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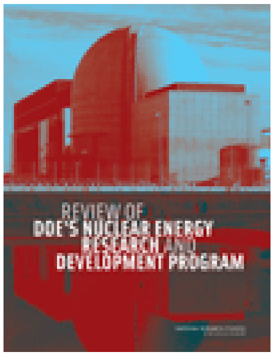

Review of DOE's Nuclear Energy Research and Development Program

Committee on Review of DOE's Nuclear Energy Research and Development Program, National Research Council

ISBN: 978-0-309-11124-9, 102 pages, 8 1/2 x 11, paperback (2008)

There has been a substantial resurgence of interest in nuclear power in the United States over the past few years. One consequence has been a rapid growth in the research budget of DOE's Office of Nuclear Energy (NE). In light of this growth, the Office of Management and Budget included within the FY2006 budget request a study by the National Academy of Sciences to review the NE research programs and recommend priorities among those programs. The programs to be evaluated were: Nuclear Power 2010 (NP 2010), Generation IV (GEN IV), the Nuclear Hydrogen Initiative (NHI), the Global Nuclear Energy Partnership (GNEP)/Advanced Fuel Cycle Initiative (AFCI), and the Idaho National Laboratory (INL) facilities. This report presents a description and analysis of each program along with specific findings and recommendations. It also provides an assessment of program priorities and oversight.

Summary

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. The Office of Nuclear Energy (NE) in the U.S. Department of Energy (DOE) is the main agent of the government's responsibility for advancing nuclear power. One consequence of the renewed interest in nuclear power for the NE mission has been rapid growth in the NE research budget: it grew by nearly 70 percent from the $193 million appropriated in FY 2003 to $320 million in FY 2006.

In light of this growth, the FY 2006 President's Budget Request asked for funds to be set aside for the National Academy of Sciences to review the NE research programs and budget and to recommend priorities for those programs given the likelihood of constrained budget levels in the future (DOE, 2005). 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. The committee's evaluation of each is summarized below, along with its assessment of program priorities and oversight and its relevant recommendations.

All but two members of the committee concur in the assessments presented in this report, and their dissenting statement is presented in Appendix A. In particular, all committee members agree that the GNEP program should not go forward and that it should be replaced by a less aggressive research program. The authors of Appendix A would "hold DOE R&D spending [on the less aggressive fuel cycle research program] to pre-2003 levels, before AFCI," and they believe that "DOE is the wrong agent for developing commercial technologies beyond the early laboratory stage."

Separately, three other committee members who do agree with all the recommendations in the report expressed their preference for an alternative to the technology preferred for GNEP. They describe this preference in Appendix B.

NUCLEAR POWER 2010

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 (ESPs).
- 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 (DCs).
- Obtain combined construction and operating licenses (COLs) in keeping with the Standardization Policy (10 CFR Part 52) of the U.S. Nuclear Regulatory Commission (USNRC).
- Develop an effective inspection, testing, analyses, and acceptance criteria (ITAAC) process to assure licensing compliance during construction.
- Implement the Energy Policy Act of 2005 (EPAct05) 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.

Current Status

A good working relationship has been achieved between DOE and its contractors. The selection of the projects funded is appropriately market driven. There is a strong focus on demonstrating the regulatory processes, finalizing and standardizing the designs, and implementing the EPAct05 standby support provisions, all of which are essential front-end activities. Yet, other activities essential to ultimate success do not seem to have achieved that same focus in planning, let alone implementation.

Overall Progress

Although progress has been made on the licensing of demonstration projects, the pace is far slower than that proposed in the near-term roadmap, and there has been further slippage against the original NP 2010 schedules. This slippage does not suggest the high priority DOE has given to NP 2010.

Recommendation. NE should make the successful completion of the NP 2010 program its highest priority. It should take all necessary steps to ensure that guidance for the loan guarantee program authorized by the EPAct05 is finalized.

Licensing Demonstration

USNRC and industry need to improve the presently planned pace of COL reviews, avoiding review of already-settled issues and setting a more challenging schedule. In spite of the substantial effort that USNRC and the industry are devoting to preparing for the COL reviews, the planned schedules are still too long. Detailed milestones and schedules need to be established at the outset of the COL hearings and reflected in a binding order issued by the USNRC at the time each application is formally docketed. The ITAAC process needs to be defined fully and demonstrated to avoid construction delays caused by questions about licensing compliance or by litigation.

Recommendation. DOE should propose and support a joint DOE/industry/USNRC high-level working group to ensure that the following transpire:

- High-quality, complete applications are submitted and response times to requests for additional information are met as stipulated in USNRC's design-centered licensing review approach.
- The schedules for review of DC, ESP, and COL applications, including the legal review by the Atomic Safety and Licensing Board, are clearly established, complete, contain mechanisms for monitoring progress, show 3 years or less for review and approval of the initial COL applications, and show shorter durations for subsequent same-design applications.
- The ITAAC is being developed so that its implementation will minimize interruptions in construction and preoperational litigation delays.
- Common safety and licensing issues among the families of reactor designs are fully standardized.

Standardized Design Completion

While it is expected that a COL application could be standardized for each reactor design, it is not clear that common safety and licensing issues would allow the COL applications to be standardized among the families of designs. Schedules for completion of the full designs need to be accelerated to be consistent with the goal of estimating costs and construction times, and completing design before the start of construction. Design standardization efforts also need to be expanded to cover

- Construction, operational, and maintenance efficiencies,
- Protocols, such as form-fit-function, to permit competitive bidding on the great variety of smaller plant components, and
- Change processes and operational standards for the plant life.

Recommendation. DOE should work with the industry consortia to increase efforts to standardize safety and licensing issues across all families of reactor designs. DOE should also provide additional cost-shared funds to accelerate the schedules in the NP 2010 Five-Year Plan.

Deployment and Infrastructure Issues

DOE and the consortia have not devoted sufficient effort to critical deployment issues such as preoperational testing, advanced construction technology or processes, and operational training.

Recommendation. NE should immediately initiate a cooperative project with industry to identify problems that have arisen in the construction and start-up of new plants and define best practices for use by the industry.

The 25-year-long suspension of new plant construction in the United States has badly weakened the infrastructure needed to support a robust and growing nuclear power industry. So far, little effort in NP 2010 has been devoted to this issue.

Recommendation. DOE should include within the NP 2010 program a DOE/industry workshop to identify activities that would revitalize infrastructure for the construction of new nuclear plants, including the nuclear qualification of vendors and constructors; manufacturing capacity; and the availability of professional staff, skilled craftspeople and construction personnel. Additional tasks that merit further DOE support should be identified at this workshop.

Recommendation. DOE should fund a taskforce to work with industry groups on construction technology and planning to ensure that consortia construction time goals of 4 years or less will be met.

R&D Relevant to the NP 2010 Program

Neither DOE nor industry has proposed any R&D for the NP 2010 program.

Recommendation. DOE should evaluate the need for a reinvigorated R&D program to improve the performance of existing nuclear plants in a DOE–industry cost-shared effort separate from NP 2010. The estimated benefits to society should substantially exceed the government investment. In the event of funding constraints, NP 2010 funding for new plant deployment should have priority over this R&D for LWRs.

THE GENERATION IV AND NUCLEAR HYDROGEN INITIATIVE PROGRAMS

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 (GIF). Three concepts are thermal neutron spectrum systems—very-high-temperature reactors (VHTRs), molten salt reactors (MSRs), and supercritical-water-cooled reactors (SCWRs)—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 (GFRs), lead-cooled fast reactors (LFRs), 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 NE program. This new GNEP priority led to reduced funding for the NGNP programs; phasing out of the SCWR, GFR, MSR, and LFR R&D programs, and refocusing of the SFR concept to near-term demonstration. With these changes, NGNP's VHTR remains the only major reactor concept that is not integrated into the GNEP program.

Next-Generation Nuclear Plant

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.

Recommendation. In assessing NGNP conceptual designs, NE should favor design approaches that can achieve a variety of objectives at an acceptable technical risk.

Recommendation. NE should size the NGNP reactor system to facilitate technology demonstration for future commercial units, including safety.

Recommendation. Because of the very high temperatures and severe material performance requirements for thermochemical water splitting, NE should maintain the flexibility to first operate the NGNP using high-temperature steam electrolysis.

Recommendation. DOE should focus on developing advanced materials for in-reactor operation at temperatures above 900ºC and fuel particles that can withstand high burnup and adverse transients. NE needs to ensure that sufficient funds are available to advance these technologies whether or not industry matching funds are available.

Recommendation. To ensure the good performance of hydrogen produced in an NGNP, NE should put more emphasis on the following:

- Conceptual integrated process development and optimizing plan flow sheets, before moving to engineering designs.
- Selecting the interface between the reactor and the hydrogen plant.
- Developing system performance tools to address unsteady conditions, such as plant start-up, plant trip, and maintenance needs.
- Assessment of total system economics.

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.

Recommendation. 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.

Other Generation IV Nuclear Energy System Programs

The second concept for development in the Generation IV program, the SFR, seems vague at this time and appears to involve selected studies of technology issues that are beneficial principally for commercialization rather than explicitly linked to the long-term technology needs of nuclear energy. The committee is concerned that the Generation IV concept evaluation criteria for reactor development adopted by the Generation IV Technology Roadmap were not applied in the selection of the VHTR and SFR. The Generation IV R&D priorities have been shifting despite minimal discussion of the criteria and the alternatives.

The program resources are barely adequate for basic studies related to NGNP and the VHTR design and entirely inadequate for exploring the SFR at a research level (unless the new GNEP program also includes basic research components), for investigating other reactor concepts, and for developing crosscutting reactor technology systems. The current program does not appear to be using the Generation IV program metrics to compare the high-temperature reactors and fast-reactor systems for dual missions—a process heat mission and a fuel cycle flexibility mission.

Recommendation. Within the Generation IV program, NE should modestly and reasonably support long-term base technology options other than the VHTR and the SFR, particularly for actinide management, using thermal and fast reactors and appropriate fuels.

Recommendation. Though NE currently focuses on the VHTR for process heat and the SFR for advanced fuel cycles, it should assess the cost-benefit of a single reactor system to meet both needs.

THE ADVANCED FUEL CYCLE INITIATIVE AND GLOBAL NUCLEAR ENERGY PARTNERSHIP PROGRAMS

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.

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 are key components of the GNEP program as currently planned: (1) a nuclear fuel recycling center, or centralized fuel treatment center (CFTC); (2) an advanced sodium-cooled burner reactor (ABR); a fast-neutron reactor; and (3) an advanced fuel cycle facility (AFCF). 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.

All committee members agree that the GNEP program should not go forward and that it should be replaced by a less aggressive research program. 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, as described in Appendix A. The GNEP program is premised on an accelerated deployment strategy that will create significant technical and financial risks by prematurely narrowing technical options. Moreover, there has not been sufficient external input—in particular, no independent, thorough peer review of the program.

- 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. As noted in Chapter 1, 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.

Recommendation. DOE should develop and publish detailed technical and economic analyses to explain and describe UREX+1a and fast reactor recycle as well as a range of alternatives. An independent peer review group, as recommended in Chapter 6, should review these analyses. DOE should pursue the development of other separation processes until a fully fact-based comparison can be made

[1]The dissenting view of two committee members is presented in Appendix A.

and a decision taken on which process or processes could be carried to engineering scale.

Recommendation. DOE should devote more effort to the qualification of recycled fuel because it poses a major technical challenge.

Recommendation. DOE should compare the technical and financial risks of such a program with the potential benefits. Such an analysis should undergo an independent, intensive peer review.

Recommendation. DOE should bring together other appropriate divisions of DOE and other federal agencies, representatives from industry and academia, and representatives from other nations well before any decisions are made on the technology.

Recommendation. DOE should defer the Secretarial decision, now scheduled for 2008, which the committee believes is not credible. Moreover, if it makes this decision in the future, DOE should target construction of new technologies at most at an engineering scale. DOE should commission an independent peer review of the state of knowledge as a prerequisite to any Secretarial decision on future research programs.

IDAHO NATIONAL LABORATORY

NE is the lead program secretarial office (PSO) for the Idaho National Laboratory (INL), and, as such, a significant part of NE's management responsibility and budget is devoted to INL. This responsibility will continue to be a major one for NE, since the management of INL's physical facilities presents two challenges.

First, new or rejuvenated facilities are required to support the new mission and vision for the laboratory. The laboratory envisions that within 10 years, INL will be the preeminent national and international nuclear energy center with synergistic, world-class, multiprogram capabilities and partnerships. To achieve its ambitious goals, INL must attract and retain world-class scientists and engineers in a multiplicity of engineering and scientific disciplines. INL must have a budget allowing it to acquire and maintain the state-of-the-art facilities and equipment that will be used by researchers of superior technical competence to lead the development of nuclear power as a valued energy option nationally and internationally.

The second challenge is to maintain the remaining infrastructure in good condition. NE/INL is the landlord for a large, multitenant site in deteriorating condition. DOE employs several metrics to assess the condition of infrastructure. Overall, the INL facilities are rated adequate and the overall utilization, good. However, the backlog of deferred maintenance is high in relation to the value of the assets. In FY 2004 the ratio stood at 11.8 percent for INL's nonprogrammatic assets; the DOE target for this ratio is 2 to 4 percent.

The committee considers that INL is an important facility and provides important capabilities to support NE's mission, which is to use nuclear technology to provide the United States with safe, secure, environmentally responsible and affordable energy. INL has developed a strategic vision and a long-term (10-year) plan on this basis. However, the funding being provided to INL by NE is substantially less than what is needed to fulfill that vision.

Recommendation. NE should set up and document a process for evaluating alternative approaches for accomplishing NE-sponsored activities, assigning these tasks appropriately, and avoiding duplication.

Recommendation. NE should set up a formal, high-level working group jointly with the Idaho Operation Office (ID) and INL (Battelle Energy Alliance [BEA]). Consideration should be given to also having one or more knowledgeable outsiders participate on an ongoing basis to provide a wider perspective.

Recommendation. For INL to accomplish its expected mission, a number of large, sophisticated and unique facilities will be needed. These could include large hot cells and associated laboratories for postirradiation examination of materials and test reactors such as the Advanced Test Reactor (ATR). The intent is for INL to have magnet facilities attracting researchers and industrial users. For these facilities to attract users, the full costs cannot be charged, and the user would pay only the justified incremental costs associated with use. This arrangement is typical of user facilities in the Office of Science laboratories.

The NE/INL budgeting system and the budget documents themselves are opaque and hard to understand. It is difficult to trace budget amounts to particular projects and programs or to specific activities within the INL subbudget. The committee concludes that a much more transparent, structured planning and budgeting process is needed.

Recommendation. NE, ID, and INL (BEA) should agree on a multiyear, resource-loaded, high-level schedule and plan for the INL facilities, such as the Primavera Project Planner (P3).

Recommendation. NE, ID, and INL (BEA) should improve the form and content of the INL facilities budget documentation. They should support a much more transparent, structured planning and budget process. Budget items should be readily traceable to specific items in the overall plan and schedule.

NE has limited experience of being the PSO for a national laboratory. As such, its procedures and processes for this responsibility are not yet well defined or developed.

Recommendation. NE should meet with DOE and National Nuclear Security Administration organizations that are PSOs for other laboratories to review and discuss their practices and processes. Based on the lessons they learned, it should develop and document its own internal processes and procedures for discharging its responsibilities as the lead PSO for INL.

PROGRAM PRIORITIES, BALANCE, AND OVERSIGHT

The NE budget has experienced wide swings in both size and content over the past 10 years. The committee has reviewed the current NE budget process for annually allocating limited resources among programs. Like the federal budget process in general, the NE process tends to subordinate long-term commitments to more immediate needs. The result of this conflict between the annual budget process and the long-term nature of much of NE's research has resulted in program goals, schedules, and budgets that are inconsistent. For that very reason, the committee is convinced that NE should set up an internal system to allocate resources consistently over time and among programs.

Program Priorities

To prioritize NE programs, the committee examined their relevance to NE's mission. The committee's judgment about priorities is summarized in Table S-1.

Program Balance

Based on these priorities, the committee's programmatic recommendations that have budget consequences are as follows:

- *Nuclear Power 2010 (NP 2010).* 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. 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.
- *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 support.* 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.
- *Generation IV.* 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.

TABLE S-1 Relative Priorities of NE R&D Programs and INL

Priority	Program	Comment
High	NP 2010 and research in support of the commercial fleet	Unless the commercial fleet of LWRs grows, nuclear power will be a diminishing energy resource for the United States and there will be little need for all of NE's longer term research programs. NP 2010 and selected commercial research projects should be fully funded as a matter of highest priority.
High	University infrastructure support	University support is largely a government responsibility in the committee's view.
Medium	Generation IV, NGNP, NHI, and AFCI	These are all longer term research programs with defined downselect decisions that could change the course of research as more is learned. These programs will perform best with research budgets consistent with steady progress toward these decision points.
Medium	INL programs to reduce deferred maintenance and to build a capacity that will sustain a useful scientific capability	These activities require steady progress but can evolve over a reasonable time. Construction of user facilities and program facilities should be carefully evaluated on a case-by-case basis to validate the need and to avoid duplication with facilities at other national laboratories.
Low	Major facility deployment (large demonstration or initial commercial plants) in GNEP	U.S. industry does not urgently require the construction of such facilities.

- *AFCI.* NE should pursue the AFCI program with some modifications, as recommended in Chapter 4, but not including construction of large demonstration or commercial-scale facilities. The committee recommends a more modest and longer term program of applied research and engineering, including new research-scale experimental capabilities as envisioned for the Advanced Fuel Cycle Facility, although the program would differ somewhat from the AFCI program before GNEP.
- *Major fuel cycle facilities.* The committee recognizes that major engineering and commercial-scale facilities will ultimately be required to test and deploy fuel cycle technology. However, it concludes that DOE should not go forward with early deployment of such facilities. These facilities should be funded only when clearly needed, and then as increases to the NE base budget.
- *INL.* It is essential to provide reasonable and predictable funding to support the PSO responsibility for site condition and capacity building. DOE should create a strategic plan based on concepts laid out in Chapter 6 (see Table 6-2) to establish the target funding level for the Idaho Facilities Management account.

Program Oversight

Recommendation. 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.

REFERENCE

Department of Energy (DOE). 2005. Department of Energy FY2006 Congressional Budget Request. Available at http://www.cfo.doe.gov/budget/.

REVIEW OF DOE'S NUCLEAR ENERGY RESEARCH AND DEVELOPMENT PROGRAM

Committee on Review of DOE's Nuclear Energy Research and Development Program

Board on Energy and Environmental Systems

Division on Engineering and Physical Sciences

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Washington, D.C.
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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report and the study on which it is based were supported by Contract No. DE-AT01-06NE64158 (Task Order No. 15) from the U.S. Department of Energy. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for the project.

International Standard Book Number 13: 978-0-309-11124-9
International Standard Book Number 10: 0-309-11124-2

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Printed in the United States of America

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Preface

In January 2005, the FY 2006 President's Budget Request asked for funds to be set aside for a review by the National Academy of Sciences of the nuclear energy research programs and budget at the U.S. Department of Energy (DOE). Following passage of the FY 2006 congressional budget, the National Research Council (NRC) developed a statement of task (see Appendix F) for a "comprehensive, independent evaluation of the goals and plans of the office of Nuclear Energy (NE) at DOE, and processes for establishing program priorities and oversight (including the method for determining the relative allocation of budgetary resources)." The NRC established a committee to carry out the project, but the committee did not meet until August 24, 2006—over 18 months after the request for funds for the study.

During that interim period, DOE's nuclear research program changed significantly with the emergence in early 2006 of a major programmatic initiative—the Global Nuclear Energy Partnership (GNEP). If executed as envisioned by its advocates, the GNEP program would result in the construction of commercial-scale facilities for spent fuel reprocessing and disposal by consuming the resultant plutonium and minor actinides together in advanced burner reactors, thereby reducing the radioactive burden on the waste repository. The budgetary implications of this new program were very substantial; if appropriated, the President's Budget Request for FY 2008 would more than double the Office of Nuclear Energy research and development budget from its FY 2006 appropriations level, mostly as a result of the GNEP program.

These developments created two issues for the committee. First, the program for which the statement of task had been prepared changed significantly between the writing of the statement of task and the start of the committee's work. Second, the dominant new program, GNEP, lacked the technical documentation, program plans, and program management organization that would ordinarily form the basis for an evaluation of program content and budget priorities. Despite these difficulties, the committee decided that the issues surrounding the design and technical approach of the GNEP program were sufficiently controversial that they could not be ignored in its review. I commend my colleagues on the committee for taking this stand and thank them for being willing to deal with the resulting frustrations of crafting a balanced evaluation of GNEP in the absence of information that would normally be available.

I wish to thank all of the committee members for the exceptional knowledge and patience they brought to this assignment. Our work probably required more of these qualities than any of us expected when we set out on this task. The support we received from the NRC staff certainly met the high standards I have come to expect of them. My appreciation especially goes to Martin Offutt, Matt Bowen, and Jim Zucchetto. Panola Golson once again made the administrative support both effective and unobtrusive.

Robert W. Fri
Chair
Committee on Review of DOE's Nuclear Energy
Research and Development Program

Acknowledgments

The Committee on Review of the DOE's Nuclear Energy Research and Development Program is grateful to the many individuals who contributed their time and effort to the National Academies' National Research Council (NRC) study. The presentations at committee meetings provided valuable information and insights. The committee thanks the following individuals who provided briefings:

Jim Bresee, U.S. Department of Energy (DOE),
Richard Chandler, Office of Management and Budget,
George Davis, Westinghouse,
John Deutch, Massachusetts Institute of Technology,
Marvin Fertel, Nuclear Energy Institute,
Timothy A. Frazier, DOE,
Ray Ganthner, AREVA,
Eugene Grecheck, Dominion Energy, Inc.,
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Dennis Spurgeon, DOE,
John Stamos, DOE,
Joe Turnage, Constellation Energy/UniStar, and
Gary Vine, EPRI.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of the independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

John Ahearne, NAE, Sigma Xi,
Jan Beyea, Consulting in the Public Interest,
Philip R. Clark, NAE, GPU Nuclear Corporation (retired),
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Kenneth Peddicord, The Texas A&M University System,
Neil Siegel, NAE, Northrop Grumman Mission Systems, and
Raymond G. Wymer, Oak Ridge National Laboratory (retired).

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Chris Whipple of ENVIRON International Corporation. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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