen, you wanted to make a comment?

Mr. MODEEN. Yes, Madame Chairman. I—just a couple of things. Listening to the answers to the—first, as an example to support Dr. Todreas, the French experience with the Phoenix and then the

Super Phoenix reactor. Phoenix, the smaller reactor, worked very well. In fact, it is still working today. Scaled up to large commercial size, 1,300, 50-megawatt electric Super Phoenix ran on and off, but eventually, after 10 or 12 years, made the decision to decommission it. They just could not make it work right at that level.

The second piece is relative to our study with the Idaho National Lab, I think our view, and I think what I am hearing from the panelists, is not so much that we don't do the research, but it is all things in time and trying to figure out what does one do first and then next and next and understand and make informed decisions based on that research prior to this construction of some of these engineered facilities and otherwise. That is, kind of, the industry's perspective.

Chairwoman BIGGERT. Thank you.

Mr. Honda, you are recognized.

Mr. HONDA. Thank you, Madame Chair.

I am trying to wrap my head around this whole discussion and this whole process, and I think what I am hearing is that we have made decisions, we have made decisions quickly, and there are some concerns about the one process to the selected process or the solution set, and there is a lot of concern about the magnitude and cost and readiness.

Mr. Johnson, you have talked of GNEP being a phase program in which a decision and plans will proceed only after sound assessments of costs, risks, and schedules are understood. You plan to conduct applied research, engineering, and environmental studies to reform these decisions. What do these studies need to show to justify the current technology down-selections and how will the studies affect these decisions should they prove to be adverse to the current plan?

Mr. JOHNSON. What we are planning to do and what we have to do over the next two years is to continue the research that has been underway in our laboratories over the last four years on the separations technology, develop the conceptual designs of these facilities, conduct the necessary National Environmental Policy Act analyses, and develop a better understanding of cost and schedule of moving forward with the demonstration facilities. We also want to have completed the types of systems analysis that have been discussed so far this morning to better understand and make a completely informed decision as to whether this is the right path to continue down or is there a course correction that is necessary or is it something to abandon altogether.

Mr. HONDA. Well, you know, that is within the context of UREX+.

Mr. JOHNSON. That is in the context of all of the demonstration facilities, sir.

Mr. HONDA. So you are saying that you would be looking at different processes and making a comparative analysis of their—the cost-effectiveness and the timeliness of these?

Mr. JOHNSON. With respect to the separation technology, the work that we have done to date in the laboratory gives us full confidence that the UREX+ process is, indeed, the correct process to continue with. So while we may continue some—a small level of effort in some other advanced aqueous processes, the majority of our work would be focused on the UREX+ process.

Mr. HONDA. Okay. I think I am getting clearer now.

On the UREX process, as if we have already made a decision that we want to go down that path, prior to looking at all processes first, is that a correct statement that there have been some decisions already made to go down that path in spite of the fact that you are saying that we are going to study others or——

Mr. JOHNSON. Yes, sir, that is a——

Mr. HONDA. And was that choice made through some sort of a peer-review process where other folks were involved in deciding that, or how was that decision made?

Mr. JOHNSON. The decision has been made from an informed position, one, knowing and understanding the PUREX process that is used internationally——

Mr. HONDA. Excuse me. Informed, meaning by peer review or by a small group of folks? Were there outside folks? Or who did that?

Mr. JOHNSON. Our federal advisory committee, our subcommittee on advanced fuel cycle program, chaired by Dr. Burton Richter, has been watching over and guiding this program since it inception.

Mr. HONDA. So he guided a group that was brought in its input within the government in the technical fields and other folks? I guess that is what you call peer review. Is that what you are saying?

Mr. JOHNSON. It is one type of peer review, sir.

Mr. HONDA. But the traditional—understanding what peer review means, is that what you are saying, or are you saying it is a narrow form of peer review?

Mr. JOHNSON. I am saying it is an independent outside body, which has done monitoring and reviewing the process and the progress made in the laboratory.

Mr. HONDA. Okay. Can you tell me who chose them or how they were chosen or——

Mr. JOHNSON. The subcommittee was selected by decision of the full federal advisory committee.

Mr. HONDA. Okay. And I suspect that you have records of the discussions and how you approached the consensus?

Mr. JOHNSON. Yes, sir. We have records of their meeting minutes.

Mr. HONDA. Okay. Thank you.

To the—it appears my time is up, but just a real quick question to the other three. Do you have any comments to the questions I had?

Dr. GARWIN. I have had the benefit of an exchange of correspondence with Dr. Richter. I don't think that they had contact with GNEP until the end of February, and I really don't understand whether the UREX process that was proposed at that time separated the plutonium and the transuranics from the lanthanide fission products or not. If not, then the fuel was by no means self-protecting by a factor of 1,000 or so. I understand now Dr. Fink's briefing of March 10 includes the lanthanides to be shipped to the advanced burner reactor plant and then removed, but this is hardly a stable program, and it could hardly be said that the transmutation subcommittee reviewed and chose it.

Dr. TODREAS. Yes, what I wanted to do is just bring you back to the criteria that I mentioned for selection, which were coordination, economics, protection of public health, and worker safety, physical protection, and safeguards. And before you settle on a process for UREX and then commit down the road for large expenditures, maybe some engineering demonstration is okay before that and more like 20 tons or something. You have got to check that. And I would just take cost, economics. I know you have had hearings on the economics of reprocessing, but this reprocessing cost is going to be expensive. It is going to raise the fuel cycle cost for nuclear power. You need a systems approach as to who is going to come up with that cost, and you need to bound that cost. And so before you pick the process, you need to have enough R&D results in hand that you know where you are on that factor. So UREX+1 may look good, but I don't think it has been through a systematic study evaluation pinning all of the points on these criteria I listed, and I would go back to cost. And it is no wonder. It has just been at lab scale. So much more R&D needs to be done.

Mr. HONDA. Thank you.

Chairwoman BIGGERT. Mr. Honda, I think that we should keep in mind that we—the laboratories have been doing reprocessing R&D for quite some time now. In fact, the—Argonne National Lab that is in my district, when I first came to Congress, was really working on the electrometallurgic reprocessing and then went to the pyroprocessing, and so I don't think that UREX is new. It is not new, and it has not been—and it has been studied. But what we are talking about really now is the R&D and demonstration. So——

Mr. HONDA. You know, if I may, Madame Chair, I think I understand what you are saying, but what I am hearing, though, even though it is R&D, that there are still other matters and parameters that still haven't been scaled out from R&D into a pilot program, and it sounds like what we are looking at is 200 tons rather than 20, and there is a concern about the whole rolling out and planning for this kind of a process.

Chairwoman BIGGERT. Well, if—I think Mr. Johnson can address that, and I would like him to, because I think that is misunderstanding there.

Mr. JOHNSON. Thank you, Madame Chairwoman.

With respect to the size of the facility, I am sure the Department has contributed more to the confusion on that matter than anyone around, and I would like to take this opportunity to point out that while initially in the internal discussions within the Department on the overall Global Nuclear Energy Partnership that—these technology demonstrations, larger numbers or larger sized facilities were discussed. Right now, though, sir, we have underway an activity looking at making a determination or recommendation on an adequately sized facility for the separations work. Like you, I will admit, a facility on the order of, you know, 200 metric tons to 500 metric tons "scares me to death." One is we don't know enough to go to that size facility. Secondly, I doubt we could afford it. So we have an activity underway which will be informed by experienced personnel from those countries who are operating such facilities today as well as scientists and engineers within our laboratory system. Making a determination of what is an appropriately-scaled sized facility for demonstrating the physical phenomena that is of most interest in understanding the processes and being able to determine the safety of operating such a facility is a key consideration. So the final design sizes have not been established. My hope is that it is significantly smaller than what the stated sizes have been to date.

Mr. HONDA. Would the Chair—may I ask another question?

Chairwoman BIGGERT. I hate to keep our other Members waiting, so let us come back to that.

The gentleman from Texas, Mr. Neugebauer, is recognized for five minutes.

Mr. NEUGEBAUER. Thank you, Chairwoman.

I want to kind of move to the more commercial application. I think one of the things that I am strongly convinced of is that we have got to do whatever is necessary to get moving again on nuclear energy in the production of electricity primarily from that. I think we have lulled ourselves here and wasted a lot of time, as the Chairwoman mentioned, not doing that. What I—as I listened to the dialogue this morning, what concerns me is that I kind of heard that Mr. Modeen, in talking about the fact that—maybe that the scientific community and the commercial community are not necessarily working in conjunction with technologies that we could bring out quickly and it is—you know, we have got some people working on the long-term, some people working on the short-term. I appreciate some of the comments that Dr. Garwin made about, you know, let us put—focus on things that work, make sense, and let us make them cost-effective. And those are wonderful words to my ears.

I think one of the things that I would ask you, the panel, is , you know, where are—we can't just—we can't go into a demonstration project and drag this out another 10 or 15 or 20 years without really getting—stepping up to, I believe, the commercial construction of new reactors in this country. So my question to the panel today is while some of these things may have some long-range research value, and that will be wonderful, but the American taxpayers today need for us to do whatever we need—can to get our dependence on foreign energy reduced fairly quickly. So what are we doing in a—at—today, and what are some of the things that we should be doing to get that process moving forward where we really need to be breaking ground on a new reactor or several new reactors within the next 12 to 18 months? And are we going to do that? And can we do that?

Mr. Johnson.

Mr. JOHNSON. Yes, sir. The Department's Nuclear Power 2010 program, which is a cost-share initiative with industry, is finalizing design of the most advanced light water reactor designs and helping demonstrate the new regulatory processes for siting and operating these facilities. The initiative has been a tremendous success and continues to be. We are fully committed to that program. Based on the work that we have done in partnership with the industry, we have seen, and hopefully you have read as well in the press, many companies which are stepping forward and making indications that they will be making decisions soon on going forward with new nuclear plant construction projects. I think the outlook looks very good.

Mr. NEUGEBAUER. Dr. Todreas, do you have comments on that?

Dr. TODREAS. I am going to leave this to DOE and EPRI. I was the co-chairman of the DOE committee that wrote the road map for nuclear power 2010. I saw it launch, but the execution remains with these people.

Mr. NEUGEBAUER. Thank you.

Dr. Garwin.

Dr. GARWIN. Yes. Well, we need to buy reactors of existing type. That is, we can't start to work now designing new reactors, so if they are not ready for a decision, we should not consider them in the near-term expansion. What we are talking about here in GNEP is beyond that, the particular part of it is the waste reduction by reprocessing and recycling with this great new gamble of a big fast reactor population. That we need to think about and design and design and design, because we can't make those decisions right now if we are not going to lock ourselves into a high-cost structure that will have to be abandoned.

Mr. MODEEN. Let me answer several ways. First, what Congress has done with the *Energy Policy Act of 2005* certainly took a lot of the risk, the investment risk, off from the utilities. The second piece is, and I would agree with Mr. Johnson, the NP–2010 initiative is very, very important. Some concern, I believe, Skip Bowman from NEI testified relative to the funding, a little bit of plus up on that. It took a bit of a hit there with the potential GNEP proposal. Yucca Mountain can't lose sight of that. It is those things, and I think we all know what they are, and we are working through them. In that regard, I would say that, just so my remarks aren't misspoken, in the area of advanced light water reactors, the industry and the government, since the late '80s, has worked very well in a public-private partnership. We are anticipating and have a strong desire to do something similar both for the high-temperature reactor for a hydrogen mission as well as then what may come out of GNEP.

Just a couple of other points relative to the balance. Again, I am with you on the near-term priorities. The longer-term for GNEP is really more a governmental role, and I think today our members are not ready to cost-share in that activity but may be later. On the point of that I can see in our paper, we justify recycling in the 2035 to 2050 time period based on energy and environmental sustainability, not non-proliferation and those types of issues. But the second point I think is important to keep in mind, again, there is sort of a rush to do something, is that the fuel supply and take-back regime that is at the center of GNEP, in the industry's view, can be sustained via a once-through cycle for quite a few decades. Ultimately, again, one needs to get to the reprocessing and recycling. That is why it is important to start and complete the research today, but again, it is a timing issue.

Mr. NEUGEBAUER. Thank you.

Chairwoman BIGGERT. Thank you.

The gentleman from Texas, Mr. Green, is recognized.

Mr. GREEN. Thank you, Madame Chairlady, and I thank the Ranking Member as well. Thank you for this opportunity to explore some new concepts, I suppose.

If we complete this project 100 percent, what percent of our electricity needed will be impacted? Dr. Johnson.

Mr. JOHNSON. Sir, I am afraid I don't have an answer for you to that particular question.

Mr. GREEN. Right now—we, right now, get about 20 percent of our electricity from nuclear reactors.

Mr. JOHNSON. Yes, sir.

Mr. GREEN. If we can successfully complete this project, what percent of our needs will be satisfied?

Mr. JOHNSON. I can't give you a percentage, but let me answer your question in a slightly different way. What this technology demonstration program we are talking about this morning is focused on is addressing issues associated with the spent fuel that is generated by these plants.

Mr. GREEN. Well, let me do this. I appreciate your comments and your commentary.

Does anyone on the panel have an answer for me?

Dr. GARWIN. It is just a different way of doing business. The cost will go up, so if you are price conscious, you will use less electricity, less——

Mr. GREEN. Yes, sir.

Dr. GARWIN.—nuclear electricity.

Mr. GREEN. So we will be at the 20 percent level still?

Dr. GARWIN. Well, one hopes to double the amount of electricity and increase the fraction that is supplied from nuclear, but that is not at all dependent on this program. That can be done with the thermal reactors, the light water reactors——

Mr. GREEN. Let me go on.

Dr. GARWIN.—and the high-temperature reactors.

Mr. GREEN. Thank you very much. Let me go on with some additional observations.

DOE Secretary Bodman concedes that GNEP may ultimately call for an investment of $20 billion to $40 billion, and this is for construction of three facilities, and annual operating costs can run into the billions. Deployment and operation of additional required reprocessing plants and a fleet of fast reactors and associated power processing facilities could cost over $200 billion. This would put GNEP in the realm of the U.S. space program in terms of long-term cost. Building two full-scale spent fuel reprocessing plants could cost $40 billion to $80 billion. At an estimated price of $3 billion to $5 billion each, deployment of a fleet of these new fast reactors could easily cost over $100 billion. My concern is this. Where will the money come from? Where is the sense of shared sacrifice in this country? Right now, we are talking about, over the next five years, cutting education $45.3 billion, health about $18 billion, income security, which includes housing and childcare, $14.9 billion, mandatory spending, which includes Medicare and Medicaid, $65 billion. We don't have a good sense of shared sacrifice with this Administration. This Administration cuts Head Start, cuts Social Security, cuts Medicare, cuts student loans, and we send people to the moon or we send people to the outer realm of the galaxy at some point, hopefully, and I support good scientific programs. I want to see us do the smart things. But there has to be some sense of shared sacrifice, and that is what is missing in all of this. We talk about spending all of these hundreds of billions of dollars, possibly in the trillions as we go through this over the long-term, but we don't talk about who is going to sacrifice for it. And I believe that there ought to be some shared sacrifice. We cannot continue to expect the least and the last and the lost to pay for space programs and to pay for nuclear programs. These have to be shared by the well-to-do, the well-off, and the well-healed. It has to be something that we all, at some point, understand is needed and we all are willing to sacrifice to have. And I commend you on what you are telling us in terms of where we must go. Clearly, there is something we can afford to do and we cannot afford to do, meaning we must do it at some cost. But there has to be some sense of shared sacrifice. And my consternation with all of this has to do with who is going to pay for it. Can we all pay for it? Or will some members of society pay for it? That causes me great consternation, and I really don't think that that is something that I have to have you respond to. It is something that the American people probably want someone here in Congress to say, and I just happen to be the guy who feels that it has to be said. I just believe there ought to be some sense of shared sacrifice that this Administration has not embraced.

And I thank you for the time, Madame Chairlady. I yield back.

Chairwoman BIGGERT. Thank you.

The gentleman from California, Mr. Rohrabacher, is recognized.

Mr. ROHRABACHER. Thank you very much.

And I would like to thank Chairwoman Biggert for letting me participate today.

Just one note, my very elegant friend who just made several good points about costs, and some of the numbers are staggering that we are talking about, but let us note that in terms of the costs that you were referring to about the reductions that are being proposed, we are not talking about cutting spending in the areas that you outlined. We are talking about reducing the growth in the budget in those areas. That is a big difference between saying we are going to cut various programs by so much money. Very—with—and that is differentiated from cutting the growth in those programs by that much money. But the point he is making, of course, however, is valid in terms of the staggering costs and who is going to pay for it. I think we all need to understand that if there is an energy shortage, as energy becomes in short supply, whatever—however that comes about, the electric bills of the American people will go up, and the energy bills of the American people will go up to the point that it is costing us those billions of dollars anyway. And there is a shared sacrifice in that. So—but it would be much better for us to invest and make sure that those energy prices don't go up so that that revenue isn't being siphoned out of the pockets of the American people.

Mr. GREEN. Would the gentleman yield for a—just one minute?

Mr. ROHRABACHER. Yes, sir.

Mr. GREEN. And I thank you for the time.

Given that this appears to be a risky investment, at best, when you compare UREX+ to PUREX, when PUREX is producing about the same thing that we hope to get from UREX+, maybe we will exceed, well, obviously we hope to, that causes me concern. And then when you couple that with the fact that—I agree with you, we are cutting not actual costs but projections. I agree with you. But the truth of the matter is these things that are being cut back on, as you stated, are needed things. We are not dispensing with things that are not needed. This is a country, the richest country in the world. One out of every 110 persons is a millionaire, and we are giving tax breaks to millionaires at the expense of these programs. There has to be a point at which we decide that we have got to debate this question of where is the money coming from and will there be the shared sacrifice.

And I yield back. Thank you, sir.

Mr. ROHRABACHER. Well, I think we both appreciate that in this democracy, we come at problems, very sincerely, from two different points of view, and of course, the Republican point of view is if you would tax that money away from millionaires, they wouldn't have the money to invest, and our economy would be growing at a lesser rate, and there would be less federal revenue for the very programs that we are talking about. So it is a difference of approach of analyzing that differentiates Republicans.

I do need to make one serious point here about energy before I get back and forth, and I appreciate the gentleman.

Mr. GREEN. Well, I thank you for the time.

Thank you.

Mr. ROHRABACHER. Okay.

I would like the—I am very—I am on the International Relations Committee, and I am, of course, on the Science Committee and other subcommittees than this one, but I have a key interest in terms of the President's proposal to expand nuclear power with, for example, India and other countries that now has decided will be an Administration initiative. And so this is really an important hearing that we are having today, not only domestically, but internationally, of course. I would like to get the panel's reaction to the—to a—the new high-temperature helium gas reactor technology, that is high-temperature helium gas reactor technology. And from what I understand, that it has the ability to reduce the production of weapons of this type grade plutonium, which is plutonium-239, I guess, that it produces 95 percent less of that as compared to the other alternative nuclear reactors. So—and especially when it is used—and in terms of using that reactor for the production of helium—excuse me, the production of hydrogen. And is this something you have looked at? I would like the panel's, you know, just—impressions of that. And also, if you have not looked at it, or have other thoughts that are more extensive, if you could send me, personally, a letter—your analysis in writing of this technology.

Mr. JOHNSON. Yes, sir.

Chairwoman BIGGERT. If we have brief—briefly, please.

Mr. ROHRABACHER. Very brief. Yes. Right.

Mr. JOHNSON. Yes, sir.

The—within the Department's nuclear R&D program and our Generation IV program, we are sponsoring research on high-temperature gas reactor technology development, which includes both fuel development, materials development, and, as you may know, there is a provision in the *Energy Policy Act of 2005* for the development and deployment of a very high temperature reactor.

Mr. ROHRABACHER. Let us cut to the chase, because we have got to—the time. Is it thumbs up, thumbs down, or don't know about the—in—General Atomics has built one of these reactors in Japan. Have we studied it? Is it good? Is it a positive reaction? Or we haven't studied? Or is it a negative reaction?

Mr. JOHNSON. It has been studied, and it has been favorably disposed to the technology.

Mr. ROHRABACHER. Okay. Favorable.

Dr. TODREAS. It is a thermal versus a fast reactor, so its transmutation characteristics are different. I would say it is like this with a little bit up in your terminology, but it is not a slam dunk, and I wouldn't jump on it yet. We have got to study it further.

Mr. ROHRABACHER. And I would appreciate a more in-depth analysis in writing, please.

Dr. TODREAS. Sure.

Mr. ROHRABACHER. Yes, sir.

Dr. GARWIN. What is important in the near-term is to be able to buy electric power generation capability. This modular high-temperature gas reactor—gas turbine reactor has been a long time in coming, and I would really like to see it take its place in the market, because that is what is most important. You would use it first in the once-through process. It would not be a proliferation risk at all. And then it has a role as a moderate transuranic burner, which could ease the demand on the repository, if it were fed with light water reactor reprocessed fuel. But that would be a long time in the future, I hope.

Mr. ROHRABACHER. It sounds like you are giving it a thumbs up.

Dr. GARWIN. Thumbs up.

Mr. ROHRABACHER. Okay.

Mr. MODEEN. From the industry perspective, the advanced light water reactors are optimized for electricity generation. We expect, as we deploy those, that they will be the reactor of choice for quite a few decades to come. However, we also are interested in the high-temperature gas reactors because of that hydrogen mission, and I think the commercial deployment, really, it is—remains to be seen as, I think, we see more consolidation on energy companies that utilities may mesh with natural gas companies and that sort of thing. But we also believe it is very promising.

Mr. ROHRABACHER. So you are giving it a—that way. And it——

Mr. MODEEN. For a longer time——

Mr. ROHRABACHER. Okay. A more detailed, if you could give it to me in writing, I would appreciate it very much.

Thank you very much, Madame Chairman.

Chairwoman BIGGERT. Okay. Thank you.

I think we are back on track. Let us just—as a reminder that the purpose of the hearing is to solve the waste problem so that we can expand the use of nuclear energy beyond 20 percent.

And with that, the gentleman from Tennessee, Mr. Davis, is recognized.

Mr. DAVIS. Thank you, Chairwoman Biggert and Ranking Member Honda, for having this event today, this meeting today. And for those who are present that are giving testimony, I would like to read a statement, as well as ask a question.

Before I get into the issues at hand, I would like to express my support for nuclear energy in this country. As America has become more addicted to fossil fuels that pollute our air and water, I believe nuclear energy can play a major role in our country's future energy needs. Opponents of nuclear energy argue, quite frankly, that is unsafe, and with that mindset, America has not ordered a new nuclear energy plan in over 25 years. However, over time, the Navy has acquired over 80 vessels that contain nuclear reactors. To date, there have been no instances reported on any of these 80-plus vessels, and none of the crew on these ships has become ill from serving on them, nor do any of the glow in the dark.

So clearly, the technology exists that can make nuclear power safe. It is my hope once we solve the nuclear waste question that we can add more nuclear power to the Nation's grids.

Now I have got some concerns. Though I believe that nuclear energy needs to play a major role in our energy future, I also have serious reservations about the GNEP proposal. My main concern stems from the fact, I believe, that it appears that the majority of important decisions about this program have already been made, such as site locations, specific technologies that could be used for GNEP. For instance, Japan has technologies. These possible actions concern me because I believe they have excluded the expertise of energy leaders and scientists who are at the forefront of nuclear energy. I believe this program, to be successful, we must include all experts and not just a selective few. As you probably know, Oak Ridge National Lab is located near my district and employs some of the brightest and most experienced scientists on nuclear technology.

For years, Oak Ridge has been at the forefront of developing and maintaining nuclear programs for the Department of Energy and the Department of Defense. However, to my knowledge, no one from Oak Ridge was involved in the development of GNEP. To make—to me, it makes sense to have people involved that have a clear and long history of working within this field to help plan the future of this technology.

I have some concerns, and I believe we must act now to deal with nuclear waste and the successful expansion of nuclear energy in America. And my hope was that today's hearing would help relieve some of those concerns.

The question I have, Mr. Johnson, what is the technical and programmatic basis for the technology that has apparently been used to choose the technology and the site locations as you went through the process? And then secondly, to follow up, do these choices represent a consensus among the industry and the technical communities?

Mr. JOHNSON. Thank you, sir.

Let me say right off the bat, there have been no decisions made on siting any of these facilities at any location, contrary to what may have been written.

Mr. DAVIS. Well, I just—I am sorry. I reclaim my time.

I just read what has been written, and you are saying those are not true?

Mr. JOHNSON. I am saying that is not true.

Mr. DAVIS. I am relieved.

Mr. JOHNSON. Thank you.

With respect to the specific technologies and the basis for what we are proposing is all based on work that has been done in our laboratories over the last four to five years and work that was performed, in large part, at the Oak Ridge National Laboratory with respect to certain parts of the UREX+ separations process. Between the work at the Oak Ridge National Laboratory, the Argonne National Laboratory, and the Idaho National Laboratory, we feel very confident that this is a process that is worthy of continued investigation and moving it out of the laboratory into a larger-scale process so that we can better understand the physical phenomena at a larger scale before embarking on decisions to commercialize the technology.

With respect to the consensus within the industry or the scientific community, I would safely say there is not consensus, much like there is not consensus on many issues of a technical nature, or any other nature, for that matter. But it is—where we are represents the best thought and experience that the Department has within its laboratory complex.

Mr. DAVIS. Reclaiming my time. I have always felt that science was pretty exact, so it would seem to me that we are talking about some pretty exact technology, and there should be a consensus before we start talking about spending billions of dollars on a new technology. That should be scientifically exact. I yield back.

Chairwoman BIGGERT. Thank you, Mr. Davis.

And let me say that I, too, share your concern that we use all of the research and the knowledge of all of the laboratories in searching out this question, not just the lead laboratory at Idaho.

And with that, the gentleman from Michigan, Mr. Schwarz, is recognized.

Mr. SCHWARZ. Very briefly, is—should we be talking about the reprocessing in this country right now for commercial use because of the need to get additional electric-generating power on line or should we be building once-through cycle nuclear electric power plants and get them up and running as soon as possible? And should we be dealing with reprocessing because of the products of reprocessing and the fact that one of those is plutonium and could get into the wrong hands and be enriched and used for the construction of weapons? So I understand Japan, France, and probably other countries are reprocessing now, Russia. Should we be in that at all? If so, briefly, why, to a lay person in this, like myself, that I can explain to people back in Michigan? And if not, should we get going right away on building nuclear plants that are once-through cycle uranium plants?

Sir?

Mr. JOHNSON. Yes. With respect to near-term deployment of new light water reactor plants to add to the baseload capacity of our country, yes. The Department is working cooperatively with industry on that, and we remain very optimistic we will see new plants in the not-too-distant future.

With respect to the question on recycling spent nuclear fuel, we are not coming before the Congress saying we are embarking on commercial reprocessing technology and advocating we move forward at the time with commercial deployment. What we are doing is asking to accelerate work that has already been going on within our research and development programs to take the research on the advanced recycling technologies to the next phase of demonstration such that we can make a better and a more fully-informed decision on this technology should a subsequent decision be made to embark on recycling of spent nuclear fuel.

Mr. SCHWARZ. Thank you.

Dr. TODREAS. My—there are two reasons we should embark on R&D and knowledge in recycling. We definitely have to launch and secure light water reactors. First reason, if you aim for the year 2050 and you want to keep 20 percent nuclear, you have got to expand nuclear by a factor of three in this country. And if you keep 20 percent, you can displace a quarter of the greenhouse gas that would otherwise be generated as extra between now and 2050. That is the motivation. If you get to 2050 with that kind of nuclear expansion, you need to move the nuclear fuel cycle to really robust ways to deal with the waste, so you need options.

The other reason now to have an R&D program is to have an influence in the world and in our own evolution. You have got to have technical knowledge to be credible for the evolution of commercial nuclear power in the world, this is Europe, Japan, and Russia. You have got to have that knowledge to develop effective safeguards from reprocessing plants that others are building.

And third, we have got to make judgments on what to do with recycling and reprocessing in this country. If we don't get in it and do R&D and get knowledgeable, we are going to be at zero relative to the ability to do those judgments.

Mr. SCHWARZ. Thank you.

I yield back.

Chairwoman BIGGERT. Thank you.

Mr. SCHWARZ. If no one else has a comment, I would yield back.

Chairwoman BIGGERT. The gentlelady from Texas, Ms. Jackson Lee.

Ms. JACKSON LEE. I thank the Chairwoman very much and for this hearing.

This is a mountain of issues. Let me say that I am slowly trying to refocus and redesign my position on nuclear energy based upon where we are today, and I obviously come from the energy capital of the world that has been premised on oil and gas in Houston, Texas, but by the very nature that the term is energy, I expect that many of the corporations that I represent will be looking at a lot of alternative issues, alternative fuels, and certainly nuclear will be something of concern.

While I am in the mold of addressing the question of the magnitude of this challenge, particularly with the apprehension of many that the excessive use of nuclear energy leaves in the marketplace materials that could be used in weapons of mass destruction and may not, as well, be environmentally safe, let me pose these questions on this particular project. And as a backdrop, let me say that I am not a fan of Yucca Mountain, and I am not a fan of it, because I question whether the capacity is such that it would be able to hold all of the fuel necessary, particularly if the current fleet of more than 100 power reactors operates for their normal plant lives.

But if we are to look at this proposal that the President has offered, I wanted to ask the question, Dr. Garwin, is this realistic in and of itself, the GNEP program, particularly the magnitude that this program or this demonstration project would offer, 200 tons, I think, as opposed to 20 tons per year? Help me understand, from your perspective, how realistic this is. And as an oversight committee, instruct us on this particular proposal. What should be the indicia or the criteria or the limitations that we should raise on this particular program? And you might add the cost as well.

Dr. GARWIN. Well, for something that is not worth doing——

Chairwoman BIGGERT. Sir?

Dr. GARWIN. Yeah.

Chairwoman BIGGERT. We are—the bells are calling us for a vote, and I think we have got one more question or so. If everybody can answer briefly so we can have the last question, and then you won't have to wait for us to come back from several votes.

Dr. GARWIN. If something is not worth doing, it is not worth doing well. So the question is to what extent is GNEP, that is the recycle—the reprocessing and burning, worth doing. It has one principal function: it saves repository space. We need the systems analysis tool or some good decision making to tell us how much repository space costs. And we can buy it not only in the expansion of Yucca Mountain that we—the President has sent now to the Congress with the request to expand it, or we can buy repository space elsewhere.

Now Mr. Davis also asked about science—the exactness of the science. We need this analysis tool so that we just don't have to build things of larger scale, so we can design them differently, so we can simulate them so that when we build we know pretty well that it is going to work. And then we will have a cheaper and simpler program.

Ms. JACKSON LEE. But if I may, Dr. Garwin, since I know my time is short, your assessment of the GNEP program demonstration and the science of it, is that workable versus a smaller demonstration? And do you see the amount—the cost worthy of the ultimate process? And this is on the reprocessing.

Dr. GARWIN. Well, this is reprocessing of light water reactor fuel. That is easy. We don't need UREX. We could do PUREX.

Ms. JACKSON LEE. All right.

Dr. GARWIN. We should do more research on UREX. We don't need to scale it up. We need to have the people out there at Argonne put their minds to understanding their process better so they can scale it up on paper and do critical experiments.

Ms. JACKSON LEE. So we don't need UREX?

Dr. GARWIN. No, the critical point is reprocessing of the fast reactor fuel. That has to happen many, many times compared with once for the light water reactor fuel, and that is the big uncertainty. There is complex of design, of fuel form, of reprocessing——

Ms. JACKSON LEE. Can PUREX be made safely?

Dr. GARWIN. PUREX will do it safely, yes. It is established. And we can wait. The main thing is that we can wait to reprocess light water reactor fuel until we build the fast reactors so that we have fuel to put into them.

Ms. JACKSON LEE. Thank you.

Chairwoman BIGGERT. Thank you.

The gentleman from South Carolina, Mr. Inglis.

Mr. INGLIS. First of all, I would like to congratulate the Chair on holding this hearing. It is an important hearing. It is important for us to develop a consensus as to energy alternatives, and surely, nuclear seems to be one very attractive alternative that we have got.

I was interested in Mr. Rohrabacher's question earlier about high-temperature reactors.

I was aware there are possibilities for the production of hydrogen. I wasn't aware that there is some benefit in terms of non-proliferation. Can somebody explain that to me? Perhaps it has already been explained, but it would be interesting to know if there is, in fact, a benefit as to non-proliferation with a high-temperature reactor.

Mr. Johnson, is that—or is——

Dr. GARWIN. Yeah. Just quickly, thermal reactors, as well as fast reactors, can transmute, meaning destroy actinides, meaning destroy plutonium. There are technical differences about downstream effects and other isotopes, but they can both do it. And so the gas reactor is in the competition to have a role in that aspect. Is that enough?

Mr. INGLIS. I think so.

I look forward—anybody else want to help me out there with—any—now the—it is a concern that the—it didn't sound like the utilities are going to exactly be excited about that possibility, the high-temperature reactor, particularly for a potential new business for them called hydrogen. And of course, if they are not interested, I suppose there are other people that are interested in other technologies by way of how to produce that and get in that business. It seems to me that utilities, though, have an opportunity. They may miss the opportunity. The railroads missed the opportunity to become airlines. So did I hear some indication that maybe utilities are going to miss their opportunity to become the hydrogen commodity suppliers?

Mr. MODEEN. No, I don't think you heard that. I think it is a matter of a sequence in priorities. And again, the very first is we need to continue to focus on the current plants. We need to deploy this next generation advanced light water reactors, and we really need to address Yucca Mountain. I think those are the top three for the commercial utility industry, no question about that.

The next, I think, in that series, from our perspective, really is high-temperature gas reactors, a hydrogen mission. I happen to have, in the EPRI program, a very small budget for that, but we have had leading utilities. Entergy, I think, is probably the most public of them. But we have taken a part of our program to really understand what has been going on in the rest of the world commercially, as well as at the labs, and try to compare and contrast that in deployment time frames for that mission. So—but it is just really a matter of what is your core business, and still, right now, it is really looking at electricity generation, and the advanced reactor—light water reactor is really optimized for that, and that is where we are putting most our effort.

Mr. INGLIS. Is it fair to say, Mr. Johnson, is that that is a role for the government if the utilities aren't concerned about investing money, at this point, in developing the high-temperature reactors, particularly in getting into the hydrogen business? Is there because there are additional breakthroughs that are needed and that is a role for some government to fund? Is that—would that be accurate?

Mr. JOHNSON. Yes, sir, I believe so. There are some technical risks or technical questions that need to be resolved, and I think that that is an appropriate role for the government in terms of some of these high-temperature operating regimes that we have very little experience in.

Mr. INGLIS. And how many years, do you think, that is away? Take a guess.

Mr. JOHNSON. Well, gas reactor technology is in operation today in other countries, and depending on the country, going from where the gas reactors that are in operation today to the higher temperature reactors, it is probably 10 years, minimum to demonstrate. But the gas reactor technology is pretty well understood. It is going to the higher temperatures needed for the hydrogen production mission that introduces some technical uncertainties.

Mr. INGLIS. I yield back.

Chairwoman BIGGERT. Thank you.

I recognize Mr. Honda for 30 seconds for a yes/no question.

Mr. HONDA. Thank you very much.

And having heard Dr. Todreas talk about the road map, I guess we are going to need a GPS.

My question is since we have—I get the sense that the Department has gone down the road to some decision-making process, and it appears that the discussion has not been as broad as I think it should be, I would like to discuss with my colleagues and the Chairwoman here the possibility of expanding the process and looking at some sort of independent panel review that would be a little bit more broad and also discuss not only GNEP but also some of the economic analysis of the plan. And there appears to be other approaches to the issue of spent fuel, so I would like to hear more of that, too, it—so that we can get a better feel of it.

And Madame Chair, I really appreciated this hearing today, because it has really opened up and put more into focus the need for more understanding, because not only does it speak to UREX or to reprocessing and to other decisions, but it also speaks to some of the foreign policy decisions Congress has to make.

Chairwoman BIGGERT. Mr. Honda, I am going to have to cut you off, because we have to adjourn this meeting.

I think that—keep in mind that we do—have requested the systems analysis, which I think will help with that. Another thing, I think, that we do need and we will schedule, would be some briefings with Members so that we can come in and really have a discussion. But we also have plans for other hearings on this. We have had one on the nuclear proliferation and one on the cost, and this has been on the waste products. So I think that, you know, this is one of many hearings that we will have, but I think it would be important for a briefing for our Members, too.

So before we bring this hearing to a close, I want to thank our panelists for testifying before this subcommittee today. If there is no objection, the record will remain open for additional statements from the Members and for answers to any follow-up questions the Subcommittee may ask for from the panelists. So without objection, so ordered.

This hearing is now adjourned.

[Whereupon, at 11:45 a.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by R. Shane Johnson, Deputy Director for Technology, Office of Nuclear Energy Science and Technology, Department of Energy

Questions submitted by Chairman Judy Biggert

Q1. Please describe the safeguards and monitoring research program under the proposed Global Nuclear Energy Partnership (GNEP). Which office at the Department of Energy (DOE) is responsible for overseeing this program?

A1. The Department's National Nuclear Security Administration (NNSA) is responsible for overseeing the safeguards and monitoring research that will help support GNEP. The program involves the assessment of proliferation risks and the development of advanced international safeguards and monitoring systems. In carrying out these tasks, NNSA will work with the Office of Nuclear Energy (NE), whose Advanced Fuel Cycle Initiative has conducted research since 2003 on enhancing proliferation resistance and monitoring. NNSA and NE will work together to ensure that features such as international safeguards, physical protection, and enhancing proliferation resistance, are incorporated "by design" into any GNEP facility, into the overall GNEP fuel cycle concept, encompassing advanced recycling, fuel fabrication and reactors (both burners and small reactors), as well as into spent fuel transport and storage.

Q2. Some experts suggest that a significant percentage of the existing spent nuclear fuel will be difficult to reprocess because of the buildup over time of certain radioactive isotopes—particularly Americium 241. How does the decay of radioisotopes in spent fuel affect the reprocessing technology decision? Is it possible that some of the waste will have passed a "point of no return" for certain reprocessing technologies before commercial reprocessing begins? Could the United States end up needing more than one reprocessing technology? Has DOE been able to quantify how much of the existing waste can and cannot be reprocessed with UREX+?

A2. Spent nuclear fuel which is aged for longer than three years can be reprocessed by using either PURER technology or UREX+ technology. Short-cooled spent nuclear fuel, defined as three to five years old, contains significantly less americium-241 (Am–241), (which is created as the result of plutonium-241 decay) than longer-cooled spent nuclear fuel. However, this short-cooled spent nuclear fuel has more curium-242 and curium-244 than longer-cooled spent nuclear fuel and these elements are highly radioactive gamma and neutron emitters. The percentage of highly radioactive isotopes such as Am-241, Cm-242 and Cm-244 affect the measures necessary to protect workers. However, neither the Am-241 growth nor the presence of Cm-242 or Cm-244 in spent nuclear fuel eliminates the ability to reprocess it. Therefore, technically a "point of no return" does not exist.

A second reprocessing technology based on electro-metallurgical treatment may be required for the spent nuclear fuel from GNEP's Advanced Burner Reactor, depending on the fuel form selected for the Advanced Burner Reactor.

UREX+ reprocessing technology can be used on all existing Light Water Reactor (LWR) spent nuclear fuel currently stored in the U.S.

While the Department's technical experts anticipate that recycling of spent nuclear fuel has significant potential, it is not currently known what percentage of existing or future U.S. inventories of spent nuclear fuel would be technologically suitable for recycling if the GNEP technologies ultimately prove to be successful. Some of the U.S. inventory of spent nuclear fuel is thought at this time to be unsuitable for recycle using UREX+. This inventory includes the Three Mile Island damaged fuel, the graphite fuel from Fort St. Vrain, spent nuclear fuel derived from the Experimental Breeder Reactor II as well as other molten salt reactors, and a few other specialized examples.

Q3. If the nuclear industry believes there is a shortage of expertise for its expansion, how does DOE plan to recruit and hire the talent necessary to construct four very large nuclear demonstration facilities at the same time that the nuclear industry begins its expansion?

A3. The Global Nuclear Energy Partnership (GNEP) is long-term in nature while the expansion of nuclear power is planned for the near- to mid-term timeframe. As new nuclear power plants are built and general interest in nuclear energy continues to grow, more and more students will be attracted to the field, giving DOE and other nuclear-related entities a strong pool of candidates from which to recruit. In addition, DOE can take advantage of capabilities and expertise within our existing infrastructure, as well as that of our international partners, to support the GNEP. France, Japan, and other countries have expressed a strong interest in joining the U.S. in the design, and possibly the supply of key components for the GNEP demonstration facilities. The Department expects significant financial and in-kind contributions from other GNEP partner countries which will help offset some of the capital needed to carry out GNEP.

Q4. If you face resource constraints in the GNEP effort, what are your highest priorities?

A4. The Department's GNEP priorities are to identify and resolve the remaining high risk technology issues. The FY 2007 funding request supports the technology development activities necessary to address the higher risk technologies associated with the fabrication of transmutation fuel, spent fuel recycling, the Advanced Burner Reactor, the Advanced Fuel Cycle Facility, and a comprehensive technical and economic systems analysis.

Questions submitted by Representative Michael M. Honda

Q1. Ninety-five percent of the volume of waste in a spent fuel rod is uranium. Reprocessed uranium from European reprocessing facilities is being managed as nuclear waste. France has been dumping massive quantities of reprocessed uranium on Russia, which has done a very small amount of work on re-enrichment. The UK reuses none of their reprocessed uranium. What is the proposed use for reprocessed uranium under the GNEP plan?

A1. First, it is important to note that uranium recovered by the UREX+ technology from spent nuclear fuel has been demonstrated to be 99.999 percent pure. All laboratory tests with actual spent fuel have resulted in uranium that could be classified and disposed of a low level waste if it were determined to have no further use. With regard to the use of this highly pure uranium, at this time we believe there are several potential alternatives for its use: 1) make-up fuel material to be mixed with the transuranics for consumption in Advanced Burner Reactors; 2) store for future use in advanced reactors; and 3) use as fuel in Canadian CANDU reactors.

*Q2. DOE recently released an advance notice to prepare an Environmental Impact Statement for the proposed demonstration reprocessing facility [*Federal Register, *March 22, 2006 (Volume 71, Number 55)]. Why has DOE not announced an advance notice to prepare a programmatic EIS for the entire GNEP program, which would be the logical first step for such a large-scale program?*

A2. In March 2006, the Department issued an Advance Notice of Intent (ANOI) expressing DOE's intent to prepare an environmental impact statement to address the GNEP technology development program activities. The Department is in the process of reviewing the comments received in response to the ANOI and has not yet made a final decision on the implementation of its NEPA review. Additionally, in March 2006, the Department issued a Request for Expressions of Interest (EOI) to perform site evaluation studies. The Department received 43 responses to the EOI. As a result, the Department will be issuing a Financial Assistance Funding Opportunity Announcement to identify sites that may potentially be considered in the NEPA review. DOE will issue the Financial Assistance Funding Opportunity Announcement in August 2006.

Q3. How many public-private entities sent in Expressions of Interest for being the host site for the proposed demonstration recycling facilities? What were the proposed sites? How will DOE allocate the $20 million to these sites, as required by the FY 2006 Energy and Water Appropriations bill? How will DOE choose between the sites? When will DOE announce the selected site?

A3. The Department received 43 responses to the Request for Expressions of Interest (EOI). This EOI was released for the purpose of notifying public and private entities that the Department was considering releasing a solicitation to perform site evaluation studies and to determine the level of interest in such a solicitation. The Department has posted the names of all interested parties who responded to the EOI on the Idaho Operations Office website at *http://www.id.doe.gov/GNEP-TDP/index.htm.* The EOI was not intended to identify sites. The Department intends to release a formal solicitation in the near future. Based on formal proposals received in response to that solicitation, the Department will make decisions about which specific sites will receive funds from the $20 million, with no more than $5 million allocated to any one site, as specified in the Conference Report for the FY 2006 Energy and Water Development Appropriations bill. DOE will release the specific criteria for deciding which entities and sites will receive funding, when it releases the solicitation. It is expected that the Department will announce its decision on the selected sites for site evaluation studies later this year.

Q4. If industry does not buy-in to the GNEP concept it will cost the taxpayer untold billions and not go forward as proposed. What has been the role of industry in developing the GNEP concept? Has DOE solicited and received feedback from industry regarding commercial development of fast reactors? Why has no U.S. vendor proceeded with development of fast reactors as envisioned in the GNEP?

A4. The GNEP proposal was developed through normal interagency process within the government. The Department currently is engaging with industry to solicit their views as to how industry could most effectively participate in the GNEP initiative.

With regard to a U.S. vendor developing fast reactor technology, the General Electric Company has been working jointly with the Toshiba Corporation on the development of a simplified sodium-cooled fast reactor that could share many of the same attributes as a sodium-cooled fast reactor currently envisioned for the GNEP program.

Question submitted by Representative Eddie Bernice Johnson

Q1. Congress has the responsibility to take on national imperatives such as lessening both our dependence on fossil fuels and the environmental impact of energy use. GNEP may be one step in that direction. What is the prospect for nuclear energy, and specifically GNEP, in replacing fossil fuels in the future?

A1. The Energy Information Administration (EIA), in its reference case, projects United States nuclear power capacity to be 109 gigawatts in 2030.[1] This projection includes continued operation of current nuclear plants, capacity expansions (uprates) at current plants and six gigawatts of new capacity, resulting from the incentives of the *Energy Policy Act of 2005* (EPACT). Under this same scenario, EIA projects that over 900 gigawatts of fossil-fired capacity will need to be added.

While nuclear is not a substitute for oil, it could be used to replace coal and natural gas, and several utilities have decided to investigate this path. The Nuclear Regulatory Commission has recently testified that the number of expected combined Construction and Operating License applications is 17 for up to 25 units. Much of this renewed interest has been sparked by the work performed by the Office of Nuclear Energy through the Nuclear Power 2010 program, which aims to streamline the licensing process for new nuclear power plants. Combined with the incentives provided in EPACT, the nuclear industry has great potential to offset coal and natural gas.

Recognizing that nuclear power could expand greatly with the licensing of these new nuclear power plants, one of the Global Nuclear Energy Partnership's (GNEP) objectives is targeted towards addressing the resulting spent nuclear fuel using an enhanced recycling technology known as UREX+. Using this recycling technology, GNEP has the potential to significantly reduce the amount of spent nuclear fuel requiring disposal, allowing for the further expansion of new nuclear power plants. Given the complexity of this approach, GNEP faces some technical development challenges and uncertainties.

The Department continues to work toward developing a systems analysis that can answer some outstanding GNEP issues and also help develop a roadmap. The Department is optimistic that GNEP holds great potential to facilitate the expansion of nuclear power (thus offsetting fossil fuels) and looks forward to the results of its analyses.

Questions submitted by Representative Lincoln Davis

Q1. GNEP will use the UREX+ process as the baseline fuel reprocessing technology, despite concerns that it may not be the best choice. What is the technical and programmatic basis for the technology selections that have apparently been made? Do these choices represent a consensus among the industry and technical communities, both domestic and international? Were the choices the result of peer reviewed process? If so, please provide records that such selections were indeed vetted through a peer review process.

[1] *Annual Energy Outlook 2006,* Energy Information Administration, DOE/EIA–383(2006), February 2006, p. 149.

A1. The UREX+ process has been under development since 2001, and has been successfully demonstrated at a laboratory scale. The recycling technologies DOE is considering are based on the results of significant research conducted since 2001 and documented in the following public reports:

Reports to Congress:

Report to Congress on Advanced Fuel Cycle Initiative: The Future Path for Advanced Spent Fuel Treatment and Transmutation Research, January 2003

Advanced Fuel Cycle Initiative (AFCI) Comparison Report, October 2003

Advanced Fuel Cycle Initiative (AFCI) Comparison Report, September 2004

Advanced Fuel Cycle Initiative: Objectives, Approach, and Technology Summary, May 2005

Advanced Fuel Cycle Initiative: Status Report for FY 2005, February 2006.

Each of these documents has been available for peer and public review and comment on the DOE website at *www.nuclear.gov* (Public Information/Congressional Reports) since its date of publication.

Additionally, the program has issued: *AFCI Quarterly Reports* four times annually since January 2001, detailing the work carried out under the AFCI program during that quarter; and *AFCI Annual Highlights,* annually since 2003, describing the AFCI program's research and development accomplishments during the year.

Also available on the *www.nuclear.gov* (Advisory Committee/Reports) website are the reports of the Department's continuing independent expert review of the program and its technology options. These independent reviews are in the form of *Reports from the Nuclear Energy Research Advisory Committee (NERAC) and its Subcommittee on Advanced Nuclear Transformation Technology (ANTT).* This Subcommittee, chaired by Nobel Laureate Dr. Burton Richter and staffed by leading experts, has provided oversight and direction on the AFCI research and development program for the past five years. ANTT reports are provided to the NERAC full committee for review, comment and disposition, which may include adopting the Subcommittee's recommendations and forwarding them as recommendations of the full committee to the Office of Nuclear Energy. The ANTT Subcommittee reported on the AFCI program in public meetings on:

- November 6, 2001
- April 15, 2002
- January 14, 2003
- October 24, 2003
- February 26–27, 2004

The ANTT Subcommittee also prepared a report during calendar year 2005, but has yet to present it to the full NERAC.

Moreover, over the past five years, UREX+ research has become an international collaborative effort attracting experts from France, who exchange their research results with the United States and review U.S. progress. In addition, the development of UREX+ technology has been reviewed by the Organization for Economic Cooperation and Development/Nuclear Energy Agency (Nuclear Science Committee) based in Paris, France.

Q2. The nuclear industry charges rate payers 0.1 cent per kilo-Watt-hour (kWh) of electricity to pay for disposal of used nuclear fuel. Please provide an estimate of how much this will increase to pay for the construction of GNEP facilities and their operation.

A2. The Department does not plan to use the Nuclear Waste Fund to fund GNEP demonstration program activities.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Richard L. Garwin, IBM Fellow Emeritus, Thomas J. Watson Research Center, Yorktown Heights, NY

Questions submitted by Chairman Judy Biggert

Q1. Dr. Todreas (and others) support the notion of a two-step approach to recycling. This approach would initially implement recycling without fast reactors. The delay would buy time for additional research and development to optimize and bring down the cost of fast reactors and fast reactor fuel. What are the pros and cons of a single step to fast reactors versus a two-step approach involving thermal reactors?

A1. I do not support a two-step approach to recycling spent nuclear fuel in the United States. First, the reprocessing of spent nuclear fuel for recycle into light water reactors produces a product after a single recycle that has as much heat in the transuranic component as do the fuel elements that were reprocessed to make that spent fuel. It would not save space in the repository.

Second, the GNEP reprocessing itself (UREX+) or PUREX are entirely comparable so far as proliferation resistance are concerned, and neither is very important when implemented in the United States.

There are no pro's for the two-step approach to recycling.

The "single step to fast reactors" as defined in the GNEP program presented to the Committee 04/06/2006 is wrong-headed in that it puts the bigger part of the effort initially into an engineering scale demonstration (ESD) of the UREX+ process for reprocessing LWR fuel with a separation effectiveness of 99.9 percent or more. This high efficiency is totally unnecessary for the single reprocessing of LWR fuel, although it might be desirable for the multi-reprocessing of ABR fuel. The technical effort in the GNEP program must be focused on the simultaneous and competitive design of the ABR, its fuel formulation, and reprocessing suitable for that fuel. The very large set of ABRs is generally agreed to be uneconomical, and attention must be focused on making such reactors economically competitive with LWRs, if they are to be inflicted on the nuclear power industry.

The nonproliferation benefits of GNEP would be achieved by the leasing of LEU fuel and the take back from foreign customers of spent fuel for direct disposal into competitive, commercial mined geologic repositories the world over. There should be a commitment to above-ground interim storage casks for spent fuel for 100 years or more, which would indeed give time for "additional research and development to optimize and bring down the cost of fast reactors and fast reactor fuel."

It is of interest that an EPRI report of May 2006 concludes that Yucca Mountain will hold at least 260,000 tons and likely 550,000 tons of spent LWR fuel.

Right now the DOE should put real money into determining the resource cost of additional uranium, including uranium from seawater, and ultimately the fast reactors will be not burners of TRU but breeders of TRU, in order to extend greatly the resource supply of uranium if nuclear power proves to be a major component of the world's energy supply.

Question submitted by Representative Eddie Bernice Johnson

Q1. Congress has the responsibility to take on national imperatives such as lessening both our dependence on fossil fuels and the environmental impact of energy use. GNEP may be one step in that direction. What is the prospect for nuclear energy, and specifically GNEP, in replacing fossil fuel in the future?

A1. Indeed nuclear power has a good possibility of replacing fossil fuel especially for the production of electricity and other uses of stationary power plants. The key lies in the deployment and operation of safe nuclear power, and it must be extremely safe, since a nuclear accident on the scale of Chernobyl is likely to repel investors the world over. Certainly a market-oriented approach is desirable, and that means that individual companies and investors must find benefit in nuclear power in competition with other forms of energy supply.

I am optimistic about nuclear power. The Department of Energy should play its role in formulating GNEP as a program for leasing fresh LWR fuel and taking back spent fuel from clients abroad. This spent fuel should be slated for direct disposal into competitive, commercial mined geologic repositories, and not only in the United States.

The fuel for a greatly expanded population of nuclear reactors could come from higher cost terrestrial resources and eventually from seawater uranium, and the

DOE should spend real money to determine whether the cost of seawater uranium is $300/kg or $1000/kg—either of which would be affordable for LWRs. But the long-term future will depend upon breeder reactors, and a modest effort should go into the design of breeder reactors to determine how they can be made economically competitive with LWRs at uranium prices of, for instance, $300/kg of natural uranium.

Unfortunately, nuclear power is capital intensive, and as such will take longer to deploy than low-cost or no-cost measures such as improving energy efficiency. Nuclear power is also somewhat inflexible in that it is primarily at present for the generation of electricity, whereas there is a vast need for the direct substitution for gasoline, Diesel fuel—and natural gas. So liquids from coal and gas from coal plants, with carbon capture and storage, deserve far more investment than they are getting from DOE at present. There should be an assured market for the product of such plants, up to about one percent of U.S. consumption, in order to get a rapid start on the deployment and improvement of such technology.

ANSWERS TO POST-HEARING QUESTIONS

Responses by David J. Modeen, Vice President, Nuclear Power; Chief Nuclear Officer, Electric Power Research Institute

Questions submitted by Chairman Judy Biggert

Q1. Dr. Todreas (and others) support the notion of a two-step approach to recycling. This approach would initially implement recycling without fast reactors. The delay would buy time for additional research and development (R&D) to optimize and bring down the costs of fast reactors and fast reactor fuel. What are the pros and cons of a single step to fast reactors versus a two-step approach involving thermal reactors?

A1. The EPRI–INL Nuclear R&D Strategy Paper discussed in my testimony strongly supported "Full Actinide Recycle,"[1] which requires fast reactors in addition to reprocessing, as the best way to implement GNEP. This path is preferred over one that includes a "thermal recycle" mode using MOX fuel in light water reactors, because this latter path does not provide significant benefits in terms of either non-proliferation or spent fuel management, and cannot presently be justified by economic considerations.

The approach suggested by this question, i.e., to begin thermal recycle before fast reactors are ready to deploy, is effectively what has been done to date by those nations engaged in reprocessing—whose initial intent was to recycle plutonium in breeder reactors for sustainability purposes. However, anticipated shortages in natural uranium resources along with an accompanying rise in fuel costs, and commercial deployment of fast reactor technology, have not materialized as soon as originally anticipated—by several decades. Hence, the "current technology" approach has, by default, become the two-step process discussed in the question. Because of the high cost of storing separated plutonium, recycling plutonium in thermal reactors in countries having implemented reprocessing became a necessary step to mitigate fuel cycle costs. Further, the existence of high inventories of separated Pu has led to international concern about the proliferation potential of these inventories if the Pu is not burned in the existing thermal reactors in a timely fashion.

The U.S. industry is not faced with these issues since it has not deployed thermal recycle commercially. Not burdened by this legacy and knowing that the economics do not currently justify closing the fuel cycle, but realizing that the economics will eventually favor this transition (and that long-term energy sustainability will further dictate this transition), *the optimum strategy for transitioning nuclear energy to a closed fuel cycle in the U.S. context requires the Nation to conduct the necessary R&D now, and to time that transition to coincide cost-effectively with the inevitable rise in nuclear fuel costs.* It will take a substantial period of time to develop and demonstrate the technologies that would enable a transition from thermal power reactors to a proliferation resistant "full actinide recycle" mode with fast reactors.

The question implicitly acknowledges the benefits of a market-driven deployment strategy for fast reactors, assuming the R&D is started now to enable deployment at the optimum time. The advantages cited in the question, "The delay would buy time for additional R&D to optimize and bring down the cost of fast reactors and fast reactor fuel," are quite valid. The point that the EPRI–INL Strategy Paper makes about these advantages is that they apply equally to the timing of deployment of the required reprocessing facilities. Again, the R&D must be done now, so that all recycling technologies are ready to deploy when needed.

Accelerating the reprocessing part of recycling ahead of fast reactor deployment (including fast reactor fuel fabrication facilities), before it is cost-effective to do so, has no advantages in terms of spent fuel management and non-proliferation. In fact, the recycling technology available today has a number of limitations that effectively eliminate it as an option to accomplish the objectives of GNEP. In comparison, the "full actinide recycle" option that GNEP supports does have significant long-term promise in accomplishing these missions. However, it will require much more R&D before being ready to deploy.

[1] Nuclear fuel cycles are divided into two distinct categories: "open" and "closed" fuel cycles. In the open or once-through fuel cycle, spent fuel discharged from reactors is disposed of in a repository. In the closed fuel cycle, spent fuel is reprocessed; uranium (U) and plutonium (Pu) are subsequently recovered for fabrication into oxide or mixed oxide (MOX) fuel for recycle back into reactors. Plutonium and some uranium recycling in LWRs are currently in use in a few European countries. "Full actinide recycle" recovers uranium and plutonium along with the minor actinides (Np, Am, and Cm) and consumes them in fast neutron spectrum reactors. Full actinide recycle is not deployed today.

A summary of the disadvantages of implementing the single-pass or MOX recycle technology in thermal reactors in the U.S. follows:

- Current reprocessing technology carries a number of additional costs and new, potentially controversial, safety licensing and environmental permitting issues associated with the processing and storage of new waste streams.
- Single pass MOX recycling without treatment and recycling of the used MOX fuel in fast reactors does not provide any significant benefits to high-level waste management in comparison to an open fuel cycle. Until recycling in fast reactors becomes operational, spent MOX fuel will need to be placed in interim storage systems. Not only is single pass MOX recycling in itself not an alternative to Yucca Mountain, it also fails to address the expanded repository space needs that would result from increased reliance on nuclear energy as a baseload energy supply source.
- Many energy policy and national security policy leaders are opposed to reprocessing on proliferation grounds (because the current technology approach separates pure plutonium).
- Reprocessing introduces its own issues associated with safeguards and public acceptance.

Examples of policy statements supporting the R&D to enable full actinide recycle, (implicitly noting its advantages over single-pass recycle) include:

- *"The NEPD Group recommends that, in the context of developing advanced nuclear fuel cycles and next generation technologies for nuclear energy, the United States should re-examine its policies to allow for research, development, and deployment of fuel conditioning methods (such as pyroprocessing) that reduce waste streams and enhance proliferation resistance. In doing so,* the United States will continue to discourage the accumulation of separated plutonium, worldwide. *(National Energy Policy, May 2001, emphasis added)*
- *"The United States should also consider technologies, in collaboration with international partners with highly developed fuel cycles and a record of close cooperation,* to develop reprocessing and fuel treatment technologies that are cleaner, more efficient, less waste intensive, and more proliferation resistant." *(National Energy Policy, May 2001, emphasis added)*
- *"In a manner consistent with the long standing moratorium on commercial reprocessing. . .*the government should continue to support research and development, for potential future application, on advanced reactor and fuel-cycle concepts offering promise of lower costs, reduced waste-management burdens, and significantly higher barriers to theft and diversion of weapon-usable material than do the current reprocessing and breeder technologies" *(National Commission on Energy Policy, December 2004, emphasis added)*

Even though reprocessing is not economic today, this cost disadvantage will diminish and potentially reverse itself over time, as uranium resources become more scarce, as R&D develops less expensive means of reprocessing, and as R&D develops fast reactor designs capable of using reprocessed spent fuel that are more cost-competitive with Light Water Reactors as power generators.

Some have argued that a reason to accelerate reprocessing is that it is needed in the near-term to avoid building additional spent fuel repositories. EPRI analyses do not support this view. As stated in the EPRI–INL Strategy Paper, *"Even with the extended timetable for introducing fuel recycle in the U.S., a single expanded-capacity spent fuel repository at Yucca Mountain is still adequate to meet U.S. needs. Construction of a second repository is not required under this timetable.* If, however, reprocessing is implemented on an accelerated schedule before it is economic to do so based on fuel costs, then the Federal Government will need to bear a much larger cost."

Others have argued that a reason to accelerate reprocessing is that it is needed to implement the assured fuel supply and used fuel take-back regime proposed by GNEP. Although this supply and take-back regime is a critically important aspect of GNEP, the deployment of recycling technologies is not a prerequisite to its implementation. For this regime to gain acceptance among user nations, the U.S. and other fuel supplier nations must provide assurance of their ability to meet commitments for both fuel supply and take-back, in order to obtain early commitments from the user nations to forgo enrichment and reprocessing. This is an important reason why completion of centralized interim spent fuel storage facilities and a permanent repository are urgent to success of the fuel supply and take-back regime, even before recycling is ready.

Q2. When would you anticipate that R&D would lower the cost—or uranium prices would rise high enough—to motivate commercial interest in recycling technologies?

A2. The EPRI–INL Strategy Paper projects that reprocessing in a large scale demonstration plant would begin operation by about 2030, with fast reactor technology demonstration in the same timeframe. Smaller scale pilot demonstrations may be feasible earlier than 2030. Full scale commercial deployment would occur in the 2050 timeframe.

The reactor technology part of this integrated strategy develops fast reactors to recycle light water reactor spent fuel in order to transmute minor actinides as well as produce electricity. Following a demonstration plant, built and operated with government funding by about 2035, new fast reactors are deployed commercially, with government subsidy as needed for the waste-transmutation mission. In the long-term, the price of uranium increases to a level that supports recycle and eventually breeding.

Thus, the EPRI–INL Strategy Paper envisions the commercial deployment of recycling facilities on a large scale basis in roughly the mid-century timeframe. On the R&D side of the question, the EPRI–INL Strategy Paper concluded that the significant technical, cost, and licensing challenges facing these advanced technologies will determine these deployment time frames, even with an aggressive technology development program. An aggressive recycling technology development program, even if it takes longer than currently envisioned, will be beneficial, and eventually strategically vital to national energy security and sustainability. On the uranium resource and market demand side of the question, the Strategy Paper assumed a mid-century rise in uranium costs sufficient to provide a market incentive for a closed fuel cycle, based on both national and international estimates of uranium fuel supplies. However, the variables in this estimate are large, and depend heavily on assumptions of future growth in nuclear energy and the rate at which the world increases its reliance on nuclear energy.

Questions submitted by Representative Michael M. Honda

Q1. If industry does not buy-in to the GNEP concept, it will cost the taxpayer untold billions and not go forward as proposed. What has been the role of industry in developing the GNEP concept? Has DOE solicited and received feedback from industry regarding commercial development of fast reactors? Why has no U.S. vendor proceeded with development of fast reactors as envisioned in GNEP?

A1. Although EPRI was not asked for input prior to the formal announcement of the GNEP program in February 2006, and EPRI is not aware of any significant industry role in developing the GNEP concept, EPRI supports the vision and goals of the GNEP, as we have formerly testified. The EPRI testimony noted six areas of significant agreement between the EPRI–INL Strategy Paper and GNEP, including a high priority for near-term deployment of ALWRs and the licensing of Yucca Mountain, as well as the need to develop fast spectrum reactors to close the fuel cycle with "full actinide burning." Industry strongly supports the non-proliferation goals of GNEP.

Based on recent discussions of the EPRI–INL Strategy Paper with DOE's Office of Nuclear Energy, it appears that industry input to GNEP will be a priority for DOE. EPRI worked closely with INL in developing the Strategy Paper, and is very confident that INL sees commercial industry input as a high priority.

EPRI looks forward to the opportunity to work with DOE on a consensus R&D strategy for the future, including near-term deployment of ALWRs, integrated spent fuel management, expansion of nuclear energy into process heat and hydrogen missions, and strategic deployment of nuclear fuel recycling in ways that are cost-effective and proliferation-resistant.

DOE has noted that GNEP is primarily a federal initiative for governmental purposes. Although EPRI cannot speak for the vendors, EPRI's utility members are presently focused on maintaining excellent performance of current plants and preparing for near-term deployment of ALWRs. These are the areas that utilities have been willing to cost-share with DOE to date. EPRI and its members are interested in helping inform the R&D agenda for long-term, higher risk programs. If the R&D is successful, history suggests that the private sector will be willing to cost share the deployment of advanced reactor and fuel cycle systems. EPRI believes that the most effective way to encourage private sector investment is to engage in joint planning efforts at an early stage, in a manner consistent with the EPRI–INL Strategy Paper and the "80–20 paradigm" discussed therein.

Question submitted by Representative Eddie Bernice Johnson

Q1. Congress has the responsibility to take on national imperatives such as lessening both dependence on fossil fuels and environmental impact of energy use. GNEP may be one step in that direction. What is the prospect for nuclear energy, and specifically GNEP, in replacing fossil fuels in the future?

A1. The prospect for nuclear energy to expand and assume a greater role in providing baseload electricity for the U.S. and other nations is very promising, with clear indications of government and investor support for that expansion in the near-term. Longer-term expansion of nuclear energy into process heat applications, not presently a part of GNEP, is also promising.

EPRI is a nonprofit scientific research organization that manages a broad collaborative energy R&D program for the Nation's electric utility industry, with significant international utility participation. Its R&D programs cover all technologies for electricity generation, transmission, distribution, and end-use. Specifically with respect to generation, EPRI advocates a diverse portfolio where nuclear plays a key role, along with clean coal, natural gas and renewables, wind, biomass and solar.

EPRI believes that national policies and private sector investment strategies will trend toward greater reliance on low-emission or emission-free generation in the future, including reduced emissions of greenhouse gases. Therefore, EPRI is focusing much of its R&D in the generation sector on technologies that would support a carbon-constrained world. This future world will depend increasingly on nuclear energy, renewable energy, and carbon capture and sequestration of fossil fuel emissions.

Questions submitted by Representative Lincoln Davis

Q1. The nuclear industry charges rate payers 0.1 cents per kilo-Watt-hour (kWh) of electricity to pay for disposal of used nuclear fuel. Please provide an estimate of how much this will increase to pay for the construction of GNEP facilities and their operation.

A1. The EPRI–INL Strategy Paper calls for an integrated and cost-effective spent fuel management plan. The linchpin of this strategy is the repository at Yucca Mountain. Not only is a permanent geologic repository needed under all strategies and scenarios for the future, but near-term progress on licensing of Yucca Mountain is essential to expanding nuclear energy.

Other key elements of this integrated strategy include:

- Allowing for expansion of the Yucca Mountain site to its full technical capacity,
- Reducing the rate of spent fuel generation per unit power output via development of high performance LWR fuel,
- Maintaining engineered cooling of the repository well in excess of 50 years prior to closure,
- Providing for interim centralized storage or "aging pads" for dry canister passive cooling,
- Deploying multi-purpose canisters approved by NRC,
- Implementing an effective spent fuel transportation system, and
- Eventual recycling of spent fuel to reduce volume and heat rate, thus making much more effective use of repository space.

These steps, if taken together and coordinated, provide ample time for the long-term R&D to be completed, before concerns arise as to the need for a second repository.

The costs of establishing centralized interim storage and of completing Yucca Mountain are covered by the Nuclear Waste fund (funded by a fee paid by nuclear generating plants). The costs of R&D and deployment of closed fuel cycle facilities are not authorized expenses to be recovered from the Nuclear Waste Fund. The Strategy Paper assumed that eventually, after centralized interim storage requirements are met and Yucca Mountain is in operation, and as uranium fuel prices justify a shift from an open to a closed nuclear fuel cycle, that Nuclear Waste Fund revenues, at the current fee rate of one mil/KWH), would be used by the U.S. Government to defray the costs of closed fuel cycle facilities.

Presently, the nuclear industry in the U.S. pays for all of its environmental externality and safety regulation costs, including high level and low level waste management, pre-paid decommissioning funds, self-insurance under Price Anderson, the full costs of nuclear plant regulation by the U.S. NRC, emergency planning expenses, etc. In the case of spent fuel management costs, roughly 18 billion dollars of the 27 billion dollars of nuclear utility ratepayers' money that has been collected into the Nuclear Waste Fund to date has not yet been appropriated for its intended purpose.

While many comparable costs for other energy generation options are paid for by taxpayers, the assumption that government would continue to charge nuclear utilities for environmental externality expenses is a reasonable expectation. However, the EPRI–INL Strategy Paper assumes that government would impose on industry the costs of the *least-cost* spent fuel management strategy available. If government, for its own reasons, implements a more costly means of spent fuel management, then the EPRI–INL Strategy Paper assumes that government would pay the difference, and that Congress would not increase the amount of this fee when recycling facilities are deployed.

Appendix 2:

Additional Material for the Record

STATEMENT OF HAROLD F. MCFARLANE
PRESIDENT-ELECT, AMERICAN NUCLEAR SOCIETY

Madame Chair:

On behalf of the 10,000 members of the American Nuclear Society, I am pleased to provide testimony to the Subcommittee on the Administration's recently released Global Nuclear Energy Partnership (GNEP) initiative.

The ANS applauds the administration for stepping forward with the GNEP concept. For more than a decade, ANS has, through a series of conferences, challenged global nuclear technology leaders articulate a broad vision of how the world can greatly expand the peaceful use of nuclear energy while minimizing the risks of proliferation.

The organizational and technological frameworks that have emerged from these meetings closely resemble the tenets embodied in GNEP. Indeed, I would submit that a GNEP-like effort to recycle spent nuclear fuel and create a multilateral "fuel bank" to facilitate the expansion of nuclear power generation to developing nations is essentially an inevitability in the decades ahead.

As such, the debate about GNEP today should not be about "if" we will accomplish the broad objectives embodied in the plan, but rather "what" we should do now to prepare for it.

The ANS recognizes that there are political hurdles that must be addressed before the benefits contemplated by GNEP can be realized; most notably the Yucca Mountain Waste Repository. ANS believes Yucca Mountain is both scientifically and environmentally sound, and that DOE should move forward with urgency to obtain a license from the Nuclear Regulatory Commission and commence operations.

Nevertheless, the central challenge to GNEP is technology. There are several scientific and engineering hurdles that need to be overcome for Congress and the administration to make a "go-no-go" decision in the next few years. As such, ANS urges Congress to provide funding sufficient to permit timely results from GNEP-related research on UREX+ recycling, transmutation, pyroprocessing, fast reactor technology and integrated safeguards technology.

Creating the technology, political, regulatory and human infrastructure needed to realize this vision will take several decades. For the benefits of GNEP to begin accumulating in the future, the ANS believes that it is essential to start building GNEP's foundation now. For the U.S., the building blocks that will enable the benefits of future nuclear expansion are new plant construction, establishing the Yucca Mountain geologic repository, accelerated research on advanced fuel cycle technologies, and development of human capital.

The ANS applauds this subcommittee for its ongoing efforts to facilitate discussion about the future of nuclear technology, and we look forward to playing a constructive role in the debate.