The Role of the U.S. Department of Energy for Sustainable and Innovative Nuclear Technology

Assistant Secretary for Nuclear Energy- Dr. Peter Lyons
U.S. Department of Energy

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Energy is the engine that drives the economy and helps to improve the quality of life. The U.S., like all countries, shares the challenges associated with ensuring their people have access to affordable, abundant, and environmentally friendly sources of energy. As economies grow, global energy demand will increase. According to the U.S. Energy Information Administration, world energy consumption and U.S. electricity use are predicted to increase substantially. U.S. electricity consumption is projected to increase by roughly 17% in the next two decades and world energy consumption is projected to increase by 50%. Nuclear power has reliably and economically provided nearly 20% of electrical generation in the U.S. over the past two decades and remains the United States' single largest contributor (more than 60 percent) of non-greenhouse-gas-emitting electric power generation. Nuclear energy is going to have to be an important part of the energy mix if we hope to achieve our clean energy goals.

Slide 2

The government can play an important role in the use and future deployment of sustainable and innovative nuclear technology. At the U.S. Department of Energy's (DOE) Office of Nuclear Energy (NE), our focus is on civil nuclear research, development and demonstration (RD&D) to improve safety and reliability to help extend the life of current reactors, develop improvements in the affordability of new reactors, develop sustainable nuclear fuel cycles and understand and minimize the risks of nuclear proliferation. DOE works internationally to collaborate on all of these issues.

A prerequisite to the continued use and expansion of nuclear power is public confidence in the safety of nuclear power plants. NE has been conducting R&D activities for decades to help make nuclear energy safer. Since the events at Fukushima, NE has engaged in a number of new research activities, often in partnership with industry, to address specific areas or issues, such as the development of accident tolerant fuel forms and accident tolerant instruments.

As we continue to pursue more advanced reactor concepts, we face additional regulatory risks. We need to manage costs, develop a long-term solution on nuclear waste, and assure that civilian nuclear power expansion does not increase the risk of nuclear weapons proliferation.

Slide 3

There are a number of other significant challenges associated with the economics of building new nuclear power plants because of their high cost and potentially risky investment. In the

United States right now, it is difficult for any energy source to compete against natural gas, especially with the absence of a “price” on carbon emissions. While the current price of natural gas in the United States is fairly low, the price has fluctuated significantly over time. Notably, the U.S. Energy Information Administration forecasts the price of natural gas doubling over the next 25 years. Therefore, some electric utilities are considering nuclear energy as a hedge against the price volatility of fossil fuels, and an important part of a diverse, clean energy portfolio.

This challenge of economics is an area where the government can contribute to new reactor deployment by reducing costs and financial risk.

Several factors have historically contributed to high capital costs, including:

- Increasing commodity prices, long construction schedules, design changes and quality related rework;

- High financing costs due to the large amount of up-front capital required over a long construction period and risk premiums. and

- Limited standardization.

To mitigate some of these cost issues, in the United States we are now pursuing various opportunities including design simplification, commodity reduction, improved materials and the use of advanced high-performance computing for modeling and simulation.

Small modular reactors (SMRs) are one way to make nuclear energy more affordable. The DOE also sees great promise in the Supercritical CO_2 Brayton energy conversion cycle to replace the steam Rankine cycle, potentially improving efficiency by up to 50 percent and reducing the size of mechanical equipment and plant footprint.

Likewise, the use of standard certified designs can significantly reduce licensing risk and uncertainty while modular and factory fabrication can reduce capital cost by improving quality and shortening construction schedules. Beyond construction, DOE anticipates these smaller more efficient plants will have reduced operations & maintenance costs.

Collaboration with the U.S. Nuclear Regulatory Commission (NRC) helps to reduce the licensing risk for new reactors. For example, DOE has been engaged with the NRC since 2008 to develop a licensing framework for high-temperature gas-cooled reactors. Through this effort, the department has made significant progress in reducing the regulatory uncertainty for gas reactors in the United States. Similarly, the department is working with the NRC to initiate the creation of a regulatory strategy for advanced reactors. The first step in this process is to develop universal general design criteria.

The U.S. Government has also established incentives to promote nuclear deployment, including:

- Loan guarantees for new reactors and front-end fuel cycle facilities; and

- Production Tax Credits for electricity production from advanced nuclear power plants.

Slide 4

DOE collaborates with industry through the SMR Licensing Technical Support (LTS) Program to reduce the regulatory risk for the first SMRs. A leading priority of the Department has been to accelerate the commercialization of SMR technologies because they may offer the potential for a "new model" of nuclear power expansion. Due to modular and factory construction and shorter construction schedules, SMRs may help to overcome some of the economic obstacles to new nuclear deployment by making nuclear technologies more affordable. SMR designs under development in the United States include passive safety features, are not susceptible to key design basis accidents, are sited underground, and have reduced source terms. In addition to safety and cost benefits, SMRs could provide high growth potential for jobs in construction, operation and maintenance of SMRs, both in the United States and globally.

The SMR LTS Program supports first-of-a-kind SMR design certification and licensing activities through cost-shared partnerships with industry in which industry contributes at least half of the cost.

The SMR LTS Program is modeled after the NP2010 program which was a great success in helping to overcome barriers to new large light water reactor deployment in the United States. NP2010 was a $1.4 billion, 50-50 cost shared government-industry program that resulted in the issuance of three Early Site Permits, two Construction and Operating License applications, and two Design Certification applications.

The first Funding Opportunity Announcement under the SMR LTS Program was issued on March 22, 2012, and a selection of the Generation mPower team was made on November 21, 2012. DOE decided that it was in the United States' best interest to select a single project that had the highest probability of achieving NRC certification and license approvals to provide the licensing blueprint for the SMR industry.

At the time of selection, the Generation mPower team had already established a path forward on their licensing requirements with the NRC. The mPower project ranked the highest among the applicants by having the highest likelihood of achieving license approvals and the robustness and safety of the design. DOE completed the cooperative agreement negotiations at the end of March 2013, and will begin providing cost-shared funding this Spring. We believe this partnership will be of benefit to all U.S. SMR designs by helping to resolve generic regulatory issues and establishing a licensing framework.

A second Funding Opportunity Announcement was issued on March 11, 2013, to support Design Certification of more innovative SMR concepts. Proposals are due on July 1, with an award anticipated by the end of 2013.

Slide 5

DOE signed a cooperative agreement with the mPower team on April 12, 2013. The mPower team consists of Babcock and Wilcox (B&W), which is responsible for design of the primary components and systems, Bechtel International, which is responsible for design of secondary side and plant layout, and the Tennessee Valley Authority which will perform the site characterization and license a site for deployment.

The mPower design is an integral PWR with all major primary systems and components inside a primary pressure boundary. Keeping the lowest penetrations higher than the fuel helps ensure the core remains covered. The reactor unit is composed of essentially three pieces, all of which are transportable to the reactor site. The reactor fuel contains no soluble boron and has a high moderator temperature coefficient which reduces reactivity at high temperatures. The fuel has a four-year life with no fuel shuffling.

The mPower team appears to be making outstanding progress toward the development of the certification and licensing applications required to meet the program goals. During the period of government-funding for the project, DOE is monitoring the project's progress through a set of agreed-upon milestones. In addition, DOE will review the licensing deliverables to ensure that the project develops quality products for NRC review.

Slide 6

For more advanced reactor concepts, technical barriers come into play. The Department can help to reduce technical risk by funding the required R&D. Therefore, in addition to funding the SMR Licensing Technical Support program, DOE also supports an Advanced SMR R&D program which performs research that supports the licensing and deployment of advanced non-light water SMR designs. These are SMRs designed from advanced and innovative concepts, using coolants such as liquid metal, helium or liquid salt, and they may offer added functionality and affordability. This program element supports laboratory, university, and industry projects to conduct civil nuclear R&D on unique capabilities and technologies and supports development of advanced SMR concepts for use in the medium- to long-term.

Our advanced SMR R&D activities focus on four key areas:

1. Developing advanced instrumentation and controls and human-machine interfaces;
2. Developing and testing of materials, components, and fuels and fabrication techniques;
3. Resolving key regulatory issues identified by NRC and industry; and
4. Developing assessment methods for evaluating advanced SMR technologies and characteristics.

This program element may also include evaluations of advanced reactor technologies that offer simplified operation and maintenance for distributed power and load-following applications, and increased proliferation resistance and security. Advanced SMR deployment would be expected to follow the near-term SMR deployment path as they mature.

DOE is also performing the necessary research to develop advanced reactor technologies and subsystems to improve nuclear power performance such as sustainability, economics, safety and proliferation resistance.

These advanced concepts will provide enhanced safety features and improved economics over the current fleet of reactors. These concepts can be considered to be inherently safe with passive safety features and therefore could potentially be co-located with industrial plants to expand the use of nuclear energy to process heat applications.

Priority research needs have been identified for sodium-, lead- and gas-cooled reactor concepts and a solicitation was recently issued for cost-shared R&D activities with industry in these areas. One area that was identified by industry was regulatory risk and as noted above, we are working with the NRC to improve the regulatory process for advanced reactors.

The Next Generation Nuclear Plant (NGNP) project recently signed a cost-shared contract to develop a credible business plan detailing how industry may best engage in developing and commercializing their technology.

From early in 2012, we sought detailed information on advanced reactor concepts from reactor vendors in order to align our R&D investments with the needs of industry.

DOE is also pursuing R&D in advanced fuel cycle technologies including accident tolerant fuels, in which we collaborate not just with industry but also our national laboratories, universities and international partners.

In the area of modeling and simulation, we are pursuing several programs, such as the Consortium for Advanced Simulation of Light Water Reactors (CASL) and the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program.

In addition, DOE's Light Water Reactor Sustainability (LWRS) program is developing the scientific basis to evaluate the extension of operating life while ensuring long-term reliability, productivity, safety, and security. The Department works to ensure that these activities are cost-shared and well coordinated with the NRC.

Progress is also being made towards cost-effective extraction of uranium from seawater. Our research is investigating the next generation of advanced adsorption techniques to enable economic recovery of uranium from seawater. Although seawater extraction of uranium will not be as economical as land mining in the foreseeable future, it may be useful as a mechanism for setting an upper limit in the uranium market place.

Slide 7

While our national laboratories and industrial entities are making strides in developing innovative nuclear technologies, the Department continues to invest in education through the Nuclear Energy University Program (NEUP). DOE provides up to 20 percent of our R&D funding each year to U.S. educational institutions. Significant elements of this research directly support projects of benefit in the advanced fuels and reactors areas. Since 2009, the Department has awarded US$233 million to universities though the NEUP. We encourage foreign universities to work cooperatively with U.S. institutions to further leverage resources in the U.S. and abroad.

Slide 8

Because the U.S. no longer has the full suite of facilities to conduct the needed research, achieving our R&D objectives simply cannot occur without effective international collaboration. DOE has comprehensive bi-lateral engagements with many countries and we are also actively involved in a variety of multi-lateral international nuclear energy cooperative activities including:

- the Generation IV International Forum;
- the International Framework for Nuclear Energy Cooperation;
- the IAEA, INPRO and OECD/NEA.

Slide 8

In conclusion, providing clean, safe and secure energy is a global issue and nuclear energy can play a key role. However, the wide-scale expansion of nuclear energy is not without challenges. Plant operators are working hard to continue the exemplary safety record and proactively applying lessons learned from Fukushima. The DOE is working with the NRC, industry, academia and international partners to further enhance the safety of the current fleet and to develop even safer and more affordable nuclear technologies that meet future market needs.

We are developing both reactor and fuel cycle technologies that improve proliferation resistance, reduce the environmental impacts and enhance the sustainability of nuclear energy.

Government can facilitate nuclear energy deployment by: reducing regulatory risk; reducing technical risk; reducing financial risk/ improving economics; and fostering international and industry collaboration.