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# Advancing Nuclear Energy: The Role of Advanced Technologies in a Changing Political and Regulatory Landscape

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Nuclear energy has long been a significant source of reliable, clean energy within the United States.[1] In 2021 alone, nuclear energy accounted for approximately 20 percent of electricity generated in the country and 50 percent of its carbon-free electricity.[2] And while some sources of carbon-free generation are necessarily intermittent, nuclear generation has a high-capacity factor, capable of running at all hours of the day.[3]

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At the same time, numerous public and private stakeholders are working toward net-zero emissions by 2050. For

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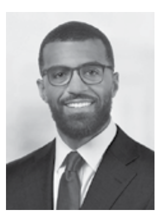

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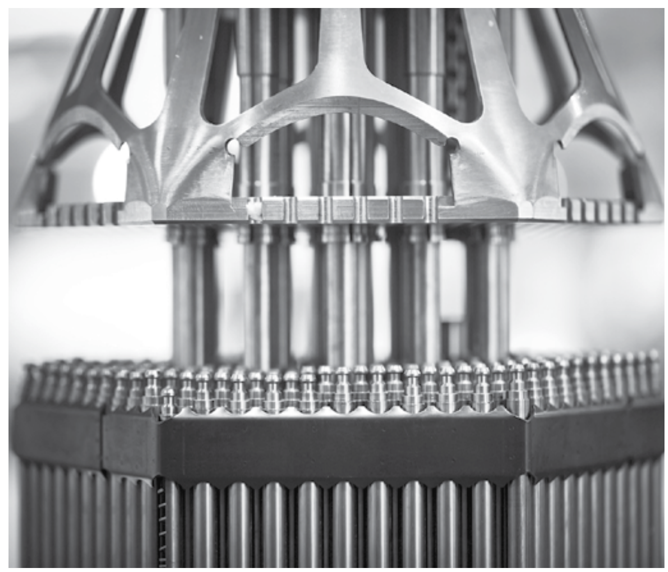

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example, many states have enacted legislation establishing strict carbon-reduction goals.[4] As of 2022, at least 13 states require some portion of their economy to achieve net-zero emissions by 2050.[5] While there has been no corresponding federal legislative action establishing national carbon policy, President Joe Biden has in Executive Order H.R. 14057 directed federal agencies to move in specific and significant ways to reduce carbon within specific timelines.[6] Additionally, many large commercial entities have also committed to achieving

*continued on page 3*

# Advancing Nuclear Energy: The Role of Advanced Technologies in a Changing Political and Regulatory Landscape

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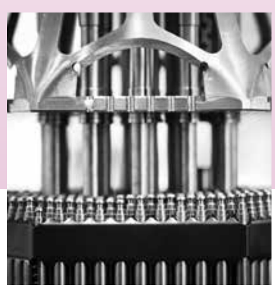
net-zero or reduced-carbon goals in the relatively near future.[7] But, complicating matters, some predictive modeling of energy demand shows a tripling of global energy power consumption by 2050, driven by factors including expected shifts away from fossil fuel use for transportation, heating, and industrial processes like steelmaking.[8]

Advanced nuclear energy, which encompasses a range of exciting technologies, offers one potential solution as part of a diversified energy portfolio for achieving net-zero emissions by 2050. Traditional nuclear technologies generate power using light-water nuclear reactors to split atoms, heat water, and create steam. Newer reactor technologies are expanding on this traditional model with the promise of safer, cheaper, and more efficient generation through emission-free outputs.[9] These new advanced reactors vary in size and output; some are microreactors, a subset of small nuclear reactors (1–20 megawatts generating capacity), some are more general small modular reactors (20–300 megawatts), and others are full-size reactors (300–1,000+ megawatts).[10]

One advanced nuclear technology that has received significant attention of late is small modular reactors (SMRs). SMRs are designed to not only produce baseload carbon-free electricity to the grid, but also provide carbon-free electricity specifically to energy-intensive processes like steelmaking.[11] In this article, we explore this promising technology in four parts. First, we discuss the principal benefits and challenges of SMRs, both practically and from a regulatory perspective, as part of a broader diversified-energy portfolio. Second, we examine as a case study Virginia, which is particularly focused on making SMRs a key part of that state's energy portfolio. Third, we briefly discuss other states that are similarly prioritizing further SMR research and development as a matter of public policy, which holds much promise for the future of the technology across the United States. Finally, we outline further steps to expedite SMR development and implementation.

**SMRs (small modular reactors) . . . use nuclear fission to harness thermal energy to generate electricity.**



### The Benefits and Challenges of SMRs in a Diversified Energy Portfolio

SMRs are an advanced nuclear reactor technology that can function as a cleaner, safer, and more flexible alternative to traditional nuclear reactor technologies.[12] Like traditional nuclear power generation, SMRs use nuclear fission to harness thermal energy to generate electricity that can ultimately be distributed to businesses and homes.[13] Unlike traditional nuclear power generation, SMRs promise lower costs, more flexibility in construction, a smaller environmental footprint, and a host of different safety measures, among other things.[14] For example, as the name indicates, SMRs are physically small, amounting to a fraction of the size of traditional nuclear reactors and offering no more than one-third of the typical generating capacity—under 300 megawatts.[15] The *modular* component of the name is in reference to the fact that SMRs are capable of being produced off-site and later transported to a location for installation, whereas traditional nuclear reactors require on-site construction.[16] In addition to the flexibility offered by their size and assembly, SMRs have been touted for their safety potential and minimal environmental footprint.[17] They employ safety systems comparable in reliability to those associated with traditional nuclear reactors, while creating minimal environmental impact due to their size and limited waste.[18]

Many of these features were intentionally designed in response to public and private obstacles that traditional nuclear technologies have traditionally faced.[19] And it is many of these features that stakeholders—both foreign and domestic—count among the reasons that they have identified SMRs as a key component of their future energy production plans.[20] Below, we discuss several of these key features in more detail.

***Flexibility/Location***

Relevant to major stakeholders, the SMRs' small size and output mean that they can be utilized in locations—potentially smaller residential areas—unsuitable for larger nuclear power plants.[21] This is important because access to energy in rural areas is often limited by inadequate infrastructure and high costs.[22] SMRs can also be placed in areas not spacious enough to develop solar or wind-powered generation, allowing for more tailored placement to meet existing and anticipated electricity needs.[23] SMRs are keenly situated to help address these concerns because their comparatively modest generating capacity and size more easily facilitate their integration into existing grids or remote installation off-grid.[24] The SMRs' smaller footprint and modularity also mean that they can be placed in a wide variety of sites, including existing nuclear facilities, industrial areas, and greenfield or brownfield sites.[25] In many cases, SMRs can replace coal- or gas-fired plants that have been or will be decommissioned.[26]

Because SMRs can also be prefabricated, allowing them to be manufactured and then shipped and installed on-site, they represent a flexible and cost-effective alternative to large power reactors that typically need to be customized for their location and require additional construction considerations.[27] The flexibility of SMRs is particularly evident with respect to microreactors, that is, SMRs with an electric generating capacity of only a few megawatts.[28] Additionally, the streamlined nature of SMR construction signals the potential of SMRs for incremental deployment—meaning that units can be constructed to match increasing energy demands rather than as a massive, up-front deployment that hopes to anticipate all future load growth.[29]

> **. . . SMRs can replace existing coal-fired plants that are unsuitable candidates for carbon capture.**

***Safety***

SMRs have also been touted for their safety potential and low environmental footprint.[30] As currently conceived, SMRs include safety features comparable to those in place for traditional nuclear facilities.[31] SMR safety measures are generally more reliant on passive safety systems triggered by physical phenomena like natural circulation and self-pressurization, resulting in quicker reaction times and less room for human error.[32] In some cases, this can significantly lower the potential for unsafe releases of radioactivity to the environment and the public in the unlikely event of an accident.[33] The smaller core size also means smaller evacuation zones and less potential human exposure in the event of an emergency.[34] Because the plants are modular, they can also more easily be removed or replaced at the end of life.[35] The greater efficiency, as well as less frequent refueling commensurate with their size, also means that there is significantly less risk associated with fuel transport.[36] The increased safety of SMRs relative to traditional nuclear reactors means that stakeholders have a viable option to bridge the gap between the public's desire for carbon-free energy and the perceived safety concerns that accompany nuclear energy.[37]

***Reduced Carbon Future***

SMRs can help facilitate corporate ESG (environmental, social, and governance) goals by providing reliable sources of dispatchable carbon-free energy that complement other low-carbon energy sources like renewables (such as wind and solar), carbon capture, and energy storage initiatives.[38] Because SMRs generate electricity using nuclear fission, they represent a reliable and carbon-free energy alternative to fossil fuel electricity generation.[39] Relatedly, SMRs can replace existing coal-fired plants that are unsuitable candidates for carbon capture.[40] Because their power generation is adjustable, SMRs work well with wind and solar offerings that often fluctuate based on weather conditions.[41] Accordingly, SMRs provide increased reliability and, more importantly, predictability to the system as a whole while society transitions away from carbon-based energy.[42]

***Cost***

Although long-term costs are still being assessed, SMRs have the potential to be a cost-effective component of a diversified energy portfolio.[43] In part, this potential stems from lower initial construction costs and shorter timelines, which can contribute to lower financing costs over time.[44] The ability to automate processes may also mean lower operating costs due to reduced labor costs.[45] However, short-term costs are likely to be high given the relatively innovative designs and technological risks, along with the lack of any real infrastructure supporting the development of this technology.[46]

### *Waste*

Commercial nuclear power plants in the United States have generated over 88,000 metric tons of spent nuclear fuel, and many are concerned that SMRs will exacerbate this issue by producing more waste per unit of energy generated.[47] According to a study published in the *Proceedings of the National Academy of Sciences*, SMR spent fuel contains relatively high concentrations of fissile nuclides; thus, additional industrial development will be needed to accommodate the storage and disposal needs of SMR spent fuel.[48] However, in a study sponsored by the U.S. Department of Energy, the conclusion was that the waste attributes of SMRs, especially from decommissioning, can vary significantly depending on technology and design choices.[49] In short, there is no unified viewpoint on whether SMRs ultimately produce more or less waste than traditional light-water nuclear reactors. And, in any event, any concerns about the waste per energy unit generated by SMRs may be resolved in the near future as the industry continues to turn its attention to SMR waste-management solutions.

### Virginia as a Case Study

When considering the multitude of benefit SMRs can provide to a well-organized diversified-energy portfolio, it should come as no surprise that stakeholders like the Commonwealth of Virginia are seeking to take advantage of this opportunity as soon as possible.[50] Virginia Governor Glenn Youngkin's proposed October 2022 state energy plan favors a diversified, "all of the above" approach to energy that includes clean energy sources like wind and solar, while placing a larger emphasis on the deployment of nuclear energy technologies like SMRs.[51] Youngkin's plan also emphasizes the importance of investing in clean energy jobs in industries like manufacturing, construction, and engineering, as well as promoting energy efficiency programs.[52]

As part of the plan's goal of increasing access to nuclear energy, Youngkin pledged to make Virginia the first state to launch a commercial SMR over the next decade.[53] In furtherance of this goal, Youngkin proposed allocating $10 million in the 2023 budget to create the Virginia Power Innovation Fund for research and development of innovative technologies, such as SMRs.[54] As discussed below, the Virginia General Assembly passed a bill creating the fund in March 2023.[55] Proponents of the plan highlight the clean, flexible, and cost-effective advantages of SMRs.

Virginia is already home to several entities experienced in the nuclear industry.[56] Indeed, a subsidiary of Dominion Energy, Inc., one of the nation's largest producers and transporters of energy, currently operates two nuclear facilities in Virginia, which generate approximately one-third of the state's energy.[57] Based on the presence of these companies and the infrastructure that they provide, Virginia is already well positioned to harness the benefits of nuclear energy and become the epicenter of energy innovation for the nation.[58] Just last year, the U.S. Department of Defense selected one Virginia-based company to construct the nation's first advanced nuclear microreactor.[59] The reactor is expected to be implemented by 2024 and will be capable of producing 1–5 megawatts of energy.[60]

**Virginia is already well positioned to harness [nuclear energy benefits] and become the epicenter of energy innovation . . .**

Most recently, Virginia laid further groundwork for SMRs in the commonwealth during the General Assembly's 2023 legislative session, passing three new bills into law. First, House Bill 2386 created the aforementioned Virginia Power Innovation Fund, with funding to be used solely for the purposes of research and development of innovative energy technologies like SMRs.[61] Second, House Bill 1779 and Senate Bill 1464 established the Nuclear Education Grant Fund and Program, which awards grants to public or private colleges and universities in Virginia that seek to offer a nuclear program.[62] Third, House Bill 1781 expanded the Southwest Virginia Energy Research and Development Authority's powers to, among other things, allow it to promote and support energy development projects, promote energy workforce development, and identify and work with the commonwealth's research and development partners.[63]

Although Virginia is actively promoting the development and construction of SMRs in the commonwealth, additional support may be needed.[64] The technology is developing, meaning initial costs may remain relatively high.[65] Accordingly, additional legislative and/or regulatory support—similar to Virginia's extensive legislative and regulatory support for solar photovoltaics, offshore wind, onshore wind, and energy storage—may be necessary to encourage SMR development and construction in the short term.[66]

### Other States Supporting SMR Development

Virginia is not alone in promoting the development of SMRs and similar technology. Several other states have undertaken similar initiatives:[67]

- In 2020, Wyoming enacted legislation allowing decommissioned coal- and gas-fired plants to be replaced with SMRs.[68]
- In 2021, Montana enacted legislation granting authority to approve the construction of nuclear facilities and approved a resolution that calls for a study on the feasibility of implementing SMRs.[69]
- In 2022, West Virginia enacted legislation that lifted a ban on nuclear plant construction.[70]
- In 2022, Indiana enacted legislation requiring state regulatory bodies to adopt rules relating to the construction, purchasing, or leasing of SMRs and included SMRs among the clean energy projects that can receive financial incentives from the state.[71]
- In 2023, Ohio announced plans that it had contracted with a company to develop two nuclear plants on a re-industrialized site.[72] These plants will provide up to 30 megawatts of clean electric power and more than 50 megawatts of clean heating, with opportunities to expand.

**. . . legislators and agencies can support increased funding for research and development of emerging technologies . . .**

In addition to these state-level actions, the federal government has contracted with several companies to bring SMRs online in three states—Wyoming, Washington, and Idaho—in the next decade.[73] Furthermore, an SMR is expected to be brought online in Tennessee in the same time frame.[74] In a more overt step by the federal government supporting SMR development, the Nuclear Regulatory Commission (NRC) announced on March 17 that it would conduct a review of a standard design approval application by NuScale Power LLC for its SMR design for a pressurized-water reactor.[75] If accepted, it would be only the seventh nuclear reactor design certified by the NRC.[76]

### Further Steps to Expedite SMR Development and Implementation

The future of SMRs is undoubtedly bright; however, there remain significant state and federal regulatory hurdles—such as NRC certification of newer SMR technologies—that SMR developers and stakeholders must address before the burgeoning technology can realize its full potential. With that said, there are a number of approaches regulators can take advantage of in order to help expedite the development and implementation of SMRs throughout the United States.

First and foremost, efforts must be undertaken to promote education and knowledge sharing among SMR developers, regulators, and the communities within which SMRs are intended to be implemented. Creating a more educated populace will galvanize support for expedited growth, hastening the certification process by minimizing public opposition. One way to further such educational efforts would be for the federal government to promote the demonstration of SMR ability to power federal facilities, which could help spur demand and smooth the adoption of this technology for use in public and private applications nationwide. In addition, regulators could partner with environmental and clean energy advocates to help educate local communities and legislators about the benefits of this versatile, clean, and cost-effective technology.

Second, engagement between regulators and SMR developers should be promoted in order to encourage consistent communication and to streamline compliance efforts. One way to further this goal would be for regulators to regularly visit SMR research and development facilities. Such visits not only would ensure consistent communication between researchers and regulators but also would allow developers to tailor their designs to best comply with evolving regulatory approaches. Ultimately, once a product is finalized under this collaborative process, regulators could expeditiously test and approve new technologies—thereby accelerating the implementation of safe SMRs. Understanding that regulators currently have limited capacity to accommodate such a program on a large scale, Congress, in turn, could provide additional funding and statutory authority to expedite the SMR testing and approval process in this way.

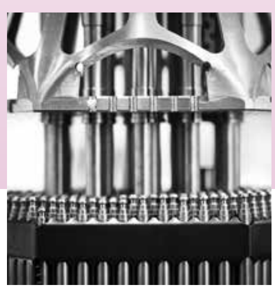
Third, legislators and agencies can support increased funding for research into and development of emerging technologies generally, which will make SMRs more efficient; safer; and, ultimately, easier to permit and construct.

Finally, state and federal legislators can help spur the advancement of SMR technology by supporting legislation that will modernize the nuclear power regulatory regime while also incentivizing participation and investment in this area. An example of this is the ADVANCE Act, a bipartisan Senate proposal offsetting a portion of the costs of NRC review; establishing prizes for first developers going through the newly proposed framework; and requiring reports on NRC-related topics, like the licensure of nuclear reactors for applications beyond electricity (such as heating) and the acceleration of approvals for reactors at brownfield sites.[77]

### Conclusion

In summary, the considerable exploration of SMR alternatives at various levels of public and private organizations paints a clear picture, to varying degrees. As the nation continues its advance toward a carbon-free future, SMRs will likely serve a critical role in realizing that goal. All indications point to their importance becoming undeniable. Many of the examples discussed above are just initial steps along the path to SMR implementation. Significant changes in the next decade and beyond are likely, if not certain.

**As the nation continues its advance toward a carbon-free future, SMRs will likely serve a critical role.**



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