A Sustainable Energy Future: The Essential Role of Nuclear Energy

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A Sustainable Energy Future: The Essential Role of Nuclear Energy

The Directors of the Department of Energy (DOE) national laboratories strongly believe that nuclear energy must play a significant and growing role in our nation's — and the world's — energy portfolio. This conclusion is based on an analysis of national and international energy needs in the context of broader global energy, environmental, and security issues. This paper provides details regarding our position in relation to nuclear energy. It is intended to be used as a basis for further discussion with stakeholders to help in developing specific near-term actions as well as a coherent long-term strategy incorporating the items listed below:

- Make maximum use of the current 'fleet' of operating light-water reactors, including plant life extensions, extended fuel burnup, and power uprates.

- Establish a national priority to immediately deploy advanced light-water reactors to meet our nation's increasing energy demand, while limiting greenhouse gas emissions and continuing to provide critical support to the Nuclear Regulatory Commission (NRC).

- Employ an integrated approach to manage used nuclear fuel and high-level waste, including interim storage, licensing of the Yucca Mountain Repository as a long-term resource, and exploration of optimal future waste management options.

- Implement an aggressive research and development (R&D) program on advanced reactors, reprocessing, waste management, and fuel fabrication concepts to enable timely identification of the technological options for a sustainable closed fuel cycle.

- Pursue partnering with other countries and implementation of an international regime that discourages the spread of enrichment and reprocessing capabilities and promotes the assurance of worldwide fuel supply and effective waste management.

- Strengthen international safeguards through aggressive R&D, thereby revitalizing U.S. safeguards technology and human capital and providing for U.S. leadership to help in assuring achievement of international security objectives and nonproliferation goals.

- Form a robust public-private partnership to ensure that (1) nuclear energy plays a more significant role in energy independence and environmental health, and (2) human infrastructure is rebuilt across industry, government, and academia.

- Incorporate independent and authoritative guidance and peer review from government and nongovernment entities to ensure that the U.S. nuclear energy agenda is responsive to current and future national needs and international conditions.

BROAD ENERGY CONTEXT

Energy is vital to human civilization and underpins national security, economic prosperity, and global stability. Worldwide demand for energy is rapidly increasing and could double by 2050. At the same time, the evidence is clear that CO_2 emissions must be reduced globally. Abundant, affordable, and environmentally responsible energy must be developed, both domestically and internationally, to meet that demand.

Reducing U.S. dependence on foreign oil will provide economic and national security benefits, including both industrial competitiveness and international trade. Crude oil expenditures represent the largest deficit item to our balance of trade. To reverse the trend on energy imports, while at the same time meeting required reductions in CO_2 emissions, the United States must use energy more efficiently. Furthermore, our nation must develop and deploy multiple energy sources in the context of a strategic and comprehensive energy plan. A broad mix of energy technologies is essential to meet the growing demand.

BENEFITS OF NUCLEAR ENERGY

Today, nuclear energy provides 16 percent of the world's electricity and offers unique benefits. It is the only existing technology with capability for major expansion that can simultaneously provide stability for base-load electricity, security through reliable fuel supply, and environmental stewardship by avoiding emissions of greenhouse gases and other pollutants. Furthermore, it has proven reliability (greater than 90 percent capacity factor), exemplary safety, and operational economy through improved performance.

We believe that nuclear energy must play a significant role in our nation's — and the world's — electricity portfolio for the next 100+ years. Nuclear energy has great potential for contributing more to our broader energy needs, however. For example, nuclear energy could supplement or even supplant fossil fuels by providing the electricity for electric-powered vehicles, or it could be used to generate hydrogen for vehicles that utilize hydrogen fuel cells. Nuclear energy could also help to generate high-temperature process heat, provide a valuable input for feedstock to chemical production and aid in the production of freshwater from seawater and contaminated surface and groundwater sources.

FOCUS EFFORTS AND INVESTMENTS: WHY NOW?

There are many reasons to focus on and invest in the expansion of nuclear energy. First, time-critical clean energy needs can be met through reactor life-time extensions, higher fuel burnup, power uprates, and additional deployment of existing light-water reactor technology. Second, to maximize the benefits of nuclear energy domestically, advanced fuel cycles that cost-effectively optimize energy utilization and waste management are needed; however, there is a long lead time for developing the required technologies. Third, the United States now has a window of opportunity to influence global directions in safety, security, and nonproliferation throughout the nuclear fuel cycle. A strong, sustained, integrated effort across all three areas must begin now.

SUCCESSFUL PATH FORWARD

The directors of the DOE national laboratories remain committed to U.S. energy security and the important role that an increased nuclear energy component can and should play in strengthening our energy security. Essentials for success are a strategy that integrates across DOE as well as other federal agencies; a concentrated effort to rebuild the necessary nuclear enterprise, including a broad-based R&D effort; and engagement with industry and the international community. Key to ensuring a successful effort is decisive leadership and a strong public-private sector partnership.

Strategy and Policy Development

To facilitate that leadership, all stakeholders must work together to develop a comprehensive strategic plan that has broad, bipartisan support and clear, consistent communications among government, researchers, the international community, industrial stakeholders, and the public. The development and implementation of a strategic plan should include:

- A clear statement of national energy policies. The full range of benefits and risks involved in nuclear energy create an inextricable link between government and industry. Furthermore, government policies and programs should be harmonized with those of the private sector. This relationship must be a partnership.

- A clear differentiation between short- and long-term goals. Private sector providers of nuclear power have expressed their priorities, but they are inevitably short term in nature and may not necessarily include long-term, national priorities.

- A sustainable approach to used fuel disposition and waste management. Confidence must exist in the ability to manage nuclear fuel and to dispose of nuclear waste safely so as to enable the sustainable expansion of nuclear energy.

- A clear focus on strengthening the nonproliferation regime. Enhanced safeguards and physical security, international fuel service arrangements, and new nuclear fuel cycle technologies can advance our nonproliferation objectives.

- A mechanism for review by the stakeholders to ensure that the strategy remains relevant to current and future national needs and international conditions.

Rebuilding of the Nuclear Enterprise

The nuclear sector stakeholders must address three key areas: manufacturing base, science and technology infrastructure, and human capital. Expansion of nuclear energy will create stresses on the industrial resources needed to build and operate nuclear power plants. Nuclear power plants require a large forged pressure vessel and head, huge civil works, a myriad of pumps and valves, miles of piping and wiring, and robust process and system controls that must be “N-stamp qualified.” To have substantial growth in nuclear energy, more suppliers are needed. The worldwide forging capacity is very limited, and

none of it resides in the United States. This example illustrates one of the many choke points in the supply chain. Transport of material, support for construction, and enrichment of uranium for the fuel supply all must be considered. Moreover, financial institutions need to have confidence that a reliable supply chain exists before they will invest in new plant construction.

The science and technology infrastructure must include modern capabilities such as irradiation systems for testing new fuels and structural materials; chemical separations and characterization capabilities; and physics facilities for radiation transport, thermo-hydraulics, cross-sections, and criticality science. These and other capabilities require modern facilities; however, our current R&D infrastructure, which was built during the Cold War, has atrophied and is obsolete. Modeling and simulation technologies have made tremendous advances since the design of the existing facilities. The design of the next-generation facilities must incorporate state-of-the-art testing and diagnostics tools and be guided by the data requirements for advancing the realism and accuracy of high-performance simulation tools and approaches.

In addition, training the next generation of engineers and scientists must be an integral part of a robust nuclear program. A recent industry study pointed out that over the next five years, half of the nation's nuclear utility workforce will need to be replaced. To satisfy the need for both professional and crafts workers, government and industry must both play important roles to stimulate workforce development for construction, operations, and R&D by providing an environment that is exciting and thriving. Industrial and federal government commitment will be required to invigorate university and trade school programs. For example, the government should establish and fund a nuclear energy workforce development program at universities and colleges to meet the expected need.

Research and Development

To reduce cost, ensure sustainability, and improve efficiency, safety, and security, investments in a sustained nuclear science and technology R&D program are needed. Such a program must effectively support and integrate both basic and applied research and use, to the extent possible, modeling and simulation capabilities to address both near-term, evolutionary activities (e.g., life extensions of the current fleet) and long-term solutions (e.g., advanced reactors and fuel-cycle facilities). Industry will pursue evolutionary R&D to further improve efficiencies along each step of the current fuel cycle. It is incumbent upon the government, however, to implement long-term R&D programs for developing transformational technologies and options for advanced nuclear fuel cycles. Including regulators in the research and evaluation of results will facilitate the development of licensing and regulation of future nuclear facilities and technologies . Review of research plans and results by expert peer reviewers and open availability of the results will strengthen these efforts.

In ternational Engagement

Thirty countries currently operate nuclear power reactors, and approximately thirty-five reactors are under construction outside the U.S. An additional two dozen countries that have never used nuclear power to generate electricity (e.g., Egypt, Indonesia, Turkey, Vietnam) are now expressing serious interest in the technology, citing stability, security, sustainability, and environmental stewardship as key drivers. As a result, the amount and types of nuclear material in the world will grow, commerce in nuclear technology and materials will increase, and there will be interest in assuring a reliable supply of nuclear fuel. Ongoing bilateral and multilateral engagement will provide opportunities for improving our understanding of the needs, plans, and initiatives of other countries; the potential benefits and risks of these initiatives; and ways to positively impact technological development and choices. The R&D of viable technical options for the United States will also maximize our ability to influence the expanding global commercial enterprise.

CHALLENGES AND O PPORTUNITIES

Important challenges and opportunities are on the horizon: near-term expansion, used nuclear fuel disposition, a sustainable "closed" fuel cycle, and nonproliferation and security. These are discussed below.

Near-term Expansion

An urgent need exists to extend the life of our existing nuclear plants; to begin building new plants, including addressing the financial constraints; and to implement further cost improvements. Relicensing for 60 years has already occurred for many existing reactors and is being aggressively sought for the remaining plants. In parallel, R&D activities that explore the technical feasibility and path forward for long-term operations to 80 years should also be pursued.

Capital investments required for construction of nuclear plants are substantial, and private se ctor investment decisions must seriously consider risks over a long planning horizon, including the ability to recover capital costs through the rate base. Since new nuclear power deployments are in the national interest, the private sector and government share the responsibility for undertaking the activities needed to ensure that the investment ri sk associated with constructing, licensing, and operating new light-water reactors is reduced sufficiently to enable commercial investment and deployment. The Energy Policy Act of 2005 provides important loan guarantees, standby support, and tax credits to mitigate financial and regulatory risks that need to be implemented: the financial community and rate regulators must be engaged to enable nuclear energy expansion. Finally, critical support of the NRC for license review and approval also needs to continue to ensure timely review of new license applications.

Further cost-effective technical improvements to light-water reactors are feasible. In addition to simplified reactor and ancillary systems, areas of emphasis include the development of sensing capabilities, robust communication systems, and development of advanced approaches to safeguards and physical protection. The achievement of a simplified safe and secure plant will also require systematic consideration of human factors as a major contributor to a plant's economics, safety, security, and operational performance. Many of these advances can also provide cost-efficient operations and maintenance of existing plants.

Used Nuclear Fuel Disposition

The disposition of used nuclear fuel must be considered from both a short- and long-term perspective. Confidence regarding the disposal of waste is needed before the NRC will grant a license for a new plant and before private investors will accept the financial risk of ordering new nuclear plants. In the short term, this confidence can be achieved by continuing the licensing of a geologic repository at Yucca Mountain and enabling the continued interim storage of used nuclear fuel in dry casks and fuel pools.

Dry cask storage is a safe and secure interim solution, either at existing reactor sites or consolidated regionally if future circumstances dictate. Through policy and investment actions, government can make it clear that interim storage is not intended to push the burden of an ultimate solution to a future generation, but rather to keep waste management options open, pending the results of continued R&D investments. The use of dry casks incorporates proven technologies and regulatory regimes to protect the public from hazards during handling, transport, and storage.

The design and operation of the repository may evolve as knowledge advances. Yucca Mountain Repository was envisioned at a time when the country did not have plans for significant nuclear energy expansion. At that time, used reactor fuel was considered “waste”; thus, direct disposal was chosen as the approach. In the long term, given the envisioned expanded use of nuclear energy, it is both appropriate and timely to reconsider the sustainability of the fuel cycle and to recognize that even with recycling, a geologic repository will be required. In our opinion, R&D must be conducted, and a comprehensive evaluation of disposition pathways must be performed.

Sustainable “Closed” Fuel Cycle

As nuclear energy expands, the traditional once-through fuel cycle will not be sustainable. To maximize the benefits of nuclear energy in an expanding *nuclear energy future*, “closing” the fuel cycle will ultimately be necessary. Simultaneously addressing such issues as the full utilization of the fuel's stored energy content, waste minimization, and strengthening of the nonproliferation regime is essential and will require systems and economic analysis; and investigation of new technologies. Thus, the immediate urgency of our efforts should be directed toward conducting broad-based R&D to support an informed decision on how to proceed. The results of these investments will yield a deeper understanding of the above issues, and will provide the basis and timing for closing the fuel cycle. We believe that the decades-long hiatus in U.S. investment provides an opportunity and an advantage to avoid reliance on a dated recycling infrastructure. As a result, our nation has the opportunity, through new technologies and business models, to determine the best path forward.

An evaluation for light-water reactor recycling in the near-term must consider the increased efficiency in the use of fissile resources, the alteration of waste forms and reductions in overall waste burden, the anticipated need for plutonium/actinides to fuel fast reactors for burning or breeding, and U.S. nonproliferation objectives. Other considerations include establishing a credible U.S. role in an international fuel supply regime, getting our nation back into industrial-scale reprocessing, and demonstrating U.S.

leadership in providing nuclear safety, safeguards and other essential disciplines in the global nuclear renaissance. Integrated analyses of the factors above have not provided sufficient direct evidence to date to support substantial Federal Government investments to deploy existing technology for commercial scale recycling in light-water reactors. It is incumbent upon the Federal Government to establish the policy framework and working with industry ensure that technologies are available for deployment that satisfy that framework, including the non-proliferation and waste management considerations discussed in this paper, while the marketplace will ultimately determine the need for implementation within that framework.

Nonproliferation and Security

Strengthening the nuclear nonproliferation regime in the context of the global expansion of nuclear energy will require a multipronged approach. While the nonproliferation regime and other institutional measures will continue to provide the primary framework to ensure that the growth of nuclear power does not increase proliferation and terrorism ri sks, there should be a strong emphasis on limiting the spread of enrichment and reprocessing capabilities and enhancing our ability to track, control, and protect nuclear materials.

Three key areas will help to accomplish this focus: an assured fuel cycle service system with incentives for foregoing enrichment and reprocessing capability, improved safeguards technologies and transparency, and “safeguards by design” (i.e., designing safeguards technologies and methodologies into new facilities or systems). These key areas should be tightly integrated with other nuclear fuel cycle R&D and be informed by a risk assessment methodology. This methodology will enhance our ability to understand the benefits and risks of fuel cycle choices in the context of the overall fuel cycle system. These choices include technology options, framework options, and policy options. As an example, formulating international frameworks that support U.S. nonproliferation policy objectives will require understanding the energy goals and objectives of other countries, options for meeting these objectives, and a clear understanding of any specific trade-offs .

COMMITMENT OF THE NATIONAL LABORATORIES

Our nation is facing urgent problems in energy, environment, and national security. Nuclear energy can play a vital role in meeting our future energy needs, reducing our dependence on foreign oil, and protecting our environment. However, a clear national strategy with bipartisan support and strong U.S. leadership is necessary. The national laboratories, working in collaboration with industry, academia, and the international community, are committed to leading and providing the research and technologies required to support the global exp ansion of nuclear energy.