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“Mini-nukes” could play vital role in decarbonization - if they can get to market on time

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Introducing Global Counsel’s Small Modular Reactor Matrix

Proponents of the next generation of nuclear power plants, known as small modular reactors (SMRs), suggest that SMRs offer substantial advancements over traditional nuclear power plants in terms of safety features and technological attributes that can enhance grid resilience and integrate with renewables. These futuristic zero-carbon generators could become integral tools in the decarbonization tool kit. However, the question of whether SMRs will be commercially available and cost competitive in time to play a pivotal role in the global energy transition remains open, with industry and investor actions in the next few years critical to the outcome.

Several SMR developers assert their technology will be operational between 2026 and 2028. But delays and cost overruns are commonplace for first-of-a-kind technologies. The previous round of advanced nuclear reactors, Westinghouse’s AP1000s, initially projected to cost $14bn for two 1,117 MW reactors in service by 2017, are now projected to be in service by 2023 and may cost as much as $28bn. If SMRs can escape the fate of the AP1000s, they could be a cost-competitive complement to renewables. For example, in an April 2022 investor presentation for NuScale Power Corp (ticker SMR on the New York Stock Exchange), costs for its VOYGR SMR were projected to be $3.3bn for a set of 12 modules with a combined capacity of 924 MW; a levelized cost of electricity (LCOE) estimated at $58 per megawatt hour (MWhr). The U.S. Energy Information Administration (EIA) estimated a higher LCOE for generic ‘advanced nuclear’ in 2027 between $98.78/MW and $76.23/MW with tax credits. EIA estimates the LCOE for offshore wind in 2027 between $170.31/MW and $86.34/MW with tax credits.

With talks of nuclear attack-back in the news following Russia’s invasion of Ukraine and the recent popular TV serialization of the events surrounding Chernobyl in the 1980s, “safe” is not frequently the first word that comes to mind when talking about new nuclear technologies. Given this backdrop, one of the most significant draws of small modular reactors is their designed high safety margins due to their passive systems and inherently lower-risk characteristics, such as low power and operating pressure. Unlike large-scale nuclear plants, no electrical supplies or pumps are needed to cool SMR reactors following an incident, as cooling is instead achieved through natural convection and a gravity coolant feed. This means that the reactors theoretically should remain safe even during severe accident conditions thus eliminating the potential for large releases of radioactivity. Proponents of SMRs argue that extensive use of passive safety systems in SMRs arguably should make the new technology highly robust, protecting the public as well as any owners or investors in the plant. Passive systems are not infallible, and certain industry experts have suggested that credible designs should include active-backup cooling systems that would increase their build costs significantly.

In addition to being faster to manufacture, and about 80% smaller, they should be significantly less expensive – over time - given the modular construction, reduction in required concrete and elimination of many cooling pump components. A report from Massachusetts Institute of Technology estimates the SMRs could initially cost 1.4-1.75 times the overnight cost per MW of the next (10th) AP1000 plant “due to the lack of economy of scale”. Essentially the more SMRs are built the more cost competitive they will become. What is not factored into costs are the array of attributes SMRs can bring to the grid, many of which could add revenue streams to SMR units. For example, most SMRs are designed to pair with renewables, increasing output when the sun and wind dimmish and decreasing output on sunny, windy days. Offering variable output for plants capable of running 24/7 will be increasingly important as more and more renewables are deployed. SMR technology can also be ‘black-start capable’: meaning able to ignite generation without a spark from the grid. This is a prized resilience measure because it enables SMRs to be 1) resistant to widespread black outs and; 2) crucial to other grid assets that do need a spark from the grid to come back online. These resilience characteristics will become even more important in the future as severe weather driven by climate change increases blackout events. Black-start capability would also enable the use of SMRs to power closed-loop micro-grids and allow them to be deployed in remote or rural areas that are not encompassed by grid infrastructure.

These SMR design capabilities go beyond generating power and in many cases are well- suited for district heating, industrial processes, green hydrogen production, and desalination, providing power to direct air capture units. Refuelling outages can be mitigated by refuelling each module sequentially, eliminating any need for redundant power; molten salt reactors are being designed to enable on-line refuelling. The combination of enhanced safety features and radically smaller physical footprints will significantly increase siting flexibility for SMRs.

According to the International Atomic Energy Agency, over 70 SMRs are under development globally. This competition could help ensure SMR technologies become commercial without excessive delays and ballooning costs. Global Counsel’s Small Modular Reactor Matrix, presented below, provides an overview of some promising SMR designs that have initiated regulatory processes comparing technological features, grid attributes, fuel type, and contracts, among other elements. Many SMR technologies evolve from traditional, large-scale power plants using pressurized or boiling water reactor models, including NuScale’s VOYGR SMR, the BWRX-300 SMR from the GE Hitachi joint venture, Holtec’s SMR-169, Rolls Royce’s UK SMR, and China’s ACP100. Other technologies go beyond traditional reactor approaches. Variations include the use of molten salts (fluorides and chlorides) to cool and slow the fission reaction because these salts, which are essentially liquid metals, have exceptionally high heat transfer abilities reducing much of the cooling equipment, cost, and thermal inefficiency of a traditional nuclear reactor. In these models, which include TerraPower and GE Hitachi Nuclear Energy’s Natrium SMR and Terrestrial Energy’s Integral Molten Slat Reactor (IMSR), fissile material is combined within a salt substrate enabling reactors to combust more efficiency and at higher temperatures, which can significantly reduce spent nuclear fuel and in some cases eliminate physical refueling outages.

You can read the Small Modular Reactor Matrix here.