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Energy Research, Development, Demonstration & Deployment (ERD3) Policy Project
ICARUS Project of the Fondazione Eni Enrico Mattei
The International Center for Climate Governance

Research, Development, and Demonstration for the Future of Nuclear Energy

KEY POINTS

- **On safety:** The Fukushima accident highlights the need for improved preparedness for events beyond the design basis for nuclear reactors, strengthened emergency response, and safer management of spent nuclear fuel. The accident has had an impact on public and investor confidence in nuclear energy, but nuclear power is likely to continue to grow in the most important nuclear markets.
- **On RD&D:** Major reductions in the cost of nuclear energy are not a major goal of current RD&D programs. Rather, current RD&D programs are targeted on offering new capabilities (such as high-temperature process heat) and improving features such as safety, waste management, sustainability of fuel resources, and proliferation-resistance, while maintaining or improving cost competitiveness.
- **On Gen IV:** Gen IV systems will probably not be cheaper than Gen III/III+ (or light water reactor, LWR) designs. Instead, their value would come from the generation of by-products (i.e., hydrogen and process heat), the ability to extend uranium resources or minimize nuclear wastes, or from improved safety and proliferation-resistance.
- **On small reactors:** Small modular reactors (both LWR and Gen IV designs) may or may not be cost competitive with large Gen III/III+ designs, but could have other benefits, such as simpler financing, improved safety, or strengthened proliferation resistance. There was disagreement about their market potential.
- **On barriers to large-scale deployment:** For nuclear energy to play a major role in meeting the energy challenges of the 21st century, issues going well beyond RD&D need to be addressed, such as public acceptance, waste management, and government support for licensing and financing.

By Laura D. Anadon, Valentina Bosetti, Matthew Bunn, Michela Catenacci, and Audrey Lee

Dramatic growth in nuclear energy would be required for nuclear power to provide a significant part of the carbon-free energy the world is likely to need in the 21st century or a major part in meeting other energy challenges. This would require increased support from governments, utilities, and publics around the world. Achieving that support is likely to require improved economics and major progress toward resolving issues of nuclear safety, proliferation-resistance, and nuclear waste management. This is likely to require both

research, development, and demonstration (RD&D) of improved technologies and new policy approaches.

To gather information on the RD&D needs for the future of nuclear energy, the future cost and performance of nuclear technologies, and on the major barriers to large-scale deployment of nuclear energy, a team of researchers at Harvard University and the Fondazione Eni Enrico Mattei (FEEM) conducted two coordinated surveys of nuclear experts. The surveys asked experts how much they would recommend that their governments spend on nuclear energy RD&D; what progress in cost and performance might be expected by 2030 if those recommendations were followed; and what other factors might constrain or promote future nuclear energy growth. Leading experts from the United States (U.S.) and the European Union (EU) participated in this expert elicitation surveys during the summer and fall of 2010. In April 2011, the FEEM and Harvard teams held a workshop in Venice, Italy with a subset of the participating EU and U.S. experts to present and discuss the results of the elicitations, in an effort to understand where there is consensus and where the most important disputes and uncertainties lie. Given the Fukushima nuclear accident in Japan, the meeting opened with a discussion of the significance of that event for the future of nuclear power and of the main lessons learned.

The participating experts emphasized that the Fukushima accident was still unfolding, which made it difficult to understand its lessons in detail. However, the experts agreed that the accident highlighted the need to strengthen preparation for events that go beyond the design basis for individual nuclear plants, to have better emergency response plans in place, and to improve approaches to managing spent nuclear fuel, in particular to prevent fuel from melting or catching fire if a spent fuel pool loses its cooling mechanism.

In the elicitation survey (which took place before the accident), experts had already pointed to safety as one of the main issues that could set back the deployment of nuclear power, predicting that an accident or terrorist attack that led to a major release of radioactivity would result in 50–100 percent reductions in future construction of nuclear reactors in the United States and in the European Union. The experts participating in the workshop disagreed as to whether the releases from Fukushima represented the kind of major radioactive release they had envisioned in making this prediction. During the workshop, experts generally agreed that the accident would have different effects on nuclear construction in different countries, but would not be likely to greatly slow nuclear growth in China, India, and Russia, the largest current nuclear markets.

A key finding that emerged in the survey and was confirmed during the workshop discussion is that experts do not expect current public RD&D investments to lead to major reductions in the capital cost of nuclear power plants by 2030, although cost competitiveness with other power generation technologies in the longer term is a goal of RD&D programs. Current RD&D is also targeted on other objectives, such as new abilities to produce hydrogen and high-temperature process heat, extension of uranium resources, improved waste management, and improved nuclear safety and proliferation-resistance. The reduction in the cost of Gen IV reactors in 2030 that the experts projected to arise from their recommended RD&D investments compared to a business-as-usual RD&D funding scenario was between 0–20 percent; the best guess of the cost of Gen IV reactors in 2030 ranges between 3,000 and 7,000 $/kW in both the United States and the European Union. In addition, the workshop confirmed that under a business-as-usual and under an expanded nuclear RD&D funding scenario, over 50 percent of U.S. and EU experts thought that the cost of SMRs in 2030 would be greater than that of Gen III/III+ reactors. Under an enhanced nuclear RD&D funding scenario, 53 percent of EU experts thought that Gen IV reactors could be less expensive than Gen III/III+ reactors in 2030, while the majority of U.S. experts still thought that Gen IV reactors would be more expensive.

Experts from both sides of the Atlantic strongly agreed on the value of nuclear RD&D to achieve objectives other than cost reduction and recommended annual

RD&D funding between $1 billion and $2 billion in each geography (the U.S. budget in 2010 excluding funding for facilities was $411 million, the average EU budget in the period 2005–2009 was $730 million). Beyond financing RD&D and promoting solutions for long-term waste disposal, experts thought that governments should provide support for licensing and siting novel reactor designs to help reduce the expected cost and the risks to the private sector.

During the workshop, U.S. and EU experts disagreed on the market for small modular factory built reactors (SMRs). While U.S. experts were split, EU experts did not foresee a large market. Consequently, U.S. experts placed more emphasis on public funding for SMR RD&D. Proponents of SMRs pointed to benefits that include: (a) less "lumpy" investments; (b) the possibility of achieving economies of scale in manufacturing to outweigh the smaller economies of scale in power generation; (c) the possibility of siting flexibility (arising from the potential for reduced water demands, potentially increased inherent safety, and possibly smaller areas for evacuation planning); (d) possible reductions in construction times (even shippability); (e) the possibility of recycling existing sites; and (f) avoiding the risk of having too much of a region's electricity dependent on a single power plant.

Finally, the group of U.S. and EU experts agreed on the high uncertainty characterizing future nuclear deployment. Less than 20 percent of the experts, in both groups, considered likely (>66 percent) the medium scenario (defined as 286 GW of nuclear energy both in the United States and in the European Union by 2050), which is the one that had the largest probability after averaging across all experts. The other scenarios were a scenario that represented no growth of nuclear power in the two geographies by 2050 and a high-growth scenario that represented 400 and 477 GW installed in the European Union and in the United States, respectively, by 2050. When presented with results from integrated assessment models of climate change and potential responses that included scenarios in which nuclear power deployments might grow to 5–10 times their current level by 2050, the experts generally took the view that growth on that scale was technically feasible, but there was disagreement over whether it was realistic given political and regulatory barriers.

Some of the experts argued that sustaining a much larger nuclear enterprise for many decades would require recycling to extend uranium resources, while others argued that uranium supply would not be a major constraint for an extended period. Some experts argued recycling would also have waste management advantages, while others argued these were not large enough to be decisive. In addition, in the surveys, experts expressed their concern about the limited progress in working out long-term nuclear waste disposal options. A majority of U.S. and of EU experts thought that a successful repository siting in the United States would increase significantly the rate of construction of nuclear plants in their region. During the workshop, experts reemphasized the importance of progress in both near-term and long-term approaches to safe management of spent fuel and nuclear waste, particularly in the aftermath of the Fukushima accident.

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This workshop was organized by the Energy Research, Development, Demonstration & Deployment (ERD3) Policy Project, Belfer Center for Science and International Affairs, Harvard Kennedy School; the ICARUS Project of the Fondazione Eni Enrico Mattei; and the International Center for Climate Governance.

The full workshop report may be downloaded here: International Workshop on Research, Development, and Demonstration to Enhance the Role of Nuclear Energy in Meeting Climate and Energy Challenges.

Statements and views expressed in this policy brief are solely those of the authors and do not imply endorsement by Harvard University, Harvard Kennedy School, or the Belfer Center for Science and International Affairs.

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ABOUT THE ERD3 POLICY PROJECT

The main aim of the ERD3 Policy Project, which is funded by a three-year grant (2008–2011) from the Doris Duke Charitable Foundation, is to produce and promote a comprehensive set of recommendations for the U.S. administration to accelerate the development and deployment of low-carbon energy technologies. The ERD3 Policy Project is based at the Belfer Center of the Harvard Kennedy School.

ABOUT THE ICARUS PROJECT

"Innovation for Climate chAnge mitigation: a study of energy R&d, its Uncertain effectiveness and Spillovers" is a three-year (2010–2012) European Research Council (ERC) Starting Grant funded by the European Commission under the umbrella of the 7th Framework Programme. ICARUS aims at producing an unprecedented analysis of energy-related innovation mechanisms. The ICARUS Project is based at the Premises of the Fondazione Eni Enrico Mattei.

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