Small Modular Nuclear Reactors Can Represent an Innovative Solution for America's Shifting Energy Sector

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EXECUTIVE SUMMARY

The United States is heavily reliant on nuclear power for its electricity. Last year, six states used nuclear power for more than 45 percent of electricity generation, with 19 percent of the nation's electricity generated by nuclear reactors.

As current U.S. nuclear energy production facilities increasingly approach the end of their planned operational lifespans, an innovative approach around Small Modular Reactors may represent the best and most practical solution available to energy decisionmakers. While solar, windpower and other renewable energy sources are becoming more prevalent, they are still decades away from becoming viable alternatives to nuclear for most Americans.

Federal regulatory officials have made important progress modernizing their systems and requirements for approving advanced reactors, a process expected to continue at both federal and state levels, and one which will largely define the future cost-effectiveness of the Small Modular Reactor approach. In particular, plans and requirements for the safe disposition of spent nuclear fuel from new reactors will be crucial.

Potential benefits of Small Modular Reactors include cost effectiveness, grid resilience, and improved safety and energy diversity.

Details follow.

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INTRODUCTION

Present and future changes in the United States' energy sector are being shaped by a number of powerful factors: leadership from the Obama Administration and other federal and state policymakers for sharply reduced carbon emissions (particularly for power plants), aging energy infrastructure, the need for more robust power grid resilience, structural changes to electricity markets and the attractiveness of energy independence prominent among them. In an otherwise fast-evolving sector, however, it seems unlikely that nuclear energy's substantial market share will be supplanted by other energy sources, at least for the immediate future. New, advanced nuclear reactor models are moving forward in many jurisdictions.

Last year, 19 percent of electricity generated in the United States came from nuclear power, according to the U.S. Energy Information Administration.[1] But the nuclear power facilities that produced this energy were built before the 1980s, and cannot be relied upon to do so forever – or even beyond the next decade.

Small Modular Reactors (SMRs) are nuclear power plants that are smaller in size (300 MWe or less) than current generation base load plants (1,000 MWe or higher). These smaller, compact designs are factory-fabricated reactors that can be transported by truck or rail to a nuclear power site.

Over the past two years, five nuclear reactors have been shuttered.[2] In two of these cases, the shutdown was due to market conditions, according to the Nuclear Energy Institute.[3] In the other cases, the shutdowns were due to the need for significant repairs to the facility.

Absent a change in course in the policy approach to nuclear energy, present trends point to a likely decline for the nation's nuclear energy sector, exacerbated by aging facilities and competition from other forms of energy, notably the natural gas sector, which has seen falling prices and increasing output in recent years.

[1] U.S. Energy Information Administration, "Frequently Asked Questions: What is U.S. electricity generation by energy source," at: http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3.

[2] "Meltdown – can US nuclear compete with shale gas and subsidized renewables?" Power Technology, March 10, 2015 Heidi Vella http://www.power-technology.com/features/featuremeltdown-can-us-nuclear-compete-with-shale-gas-and-subsidised-renewables-4516862/

[3] http://www.nei.org/Master-Document-Folder/Backgrounders/Fact-Sheets/Market-Driven-Reactor-Shutdowns-Threaten-Local-Eco

While the construction of new nuclear power reactors is underway in several states, it is unclear that progress will keep pace with energy demand. According to the Congressional Research Service, 33 of the nation's existing energy reactors will be required to close by 2030 under current licensing agreements, and the rest will be required to shutter by 2049.[4]

The aging of the nation's nuclear power plants has looming implications for its energy policy, particularly for states where nuclear plants account for significant shares of their electricity production within the state. According to the Nuclear Energy Institute, nuclear energy accounted for more than 45 percent of electricity generated in six states.[5] Among these states, Illinois, in particular, has seven nuclear power plants with operating licenses expiring within the next twelve years.

Table 1 – Nuclear Plants with Operating Licenses that Will Expire in the Next 12 Years

Plant Name	Location	Licenses Expiration
Braidwood Station 1	Braceville, IL	2026
Braidwood Station 2	Braceville, IL	2027
Byron Station 1	Byron, IL	2024
Byron Station 2	Byron, IL	2026
Callaway Plant, Unit 1	Fulton, MO	2024
Clinton Power Station, Unit 1	Clinton, IL	2026
Davis-Besse Nuclear Power Station, Unit 1	Oak Harbor, OH	2017
Diablo Canyon Power Plan, Unit 1	Avila Beach, CA	2024
Diablo Canyon Power Plant, Unit 2	Avila Beach, CA	2025
Fermi, Unit 2	Near Toledo, OH	2025
Grand Gulf Nuclear Station, Unit 1	Port Gibson, MS	2024
Indian Point 2	Buchanan, NY	2013
Indian Point 3	Buchanan, NY	2015
LaSalle County Station, Unit 1	Marseilles, IL	2022
LaSalle County Station, Unit 2	Marseilles, IL	2023
Limerick Generating Station, Unit 1	Limerick, PA	2024
Perry Nuclear Power Plant, Unit 1	Perry, OH	2026
River Bend Station, Unit 1	St. Francisville, LA	2025
Sequoyah Nuclear Plant, Unit 1	Soddy-Daisy, TN	2020
Sequoyah Nuclear Plant, Unit 2	Soddy-Daisy, TN	2021
South Texas Project, Unit 1	Bay City, TX	2027
Waterford Steam Electric Station, Unit 3	Killona, LA	2024

Source: U.S. Nuclear Regulatory Commission, "Operating Nuclear Power Reactors (by Location and Name), at: http://www.nrc.gov/info-finder/reactor/ (April 24, 2015).

[4] Mark Holt, *Nuclear Energy: Overview of Congressional Issues*, Congressional Research Service, March 14, 2014.

[5] Vermont (72 percent), South Carolina (54 percent), New Hampshire (52 percent), Illinois (48 percent), New Jersey (47 percent), and Connecticut (47 percent) . Nuclear Energy Institute, "US Nuclear Power Plants: General U.S. Nuclear Info," at: http://www.nei.org/Knowledge-Center/Nuclear-Statistics/US-Nuclear-Power-Plants.

Some states have significant reliance on nuclear plants that are nearing their end of their operating licenses. Mississippi, for example, gets one-fifth of its electricity from nuclear power, all of which comes from the Grand Gulf nuclear power facility. Grand Gulf's operating license is set to expire in 2024, and its owners have indicated that they hope to gain approval for a renewal license.[6] A list of nuclear plants with operating licenses set to expire in the next 12 years can be found in Table 1.

As of 2012, EnergyTrends.org reports that South Carolina, Alabama, Vermont, Illinois, and New Hampshire were the states with the highest amounts of nuclear energy produced per person, in that order.[7] Vermont's Yankee Nuclear Power Plant was decommissioned in 2014,[8] even though the plant had generated 70 percent of the state's electricity.[9]

Byron Station houses two of Illinois' seven nuclear power plants with licenses set to expire in the next twelve years. (Image: Wikimedia)

Over the next decade, the debate over the renewal or extension of these licenses will intensify. Efforts to renew licenses may face opposition from some elected officials and the public. For example, Indian Point Energy Center is the venue of two of the nation's older nuclear power facilities: Indian Point Nuclear Generating Unit 2, which saw its license expire in 2013,[10] and Indian Point Nuclear Generating Unit 3, which is set to expire in December 2015.[11] Located less than 40 miles north of Manhattan, the Center provides between 20 to 40 percent of the power consumed in New York City and Westchester County, according to a news report by *Breaking Energy*.[12] Some opponents are mounting legal challenges aimed at stopping the plant's relicensing.[13]

After Indian Point, the Davis-Besse power station located near Toledo, Ohio is set to see its license expire in April 2017.[14] First-Energy, which operates the facility, is pursuing plans to upgrade

[6] U.S. Energy Information Administration, Mississippi State Profile, http://www.eia.gov/state/analysis.cfm?sid=MS.
[7] See, EnergyTrends.org, "Electricity Generated – Nuclear Per Person 2012," at: http://www.energytrends.org/electricity-generated-nuclear/.
[8] Jack Newsham, "Vermont Yankee nuclear plant shutdown complete," December 29, 2014, *Boston Globe*.
[9] Christina Nunez, "Another Reactor Closes, Punctuating New Reality for U.S. Nuclear Power," National Geographic, January 1, 2015.
[10] U.S. Nuclear Regulatory Commission, "Indian Point Nuclear Generating Unit 2," at: http://www.nrc.gov/info-finder/reactor/ip2.html.
[11] U.S. Nuclear Regulatory Commission, "Indian Point Nuclear Generating Unit 3," at: http://www.nrc.gov/info-finder/reactor/ip3.html.
[12] Jared Anderson, "Exclusive Interview: Current Status of Indian Point Nuclear Plant Relicensing," *Breaking Energy*, April 23, 2015.
[13] *Ibid.*

and renew the facility's license. But they are facing opposition from some who have alleged that the facility has been "plagued by near-catastrophes since its inception."[15]

Some nuclear facilities may shutter due to economic conditions, including competition and market pressure from other sources of energy, particularly low-cost natural gas. The need for expensive repairs in the face of lower-cost alternatives closed three nuclear plants over the past two years, and threatens others.[16]

Earlier this year, an agreement to keep upstate New York's Ginna Nuclear Generating Station online required customers of Rochester Gas & Electric to pay above-market rates to subsidize continued operation.[17]

The Economist observed in 2013, America's "nuclear renaissance" was put on hold "thanks to cheap natural gas."[18]

MEETING SAFETY CONCERNS IN THE POST-FUKUSHIMA WORLD

The problem of replacing aging nuclear facilities is not unique to the United States, and the impact to date of the 2011 Fukushima disaster continues to bear profound resonance.

Japan, one of the nations that has historically been most dependent on nuclear energy, has seen many of its nuclear facilities shuttered since 2011. According to Reuters, Japanese officials were in the process of decommissioning five nuclear reactors in March 2015.[19] Their 2014 analysis found that it was possible that only one-third of Japan's nuclear facilities would be able to be restarted, due to inabilities to meet new safety requirements or address other challenges, including economic and political factors.[20]

But many hold the view that Japan will have little choice but to maintain some significant reliance on nuclear power. Despite strong public opposition, Japanese Prime Minister Shinzo Abe has sought to restart the nation's nuclear energy sector.[21] In April, a Japanese court issued an injunction halting plans to restart two nuclear reactors, citing questions over the new safety standards.[22]

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[14] U.S. Nuclear Regulatory Commission, "Davis-Besse Nuclear Power Station, Unit 1," at: http://www.nrc.gov/info-finder/reactor/davi.html.
[15] Connie Kline, "The case against the Davis-Besse nuclear power plant," Cleveland.com, March 29, 2015.
[16] Mark Holt, *Nuclear Energy*, p.2.
[17] Scott Waldman, "Ratepayers Will Subsidize Operation of Ginna Plant," *Capital New York*, February 13, 2015, at: http://www.capitalnewyork.com/article/albany/2015/02/8562333/ratepayers-will-subsidize-operation-ginna-plant.
[18] "Fracked Off: Thanks to Cheap Natural Gas, America's nuclear renaissance is on hold," *The Economist*, June 1, 2013.
[19] Reuters, "Japan utilities set to scrap five aging nuclear reactors," March 17, 2015.
[20] Reuters, "Japan may only be able to restart one-third of its nuclear reactors," April 1, 2014.
[21] Nick Cunningham, "A return to nuclear may be Japan's only option," OilPrice.com, April 5, 2015.
[22] Will Ripley, Tim Hume and Yoko Wakatsuki, "Japanese Court Halts Restart of Two Nuclear Reactors Due to Safety Concerns," CNN, April 15, 2015.

Germany, which had also relied on nuclear power for 30 percent of its electricity, closed eight nuclear plants in response to the Fukushima tragedy and announced plans to close all remaining plants by 2022.[23] While Chancellor Angela Merkel has referred to the plan as a "Herculean Task," factors including a renewable energy surcharge which reportedly raised the average family's energy bill by 47 percent in 2013 can be expected to present a formidable test as the plan moves forward.[24]

The European Union also faces problems with its aging nuclear facilities, which average more than 30 years old.[25] According to the European Commission, nuclear power plants generate nearly 30 percent of its electricity.[26]

In the United States, the nuclear energy sector has faced questions about safety following the Three Mile Island accident in 1979. The Fukushima disaster heightened safety concerns and prompted swift regulatory action to raise safety standards. In 2012, the Nuclear Regulatory Commission (NRC) approved a task force's recommendation imposing new safety requirements. The commission also strengthened its security requirements for nuclear facilities following the terrorist attacks of September 11, 2001.

Nearly two dozen nuclear reactors currently in use in this country have the same kind of safety systems, and the same containment for spent nuclear fuel, that produced the Fukushima disaster. But implementation of passive safety features and more robust backup electricity supplies are improvements widely viewed as significant safety improvements.[27] Strategies for storing spent nuclear fuel, often a political hot-potato in U.S. policy deliberations, are vital for ensuring safety in new nuclear facilities.

Conceptual drawing of an underground containment structure housing two B&W mPower™ reactor modules.

The U.S. Government Accountability Office reported in 2014 that all of the 16 nuclear regulatory bodies reviewed moved to enhance nuclear safety since 2011.[28]

Fukushima's aftermath has certainly produced political implications as well as regulatory action, triggering new public resistance to nuclear power, including renewing nuclear facility licenses that are set to expire in the United States.

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[23] Holt, *Nuclear Energy*, p. 3.
[24] Tim Smedley, "Goodbye Nuclear Power: Germany's Renewable Energy Revolution," *The Guardian*, May 10, 2013.
[25] Nina Chestney and Susanna Twidale, "Insight—The cost of caring for Europe's elderly nuclear plants," August 17, 2014.
[26] European Commission, "Nuclear Energy: safe nuclear power," at: http://ec.europa.eu/energy/en/topics/nuclear-energy.
[27] David Biello, "How Safe are U.S. Nuclear Reactors?" *Scientific American*, March 9, 2012.
[28] U.S. Government Accountability Office, "Nuclear Safety: Countries' Regulatory Bodies Have Made Changes in Response to the Fukushima Daiichi Accident," GAO-14-109.

It is likely that the U.S. has little choice but to retool its nuclear energy production, given the anticipated increases in demand for energy and the nation's current reliance on nuclear power. Overall U.S. electricity consumption, for example, is expected to increase by 29 percent by 2040, according to the U.S. Energy Information Administration annual outlook for 2015.[29] New sources of energy, such as increased supply of liquid natural gas, may be able to replace some of the demand on the nuclear sector; however, other sources of energy, such as renewables, are unlikely to serve as a replacement for nuclear power in time to keep pace with demand.

For example, the Energy Information Administration estimates that electricity generation from renewable sources of energy will increase from 13 to 16 percent by 2040,[30] which suggests that renewables cannot replace the roughly 19 percent of U.S. electricity generated by nuclear power over that timeframe. Moreover, given the history of the energy sector, a national energy policy should anticipate potential changes in global energy demand and production, and potential price shocks, which underscores the need for a diversified approach to the nation's energy production. Any long-term strategy to replace or expand the nuclear sector will require a reconsideration of what technologies offer the strongest economic case for long-term viability of new facilities.

These challenges require policymakers to consider new ways that nuclear energy could be modernized to address potential concerns about cost and safety, while also maintaining nuclear power as one of the key sources of energy.

POTENTIAL BENEFITS OF SMALL MODULAR REACTORS

Small Modular Reactors (SMRs) are one solution to the challenge of creating nuclear energy facilities expected by some industry observers to grow a substantial market share over the next two decades. The World Nuclear Association examined the potential for small reactors to satisfy increasing interest in nuclear power, and suggested that SMRs would have the following potential benefits: "greater simplicity of design," "economy of mass production", "reduced sitting costs," and "a high level of passive or inherent safety" in the event of malfunction or potential terrorist attack.[31]

A recent report by the Washington, DC-based think tank Third Way described the potential of this emergent technology:

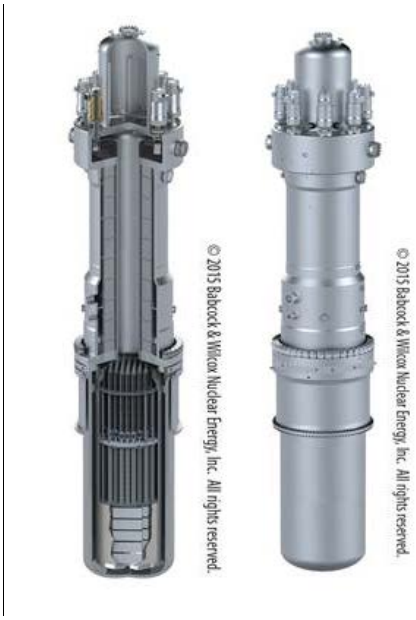
> *With a lower initial capital investment and shorter construction timeline than Light Water Reactors, SMRs could replace aging and carbon-emitting coal power plants. The next generation of nuclear reactors hold even greater promise of addressing challenges faced by the*

[29] "Annual Energy Outlook 2015," U.S. Energy Information Administration, April 14, 2015, at: http://www.eia.gov/forecasts/AEO/MT_electric.cfm.
[30] Energy.Gov, "EIA Report Estimates Growth of U.S. Energy Economy Through 2040," December 5, 2012.
[31] World Nuclear Association, "Small Nuclear Power Reactors," April 2015, at: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Small-Nuclear-Power-Reactors/

nuclear industry including nuclear waste management, proliferation concerns and costs of construction.[32]

Potential CMR benefits include:

Cost-Effectiveness: Small Modular Reactors offer important benefits that could ease the problems of cost effectiveness. Some experts predict that SMRs can be created and installed in a manner that may be more cost effective than the construction of larger, traditional nuclear power plants. This is due, in part, because they can be manufactured in a factory. Multiple SMRs can be made either for domestic or international customers, and the product may be shipped via transit or rail to the plant site. The presence of multiple suppliers producing components in different production facilities can drive down construction and maintenance costs, especially as parts become more standardized.



A single B&W mPower™ reactor module.

The Energy Policy Institute examined SMRs in 2010 and reported that primary economic advantages include "the initial reduced capital costs compared to traditional nuclear facilities and the potential for small nuclear facilities to provide power in areas where the infrastructure to support large reactors may be lacking."[33] For example, one analysis found that a small modular nuclear reactor would cost a few billion dollars, compared to an estimated $10 billion for a traditional, large reactor.[34] The extent of the potential cost effectiveness of SMRs remains an open question,[35] as plans are underway for the current plant proposal under consideration of the U.S. Nuclear Regulatory Commission,[36] meaning that the economic impact of SMRs will depend on the outcome of these and other future projects.[37]

In April 2014, the Babcock and Wilcox Company made public its plans to restructure its SMR program, slowing its project timeline to focus on technology development. President and CEO E. James Ferland

[32] "Introducing the Advanced Nuclear Industry," Third Way, June 2015, p. 11.
[33] David Solan, *et al*, "Economic and Employment Impacts of Small Modular Nuclear Reactors," Energy Policy Institute, Center for Advanced Energy Studies.
[34] Kevin Bullis, "Can Small Reactors Ignite a Nuclear Renaissance," March 28, 2013, *MIT Technology Review*.
[35] For a critical examination of SMRs, see: Mark Cooper, "Small modular reactor and the future of nuclear power in the United States," *Energy Research and Social Science*, July 2014.
[36] According to this press report, the U.S. Department of Energy is currently considering the application of Energy Northwest and NuScale to build a small modular nuclear reactor prototype at Idaho Falls by 2023. John Stang, "Nuclear power measures face questions," CrossCut.com, March 25, 2015.
[37] According to the Nuclear Regulatory Commission's website, the NRC is currently considering applications for design certification for four advanced reactors and small modular reactors, as of April 1, 2015. See: U.S. Nuclear Regulatory Commission, "Advanced Reactors and Small Modular Reactors," at: http://www.nrc.gov/reactors/advanced.html.

described a new target for licensing and deployment in mid-2020, noting that "there is still significant work involved in bringing this climate-friendly technology to reality."[38]

Improved Safety: SMRs offer potential safety enhancements compared to traditional nuclear reactors. For example, the Department of Energy points out that SMRs will be typically built below ground, creating benefits for security and safety.[39] Beyond these security improvements, the World Nuclear Association cited additional reasons why small reactors may be safer, including that, "Most are designed for a high level of passive or inherent safety in the event of malfunction."[40] They also reported that a "2010 report by a special committee convened by the American Nuclear Society showed that many safety provisions necessary, or at least prudent, in large reactors are not necessary" in designs for small nuclear power reactors.[41]

In February 2015, the NRC approved the safety evaluation report of Westinghouse Electric for the company's SMR plans.[42] One advantage that small modular nuclear reactors may have over a larger, traditional nuclear plant is that some of the reactors are designed to keep and store spent fuel on site, which addresses one prominent Fukushima-rooted concern related to safety.

Ability to Improve Market Diversity and Potential Resilience: Another benefit of the potential use of small modular nuclear reactors would be to improve market diversity and resilience. Several incidents, including the assault against the power substation in Metcalf, California[43] and the 2003 North American Power Outage, highlight the need for additional diversity and resilience within the energy sector to prepare for potential manmade incidents or natural disasters that result in the loss of energy for large areas. Installing small modular nuclear reactors across the country could increase the resilience of the overall national energy sector. A particular benefit of SMRs, as compared to traditional, large nuclear facilities, is that they could be constructed in rural locations that may not be able to afford a large-scale reactor, if the anticipated cost efficiencies of the smaller design are realized.

CHALLENGES TO THE DEPLOYMENT OF SMALL MODULAR REACTORS

The economic, practical, regulatory and policy factors on which potential deployment of small modular nuclear reactors will hinge have been the focus of a number of recent studies. A 2011 analysis published by the U.S. Commerce Department examined a range of challenges, including changes in the

[38] "B&W Announces Restructuring of Small Modular Reactor Program," Babcock & Wilcox press release, April 14, 2014.
[39] "Small Modular Nuclear Reactors," Office of Nuclear Energy, U.S. Department of Energy, at: http://www.energy.gov/ne/nuclear-reactor-technologies/small-modular-nuclear-reactors (accessed April 4, 2014).
[40] "Small Nuclear Power Reactors," World Nuclear Association, at: http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Small-Nuclear-Power-Reactors/, accessed April 4, 2014).
[41] *Ibid.*
[42] "NRC approves safety report for Westinghouse small modular nuclear reactor," *Power Engineering*, March 18, 2015.
[43] Shane Harris, "Military-Style Raid on California Power Station Spooks U.S.," December 27, 2013, *Foreign Policy*, at: http://foreignpolicy.com/2013/12/27/military-style-raid-on-california-power-station-spooks-u-s/ (Accessed April 4, 2015).

manufacturing sectors, tariffs on nuclear reactor components, NRC regulations requiring emergency planning zones, and potential public opposition to the deployment of new nuclear facilities.[44]

Construction delays and subsequent cost overruns are nothing new in U.S. nuclear reactor projects. They have reportedly already been a factor in two current SMR projects in Georgia and South Carolina, according to a *Wall Street Journal* report. Delays receiving essential components from vendors and shortages of qualified employees were two factors cited, as were specific quality control requirements on some 2,000 pre-built modules, imposed by the NRC.[45]

The state and federal regulatory climate will largely define the financial viability of SMR projects and the role they play in meeting future energy needs.

As the NRC has revised its licensing and regulatory approval process for new nuclear reactors, it has established processes and review standards specifically for SMRs. Shortening the schedule for application reviews has been an important goal of these changes.

In a 2015 paper published by Stanford University's Hoover Institution, NRC Commissioner William Ostendorff and senior official Amy E. Cubbage offer seven recommended strategies for operators to prepare for an efficient application review, with an emphasis on early, substantive engagement with federal regulators.[46]

MIT researcher Samuel Brinton noted in a 2014 paper that SMR reactors should generally be expected to produce increased quantities of spent nuclear fuel than their predecessors, particularly as more of these reactors are deployed. This calls for a policy-level strategy for the disposition of used nuclear fuel that will hold up to scrutiny brought to light during the Fukushima disaster.[47]

"With the risk of licensing and construction delays reduced, small modular reactors may represent a new paradigm in nuclear construction."
Steven Chu and Arun Majumdar, 2012

In 2012, the U.S. Department of Energy established a Small Modular Reactor Licensing Technical Support program. Pre-application dialogue between project managers and federal regulators has been a point of emphasis for this new process.

The federal agency also issued a revised fee structure for nuclear reactors that including calculating rates based on power levels of energy output – a development intended to offer reduced fees for smaller projects like SMRs.

[44] "The Commercial Outlook for U.S. Small Modular Nuclear Reactors," U.S. Department of Commerce, International Trade Association, February 2011, at: http://trade.gov/publications/pdfs/the-commercial-outlook-for-us-small-modular-nuclear-reactors.pdf.
[45] Rebecca Smith, "Prefab Nuclear Plants Prove Just as Expensive," *The Wall Street Journal*, July 27, 2015.
[46] William C. Ostendorff and Amy E. Cubbage, "Licensing Small Modular Reactors," Hoover Institution Schultz-Stephenson Task Force on Energy Policy, 2015.
[47] Samuel O. Brinton, "Used Nuclear Fuel Storage Options Including Implications of Small Modular Reactors," Massachusetts Institute of Technology, June 2014.

State-level legislative and regulatory frameworks are major market factors which are just as likely to tip the balance for or against the success of SMR projects.

For example, the National Conference of State Legislatures reports that 13 states have created restrictions for the construction of nuclear power plants: California, Connecticut, Hawaii, Illinois, Kentucky, Maine, Massachusetts, Minnesota, Oregon, Rhode Island, Vermont, West Virginia, and Wisconsin.[48] Minnesota, for example, has banned the creation of new nuclear plants.[49]

Other states have imposed additional requirements (including either voter approval, state legislative approval, or proof of economic feasibility) or technological requirements related to waste disposal.[50]

Federal funding, which has been a major driver in the growth of renewable energy projects, especially since the Recovery Act of 2009, will also play a substantial role. The Department of Energy provided $888.4 million in nuclear energy funding for FY2014, which the White House proposed reducing to $863.4 in its budget request.[51]

WHY SMALL MODULAR NUCLEAR REACTORS MAY OVERCOME CHALLENGES

2011 Fukushima disaster.
(Image: Digital Globe/Wikipedia)

Advocates of small modular nuclear reactors cite advantages over the large, light-water reactors they would be replacing. For example, the safety factors that are built into the design of small modular nuclear reactors could prove reassuring to approving the creation of new facilities. For example, one SMR reportedly is designed to store all of its spent fuel for its entire 60-year operating life, which could address the legal requirements of restrictive states related to plans for waste disposal.

Absent costly regulatory requirements, the lower start-up costs of installing a small modular nuclear reactor could also provide an attractive option to states that are more reliant on nuclear energy, anticipating the ending of existing licenses for aging facilities. Moreover, states or nuclear and energy regulators could respond to changes in the energy market, including the potential for closures of aging plants, to install small modular nuclear reactors, since some models take less than two years to construct.

[48] Scott Hendrick, "State Restrictions on New Nuclear Power Facility Construction," National Conference of State Legislatures, March 2015.
[49] *Ibid.*
[50] *Ibid.*
[51] Holt, *Nuclear Energy*, p. 7.

A related factor is the potential for SMR projects to take substantially less time to build: three years as opposed to eight to ten according to one industry executive.[52] This potential, too, is heavily dependent on the regulatory landscape.

CURRENT OUTLOOK

"It is possible that safe nuclear power can be made more accessible through the economy of constructing dozens of reactors in a factory rather than one at a time on each site," wrote federal Energy Secretary Steven Chu and senior energy official Arun Majumdar in 2012. "Also, with the risk of licensing and construction delays reduced, small modular reactors may represent a new paradigm in nuclear construction."[53]

The 2015 Third Way analysis identified six SMR reactor projects currently underway by major corporate players in the nuclear industry, each in a different state.[54]

One of these is a plan for a demonstration plant in the Western United States under the "Western Initiative for Nuclear," which has earned the support of several governors in the region.[55] The energy company NuScale intends to have the demonstration plant in place in Idaho by 2024. A key hurdle is the expected five-year process for passing the NRC's approval process. As of April 2015, NuScale reportedly was on track to submit a plan to the Commission in 2016.[56]

Limerick Generating Station, Pennsylvania. (Image: Wikimedia)

Other SMR projects are underway in North Carolina (Babcock & Wilcox Company/Bechtel collaboration), Florida (Holtex), Missouri (Westinghouse), California (General Atomics), and New York (Radix Power and Energy).[57]

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[52] Andrew Bounds and Chris Tighe, "Home-Grown Small Reactors on Agenda to Revive Nuclear Programme," *Financial Times*, April 7, 2015.

[53] Steven Chu and Arun Majumdar, "Opportunities and Challenges for a Sustainable Energy Future," Nature 488, 294-303, August 16, 2012.

[54] "Introducing the Advanced Nuclear Industry," p. 10.

[55] Bennett Hall, "NuScale unveils plan for Idaho reactor," July 2, 2013, *Corvallis Gazette-Times*, July 2, 2013, at: http://www.gazettetimes.com/news/local/nuscale-unveils-plan-for-idaho-reactor/article_190f15fa-e279-11e2-aee3-001a4bcf887a.html.

[56] Wendy Culverwell, "Portland nuclear firm hits another small module milestone," *Portland Business Journal*, April 2, 2015, at: http://www.bizjournals.com/portland/blog/sbo/2015/04/portland-nuclear-firm-hits-another-small-module.html.

[57] "Introducing the Advanced Nuclear Industry," p. 10.

CONCLUSION

The aging of the nation's current nuclear energy production facilities and infrastructure raises a crucial challenge for decisionmakers: How will the United States replace or supplement the 19 percent of American power that is provided by nuclear energy as the nation's current nuclear power facilities likely continue to close over the decades ahead? How we answer this question will be based on a range of factors, such as affordability, the economic dynamics of the energy sector, safety, and environmental concerns.

Small modular nuclear reactors offer a promising solution that may answer the affordability and economic questions as well as improve safety. As the regulatory landscape will largely define the market factors which will determine whether SMRs will be a viable future source of carbon-emission-free power for the future, it will be increasingly necessary for state and federal regulators and lawmakers to work with industry to solve the crucial factors that will determine whether this technology will live up to its potential.

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