Statement of Charles D. Ferguson
President, Federation of American Scientists
before the
House Committee on Science and Technology for the hearing on
Charting the Course for American Nuclear Technology: Evaluating the Department of Energy's Nuclear Energy Research and Development Roadmap

May 19, 2010

Introduction

Thank you, Chairman Bart Gordon, Ranking Member Ralph Hall, and Members of the Committee. I appreciate the opportunity to appear before you and comment on the Department of Energy's Nuclear Energy Research and Development Roadmap.

In his invitation letter, Chairman Gordon requested that I begin by providing a very brief overview of the Federation of American Scientists (FAS) and its *Future of Nuclear Energy in the United States* project. FAS was founded in 1945 by many of the atomic scientists who had developed the first atomic bombs in the Manhattan Project. They dedicated themselves to preventing nuclear war and reducing nuclear dangers by stopping the further spread of nuclear weapons to more states and terrorist groups. Several of the founders such as physics Nobel laureate Hans Bethe supported widespread use of peaceful nuclear energy. They realized, however, that to achieve safe and secure use of nuclear power, governments needed to make stopping nuclear proliferation a top priority. Because misuse of commercial nuclear technology to make weapons may harm business and the prospects for further expansion of commercial nuclear power, industry also has a vital stake in ensuring peaceful use.

Building on this legacy of more than six decades, FAS has recently begun the *Future of Nuclear Energy in the United States* project in partnership with Washington and Lee University. With generous grant support from the Lenfest Foundation, Professor Frank Settle of Washington and Lee University and I are leading a multiple author-project. The goal of the project is to assess lessons learned from the past, examine the present status of U.S. nuclear energy, and explore where nuclear energy development in the United States is headed. The main product will be a book-length report with chapters on licensing, financing, safety, security, the fuel cycle, waste management, comparison of nuclear energy to other energy sources, and nuclear energy's role in transportation and the smart grid. The publication date is early next year. Immediately after publication, Dr. Settle, the authors, and I will disseminate the results through briefings to Executive and Legislative officials, the news media, and other analysts. We will keep the House Committee on Science and Technology apprized of the progress of the project.

Small Modular Reactors

Because of the renewed attention to small modular reactors (SMRs), I will start my analysis of the Department of Energy's proposed plans with this subject.[1] In many respects, small power reactors are not new technologies but the potential for modularity, efficient factory construction, relatively quick deployment once built, and applications other than electricity generation offer the promise of cost competitive energy sources for markets that are not appropriate for large power reactors. As a matter of liability insurance, small power reactors are defined as generating 300 Megawatts (MWe) or less of electrical power. Medium power reactors range in power from greater than 300 MWe to 700 MWe. The typical large power reactors now being marketed can generate from 1,000 MWe to 1,600 MWe.

The United States and several other countries have considerable experience in building and operating small and medium power reactors. The U.S. Navy, for example, has used small power reactors since the 1950s to provide propulsion and electrical power for submarines, aircraft carriers, and some other surface warships. China, France, Russia, and the United Kingdom have also developed nuclear powered naval vessels that use small reactors. Notably, Russia has deployed its KLT-40S and similarly designed small power reactors on icebreakers and has in recent years proposed building and selling barges that would carry these types of reactors for use in sea-side communities throughout the world. China has already exported small and medium power reactors. In 1991, China began building a reactor in Pakistan and started constructing a second reactor there in 2005. In the wake of the U.S.-India nuclear deal, Beijing has recently reached agreement with Islamabad to build two additional reactors rated at 650 MWe.[2]

One of the unintended consequences of more than 30 years of sanctions on India's nuclear program is that India had concentrated its domestic nuclear industry on building small and medium power reactors based on Canadian pressurized heavy water technology, or Candu-type reactors. Pressurized heavy water reactors (PHWRs) pose proliferation concerns because they can be readily operated in a mode optimal for producing weapons-grade plutonium and can be refueled during power operations. Online refueling makes it exceedingly difficult to determine when refueling is occurring based solely on outside observations, for example, through satellite monitoring of the plant's operations. Thus, the chances for potential diversion of fissile material increase. This scenario for misuse underscores the need for more frequent inspections of these facilities. But the limited resources of the International Atomic Energy Agency have resulted in a rate of inspections that are too infrequent to detect a diversion of a weapon's worth of material.[3]

---

[1] Steven Chu, "America's New Nuclear Option: Small Modular Reactors will Expand the Ways We Use Atomic Power," *Wall Street Journal*, March 23, 2010.

[2] Agence France Presse, "China to Build Two Nuclear Reactors in Pakistan," April 29, 2010.

[3] Thomas B. Cochran, "Adequacy of IAEA's Safeguards for Achieving Timely Detection," Chapter 6 in Henry D. Sokolski, editor, *Falling Behind: International Scrutiny of the Peaceful Atom* (Strategic Studies Institute, U.S. Army War College, February 2008).

The opening of the international nuclear market to India may lead to further spread of PHWR technologies to more states. For example, last year, the Nuclear Power Corporation of India, Ltd. (NPCIL) expressed interest in selling PHWRs to Malaysia.[4] NPCIL is the only global manufacturer of 220 MWe PHWRs. New Delhi favors South-to-South cooperation; consequently developing states in Southeast Asia, sub-Saharan Africa, and South America could become recipients of these technologies in the coming years to next few decades.[5] Many of these countries would opt for small and medium power reactors because their electrical grids do not presently have the capacity to support large power reactors and they would likely not have the financial ability to purchase large reactors.

What are the implications for the United States of Chinese and Indian efforts to sell small and medium power reactors? Because China and India already have the manufacturing and marketing capability for these reactors, the United States faces an economically competitive disadvantage. Because the United States has yet to license such reactors for domestic use, it has placed itself at an additional market disadvantage. By the time the United States has licensed such reactors, China and India as well as other competitors may have established a strong hold on this emerging market.

The U.S. Nuclear Regulatory Commission cautioned on December 15, 2008 that the "licensing of new, small modular reactors is not just around the corner. The NRC's attention and resources now are focused on the large-scale reactors being proposed to serve millions of Americans, rather than smaller devices with both limited power production and possible industrial process applications." The NRC's statement further underscored that "examining proposals for radically different technology will likely require an exhaustive review" … before "such time as there is a formal proposal, the NRC will, *as directed by Congress*, continue to devote the majority of its resources to addressing the current technology base."[6] Earlier this year, the NRC devoted consideration to presentations on small modular reactors from the Nuclear Energy Institute, the Department of Energy, and the Rural Electric Cooperative Association among other stakeholders.[7] At least seven vendors have proposed that their designs receive attention from the NRC.[8]

Given the differences in design philosophy among these vendors and the fact that none of these designs have penetrated the commercial market, it is too soon to tell which, if any, will emerge as market champions. Nonetheless, because of the early stage in development, the United States has an opportunity to state clearly the criteria for

---

[4] P Vijian, "India Keen to Sell Nuclear Reactors to Malaysia," BBC Monitoring Asia Pacific — Political, April 27, 2009.

[5] More in depth analysis on Asia and nuclear energy developments will appear later this year in a book chapter I am writing for the National Bureau of Asian Research.

[6] U.S. Nuclear Regulatory Commission, "For the Record: 'Small' Reactor Reviews," December 15, 2008. [Emphasis added.]

[7] See, for example, presentations for the panel "Increasing Interest in Small Modular Reactors" at the RIC 2010 conference, March 11, 2010.

[8] U.S. Nuclear Regulatory Commission, "Advanced Reactors," www.nrc.gov/reactors/advanced.html, November 4, 2009.

successful use of SMRs. But because of the head start of China and India, the United States should not procrastinate and should take a leadership role in setting the standards for safe, secure, and proliferation-resistant SMRs that can compete in the market.

Several years ago, the United States sponsored assessments to determine these criteria.[9] While the Platonic ideal for small modular reactors will likely not be realized, it is worth specifying what such an SMR would be. N. W. Brown and J. A. Hasberger of the Lawrence Livermore National Laboratory assessed that reactors in developing countries must:

- "achieve reliably safe operation with a minimum of maintenance and supporting infrastructure;
- offer economic competitiveness with alternative energy sources available to the candidate sites;
- demonstrate significant improvements in proliferation resistance relative to existing reactor systems."[10]

Pointing to the available technologies at that time from Argentina, China, and Russia, they determined that "these countries tend to focus on the development of the reactor without integrated considerations of the overall fuel cycle, proliferation, or waste issues." They emphasized that what is required for successful development of an SMR is "a comprehensive systems approach that considers all aspects of manufacturing, transportation, operation, and ultimate disposal."

Considering proliferation resistance, their preferred approach is to eliminate the need for on-site refueling of the reactor and to provide for waste disposal away from the client country. By eliminating on-site refueling the recipient country would not need to access the reactor core, where plutonium—a weapons-usable material—resides. By removing the reactor core after the end of service life, the recipient country would not have access to fissile material contained in the used fuel. Both of these proposed criteria present technical and political challenges.

Ideally, the reactor would have a core life of 30 or more years. Such reactors are presently in use in the U.S. Navy. But the problem from a proliferation standpoint is that these reactors are fuelled with weapons-grade uranium. Thus, if a client country seized such a reactor and if it could break into the reactor's core, it could have bomb-usable fissile material. While the transfer of U.S. naval reactor technology is not advisable, perhaps there are other methods to achieve lifetime cores. A Japanese group of researchers, for example, examined a conceptual design for a small lead-bismuth cooled

---

[9] See, for example, U.S. Department of Energy, Office of Nuclear Energy, Science, and Technology, *Report to Congress on Small Modular Nuclear Reactors*, May 2001.

[10] N. W. Brown and J. A. Hasberger, "New Concepts for Small Power Reactors Without On-Site Refueling for Non-Proliferation," Paper for the Advisory Group Meeting on Small Power and Heat Generation Systems on the Basis of Propulsion and Innovative Reactor Technologies, Obninsk, Russian Federation, Convened by the International Atomic Energy Agency, July 20-24, 1998.

fast neutron reactor that computer simulations indicate the fuel could last for 30 years.[11] Fast reactors, however, have had a history of poor performance and have generally cost much more than thermal reactors.[12] Only Russia presently has a large commercial fast reactor in operation although China, Japan, and India have active fast reactor programs. A more promising method for lifetime cores may involve thorium, a fertile element that can be used to make fissile fuel. Depending on the reactor design, thorium-based fuels offer favorable proliferation-resistant properties. Concerning long-lived cores, a research group has recently shown via computer simulations that thorium-type small reactors may not need refueling until after 10 years and further design may result in even longer lived cores.[13]

But these concepts will likely require many years of development before they are ready for the commercial market. And although thorium reactors, in principle, look promising, the dominant paradigm has been to favor uranium-fuelled reactors.[14] Marketplace inertia and comfort level with the uranium-based technologies have erected barriers to different concepts. Moreover, all, but one, of the small reactor designs that are further along in development do not have lifetime cores.

The one exception is Toshiba's 4S reactor, which is a 10 MWe design. The first that may be constructed is under consideration for the small community of Galena, Alaska. Toshiba intends to request a design certification review by the Nuclear Regulatory Commission later this year. Computer studies indicate the 4S may have a 30-year lifetime without refueling, but full scale testing is still needed. This fast neutron reactor would use liquid sodium as a coolant.

Even if proliferation-resistant lifetime core reactors were available, the other challenge is to provide a proliferation-resistant pathway to nuclear waste management. As indicated by Brown and Hasberger, the ideal would be to remove as soon as possible the used fuel from the recipient country. But then the question is: What country will accept the used fuel and the other radioactive materials? No country has opened up a permanent repository for domestically generated nuclear waste. However, Russia has accepted used fuel from client states under the condition that Russia reprocesses the used fuel to extract plutonium for reuse. Also, Britain and France have reprocessed used fuel from client states under the condition that high level waste is returned to the clients.

Another option is to send used fuel from SMRs and perhaps other reactors fueled under a fuel leasing agreement to territory designated as an international zone. Such a zone would have to have rigorous security. In addition to making the difficult decision as to where to

---

[11] Yoshitaka Chikazawa et al., "A Conceptual Design of a Small Natural Convection Lead-Bismuth Cooled Reactor Without Refueling for 30 Years," *Nuclear Technology*, Vol. 154, 2006, pp. 142-154.

[12] Thomas B. Cochran, Harold A. Feiveson, Walt Patterson, Gennadi Pshakin, M. V. Ramana, Mycle Schneider, Tatsujiro Suzuki, and Frank von Hippel, *Fast Breeder Reactor Programs: History and Status*, A Research Report of the International Panel on Fissile Materials, February 2010.

[13] Iyos Subki et al., "The Utilization of Thorium for Long-Life Small Thermal Reactors Without On-Site Refueling," *Progress in Nuclear Energy*, March-August 2008, pp. 152-156.

[14] Leslie Allen, "If Nuclear Power Has a Promising Future … Seth Grae Wants to be the One Leading the Charge," *Washington Post,* August 9, 2009.

site this zone, supplier states would also have to reach agreement on whether to just store the used fuel or to reprocess it in order to recycle the plutonium and other fissionable materials. The political obstacles to creating this option for used fuel disposal appear formidable.

Market-based incentives may offer the way forward to convince clients to buy SMRs. If a client especially one without an existing nuclear waste storage facility wants to save costs, its government may be willing to pay a fee for disposal of the waste in a supplier state. Doing so will obviate the need for the client to pay for the expenditure of a disposal facility. But achieving agreement will require a major policy shift on the part of supplier states. Their governments will have to convince their publics to accept the waste. If the disposal fee were large enough but also fair to the client, then a market could be created. If the populace near the disposal site were assured that the project would create considerable number of jobs and would uphold the highest safety and security standards, then acceptance may follow. Because the used fuel from SMRs would be much more compact than used fuel from large reactors, the barrier to acceptance of the SMR used fuel may also be lower. As a possible precedent, the United States has repatriated used U.S.-origin fuel containing highly enriched uranium. This material has fueled research reactors provided to client states under the Atoms for Peace Program.

A systems analysis of the economics of SMRs is considerably different than the economics of more traditional large reactors. On a per kilowatt cost basis, a large reactor is more cost competitive as compared to a single SMR. But as two researchers for the International Atomic Energy Agency have pointed out, it is futile to make such a comparison because "SMRs are suitable for those locations that might not be appropriate for larger plants."[15] Such locations include countries with weak electrical grids, remote places, and locales favoring having the reactor near a population center to provide electrical and non-electrical needs such as district residential heating, industrial heating, or desalination. The researchers note that "SMRs have a potential to be competitive by employing alternative design strategies, taking advantage of smaller reactor size, offering a less complex design and operation and maintenance, relying on deployment-in-series approaches, taking an advantage of the accelerated learning, multiple unit factors and shorter construction duration." They caution that "the economic data does not exist or is not available at a fine enough level of detail to perform the complex comparative analyses normally associated with 'business models.'"[16]

Nonetheless, the IAEA has sponsored research that has assessed the cost competitiveness of constructing several SMRs at a site versus building one large reactor.[17] In particular, the IAEA study has estimated the overall cost of four SMRs of 300 MWe each to one

---

[15] V. Kuznetsov and N. Barkatullah, "Approaches to Assess Competitiveness of Small and Medium Sized Reactors," *Proceedings of the International Conference on Opportunities and Challenges for Water Cooled Reactors in the 21st Century*, October 27-30, 2009, IAEA, Vienna, Austria, Paper 1S01.

[16] Ibid.

[17] IAEA Nuclear Energy Series Report "Approaches to Assess Competitiveness of SMRs," *Status: submitted for pre-publication review and clearances; Targeted publication date: 2010; draft available at:* http://www.iaea.org/NuclearPower/Downloads/SMR/docs/Approaches-to-assess-competitiveness-of-SMR-Draft.pdf

large 1,200 MWe reactor. Thus, the cumulative power ratings are equivalent. The SMRs would be built sequentially so that once one has been completed another will begin construction nine months later. The estimated construction time for each SMR is less than half the time to build one 1,200 MWe reactor. While the economy of scale economic factor alone would indicate that the 1,200 MWe reactor has a 1.74 ratio cost advantage, other factors even the playing field for the combined SMRs. By building multiple units, the SMRs are estimated to achieve a 0.78 cost reduction. The speedier construction schedule per SMR gives an advantage, but balanced over the total construction time of the four SMRs, the cost reduction is only 0.94. The factory-built modular design provides a significant cost reduction of 0.85. The timing of the units to achieve favorable financing may result in another factor reduction of 0.95. Combining these cost reductions, the IAEA study indicates that the overall cost of the four SMRs is only 1.04 times greater than one large reactor, meaning nearly equivalent. It is important to underscore that these estimates are based on computer studies and have not been field tested by actual construction. As with practically all first-of-a-kind endeavors, the first SMRs will most likely exceed cost estimates. But with learning and deploying enough of these reactors, costs may very well come down.

It is also worth pointing out that in the United States, Alaska and Hawaii may derive the most benefit from SMRs. Based on a 2001 DOE assessment, "SMRs could be a competitive option" in those states because "the industrial rate for electricity charged by selected Alaska and Hawaii utilities varied from 5.9 to 36.0 cents per kWh" and for a generic 50 MWe SMR, "the range of electricity cost is estimated at 5.4 to 10.7 cents per kWh," while the "range of cost for a 10 MWe SMR is 10.4 to 24.3 cents per kWh."[18] Moreover, SMRs could help Hawaii reduce its substantial dependence on imported oil to generate electricity. According to the Energy Information Administration, petroleum provides about three-fourths of Hawaii's electricity.[19] In comparison, petroleum is used in the United States as a whole to generate about two percent of the nation's electricity.

Nuclear Energy Research and Development Roadmap

Because the United States relies on nuclear power to provide about 20 percent of its electricity and because this energy source provides the largest share of near-zero carbon emission electricity, the United States has a clear interest in protecting its investment in the current fleet of 104 commercial reactors. Many of these reactors have already reached their nominal 40-year lifespan. Dozens of these reactors have been recently receiving 20-year license extensions. Because the United States has not constructed a new reactor since 1996 with the completion of TVA's Watts Bar I, which was ordered in the early 1970s, the existing fleet is relatively old. If no new reactors are built in the next 20 years and if there are no further life extensions beyond 60 years, within a few years after 2030 about 40 percent of the current fleet will have to be decommissioned. While 20 years may

---

[18] U.S. Department of Energy, Office of Nuclear Energy, Science, and Technology, *Report to Congress on Small Modular Nuclear Reactors*, May 2001, p. iv.

[19] U.S. Energy Information Administration, "Hawaii," Updated May 13, 2010, http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=HI

appear to be a long time away, understanding the science and engineering demands for extended reactor life will require at least several years of R&D. Consequently, I concur with DOE’s emphasis in R&D Objective 1 to invest in improving the reliability, sustaining the safety, and extending the life of the current fleet. The challenges in this objective are largely technical and play to DOE’s strength.

The challenges in R&D Objective 2 to make nuclear power more affordable are more complex in that they are a mix of political, technical, regulatory, and financial factors. Factors outside DOE’s control include streamlining the regulatory process for new reactors and placing a price on carbon emissions. The latter factor would likely have the greatest effect in making nuclear power and other low carbon emission sources more cost competitive with fossil fuels.

Factors primarily within DOE’s control include: R&D into new reactor fuels that can provide more efficient use of fissionable material and can create isotopic compositions of fissile material that are less desirable for weapons-use, R&D into very high temperature reactors that can produce hydrogen for fuel cells and process heat for industrial applications, advanced computer modeling and simulation, fundamental research in materials science, and systems analysis. While the R&D Roadmap emphasizes “systems design for revolutionary new reactor concepts,” there is an urgent need for systems analysis along at least two fronts.

First, DOE should, if not already doing so, examine the competition among currently available reactor designs and the newer designs envisioned in the roadmap. An investment in a new nuclear reactor is at least a 60-year commitment in operations. Financial incentives for utilities to buy the currently available technologies may result in little or no demand for the more innovative technologies outlined in the roadmap.

Second, DOE should, if not already doing so, continually perform a systems analysis of the competition among the various electricity sources. Particular attention should be made in assessing how future changes in the electrical grid using “smart” systems may allow for greater use of decentralized sources of renewable energies and how developments in energy storage systems could affect the use of large and small power generators.

The third R&D objective seeks to develop sustainable nuclear fuel cycles. I agree with the general principles specified in the roadmap to “improve uranium resource utilization, maximize energy generation, minimize waste generation, improve safety, and limit proliferation risk.” It makes sense to “enable future decision makers to make informed choices about how best to manage the used fuel from reactors.” A long term R&D program that seriously examines all three types of nuclear fuel cycles is needed. While the plan outlined in the roadmap appears sound in terms of fundamental R&D, I would encourage DOE to perform a systematic economic analysis of the lifecycles of all three fuel cycles. Similarly, it is important to determine the extent to which industry will provide financial support for the two types of fuel cycles currently not used in the United States: the modified open cycle and full recycling.

Recommendations

- Determine the proportion of cost sharing industry can commit to in developing the Department of Energy's roadmap.

- Provide adequate R&D funding for development of lifetime core SMRs that do not use or produce fissile material that would be desirable for nuclear weapons production.

- Determine what resources the Nuclear Regulatory Commission will require to continue with rigorous evaluations of the many applications for large reactors while expediting the examination of small modular reactors.

- Implement a variable fee structure for NRC license applications in order to lower the financial barrier for SMR applicants. In March 2009, the NRC published an advanced notice of a proposed rulemaking to institute such a structure.[20]

- Provide flexibility for the combined construction and operating license (COL) process to facilitate adding multiple SMRs to a site over a several years to few decades period.

- Reevaluate the requirement for all Emergency Planning Zones (EPZs) to be 10 miles in radius from the reactor site. Even a "large" SMR will have a power rating one-fourth or less than the rating of a typical large reactor. Because an SMR is less powerful, its radioactivity content is considerably less than for a large reactor. Emergency Planning Programs may then require smaller EPZs for SMRs. But as more SMRs are added to a site, the EPZ may need to change to scale with the growth in power capacity.

- Request the Obama administration to provide a strategy for international sales of SMRs that only meet high standards of safety, security, and proliferation-resistance. Achieving adoption of these criteria will likely face resistance from states that have available small and medium power reactors that fall short in one or more of the standards.

- Require clear pathways for safe and secure disposal of used fuel and other radioactive waste before selling SMRs to countries without disposal facilities or to countries where regional security concerns may increase the likelihood of diversion of fissile material into weapons programs.

---

[20] Charles F. Rysavy, Stephen K. Rhyne, and Roger P. Shaw, K&L Gates LLP, "Small Modular Reactors," Special Committee on Nuclear Power, American Bar Association Section of Environment, Energy, and Resources, December 2009.

Brief Bio

Dr. Charles D. Ferguson is the President of the Federation of American Scientists (FAS). He is also an Adjunct Professor in the Security Studies Program at Georgetown University and an Adjunct Lecturer in the National Security Studies Program at the Johns Hopkins University. Prior to FAS, he worked as the Philip D. Reed Senior Fellow for Science and Technology at the Council on Foreign Relations, where he was the project director of the *Independent Task Force on U.S. Nuclear Weapons Policy*, chaired by William J. Perry and Brent Scowcroft. Before his work at CFR, he was the Scientist-in-Residence in the Monterey Institute's Center for Nonproliferation Studies, where he co-wrote (with William Potter) the book *The Four Faces of Nuclear Terrorism* (Routledge, 2005). While working at the Monterey Institute, he was the lead author of the report *Commercial Radioactive Sources: Surveying the Security Risks*, which was the first in-depth, post-9/11 study of the "dirty bomb" threat. This report won the 2003 Robert S. Landauer Lecture Award from the Health Physics Society. Dr. Ferguson has consulted with Sandia National Laboratories and the National Nuclear Security Administration on improving the security of radioactive sources. He also serves on the advisory committee for Oak Ridge National Laboratory's Energy and Engineering Sciences Directorate. He has worked as a physical scientist in the Office of the Senior Coordinator for Nuclear Safety at the U.S. Department of State. He is writing a book for Oxford University Press titled *Nuclear Energy: What Everyone Needs to Know* (forthcoming, January/February 2011). He graduated with distinction from the United States Naval Academy and served in the U.S. nuclear Navy, receiving training as a nuclear engineer at the Naval Nuclear Power School. He earned a Ph.D. in physics from Boston University.