Nuclear Freeze: Why Nuclear Power Stalled-and How to Restart It

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Abstract (summary)

The long-term role that nuclear power will play in the global energy market remains uncertain. The slow pace of nuclear innovation results primarily from the high costs and risks the industry presents to would-be first movers. And in the last few years, utilities have lost interest in building new reactors in the US thanks to the boom in the domestic production of shale gas, which has made natural gas the preferred fuel for new US power plants. Natural gas prices are historically quite volatile, and although US shale gas is certainly cleaner than coal, it is nevertheless a fossil fuel, and burning it still produces harmful levels of carbon dioxide. Nuclear power remains the best way to reliably produce electricity for homes and businesses on a large scale. That is why the continuing deficit in nuclear innovation is so troubling -- and why Washington needs to seek additional strategies to incentivize and support nuclear innovation.

Full Text

These days, the long-term role that nuclear power will play in the global energy market remains uncertain. That would have come as a surprise to the scientists and engineers who, during the 1950s and 1960s, pioneered the study of nuclear fission, built test reactors, and designed nuclear-powered airplanes and rockets. They would also have been surprised, and likely dismayed, that the light-water reactor—the technology that powered the first nuclear submarine, in 1954—remains the dominant commercial technology for producing fission energy. The glacial rate of change in nuclear technology over the last 60 or so years is why many energy analysts characterize current nuclear reactor technologies as "mature."

Other highly regulated U.S. industries, such as biotechnology, commercial aviation, and even commercial space launch, have enjoyed far faster rates of innovation than nuclear energy. The slow pace of nuclear innovation results primarily from the high costs and risks the industry presents to would-be first movers: even before they begin the time-consuming process of building a new plant, utility companies and the firms that manufacture reactors must invest a great deal of capital and then wait a long time to acquire licenses from the U.S. government. And in the last few years, utilities have lost interest in building new reactors in the United States thanks to the boom in the domestic production of shale gas, which has made natural gas the preferred fuel for new U.S. power plants.

But cheap U.S. shale gas is no long-term solution for the economic and environmental costs of global energy production. Natural gas prices are historically quite volatile, and although U.S. shale gas is certainly cleaner than coal, it is nevertheless a fossil fuel, and burning it still produces harmful levels of carbon dioxide. Nuclear power remains the best way to reliably produce electricity for homes and businesses on a large scale. That is why the continuing deficit in nuclear innovation is so troubling--and why Washington needs to seek additional strategies to incentivize and support nuclear innovation.

DIFFICULT TIMES

Since the late 1970s, there has been a marked slowdown in the growth of nuclear power in the United States. By 1978, U.S. utility companies had ordered 264 nuclear plants; since then, only half of those have been built. And those that were built cost a great deal and took a long time to complete. The 54 U.S. nuclear power plants that completed construction between 1970 and 1980 took an average of 5.7 years to build; after 1980, the average construction time increased to 12.5 years, and average construction costs more than doubled, adjusting for inflation.

Many factors contributed to these rising costs and longer construction times. For one thing, work on nuclear plants slowed down after the federal government stiffened regulations in the wake of the Three Mile Island accident in 1979, when a reactor at a nuclear plant in Pennsylvania partially melted down and released small amounts of radioactive material into the environment. But perhaps the most important obstacles resulted from the fragmented structure of the U.S. utility industry and the extraordinary diversity of the plant designs that utility companies ordered. For decades, U.S. reactor construction was dominated by four major companies that designed and built nuclear plants: Westinghouse, ge, Combustion Engi- neering, and Babcock & Wilcox. As nuclear technology advanced, these manufacturers frequently changed and updated their designs to increase power output, believing that doing so would reduce costs for the utilities that owned and operated the plants and thus increase the plants' value. Instead, the frequent updates significantly increased construction costs, sometimes leading utility companies to abandon the projects altogether.

The utilities themselves made things worse by customizing the nonreactor elements of their plants to fit their individual visions for how the plants should operate. Indeed, utilities often started construction on plants after having completed as little as 40 percent of the design process. This made it difficult for suppliers and vendors to reduce costs through standardization, since each plant they serviced had its own particular requirements.

On the other hand, the near-total lack of standardization also had a silver lining: because each plant presented its own set of challenges to engineers and technicians, it encouraged innovation in operations and maintenance. Thus, while innovation in reactor design has been slow, the industry has excelled at small-scale innovation: tweaks and improvements that allowed existing plants to operate better and better over the last four decades. Moreover, the diversity of the plant designs compelled the U.S. Nuclear Regulatory Commission to develop a substantially stronger and more independent system of...
Two other factors allowed for small-scale innovation and improvements within the nuclear industry. The U.S. utilities industry consists of regional monopolies that do not compete directly with one another, which means they can cooperate more closely than firms in most other industries. And after the Three Mile Island accident, every utility company that ran a nuclear plant realized that the future of the industry depended on preventing future accidents. That realization prompted U.S. utilities to cooperate with one another even more, by sharing detailed information about their operations, an effort that paid off by greatly improving the reliability of U.S. nuclear plants.

FISSION VISION

The structural factors that fostered innovation in the operation and maintenance of existing nuclear plants did not have the same positive effect on innovation in the design and construction of new nuclear plants. Still, although large-scale innovation has lagged, the U.S. nuclear industry has made two major strides over the last two decades when it comes to nuclear plant technology.

Arguably the most important advance has been the development of passive safety systems for reactors, which are featured in two recent U.S. models, Westinghouse's AP1000 and GE's Economic Boiling Water Reactor. One of the main challenges nuclear engineers face is how to keep a reactor cool in the event of an accident. When a reactor shuts down, as it is designed to do when something goes wrong, the radioactive byproducts of nuclear fission continue to generate heat. Failure to remove that heat can damage the reactor's nuclear fuel and result in the release of radiation. The vulnerability of traditional safety systems, which rely on electric power to remove the heat, was demonstrated by the 2011 Fukushima Daiichi nuclear disaster in Japan, in which the primary cause of the accident was the loss of all sources of electric power after a tsunami. Passive safety systems, by contrast, rely on gravitational forces to remove excess heat. With the advent of improved computer modeling in the 1990s, designers were able to demonstrate the reliability of these passive systems and thus obtain licenses to build reactors that used them.

In addition to eliminating the need for external electric power sources, passive safety systems also reduce the number of valves and pumps in nuclear plants by at least 50 percent, which decreases the amount of space needed to house a reactor. And by eliminating equipment and power sources that plant personnel have to inspect and maintain frequently and that security forces must guard, passive safety systems also make plants less labor-intensive and less vulnerable to sabotage.

The second major advance in nuclear power is the use of modular construction methods, which were pioneered by the shipbuilding and petrochemical industries. Modular construction involves manufacturing parts of buildings in a factory and then moving those modules into place and assembling them at a construction site: think IKEA furniture assembly, but with welding. Cruise ships, among other things, have been built this way since the 1990s. The nuclear industry embraced modular construction more recently and has benefited from computer-aided manufacturing tools that now make it easier to build so-called small modular reactors (SMRs).

Because SMRs are smaller than traditional reactors, building them takes less time. Utility companies can also use SMRs to increase the power output of a nuclear plant gradually over time, as needed, instead of sinking capital into building large reactors based on long-range estimates of expected future demand. And since the risk that fuel will be damaged during an accident increases along with a reactor's size, SMRs also improve safety, by dividing the fuel used at a nuclear plant among a group of smaller reactors.

The development of SMRs has benefited from collaborative relationships among universities, for-profit companies, and the U.S. government. The experience of an American energy start-up called NuScale Power serves as a good example. The company grew out of a research collaboration begun in 2000 between the Idaho National Engineering and Environmental Laboratory (now the Idaho National Laboratory) and Oregon State University. With critical funding from the U.S. Department of Energy, the research team began experiments to design a small reactor. Their success attracted venture capital funding, which allowed the researchers to design a smaller reactor than previously possible, one that features a fully passive safety system. In 2007, the university spun off its research to create NuScale, which is currently seeking certification for the new design.

Following on NuScale's preliminary success, three more U.S. reactor manufacturers have begun the design and licensing process for new SMR models—a bit of momentum that owes a great deal to federal funding. Government support of that kind helps would-be first movers by reducing the risk that free-riding competitors will take advantage of any breakthroughs without sharing any of the significant initial costs.

ATOMS FOR PROFIT

Despite the progress represented by passive safety systems and modular construction, the U.S. nuclear industry struggles to get American-made equipment into new reactors when they are built overseas. And the promise of these new technologies has been overshadowed by the general lack of enthusiasm in the United States for new reactor deployment—a result of the low domes- tic energy prices produced by the boom in shale gas. The boom is already showing signs of slowing down, and future prices for U.S. natural gas will almost certainly be as volatile as their historical values. Nevertheless, thanks to the United States' extraordinarily rich shale resources and extensive natural gas distribution system, U.S. prices will probably remain substantially lower than average prices worldwide.

That means that utility companies in the United States will continue to treat nuclear energy with a certain level of skepticism—especially when it is produced with cheap, safe, and innovative technologies such as SMRs. That will make it hard for U.S. manufacturers of SMRs to sell enough reactors to recover their development costs, which means they will increasingly search for markets overseas for their innovations, most likely through multinational commercial joint ventures. One place they might find opportunities is China, which currently has 20 nuclear plants in operation, with 28 more under construction and plans for an even larger expansion in the future.

U.S. manufacturers will also continue to rely on assistance from the federal government. Taking a cue from the important role that federal funding has played in the development of SMRs, Washington should consider supporting a whole range of exciting new innovations in nuclear energy. The best approach is for the government to establish performance objectives without prescribing the methods to achieve them: federal policies work better when they establish goals, reduce barriers, and reward innovation, but do not select the means. In addition to providing financial support, Washington needs to reduce the amount of time it takes the government to certify U.S.-manufactured components for export, so that American firms can compete more easily with foreign suppliers that face less cumbersome regulatory procedures.
Moreover, in order to make American technological leadership more credible, Washington must put its own nuclear house in order. Today, the United States has no federal nuclear waste program, following the Obama administration’s 2009 decision to abandon the long-planned Yucca Mountain nuclear waste repository in Nevada, which was selected as a central storage site in 1987 but never built. Last summer, a bipartisan group of four U.S. senators introduced the Nuclear Waste Administration Act of 2013, designed to implement the suggestions of the Blue Ribbon Commission on America’s Nuclear Future (of which one of us was a member), which President Barack Obama established in 2010. The bill would launch a new consent-based process to identify and develop new storage and disposal facilities and would create a federal agency to negotiate long-term agreements with state, local, and tribal authorities. The bill does not preclude a future decision to license and construct the Yucca Mountain site; instead, it represents a new effort to innovate, and to find a better solution to the problem of nuclear waste, as still required by current U.S. statute.

The Senate bill has yet to come up for a vote, and even if it passes, it faces likely resistance in the House. But its passage is crucial to the future of nuclear energy; without a reliable plan for how to store or dispose of nuclear waste, the United States will squander the opportunities represented by the promising innovation taking place in the nuclear industry. If the industry and Washington can work together to solve the problems of waste storage and disposal and foster innovations that will make nuclear power even cheaper and safer than it already is, the technology’s best days might yet lie ahead.©

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