IAEA SCIENTIFIC FORUM

UNITED STATES DEPARTMENT OF ENERGY
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DENNIS R. SPURGEON

INNOVATION, RESEARCH AND DEVELOPMENT FOR THE NEXT QUARTER CENTURY

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I would like to thank the International Atomic Energy Agency for the opportunity to address the Scientific Forum. The IAEA serves the entire world through dedicated work in all areas of the civilian nuclear fuel cycle, in the security and safeguards of nuclear materials and technology, and in their tireless efforts to promote nuclear non-proliferation.

As the world seeks to increase its energy supplies to sustain its continued economic growth, while responsibly addressing greenhouse gas emissions, nuclear power is uniquely positioned to play a much greater and more significant role than ever before. This expanded role stands to catalyze the greatest period of innovation and development since the advent of nuclear power.

Nuclear power, born over sixty years ago through the extraordinary and consistent efforts of leading scientists and engineers, is poised for some of the most significant advancements ever conceived over the next quarter century. It is again a consistent and dedicated effort that is required to develop the necessary technological advancements.

Every day that passes we are reminded of the energy challenges facing the world. In the United States we look to focus our efforts on the expansion of clean, reliable electricity, and the removal of barriers that inhibit deployment. The expansion of electricity supply and delivery is pre-eminent to our collective future: to a cleaner and safer environment, to successful economic expansion, and to our improved quality of life.

We expect a fifty percent increase in United State electricity demand by 2030, and global electricity demand to nearly double over the same period. To ensure that nuclear power contributes to these staggering projections in electricity demand, we must foster new technologies and greater efficiencies.

As we set our vision for the next twenty-five years, those new technologies and greater efficiencies will be the products of novel technology development, improvements to existing technologies and work on every aspect of the nuclear fuel cycle.

Novel technology development in the area of nuclear energy entails some of the most exciting work being done in the United States, including simulation and modeling of future reactor designs. Because of the complexity of advanced reactors, conventional methodology's heavy reliance on an empirical trial and error approach is time consuming and costly. We are employing the full power of the advances in computational sciences to develop computer codes to predict reactor and fuel behavior through the analysis of fuel fabrication and fuel performance, and fully coupled neutronic, stress, and thermal hydraulic capability. Advanced simulation and modeling can allow for designs to be tested and modified with the click of a mouse.

Recycling of spent nuclear fuel and reducing the quantity of nuclear waste requiring disposal is essential to the long-term viability of nuclear power. In addition to recycling fuel, we are also investigating recycling the non-fuel materials such as cladding hulls, which represent twenty-five percent of the mass of spent fuel. Through chemical decontamination techniques, hulls can be reused for fresh fuel. Further research is focused on cladding and structural material, using nano-scale synthesis methods to develop new ways to mitigate radiation damage, and to enable these materials to withstand higher temperatures and longer exposures. This research could ultimately lead to reactor designs with higher thermal efficiencies and safer operations.

Work is being done in the basic science arena related to reprocessing spent nuclear fuel, specifically, understanding the chemistry of interfaces in high-radiation and corrosive environments over long exposure times. Research is on-going to better understand electron interactions develop designer molecules for use in separations processes, and development of actinide containing nuclear fuel. This research will lead to a better understanding of how to develop transuranic-element based nuclear fuel for fast reactor transmutation, and improved processes for recycling of fuel to extract the fissionable isotopes, while enhancing proliferation resistance.

Improving upon existing nuclear reactor technology to increase efficiency and life-cycles is an important aspect of nuclear expansion. Extending the operating lifetime of our existing light-water reactor fleet in the United States has proven to be both safe and economical, adding some of the least capital-intensive electricity generation capacity to the grid. Approximately one-half of the current 104 operating reactors in the United States are approved or under-review for license renewals, which extend operations for 20 additional years. The extension of the operating lives of these reactors would deliver 16,000 terawatt-hours of clean, reliable, baseload electricity. To improve efficiencies even further, we are pursuing R&D to support the option of further extending the license period from 60 years to 80 years. This includes studying structural component aging, electrical and instrumentation aging, and material degradation. This work will have applicability to both the current fleet of operating reactors and the next generation of nuclear power plants.

Further improvements can be made to existing reactors in the areas of power-up rates, fuel and component efficiency and standardized plant designs. Improved power up-rates refer to the increase in reactor thermal output and subsequent electricity generation by improving instrumentation and control precision. Additional improvements can be made by investing in state-of-the-art high-pressure turbines, condensate pumps and motors, and main generators or transformers. This can prove to be capital intensive, but the improvements create long term economic benefits and can significantly increase power output. This positive cost-benefit ratio has been exemplified by the rise in the average capacity factor of the U.S. reactor fleet from less than seventy percent in 1990 to more than ninety percent in 2006.

The U.S. has identified improved fuel efficiency as an opportunity to enhance safety and productivity. Over the next two decades advanced fuels will be a major area of research focusing on improving sustainability, reliability, and economic competitiveness for nuclear energy. Private and public sector collaboration to research, develop, test, and license high-performance reactor fuel and clad materials could achieve longer operating cycles and higher burn-up limits.

Another area of opportunity in nuclear technology can be found in the standardization of reactor designs. In the United States, a joint government and industry effort is underway to license and bring to market standardized advanced nuclear plant designs. Two current Generation III + reactor designs being developed include the Westinghouse AP1000 Reactor and the General Electric Economic Simplified Boiling Water Reactor. While other reactor designs will likely be certified and built, maximizing efficiencies in licensing, manufacturing of components, construction, operation, and maintenance can be realized by reducing the total number of designs.

Beyond the scope of near-term improvements to existing technologies, the United States is engaged in robust research programs supporting the development of the next generation of nuclear power. In the pursuit of Generation IV reactor designs, the United States is emphasizing two primary goals, expanding the use of nuclear energy beyond electricity generation to include a multitude of process heat applications, and further reducing the environmental impacts of nuclear energy.

Expanding nuclear energy beyond electricity generation is being pursued through the Next Generation Nuclear Plant project. NGNP is a very high-temperature gas-cooled reactor designed to provide large quantities of usable process heat and hydrogen. The United States plans to demonstrate the NGNP technology at a commercial-scale by 2018. The advent of these systems can revolutionize the petro-chemical industry by substituting nuclear-generated process heat for traditional fossil fuels for industrial applications ranging from petroleum and bio-fuels to the conversion of tar-sands, oil shale and coal into liquid fuels, while minimizing greenhouse gas emissions from production of these liquid fuels. Furthermore, the production of hydrogen from these reactors may serve to offset traditional processes for producing hydrogen such as reformation of natural gas, and open the door to a significant source of fuel, not only for industrial uses, but also for hydrogen powered vehicles. All of these applications have the potential to replace significant amounts of fossil fuels that would otherwise produce greenhouse gas emissions.

Development of future reactors also requires attention to the need for multiple reactor size options. Most of the world's developing countries and many smaller developed and emerging countries cannot accommodate currently available reactors. We are looking at ways to facilitate the development, demonstration and deployment of grid-appropriate reactors that will include numerous features such as: fuel designs that could last the entire life of the reactor, effective and inexpensive safeguard techniques, standardized modular designs, advanced safeguard systems, and fully passive safety systems. This approach to reactor designs could help meet the rising power demands by accessing markets with much smaller grids and less developed technical infrastructure.

Technology and innovation in nuclear energy must be focused on the long-term goal of a closed nuclear fuel cycle. A closed nuclear fuel cycle includes enrichment technology, waste management and recycling, the establishment of reliable fuel services, and advanced nuclear safeguards.

Today, enrichment technology is replacing gaseous diffusion technology with gas centrifuge technology. In the future, that same gas centrifuge technology could be replaced by the Separation of Isotopes by Laser Excitation or "SILEX", technology currently being developed in the United States. Each new generation of enrichment technology offers improved operational efficiencies. For example, centrifuges consume as little as five percent of the electrical power required by a gaseous diffusion plant for the same enrichment output, and laser technology may result in the ability to re-enrich spent fuel to be recycled that would otherwise be treated as waste.

New waste management strategies and the development of advanced recycling technologies can remove barriers to closing the fuel cycle and address the issue of nuclear waste through a durable and long-term path forward. Waste management and recycling of spent nuclear fuels are also intrinsically intertwined. Domestically, the United States is pursuing a geologic repository, and with international partners, developing different paths for fuel recycling. Under any scenario, the United States and others will require waste repositories; however, recycling will significantly reduce the amount of waste destined for disposal. Developing advanced spent fuel separation technologies will allow us to separate uranium at a very high level of purification for possible re-enrichment and use as fresh fuel. In addition, we will also be able to isolate long-lived fission products to recycle into fuel, and short-lived fission products for storage or disposal. Further separation can also isolate the transuranic elements such as plutonium, neptunium, americium and curium, which can then be fabricated into fuel or targets for use in an advanced recycling reactor. Consuming these transuranic elements in electricity-producing fast reactors can further increase the capacity of a geological repository by reducing the heat loading, and radiotoxicity of the waste material.

Significant radiotoxicity and heat produced from radionuclides would require long-term isolation in durable waste forms. To provide optimum waste forms and to determine long-term performance, the behavior of materials must be understood to provide predictive capability. Understanding the proprieties of waste forms will lead to calculation of long-term behavior through coupled theory, modeling and experimentation. In addition, we are testing the performance of these candidate waste forms in a range of geological settings including, deep rock formations and subterranean salt storage. Having a predicative capability can lead to development of "tailored" waste forms for specific geological settings.

Recycling development can be thought of in two broad perspectives, near-term technologies and long-term technologies. Although the long-term goal is the use of fast rectors for transuranic material, the only viable near-term option involves manufacturing recycled fuel for the current fleet of light-water reactors. Currently, thermal recycling using mixed-oxide fuel in light-water reactors is already underway in several countries. Thermal recycling produces increased numbers of higher mass actinides such as curium, and we are exploring separation strategies that would allow decay storage, instead of recycling. Transuranics such as plutonium and americium, may in theory be effectively recycled repeatedly in light-water reactors, as long as enriched uranium continues to be introduced to support the fission process, but this scenario has never been commercially demonstrated and requires further study.

Long-term development and commercialization of nuclear fuel recycling relies on the development and deployment of fast reactor technology. The United States and the international nuclear research community benefit from significant past experience in fast reactor technology. The principal challenges to further development of fast reactor recycling are associated with developing and qualifying transmutation fuels or targets and improving the economics of fast reactor systems. The United States is conducting research on advanced materials that will improve the system reliability, as well as studies of improved thermal efficiency, simplified safety systems, and new techniques for in-service inspection and repair.

Further advancements in closing the fuel cycle and development of advanced safeguards technology are being pursued in the area of a sodium-cooled fast reactor. Future wide-spread commercial scale deployment of these reactor systems will require long-term technology demonstration and deployment programs to improve performance and reduce overall costs. The U.S. is not alone in pursuing these objectives, other nations such as Japan, France, and Russia are also pursuing advanced commercial-scale sodium-fast reactors. Multi-national collaboration analogous to the cooperation in the International Thermonuclear Experimental Reactor would aid in advancements and development of many future fast reactor and recycling technologies. Deployment of these reactors would allow for increased efficiency in the fuel supply and would ensure that even with the expansion of nuclear energy, the burden on nuclear waste repositories would be greatly reduced.

One challenge of the current nuclear renaissance and one subject that is on the minds of many — is that of minimizing proliferation risks. To reduce the threat of proliferation and incentivize non-fuel cycle nations to refrain from developing enrichment and reprocessing capabilities, the U.S., in cooperation with international partners and the IAEA, seeks to create a framework for reliable nuclear fuel services. This is a cornerstone of the Global Nuclear Energy Partnership or GNEP, which will create an assured supply of fresh fuel and provide disposition pathways for spent nuclear fuel for GNEP partner countries. Reliable fuel services would eliminate the need for countries to develop expensive domestic enrichment or reprocessing facilities, thereby creating economies of scale relative to the creation of indigenous facilities.

Safeguards will need to be adapted to the innovations in nuclear power. In close cooperation with the IAEA, the United States will continue to support the development of enhanced international safeguards to effectively monitor nuclear materials and facilities, to ensure nuclear energy systems are used only for peaceful purposes. In an effort to meet this objective, the United States will continue to develop, with international partners and the IAEA, new technological approaches to meet evolving safeguarding requirements. Current development projects include the Next Generation Surveillance System, new and updated seals, advanced neutron, gamma-ray and heat based nondestructive systems and faster electronics. In all of these areas, the United States and other IAEA member states work with the Agency to develop mission and equipment performance requirements, and cooperate in the testing and deployment of the new technologies. This cooperation is fundamental to ensuring the continued efficiency and effectiveness of international safeguards.

Nuclear Power innovations necessitate steady incremental advancements coupled with ingenuity in a range of technologies to further expand nuclear power as the most significant source of emission-free energy in the world.

Innovations and development in nuclear energy afford many opportunities in the United States and throughout the world. Improving efficiency, reducing capital costs, enhancing safety and security, and developing a closed fuel cycle are keys to nuclear power's expansion. The challenge and promise of the rebirth of nuclear power is attracting some of our most brilliant minds to pursue research that could impact our lives like never before.

The future for nuclear innovation is as bright as it has been in many years. It is now up to us to embrace this opportunity and see it to fruition.

I again thank the IAEA for allowing me to address this distinguished forum on behalf of the United States.

Thank you