Opportunities for Small Modular Reactors in Electric Utility Resource Planning

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New trends are emerging that are dramatically changing the needs of future electricity generation portfolios. As states and utilities establish and pursue goals to decarbonize the electricity sector, the changing mix of generation in utilities' portfolios are impacting the reliability, resilience and cost of electricity. Against this backdrop, the electric sector is innovating rapidly with new technologies that were only imagined a decade ago. This includes generation technologies such as wind, solar, Small Modular light-water Reactors (SMRs),[1] advanced nuclear reactors, carbon capture and sequestration and energy storage.

These trends create new challenges and opportunities for electric utilities' resource planning and procurement of new generation. Utility resource planning seeks to provide lowest cost of service to reliably meet forecasted electricity demand, with a growing need for the generation source to be clean and resilient. The lowest cost may not always be the generation source with the lowest levelized cost of electricity, as each new generation technology has different costs associated with integrating into the grid. History has also shown that a diverse generation portfolio is key to achieving the lowest cost to the consumer. Utilities typically plan over a 10 to 20-year time horizon and thus should consider the full range of potential generation sources, even those that are not currently feasible or cost effective, because they could evolve to become a viable technology in the future.

SMRs are an innovative technology that provide firm, clean and dispatchable electricity and partner well with renewables, energy storage and other zero-carbon sources. This report describes the strategic roles that SMRs can play in a utility's generation portfolio and the benefits that this technology brings to their customers. To-date, a number of utilities are considering adding SMRs to their generation portfolio as a cost effective and environmentally friendly option. This report provides the information that resource planners and other stakeholders need in order to consider and model SMRs in their integrated resource plans.

[1] SMRs are defined as less than 300 MWe in capacity for a single reactor, and may include two or more reactors in a standard plant design resulting in a higher total capacity. SMRs are used in this paper to refer to designs utilizing water cooling, similar to the designs in use today, but with additional features that improve safety and simplicity.

Electric utilities develop integrated resource plans (IRPs) to identify approaches to meet forecasted energy demand. The purpose of IRPs, which are often times required by state legislation or regulation, is to ensure that future supply and demand-side resources provide reliable, resilient, clean and affordable electricity to consumers. Prudent integrated resource planning seeks to find the lowest cost of service to reliably meet forecasted electricity demand. In preparing an integrated resource plan, utilities typically identify a set of future scenarios, and assess the ability of different strategies and portfolios to serve these potential future conditions. The outcome is a mix of generation sources that the utility expects will be the best portfolio to serve customers in the future. Although the integrated resource plan does not commit a utility to specific procurements for any particular generation source, it does typically identify the actions that a utility plans to take in order to ensure that the generation sources will be available when they are needed.

New trends are emerging that are dramatically changing the needs of future electricity generation portfolios. These trends in turn create new challenges and opportunities for electric utilities' resource planning and procurement of new generation.

Decarbonization – There are a number of states that have already taken action to establish clean energy policies (Governor support, legislation enacted or introduced) that include all zero-carbon technologies, including renewables, nuclear, natural gas with carbon capture sequestration, and storage, and it is expected that many of the other states will eventually follow their lead. There are also over 20 utilities that have committed to reducing carbon emissions by 2050, some with targets to get to zero-carbon emissions. A clean energy future creates new challenges and opportunities. As carbon emitting generation is retired, utilities will need to manage the pressures of higher costs from early deployment of replacement power, and the potential impacts to the local communities.

Reliability and Resilience – The U.S. is losing dispatchable generating resources at a rapid pace, which is one of the reasons that the electricity capacity reserve margins are quickly eroding. Much of these losses are from early retirements of coal plants as States and utilities move toward a carbon-free generation portfolio. Loss of capacity margin in deregulated markets has also resulted from rules that put nuclear power plants at a competitive disadvantage. Replacement of dispatchable generation sources with non-dispatchable generation has led to supply and demand imbalances, even when there are large amounts of excess capacity. The reason is that the non-dispatchable generation resources do not always generate electricity when it is needed. While energy storage systems can help to move electricity from one time of the day to another, the lowest system costs will always include a significant amount of dispatchable generation. Concerns about the resilience of the electricity system are also growing as the impacts of a changing climate continue to grow. Electricity generation sources will need to be resilient to extreme weather and other natural phenomenon, and to physical, cyber and other security threats.

Transmission and Distribution – Decisions on generation sources need to consider the associated impacts on the transmission and distribution infrastructure, since new generation ultimately needs to be connected to the consumer through that system. Locating new generation sources at a site of a recently retired plant is an effective way to minimize impacts and costs on the system. Replacing retired plants with new generation can also retain jobs and continue to fuel the local economy. Other generation sources may need to be spread out across a wide geographic area or located in areas for which there is no existing transmission and distribution infrastructure. There is also increasing interest in distributed generation and micro-grids that are closer to the consumers, and have the potential to increase reliability and resilience.

New Technologies – The electric sector is innovating rapidly with new technologies that are available today, or expected to be available in the coming years. This includes generation technologies such as wind, solar, SMRs, advanced nuclear reactors, carbon capture and sequestration and energy storage. This innovation also includes technologies that could increase demand for zero carbon generation to produce heat, hydrogen and electricity to also decarbonize the transportation and industrial sectors. Rapid innovation makes it difficult for utilities to predict the future state of technology, including costs, over the next decade, and to include it into their long-range resource plans. However, innovation also creates opportunities to generate more reliable, resilient and clean energy at lower costs. Thus, utilities' integrated resource plans should consider the full range of potential generation sources, including technologies that are not feasible or cost effective today, because they could evolve to become a preferred technology within a few years.

Utilities will need to consider these trends as they plan their future generation portfolios, in order to continue to provide the lowest cost solution to provide reliable, resilient and clean electricity. The lowest cost may not always be the generation source with the lowest levelized cost of electricity, as the utility also needs to consider the system costs associated with integrating the new generation. According to a recent study, the cost of decarbonizing the electricity system increases significantly without a balanced portfolio.[2] Utilities will also need to predict reliability and resilience challenges 10 years ahead or more, since new generation deployment takes years and once problems are noticed, there will be insufficient time to respond.

[2] Energy + Environmental Economics (E3). "Pacific Northwest Zero-Emitting Resources Study." https://www.ethree.com/wp-content/uploads/2020/02/E3-Pacific-Northwest-Zero-Emitting-Resources-Study-Executive-Summary-Jan-2020.pdf.

The most fundamental consideration of the IRP process are the laws governing IRPs, and ensuring that the IRP focuses on the requirement for serving its customers. These requirements typically include cost and reliability, and can include other factors such as resilience, environmental impacts and economic benefits. Stakeholder input is an important consideration in the development of IRPs. Customers, regulators, state policy makers, and other affected parties have valuable perspectives that should be considered in the IRP process. While new technology sometimes carries higher risks in terms of availability, performance and cost, it can also have the potential for significant benefits in any of these areas. IRPs typically consider time horizons of 10 to 20 years, and a lack of planning for new technologies could preclude the pursuit of new technologies that have an opportunity to dramatically improve the utility's ability to provide least cost, reliable, resilient and clean electricity. Thus, it is important that IRPs consider all technologies, even those that are new or not yet deployed but which could be available within the planning horizon. These technologies include wind, solar, carbon capture, energy storage and SMRs. Among these, SMRs are one of the newest and least understood generation technologies.

SMRs are an emerging technology with the potential to provide a unique and valuable set of benefits to utilities and customers that are not available with other electricity generation sources. Appendix A describes the strategic roles that SMRs can play in a utility's generation portfolio and the benefits that this technology brings to their customers. To-date, a few utilities have included SMRs in their IRPs, including Salt River Project and the Tennessee Valley Authority. Utility interest in SMRs is growing rapidly as clean energy standards and commitments grow, and as awareness of the characteristics of this technology in relation to utilities' timing, cost or risk requirements continues to grow.[3] To-date, several utilities in the U.S. and Canada (including UAMPS, Ontario Power Generation, and Energy Northwest) have expressed plans to deploy an SMR before or around 2030, and we expect these utilities to be the forefront of a demand wave for SMRs. As utilities prepare updates to their IRPs, it is important that they consider the following facts about SMRs:

SMRs are Timely

The first SMR is expected to begin operation as early as 2026 by UAMPS near Idaho Falls, ID. Additional SMRs could be deployed in the mid to late 2020s. The planning, licensing and construction of SMRs, while likely to be shorter than the larger nuclear plants that have been built in the past, are still expected to take longer than some other generation sources. Generally, it is prudent for a utility to allow 8 to 10 years for the first of a kind new SMR project, which includes roughly two years to prepare for a license application, three years to license an SMR plant, and another three years to manufacture and construct the SMR. With experience and streamlining of the regulatory process, the Nth-of-a-kind SMRs could be deployed in 5 to 7 years. It is expected that this project duration will decrease over time as the industry and the Nuclear Regulatory Commission (NRC)[4] gain more experience in the licensing and construction of SMRs.

[3] SRP, *Integrated Resource Plan Report 2017-2018*, and TVA, *2019 Integrated Resource Plan*

[4] The U.S. Nuclear Regulatory Commission is the federal agency that regulates nuclear power plants and radioactive material.

There are currently three U.S. companies with SMR designs of varying sizes and features for which the first plant could be deployed within an 8 to 10-year timeframe.[5] These companies and the associated capacity of the standard plant design are:

GE Hitachi BWR X-300	Holtec SMR-160	NuScale Power Module
300 MWe (1 module)	160 MWe (1 module)	720 MWe (12 modules, each producing 60 MWe)

SMRs are Cost Competitive

SMR cost and performance characteristics are sufficiently credible to be incorporated into IRP models and compared against other generation sources. Appendix B provides the cost and performance characteristics (such as capital, fuel and operations & maintenance (O&M) costs, electric capacity, availability and life) that utilities can utilize to model SMRs in their IRP. We have published *The Economics of Small Modular Reactors,*[6] which contains more detailed information on the economics of SMRs that would be useful in resource planning. SMR developers are also able to provide more details about the cost and performance characteristics of individual designs.

The SMR Start economics analysis evaluates the cost competitiveness of SMRs with other low-cost generation sources. In this analysis, it was concluded that under many future scenarios, SMRs can be cost competitive, especially when the carbon-free attribute of SMRs is appropriately valued in the market. One limitation of this analysis is that it compared estimates of the levelized cost of electricity (LCOE) of SMRs and other technologies that did not include the total cost of integrating the resource into the grid and the utility's portfolio. In this regard, it is expected that when utilities include the broader system costs in their evaluation of generation sources, the relative cost of SMRs would be even more favorable. SMRs are expected to have lower system integration costs due to their small footprint[7], firm capacity, and ability to be dispatched when power is needed. Long term price stability and a long asset life are also value-added features that should be considered in IRPs. SMRs may also be valued for their ability to be integrated with renewables generation sources and energy storage.

It is important to recognize that the first deployments of any new technology typically have higher costs than later deployments. This was true for renewable sources and it is expected to be true for SMRs. Government support for the first deployments of any new technology is important, since utilities will deploy the least cost solution, and will not be willing to pay more for a generation source solely because it is new. The first SMRs will have strong Federal government support[8] in the form of production tax credits, loan guarantees, and support for the development and licensing. Congress and the Department of Energy are also pursuing additional pathways to support the deployment of the first SMRs that would enable Federal power purchase agreements to compensate for the resilience value provided by SMRs and direct support for projects that demonstrate the capabilities of a new design. The Federal

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[5] A new SMR project includes preparation, licensing, and construction. Projects that can rely on prior work, such as an early site permit or previous deployment of the design, are expected to have shorter timelines.
[6] SMR Start, *The Economics of Small Modular Reactors* (www.smrstart.org)
[7] STRATA *The Footprint of Energy: Land Use of U.S. Electricity Production*
[8] SMR Start, *Policy Statement on U.S. Public-Private Partnerships for Small Modular Reactors*, October 2019

government support can be supplemented with state support. Idaho, one of several states that have expressed interest in supporting SMRs, recently expanded tax incentives to include SMR projects. There are also several states that have policies in place that allow utilities to recover the capital costs during construction, helping to reduce the financing costs that would otherwise be passed along to the consumer. These are a few of the many options that states have to support SMRs[9] to achieve their energy, environmental and economic development goals. The SMR Start economic analysis concluded that with government support, the first SMRs can be cost competitive with other low-cost generation sources. The report also estimates that cost reductions gained through experience and repetition will enable SMRs to be economically competitive without further government support after the first four to six plants of a given design are deployed.

SMRs are Environmentally Friendly

The environmental impact of generation sources is an important consideration in the IRP process by utilities and other stakeholders that value sustainability and being good stewards of the planet. Utilities will also need to justify that the environmental impacts are acceptable in order to comply with the National Environmental Protection Act (NEPA), and other laws, and therefore it would be imprudent to include generation sources that would be unable to comply with U.S. environmental laws and regulations.[10] Environmental considerations cover the potential impacts to the air, land and water directly from operations of the generation source. Environmental considerations may also consider impacts from the entire life cycle from sourcing of raw materials to the disposal of byproduct material.

Air impacts of generation sources include carbon and criteria air pollutants defined by the Environmental Protection Agency (EPA). Nuclear, including SMRs, has not only some of the lowest carbon emissions but also one of the lowest total carbon footprints of any generation source.[11] Nuclear energy, including SMRs, also does not emit SOx, NOx or other air pollutants.

Traditional nuclear power plants rely on a body of water as an ultimate heat sink for the heat that was not converted into electricity. Some SMRs are being designed with the ability to provide dry air cooling, which would avoid the need to utilize a body of water. Dry air cooling would enable SMRs to be deployed where water is scarce or expensive.

Minimization of land use is a distinct feature of SMRs, and other nuclear plants. The fission process is an energy dense form of producing heat that can then be converted into electricity through a thermal power cycle. This dense form of energy results in very small plants with capacities in the hundreds of megawatts. Coupled with the high capacity factors associated with the ability to operate 24/7 365 days a year for up to two years, and an ability to run the plant for 60 years or beyond, the total energy output

[9] SMR Start, *State Options to Support New Nuclear Power Plants*, June 2017

[10] The NRC evaluates the compliance of proposed nuclear plants with NEPA and other environmental laws during the licensing process. The NRC has licensed over 100 nuclear power plants in the U.S. and concluded that these nuclear power plants comply with relevant environmental laws and regulations. SMRs are being designed with innovative features that are expected to further reduce the potential environmental impacts from these designs.

[11] United Nations Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2014 – Mitigation of Climate Change, Annex III*

over the lifetime of an SMR per acre of land is higher than any other energy source. The following table compares the land impacts for SMRs and other generation sources.

Table 1: Land Impacts of Selected Generation Technology (per 1,000 MWe)

	SMR	**NGCC**	**Wind**	**Solar**
Capacity factor (%)[12]	95	55[13]	35	25
Plant life (years)	60 to 80	40 to 50	20 to 25	20 to 25
Lifetime TWh	647	241	76	55
Land required (acres)[14,15,16]	50[17]	343	85,240	7,900
Land Utilization (acres per Lifetime TWh)	<0.1	1.4	1,125	144

SMRs use very little land to generate large amounts of electricity, allowing more land to be used for other purposes, whether this is left to nature, used for agriculture, designated for recreation, or used for cities and the infrastructure needed to support modern society.

An environmental impact that SMRs, and other nuclear plants, have is that they generate radioactive material. Nuclear plants are not alone in this regard; in fact, coal plants emit radioactive material through the process of burning coal. The environmental impacts of radioactive material are considered by the NRC and have been found to be acceptable for the approximately 100 nuclear plants that have been licensed in the U.S. A more appropriate name for nuclear waste is used fuel, since the byproduct still contains over 95% of the potential energy that could be released in fission. Some stakeholders have the misconception that there is no pathway to used fuel disposal in the U.S. The truth is that there is a viable pathway to disposal of used fuel in that the costs of disposal are fully paid for, the technology exists to safely dispose of the material, there is a law that outlines the location of used fuel disposal and the responsibilities of the government to do so, and there are private companies pursuing options to move the used fuel to a centralized storage location until the final disposal facility is available. The current delay comes from a DOE decision several years ago to stop progress on the used fuel disposal program, and absence of Congressional direction to force DOE to resume the program. Another misunderstanding of used fuel is just how little there is. The total amount of used fuel generated to-date in the U.S. could fit on

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12 2018 Average capacity factors were used. SMRs are expected to be able to achieve capacity factors that are higher than the 92% achieved by today's nuclear power plants. NGCC plants are able to achieve higher capacity factors if operated as baseload plants. U.S. Energy Information Administration, *Electric Power Monthly*

13 NGCC plants are able to achieve high capacity factors, however 55% was used here based on U.S. Energy Information Administration's average capacity factor in 2018.

14 STRATA, *The Footprint of Energy: Land Use of U.S. Electricity Production*

15 U.S. Department of Energy, *Wind Vision - A New Era for Wind Power in the United States*

16 National Renewable Energy Laboratory, *Land-Use Requirements for Solar Power Plants in the United States*

17 It is expected that the land usage for SMRs will be less than current nuclear power plants, which have larger owner controlled areas.

a single football field about 10 yards tall.[18] In other terms, the total energy consumed by a person in the U.S. in a lifetime, if produced by nuclear energy, would result in used fuel that would fit in a soda can.

The costs of disposal and decommissioning of generation sources is a consideration that is often overlooked in IRPs. SMRs include the costs of used fuel disposal and decommissioning of the plant in their cost inputs, and these costs are paid for during the operation of the plant. Most other generation sources do not include these activities in their cost basis, or even plan for or fund the disposal and decommissioning prior to deciding to cease operations.

SMR Risks are Manageable

Risks that impact the timing, cost and performance of a generation source are key consideration in the IRP. For SMRs, risks are generally categorized as technical, licensing and construction. SMR technical risks that would impact the ability to meet the performance goals are relatively minor. SMRs are based on light-water technology that has been used by nuclear plants in the U.S. for over 60 years, with performance characteristics that are well known. SMRs do have novel features that improve their simplicity and safety. While there are some risks that the plant performance (e.g., power output, availability) does not meet expectations, these risks are still relatively low for several reasons. First, the number of novel features in SMRs are relatively small compared to the more proven aspects of the design, and the features typically rely on natural forces, which are well understood. Second, the NRC requires a significant amount of design information in order to issue a license, which in turn requires completion of a lot of engineering, design and testing that provides greater certainty that the plant will perform as expected. Finally, utilities require performance warranties in their contracts to ensure that the plant meets the advertised performance.

SMR licensing risks are related to the ability to obtain NRC approval of a plant license on the expected schedule and cost. NRC earned a reputation as a slow and costly regulator from the performance of its reviews of nuclear power plant license applications in the 90's and 2000's. However, since that time, the NRC has made strides in reducing their schedule, improving schedule predictability and continuing efforts to make future reviews even more efficient. The recent NRC reviews of the TVA early site permit and the NuScale design certification have been on or ahead of schedule. Future reviews are expected to gain greater efficiencies, in part due to the simplicity and safety of SMR designs.

Construction risks continue to be a concern, based on recent performance of new nuclear construction in the U.S. However, there is experience in building new nuclear plants on-time and on-budget and it is possible to learn from these successes to greatly reduce construction risk for future plants. Industry is undergoing efforts to learn these construction best practices and apply them in the construction of SMR plants. The expectation is that with proper practices and diligence in the construction of SMRs, plants can be constructed to meet the current cost and schedule estimates. SMR designs are also inherently smaller and have more work performed in the factory, allowing for better control of risks.

[18] U.S. Department of Energy. "5 Fast Facts about Nuclear Waste." https://www.energy.gov/ne/articles/5-fast-facts-about-nuclear-waste.

SMRs are Economic Engines

Construction and operation of a 600 megawatt SMR plant with multiple reactors is estimated to employ about 900 manufacturing and construction workers for about 4 years and about 300 permanent positions for the 60 or more years the SMR operates. It is estimated that for every 100 permanent jobs at nuclear power plants, 66 additional jobs are created in the local community.[19] Nuclear jobs pay 20 percent more, on average, than jobs supported by other energy sources.[20] .

Based upon experience with today's nuclear facilities, a 600 MWe SMR plant is expected to generate over $500 million in direct and indirect economic output annually.[21] This includes savings of over $20 million annually for the ratepayers, by having nuclear in their energy portfolio.[21] This also includes over $270 million in the plant's electricity sales and induced spending at the local, state and national levels

[19] Nuclear Energy Institute, Jobs
[20] Oxford Economics, *Nuclear Power Pays*
[21] The Brattle Group. *Nuclear Industry's Contribution to the US Economy*

Utilities could include SMRs in IRPs in a number of ways depending on the ability of SMRs to meet the future generation needs.

Preferred solution – For some utilities the characteristics of SMRs may be identified as the best fit to meet future generation needs. This could be to meet one or more of the opportunities identified in Appendix A for SMRs to play an instrumental role in meeting future energy needs. For example, SMRs may be needed to meet clean energy goals with a flexible and reliable source of energy.

Contingent solution – For utilities that identify the likely future scenarios are best served by other generation sources, they may also determine that less likely scenarios could result in conditions where SMRs would be a viable generation source. An example of this is the unplanned retirement of a fossil fuel plant and the need to replace it with firm generation capacity.

Option creation – Utilities that identify that SMRs are not a best fit in the likely or other future scenarios, should also consider the inherent uncertainties in planning for the future. The costs of the preferred and contingent generation sources may increase suddenly and dramatically, or changes in regulation or perception could lead to these sources no longer being viable. The nuclear energy industry is working hard to reduce the cost, schedule and risks of SMRs, so that they can be a more attractive option in the future. Including SMRs as an option provides utilities with the flexibility and choices to be prepared to deal with uncertainties.

Utilities can also identify various actions that can be taken to prepare for the planned or unplanned deployment of SMRs to meet future generation needs.

Project initiation – For utilities that identify the need or potential need for an SMR within the next 8 to 10 years, there is a need to move quickly to begin the project. This includes assembling the internal project team, evaluating potential designs, and preparing for the work to license and construct an SMR. The utility should then make a design selection and obtain a combined operating license (COL) or construction permit (CP) from the NRC that enables construction to begin.

Reducing project timelines/risk for longer-term deployments – For utilities that identify the potential need for an SMR is more than 10 years away, there are actions that can be taken in the near term to help reduce project risk and timelines. If the utility is ready to make a design selection, obtaining a COL or CP from the NRC enables the utility to greatly reduce the licensing risk and schedule. The COL resolves all licensing topics related to the site and design, and grants the utility a license to construct and operate. The CP resolves licensing topics related to the site and design, and allows the utility to apply for an operating license prior to completing construction. Obtaining a COL or CP well in advance of a decision to deploy an SMR can provide the utility with flexibility, such that they could deploy an SMR in roughly 3 years from the time they decide to build a reactor until it becomes operational. If the utility is not ready to make a design decision, but is ready to select a site, then they could reduce risk by obtaining an early site permit (ESP) from the NRC. While the utility with an ESP would still need to obtain a COL or CP once a technology is selected, the ESP does reduce risk by resolving significant site specific licensing topics, such as environmental reviews, while at the same time preserving the option to make a technology decision at a later date. Deployment of an SMR at a retired fossil fuel site – thereby leveraging existing site infrastructure – is another way of reducing project schedule and risk, while also restoring jobs to the local area.

Creating options – Utilities that are interested in creating options with minimal investment can evaluate potential sites for SMRs, and when ready, select a preferred site. The next steps would be to begin the site characterization activities needed to support a license application to the NRC. Utilities could also obtain an ESP for the preferred SMR site. Each of these discreet steps in creating an SMR option further reduces the risk and timeline for a potential SMR deployment in the future.

Building capabilities – Utilities that are unfamiliar with nuclear energy should consider developing the capabilities that would be needed to own an SMR. Capability building is important whether the utility is considering a near term deployment, potential long-term deployment, or just creating options. Capabilities that utilities should develop include familiarity with the technology, licensing process and the requirements associated with owning and operating a nuclear power plant. The utility will also need to determine whether it plans to develop these as internal capabilities or whether they would rely on partners that have nuclear experience, for example to perform the licensing, construction or operation of the SMR.

Monitoring SMR developments – Utilities should monitor the development of SMRs so that improvements in the performance, cost, schedule and risk can be understood in the context of the IRP and future generation needs. This is true even for utilities that currently do not have a desire to develop and SMR as an option to mitigate risks related to uncertainties in the future generation needs. One option is to join nuclear industry groups with the companies and individuals that are experts and willing to share their knowledge and experience.

Nuclear energy has long been a staple generation source for many utilities in the United States. Today, nuclear energy generates over half of the carbon-free electricity and nearly 20% of the total electricity in the U.S. Nuclear energy has unparalleled reliability, operating with a capacity factor of over 92%, and resiliency, operating during hurricanes and polar vortices. The industry average cost of operations was $32/MWh in 2018, including fuel and new capital expenditures, which is among the lowest of any generation source. Nuclear energy has a long operational life, with most plants having received license extensions to operate for up to 60 years, and many of these plants planning to seek additional license extensions to operate up to 80 years.[22] For example, Turkey Point Nuclear Power Plant was recently approved for 80-year license and Peach Bottom Atomic Station and Surry Power Station are anticipated to receive extension of their license to 80-years in the next coming months.

SMRs are a rapidly emerging nuclear technology that are available in the near term and are one of the options that utilities should begin including in their IRPs as a potential future generation source. The first SMR, to be owned by the Utah Associated Municipal Power System (UAMPS), is planned to begin operations in 2026, well within the planning horizon of IRPs that will be updated in the coming years. SMRs are also projected to be competitive with other generation sources when all costs and benefits are considered. SMRs are complement to large nuclear reactors and a better option for utilities that need smaller amounts of generation (SMRs are defined as less than 300 MWe per module) or an ability to gradually add generation (modules).

There are a number of reasons why a utility may want to add an SMR to their generation portfolio:

1. **Fuel Diversity** – A diverse generation portfolio – including nuclear energy as a significant fuel source – is an essential characteristic of an affordable, robust and resilient system. It is widely agreed that an overdependence on one or two energy sources can increase system costs and vulnerabilities. For example, an over-dependence on natural gas fueled electricity generation could expose consumers to punishing volatility and loss of reliability if there are constraints introduced through increased environmental restrictions to the extraction or use of natural gas, or constraints in the supply of fuel through an infrastructure or weather disruption. A recent study has shown that an over-dependence on renewable sources like wind and solar could result in unacceptably high system costs and could require excessive amounts of capacity margin either through low utilization of dispatchable sources or the addition of energy storage systems.[23] Utilities with diverse generation portfolios that include nuclear energy would benefit from lower electricity costs.[24]

2. **Carbon-Free Generation** – There is growing recognition at the State, Federal and International levels that carbon emission must be reduced in order to address changes to the climate. There is also widespread recognition that nuclear energy is an essential generation source in any electricity portfolio that seeks to make meaningful reductions in carbon emissions. Nuclear energy generates zero carbon during operations and has the smallest total carbon footprint –

[22] Nuclear Energy Institute, *Nuclear By the Numbers*
[23] Jesse Jenkins, et al, *The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation*
[24] Energy + Environmental Economics (E3), *Pacific Northwest Zero-Emitting Resources Study*

which includes all activities from mining to disposal – of any other generation source except for wind.[25,26] There is growing consensus that renewable portfolio standards must evolve into clean energy standards that include nuclear energy in order to meet carbon reduction goals. There is also growing commitments from utilities to move toward zero carbon emissions before 2050. SMRs should be included in IRPs as an option to meet future carbon emissions goals or, where goals are not currently established, should be included as an option to hedge against goals that may be established in the future.

3. **Integration with Renewables and Storage** – There is broad recognition that nuclear energy must be included in any realistic plan for achieving zero-carbon emissions.[27,28] The CEO of the Midcontinent Independent System Operator, recently said that "Already, we have learned that renewable penetration of 30% would challenge our ability to maintain the planning reserve margin and operate the system within acceptable voltage and thermal limits. Maintaining reliability at the 40% renewable level becomes significantly more complex." The firm clean attribute of SMRs allows SMRs to adjust output to partner with renewable sources to better match supply with demand in a zero-carbon energy system. SMRs can adjust power output to load-follow and power hybrid energy systems to produce heat, hydrogen or desalination facilities in order to continue operating at 100% power while renewable sources are operating, and then switch back to electricity when renewable sources are not producing power. The integration of SMRs and renewable energy sources will reduce the need for excessive amounts of low utilization capacity. Flexible dispatchable sources, like SMRs, are also the only current solution to addressing the seasonal variations of grid-scale renewable generation. In this manner, the integration of SMRs, renewables and storage can result in a more optimized diverse portfolio of energy sources to produce reliable, resilient, clean and affordable electricity. Furthermore, the subsidies provided to wind and solar are set to expire in the next few years, as they have achieved the goals of helping to deploy these new technologies. An increase in the costs to the customer for new renewable generation will open the market for competition from other zero-carbon energy sources, including SMRs.

4. **Repowering Retired Fossil Fuel Sites –** Sites with retired coal plants, and in the future retired natural gas plants, are typically in ideal locations for the generation of electricity. These sites also typically have retained their transmission capabilities, and have access to transportation and other infrastructure that is important to support the generation of electricity. Many of the retired fossil fuel sites are located near population centers, which is not optimal for larger nuclear power plants, and/or have limited access to land, which is insufficient for renewable generation. SMRs can be deployed at retired fossil fuel sites that are closer to population centers and can be deployed in remote areas where the grid is small. Repurposing retired fossil fuel sites reduces

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[25] United Nations Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2014 – Mitigation of Climate Change, Annex III*
[26] University of Texas at Austin – Energy Institute, *Nuclear and Wind Power Estimated to have Lowest Levelized CO2 Emissions*
[27] Jesse Jenkins, et al, *The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation*, 2018.
[28] C2ES, *Getting to Zero: A U.S. Climate Agenda*, 2019.

the costs of electricity from SMRs by making use of the existing infrastructure. These SMRs can also restore lost jobs by retraining and utilizing the local workforce. In many cases, the power plant is the engine of economic activity, and replacing this engine with an SMR can help restore the local economy. It is important to note that nuclear plants are good neighbors and the communities surrounding existing nuclear plants are highly supportive of nuclear energy. Nuclear plants also provide millions of dollars in tax revenues that provide the funding needed for schools, police, firefighters and roads.

5. **Flexible Dispatchable Generation –** SMRs can operate 24/7 365 days of the year for up to 2 years without shutting down for refueling, enabling them to achieve capacity factors of 95% or more. SMRs are also being developed to have the ability to be flexible, enabling them to quickly adjust electrical output and to switch from producing electricity for the grid to producing hydrogen for other types of energy products. SMRs produce thermal energy in the form of heat and steam, which can be used directly to expand the technology choices of energy storage or to power industrial processes directly. Energy storage systems that rely on heat as the medium, instead of electricity, can operate more efficiently, thus reducing costs and impacts to the environment. SMRs could be used to help decarbonize the transportation and industrial sectors, which account for more than 60% of the U.S. carbon emissions, in addition to decarbonizing the electricity sector.[29]

6. **Resilience for Mission Critical Activities** – SMRs are being designed with the capability to operate independent from the grid, to withstand severe natural phenomena such as earthquakes and hurricanes, and to protect against physical and cyber threats. These features enable SMRs to offer the potential for high levels of resilience to power national security and mission critical activities, such as military bases and hospitals.

[29] Lawrence Livermore Carbon Emissions Flow Chart, 2014

The following information for a "representative" SMR are illustrative of the expected performance and costs for the use in modeling SMRs in utility IRPs. While these inputs are based upon information obtained from SMR developers, they are not intended to describe the actual values for a particular design or actual project. The IRP modeling inputs include values that are expected of a First of a Kind plant, and for an Nth of a Kind plant, which has incorporated efficiencies based upon the lessons learned from the first plants.

The timelines and costs for a new build project are based on the simplified design of SMRs and can serve as a basis for discussions and high-level planning. The values are reasonable based on a range of sites and SMR designs, but are not bounding and actual projects may see larger or smaller schedules and costs. The table does not reflect the likely overlap of the 1 to 2 years of overlap that the manufacturing of long lead procurement is likely to have with the licensing application phase.

Performance Inputs

Parameter	First of A Kind	Nth of A Kind
Capacity	600 MWe (two 300 MWe reactors)	
Net Dependable Capacity	570 MWe (285 MWe reactors)	
Heat at Turbine	2,000 MW-thermal	
Availability / Capacity Factor	up to 95%	
Design Life	60 years[30]	
Staffing	200 to 300	
Construction Time	36 months	26 to 30 months
Time btwn 1st and 2nd unit	3 months	2 months

Cost Inputs

Parameter	First of A Kind	Nt^{h} of A Kind
Overnight Capital Cost	$3,800 ($/kWe)	$2,400 to $3,400 ($/kWe)
Fixed and Variable O&M	$22 ($/MWh)	$14 to $18 ($/MWh)
Fuel	$7 ($/MWh)	

Cash Flow

For a 600 MWe 2-Unit SMR	Pre-Application	Licensing Application	Manufacturing and Construction
First of a Kind			
Duration	2 to 3 years	3 years	3 years
Cost	$30M to $50M	$30M to $50M	$2.3B
Nt^{h} of A Kind			
Duration	2 to 3 years	2 to 3 years	2 to 3 years
Cost	$20M to $40M	$20M to $40M	$1.4B to $2B

[30] The initial operating license from the U.S. NRC is 40 years. The 60 year design life is based on an expectation for a 20 year license without any significant plant modifications. Additional license extensions in 20 year increments are possible.

First-of-a-Kind Private-Public Partnerships

Government support through private-public partnerships is available for first-of-a-kind deployments.

Production Tax Credit (PTC): The Energy Policy Act of 2005 establishes a nuclear PTC that currently provides a credit of $18/MWh for the first 6,000 MWe of nuclear capacity in the U.S. The nuclear PTC was amended in 2018 to eliminate required in-service dates and to allow it to be transferable from public entities to non-public project participants. More recently, discussions have considered indexing the nuclear PTC to inflation, a feature that is included in PTCs for other generation technologies, and would increase the value to $25/MWh.

Loan Guarantee (LG): The current DOE Loan Guarantee program allows participants to increase the share of debt in the project, and to fund the debt at a lower rate. The nuclear loan guarantee is designed such that it is fully paid for by the nuclear industry and does not cost the taxpayers any money.

Advanced Cost Recovery (ACR): The ACR (also known as Construction Work in Progress – CWIP) is available in some states, such as Florida, Georgia and South Carolina. ACR typically allows for full recovery of the financing charges as they are incurred, resulting in lower costs to the consumer.