The Future of Nuclear Energy in a Carbon-Constrained World: an MIT Interdisciplinary Study

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Chairman Weber, Ranking Member Veasey, members of the committee,

My name is John E. Parsons. I am a Senior Lecturer in the Finance Group at the MIT Sloan School of Management and a Co-Director of the recently released MIT study on the Future of Nuclear Power in a Carbon-Constrained World.

Thank you for inviting me to discuss the findings of our report, which is the culmination of two years of research by a team from MIT and other institutions (among them, INL). Our team confronted a stark disparity that has developed in recent years between the opportunities for growth of the nuclear industry—opportunities created by the global growth in demand for electricity and the urgent need to reduce global carbon emissions—and the dim reality of stagnation for the industry worldwide, but especially here in the U.S.. We sought to understand the reasons for the disparity. In particular, we took a fresh look at the assumption that nuclear power is needed to decarbonize the electricity sector. We also examined the factors behind the alarming rise in the cost of new nuclear power plants, and we explored technologies and design options that may radically reduce the cost. In particular, we examined the value proposition for advanced nuclear technologies. Finally, we explored the appropriate role that governments could play in the development and demonstration of new nuclear technologies.

The analysis in our study demonstrates that nuclear power has a vital role to play in achieving decarbonization of the electricity sector. In most regions of the U.S., as well as many other countries, serving projected load in 2050 while simultaneously reducing emissions will require a mix of electrical generation assets that is different from the current system. While a variety of low- or zero-carbon technologies can be employed in various combinations, our analysis shows that nuclear's role as a dispatchable low-carbon technology makes a distinct contribution to the portfolio. Without that contribution, the cost of achieving deep decarbonization targets increases significantly. Lowering the cost of nuclear has a significant impact on reducing the cost of decarbonization.

Nevertheless, the prospects for the expansion of nuclear energy remain decidedly dim in the U.S. and many other parts of the world. The fundamental problem is cost. Other generation technologies have become cheaper in recent decades, while new nuclear plants have only become costlier. Another problem is the failure to remunerate nuclear plants for the value of the low carbon electricity they provide.

We examined what is needed to arrest and reverse that trend. To address cost concerns, we recommend:

(1) An increased focus on using proven project and construction management practices to increase the probability of success in the execution and delivery of new nuclear power plants.

The recent experience of nuclear construction projects in the United States and Europe has demonstrated repeated failures of construction management practices in terms of their ability to deliver products on time and within budget. We detail the corrective actions that are urgently needed.

(2) A shift away from primarily field construction of cumbersome, highly site-dependent plants to more serial manufacturing of standardized plants.

Opportunities exist to significantly reduce the capital cost and shorten the construction schedule for new nuclear power plants. First, the deployment of multiple, standardized units, especially at a single site, affords considerable learning from the construction of each unit. In the United States and Europe, where productivity at construction sites has been low relative to manufacturing, we also recommend expanded substitution of factory production for on-site construction. The use of an array of cross-cutting technologies, including modular construction in factories and shipyards, advanced concrete solutions (e.g., steel-plate composites, high-strength reinforcement steel, ultra-high performance concrete), seismic isolation technology, and advanced plant layouts (e.g., embedment, offshore siting), could have positive impacts on the cost and schedule of new nuclear power plant construction.

It is important to emphasize the broad applicability of these recommendations across all reactor concepts and designs. Cost-cutting opportunities are pertinent to evolutionary Generation-III LWRs, small modular reactors (SMRs), and Generation-IV reactors. Without design standardization and innovations in construction approaches, we do not believe the inherent technological features of any of the advanced reactors will produce the level of cost reductions needed to make nuclear electricity competitive with other generation options.

In addition to its high cost, the growth of nuclear energy has been hindered by public concerns about the consequences of severe accidents in traditional Generation-II nuclear power plant designs. These concerns have led some countries to renounce nuclear power entirely. To address safety concerns, we recommend:

(3) A shift toward reactor designs that incorporate inherent and passive safety features.

Core materials that have high chemical and physical stability, high heat capacity, negative reactivity feedbacks, and high retention of fission products, together with engineered safety systems that require limited or no emergency AC power and minimal external intervention, will likely make operations simpler and more tolerable to human errors. Such design evolution has already occurred in some Generation-III LWRs and is exhibited in new plants built in China, Russia, and the United States. Passive safety designs can reduce the probability that a severe accident occurs, while also mitigating the offsite consequences in the event an accident does occur. Such designs can also ease the licensing of new plants and accelerate their deployment in developed and developing countries. We judge that advanced reactors like LWR-based SMRs (e.g., NuScale) and mature Generation-IV reactor concepts (e.g., high-temperature gas reactors and sodium-cooled fast reactors) also possess such features and are now ready for commercial deployment. Further, our assessment of the U.S. and international regulatory environments suggests that the current regulatory system is flexible enough to accommodate licensing of these advanced reactor designs. Certain modifications to the current regulatory framework could improve the efficiency and efficacy of licensing reviews.

Lastly, key actions by policy makers are also needed to capture the benefits of nuclear energy:

(4) Decarbonization policies should create a level playing field that allows all low-carbon generation technologies to compete on their merits.

The fact that nuclear power plants produce no carbon emissions is one of their most valuable attributes. Unfortunately, in many U.S. electricity markets these plants earn no return on that attribute whatsoever. In the few that provide some recognition of this value, the level is minimal. Investors in nuclear innovation must see the possibility of earning a profit based on selling their products at full value, which should include factors such as the value of reducing CO_2 emissions. Policies that foreclose a role for nuclear energy discourage investment in nuclear technology, raising the cost of decarbonization and slow progress toward climate change mitigation goals. Incorporating CO_2 emissions costs into the price of electricity can more equitably recognize the value to all climate-friendly energy technologies. Nuclear generators, both existing plants and the new builds, would be among the beneficiaries of a level, competitive playing field that fully rewards the contribution to decarbonizing the electricity sector.

(5) Governments should establish reactor sites where companies can deploy prototype reactors for testing and operation oriented to regulatory licensing.

Such sites should be open to diverse reactor concepts chosen by the companies that are interested in testing prototypes. The government should provide appropriate supervision and support—including safety protocols, infrastructure, environmental approvals, and fuel-cycle services—and should also be directly involved with all testing.

(6) Governments should establish funding programs around prototype testing and commercial deployment of advanced reactor designs using four levers: (a) funding to share regulatory licensing costs, (b) funding to share research and development costs, (c) funding for the achievement of specific technical milestones, and (d) funding for production credits to reward successful demonstration of new designs.

Many more findings emerged in the course of the research undertaken for this study. A copy of the full study is available at this link:

http://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world