Written Testimony of

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Mr. Chairman and Members of the Committee:

My name is Robert Fri. I am a Visiting Scholar at Resources for the Future, an organization dedicated to improving environmental and natural resource policymaking through objective social science research of the highest caliber. Today, however, I am representing the National Research Council as Chair of its Committee on Review of DOE's Nuclear Energy Research and Development Program, which produced the report, *Review of DOE's Nuclear Energy Research and Development Program.*

The FY 2006 President's Budget Request asked for funds to be set aside for the National Academy of Sciences to review the Office of Nuclear Energy (NE) research programs and budget and to recommend priorities for those programs given the likelihood of constrained budget levels in the future. The programs to be evaluated were Nuclear Power 2010, the Generation IV reactor development program, the Nuclear Hydrogen Initiative, the Global Nuclear Energy Partnership (GNEP)/Advanced Fuel Cycle Initiative (AFCI) and the Idaho National Laboratory facilities program. Our Committee began its work in August, 2006, and completed its report in October, 2007.

In the balance of this statement, I summarize the results of our work. To avoid covering too many topics, I have not included our recommendations on the Idaho National Laboratory. However, that laboratory is intended to be the Department's center for nuclear energy research and as such plays an essential supporting role in many DOE programs.

BACKGROUND

Growing energy demands, emerging concerns about the emissions of carbon dioxide from fossil fuel combustion, the increasing and volatile price for natural gas, and a sustained period of successful operation of the existing fleet of nuclear power plants have resulted in a renewal of interest in nuclear power in the United States. One consequence of the renewed interest in nuclear power for the DOE mission has been rapid growth in the DOE research budget: it grew by nearly 70 percent from the $193 million appropriated in FY 2003 to $320 million in FY 2006.

Despite these changes in program and budget experienced by the NE research program, there are some constant features that set the context for the committee's evaluation approach. In this regard, two observations have influenced the committee's approach to this project.

Stable Major Goals: One is that while the details of the NE program have shifted considerably, its high-level goals have changed little if at all. While stated in somewhat different words in various reports, the committee believes that a reasonable summary of the goals for technology development in support of the NE mission is:

- Assist the nuclear industry in providing for the safe, secure, and effective operation of nuclear power plants already in service, the anticipated growth in the next generation of light water reactors, and associated fuel cycle facilities.

- Provide for nuclear power at a cost that is competitive with other energy sources over time.
- Support a safe and publicly acceptable domestic waste management system, including options for long-term disposal and the related waste forms.
- Provide for effective proliferation resistance and physical protection of nuclear energy systems, both domestically and in support of international non-proliferation and nuclear security regimes.
- Create economical and environmentally acceptable nuclear power options for assuring long term non-nuclear energy supplies while displacing insecure and polluting energy sources; such options include electricity production, hydrogen production, process heat, and water desalinization.

Uncertain Future Development: A second observation is that predicting the course of nuclear technology development over the next several decades entails substantial uncertainties. Indeed, the committee heard presentations from several respected analysts about how this development might take place. Their views of the technological future differed in important ways. A major reason for this divergence is that the development of new nuclear technology requires a planning horizon measured in decades, in no small part because of the capital intensity of the commercial nuclear energy sector. Over such a time period, the committee believes that the success of various candidate technologies will depend on policy and other forces outside the control of any NE technology development program. For example:

- Waste management options and associated regulatory regimes and their likely acceptance by the public range from long term storage at reactor sites or centralized interim storage, to direct disposal of all spent fuel in geologic repositories and the reduced waste forms envisioned by GNEP.
- Environmental policy, especially regarding climate change, not yet formulated could have decisive impacts on the attractiveness of nuclear power.
- Opinion on the cost and availability of natural uranium and associated enrichment capacity varies widely.
- Non-proliferation and physical protection regimes are in flux, especially as international agreements continue to evolve.
- The rate of near term expansion of nuclear power plants matters, both domestically and internationally, since this rate drives the timing and need for advanced reactors and fuel cycle technology.

NP2010

The Nuclear Power 2010 (NP 2010) program was established by DOE in 2002 to support the near-term deployment of new nuclear plants. NP 2010 is a joint government/industry 50/50 cost-shared effort with the following objectives:

- Identify sites for new near-term nuclear power plants and obtain early site permits.
- Complete detailed, first-of-a-kind design engineering on two advanced light water reactor (ALWR) plants and confirm the safety of the designs by obtaining design certifications.
- Obtain combined construction and operating licenses in keeping with the Standardization Policy of the U.S. Nuclear Regulatory Commission
- Develop an effective inspection, testing, analyses, and acceptance criteria (ITAAC) process to assure licensing compliance during construction.
- Implement the Energy Policy Act of 2005 standby support provisions for the construction of new nuclear plants.
- Estimate the capital costs and operation and maintenance costs, construction time, and levelized cost of electricity for the two plants.
- Evaluate the business case for building new nuclear power plants and pave the way for an industry decision to build new ALWR nuclear plants in the United States. Construction would begin early in the next decade.

NP 2010 and selected commercial research projects should be fully funded as a matter of highest priority. Unless the commercial fleet of light water reactors (LWRs) grows, nuclear power will be a diminishing energy resource for the United States and there will be little need for all of DOE's longer term research programs. Although increases in the NP 2010 budget are likely, they do not account for a large fraction of the total NE funding. The NP 2010 requirements should be fully supported.

In addition, DOE should augment this program to ensure timely and cost-effective deployment of the first new reactor plants. Of particular importance is the need to address industrial and human resource infrastructure issues. Specifically, DOE should support:

- *Research in support of the commercial fleet.* The committee does not recommend a large federal research program, because most of this research should be industry-supported. However, some specific projects have sufficient public benefit to warrant federal funding, for which DOE should share about 20 percent of the costs and support user facilities at incremental cost. These elements of the program should be fully funded when the NP 2010 licensing and design completion efforts come to an end.

- *University infrastructure.* A sizeable buildup in nuclear energy production, research, and development necessitates strengthening university capabilities to educate a growing number of young professionals and scientists in the relevant areas. DOE should include this program in its budget at the levels authorized by the Energy Policy Act of 2005.

ADVANCED FUEL CYCLE INITIATIVE/ GLOBAL NUCLEAR ENERGY PARTNERSHIP

Since 2002, the United States has been conducting a program for reprocessing spent fuel under the Advanced Fuel Cycle Initiative (AFCI). Then, in February 2006, it announced a change in its nuclear energy programs. Recycling would be developed under a new effort, GNEP, which would incorporate AFCI as one of its activities. If the recycling R&D program is successful and leads to deployment, GNEP would eventually require the United States to be an active participant in the community of nations that recycle fuel, because one aspect of the partnership is that some nations recycle nuclear fuel for other user nations.

At the time of our report, GNEP has two key stated technical objectives:

- Develop, demonstrate, and deploy advanced technologies for recycling spent nuclear fuel that do not separate plutonium, with the goal over time of ceasing separation of plutonium and eventually eliminating excess stocks of civilian plutonium and drawing down existing stocks of civilian spent fuel. Such advanced fuel cycle technologies would substantially reduce nuclear waste, simplify its disposition, and help to ensure the need for only one geologic repository in the United States through the end of this century.
- Develop, demonstrate, and deploy advanced reactors that consume transuranic elements from recycled spent fuel.

Three facilities were key components of the GNEP program as then planned: (1) a nuclear fuel recycling center, or centralized fuel treatment center (2) an advanced sodium-cooled burner reactor -- a fast-neutron reactor; and (3) an advanced fuel cycle facility. At the time of the writing of this report, the latest information the committee had was that the baseline separation process was UREX+1a, although some other comparable separation technology, most notably pyroprocessing, may be adopted at a later stage.

The GNEP program is premised on an accelerated deployment strategy that will create significant technical and financial risks by prematurely narrowing technical options. Specifically:

- The domestic need for waste management, security, and fuel supply is not great enough to justify early deployment of commercial-scale reprocessing and fast reactor facilities. In particular, the near-term need for deployment of advanced fuel cycle infrastructure to avoid a second repository for spent fuel is far from clear. Even if a second repository were to be required in the near term, the committee does not believe that GNEP would provide short-term answers.

- The state of knowledge surrounding the technologies required for achieving the goals of GNEP is still at an early stage, at best a stage where one can justify beginning to work at an engineering scale. However, it seems to the committee that DOE has given more weight to schedule than to conservative economics and technology. The committee concludes that the case presented by the promoters of GNEP for an accelerated schedule for commercial construction is unwise. In general, it believes that the schedule should be guided by technical progress in the R&D program.

- The cost of the GNEP program is acknowledged by DOE not to be commercially competitive under present circumstances. There is no economic justification for going forward with this program at anything approaching a commercial scale. DOE claims that the GNEP is being implemented to save the United States nearly a decade in time and a substantial amount of money. In view of the technical challenges involved, the committee believes that just the opposite is likely to be true.

- Several fuel cycles could meet the eventual goal of creating a justifiable recycling system. However none of the cycles proposed, including UREX+ and the sodium fast reactor, is at a stage of reliability and understanding that would justify commercial-scale construction at this time. Significant technical problems remain to be solved.

- The qualification of multiply-recycled transuranic fuel is far from reaching a stage of demonstrated reliability. Because of the time required to test the fuel through repeated refabrication cycles, achieving a qualified fuel will take many years.

The committee believes that a research program similar to the original AFCI is worth pursuing.[1] Such a program should be paced by national needs, taking into account economics, technological readiness, national security, energy security, and other considerations. However, considerable uncertainty surrounds the technology and policy options that will ultimately satisfy these needs. For this reason, the committee believes that the program described below should be sufficiently robust to provide useful technology options for a wide range of possible outcomes. On the other hand, the program should not commit to the construction of a major demonstration or facility unless there is a clear economic, national security, or environmental policy reason for doing so. Because of these complexities, the committee recommends DOE obtain much more external input than it so far has -- in particular, an independent, thorough peer review of the program.

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[1] A majority of the committee favors fuel cycle and fast reactor research, as was being conducted under AFCI; however, two committee members recommend against such research.

GENERATION IV REACTORS

DOE has engaged other governments in a wide-ranging effort to develop advanced next-generation nuclear energy systems, known as Generation IV, with the goal of widening the applications and enhancing the economics, safety, and physical protection of the reactors and improving fuel cycle waste management and proliferation resistance in the coming decades. Six nuclear reactor technology concepts were identified in the DOE-initiated, international Generation IV Technology Roadmap completed in 2002. Each of the six technologies, as well as several areas of crosscutting research, is now being pursued by a consortium of countries as part of the Generation IV International Forum. Three concepts are thermal neutron spectrum systems—very-high-temperature reactors, molten salt reactors, and supercritical-water-cooled reactors—with coolants and temperatures that enable hydrogen or electricity production with high efficiency. In addition, three are fast neutron spectrum systems—gas-cooled fast reactors, lead-cooled fast reactors, and sodium-cooled fast reactors (SFRs)—that will enable better fuel use and more effective management of actinides by recycling most components in the discharged fuel.

From 2002 to 2005, the primary goal of the U.S. Generation IV program was to develop the Next Generation Nuclear Plant (NGNP), focusing on high-temperature process heat (850ºC-1000ºC) and innovative approaches to making energy products, such as hydrogen, that might benefit the transportation industry or the chemical industry. At the end of 2005, DOE shifted the fundamental emphasis of the overall Generation IV program, making spent fuel management using a closed fuel cycle the main goal of the program. This new GNEP priority led to reduced funding for the NGNP programs; phasing out of the other programs, and refocusing of the SFR concept to near-term demonstration. With these changes, NGNP's very high temperature gas reactor (VHTR) remains the only major reactor concept that is not integrated into the GNEP program.

Economic benefits of early commercialization of high-temperature reactors (HTRs) and VHTRs based on NGNP technology could be realized in four market segments where HTRs could make products at a lower cost than competing technologies: base-load electricity, combined heat and power, high-temperature process heat, and hydrogen. A long-term goal for the NGNP is to demonstrate hydrogen production as an energy carrier for a hydrogen economy. However, in each of those four segments, there are specific applications where HTRs will have near-term advantages. By directing NGNP and the Nuclear Hydrogen Initiative (NHI) R&D toward those specific applications, stronger near-term industry interest and investment is more likely, which in turn will support continued R&D investments for subsequent expansion of HTR technology into additional market segments and, in the longer term, support the transition to a hydrogen economy.

The NGNP program has well-established goals, decision points, and technical alternatives. A key decision point is the nuclear licensing approach. However, little planning has been done on how the fuel for the NGNP would be supplied. There is a particle fuel R&D program, but it will take up to two decades to complete the development and testing of this new fuel. To keep to the apparently preferred schedule, which has a FY 2017 plant start-up date, some of the technical decisions must be made quickly, so that detailed design, component and system testing, and licensing can be initiated. However, it is unlikely that the plant can begin operation by 2017 owing to the significant funding gaps that developed in FY 2006 and FY 2007 and affected the scope and schedule for testing fuel and structural materials as well as the heat transport equipment. A schedule that coordinates the elements required for public-private partnership, design evolution, defined regulatory approach, and R&D results should be articulated to enhance the potential for program success.

The main risk associated with NGNP is that the current business plan calls for the private sector to match the government (DOE) funding. So far, however, not a single program has been articulated that coordinates all the elements required to successfully commission the NGNP. The current disconnect between the base NGNP program plan and the complementary public/private partnership initiative must be resolved. DOE should decide whether to pursue a different demonstration with a smaller contribution from industry or, alternatively, a more basic technology approach for the VHTR.

NE should sustain a balanced R&D portfolio in advanced reactor development. The program requires predictable and steady funding, but its goals can be more modest and its timetables stretched. A revised program can be conducted within levels recently appropriated for Generation IV and for SFR-related R&D under GNEP.

NUCLEAR HYDROGEN INITIATIVE

NHI is DOE's research program for developing technologies to produce hydrogen and oxygen from water feedstock using nuclear energy. The program includes a small effort supporting advanced low-temperature electrolysis, but its primary focus is three methods that use high-temperature process heat to achieve greater efficiency. The high-temperature methods could realize 60-80 percent greater efficiency than conventional electrolysis. These methods involve challenging high-temperature materials problems, which are being addressed with laboratory-scale research at this time. Key technology downselections to allow testing at the pilot and engineering scales are scheduled for 2011 and 2015. The NHI program is tightly tied to the NGNP program to develop a reactor capable of producing high-temperature process heat. NHI activities are coordinated with the larger DOE hydrogen program, led by the Office of Energy Efficiency and Renewable Energy, as well as with NGNP.

NHI is well formulated to identify and develop workable technologies, but the schedules and budgets need to be adjusted to assure appropriate coupling to the larger NGNP program. DOE should expand NHI program interactions with industrial and international research organizations experienced in chemical processes and operating temperatures similar to those in thermochemical water splitting. NE should also broaden the hydrogen production system performance metrics beyond economics—for example, it could use the Generation IV performance metric of economics, safety, and sustainability.

BALANCE AND OVERSIGHT

The AFCI, GEN IV, and NHI programs require steady progress and should evolve over a reasonable time. Given this need, and as a counterbalance to the short-term nature of the federal budget process, NE should adopt an oversight process for evaluating the adequacy of program plans, evaluating progress against these plans and adjusting resource allocations as planned decision points are reached.

The senior advisory body for NE has been the Nuclear Energy Research Advisory Committee (NERAC). A modified NERAC seems the obvious starting point for reestablishing oversight of the NE programs. In the committee's opinion, the key will be to ensure its independence, transparency, and focus on the most important strategic issues. The committee has not attempted to design a specific oversight capability, but the following characteristics would be appropriate for the body it has in mind:

- Encourage objectivity by recognizing that knowledgeable persons have different points of view and that balance is therefore best achieved by diversifying the membership of the oversight body.
- Avoid conflicts of interest by requiring public disclosure of members' connections with study sponsors or organizations likely to be affected by study results. Persons directly funded by sponsors are rarely appointed to such bodies.
- Ensure transparency by requiring that both the statement of task and the final report for each project are routinely made public in a timely fashion.

Robert W. Fri is a visiting scholar and senior fellow emeritus at Resources for the Future, where he served as president from 1986 to 1995. From 1996 to 2001 he served as director of the National Museum of Natural History at the Smithsonian Institution. Before joining the Smithsonian, Mr. Fri served in both the public and private sectors, specializing in energy and environmental issues. In 1971 he became the first deputy administrator of the U.S. Environmental Protection Agency (EPA). In 1975, President Ford appointed him as the deputy administrator of the Energy Research and Development Administration. He served as acting administrator of both agencies for extended periods. From 1978 to 1986, Fri headed his own company, Energy Transition Corporation. He began his career with McKinsey & Company, where he was elected a principal. Mr. Fri is a senior advisor to private, public, and nonprofit organizations. He is a director of the American Electric Power Company and a trustee of Science Service, Inc. (publisher of *Science News* and organizer of the Intel Science Talent Search and International Science and Engineering Fair). He is a member of the National Petroleum Council, the Advisory Council of the Electric Power Research Institute, the Advisory Council of the Marian E. Koshland Science Museum, and the steering committee of the Energy Future Coalition. In past years, he has been a member of the President's Commission on Environmental Quality, the Secretary of Energy Advisory Board, and the University of Chicago board of governors for Argonne National Laboratory. He has chaired advisory committees of the National Research Council (NRC), including the recent Committee on Review of DOE's Nuclear Energy Research and Development Program, the Carnegie Commission on Science, Technology and Government, EPRI, and the Office of Technology Assessment (OTA). From 1978 to 1995 he was a director of Transco Energy Company, where he served as chair of the audit, compensation, and chief executive search committees. He is a member of Phi Beta Kappa and Sigma Xi and a national associate of the National Academy of Sciences. He received a B.A. in physics from Rice University and an M.B.A. (with distinction) from Harvard University.