Sustainability

Q&A quick guide: Small modular reactors

29 July 2025

Key takeaways

- Amid surging electricity demand, driven in part by the rise in AI/data centers, nuclear energy offers a potential solution. And new advancements in technology may now make the tipping point in sight for small modular reactors (SMRs) to reshape nuclear energy supply chains over the next decade, according to BofA Global Research.
- If commercialized, SMRs would offer five major advantages over conventional, large-scale nuclear power plants (NPPs), according to BofA Global Research: 1) better affordability; 2) enhanced safety; 3) modularization; 4) smaller footprint; and 5) reduced CO2 production.
- With momentum building around SMRs in 2025, we unpack seven questions to better understand the road forward.

#1. What are nuclear reactors?

A nuclear reactor is a device that contains and controls a fission nuclear chain reaction, a process that produces heat. The heat is transferred to a coolant, which is then used to produce steam. The steam drives a turbine, which in turn creates electricity. Simply put, a nuclear reactor could be viewed as the heart of a nuclear power plant (NPP).[1]

#2. What are small modular reactors (SMRs)?

Small modular reactors (SMRs) are zero carbon, advanced nuclear fission reactors that provide base load power with capacity ranging from 20-300 megawatts electric (MW(e)) per unit or module. They are designed to be smaller in scale, prefabricated versions of traditional, large-scale AP-1000 type reactors.

Over the past decade, both public and private institutions have actively made efforts to bring SMR technology to fruition, given its major advantages over NPPs, according to BofA Global Research.

When compared to traditional, large-scale NPPs, SMRs require less land, shorter construction periods, and have enhanced safety features (Exhibit 1). As of 2024, two SMRs are in operation. And currently, over 80 commercial SMR designs are being developed around the world, targeting varied outputs and versatile applications.

Value chain

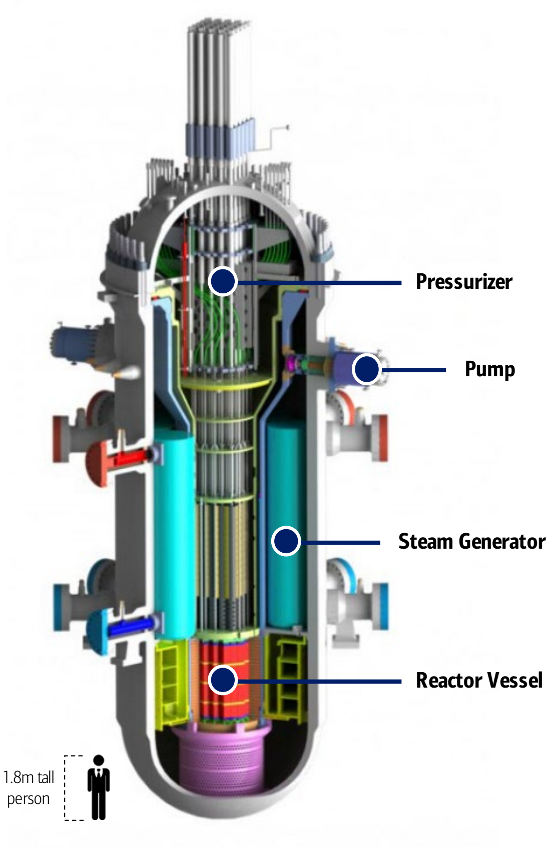
The SMR value chain mirrors that of large nuclear reactors, with three phases: design, equipment, and construction. The industry operates with a "fabless" production model, meaning that design companies outsource fabrication (i.e. "fab") to a third-party. High upfront costs make project funding crucial, with major tech firms increasingly investing or signing long-term power purchase agreements (PPAs) to secure power.

In the manufacturing and construction stages, a few key nuclear steam supply system (NSSS) manufacturers with foundry capabilities (i.e. they can melt, cast, and form essential metal components) serve as core suppliers, while construction firms handle site work. These companies are forming early partnerships with SMR developers or making equity investments to secure future manufacturing and construction contracts.

[1] Office of Nuclear Energy. (2025, May 19). *Nuclear 101: How does a nuclear reactor work?* US Department of Energy. NUCLEAR 101: How Does a Nuclear Reactor Work? | Department of Energy

Exhibit 1: SMRs are zero carbon, advanced nuclear fission reactors that provide base load power with a capacity ranging from 20-300 MW(e) per unit/module
SMRs at a glance

Small Modular Reactors – Bird's Eye View



Five major advantages of SMR

Better affordability

SMRs offers better affordability given lower upfront capital cost and economy of serial productions compared with large nuclear power plant.

Enhanced safety: "passive" safety features

SMRs are considered safer than large-scale traditional reactors due to the simpler design and smaller size.

Modularization: Shorter construction timeframes

SMRs are designed to be modular, meaning that factories fabricate the units and transport them to their operating location, reducing construction times and allowing for rapid scaling and the centralization of a skilled workforce.

Smaller footprint: Siting flexibility

SMRs' small size allows for more siting flexibility with many options available at current nuclear plant sites or retired coal plant sites.

Reduced CO2 production

SMRs are able to produce baseload zero-carbon generation to the grid with minimal outages.

	Small Modular Reactors (SMRs)	Nuclear power plant (NPP)
Electrical output	300MW or below	1,000MW
Energy production	7.2mil kWh	24mil kWh
Land efficiency	100m2/MW	$573m^2$/MW
Building process	Fabricated in factory	Built at site
Construction period	Below 3 years	Over 6 years
Construction cost	Lower fixed cost	Higher fixed cost
Safety	Advanced safety mechanisms utilized	More Prone to human errors

Source: Company data, BofA Global Research

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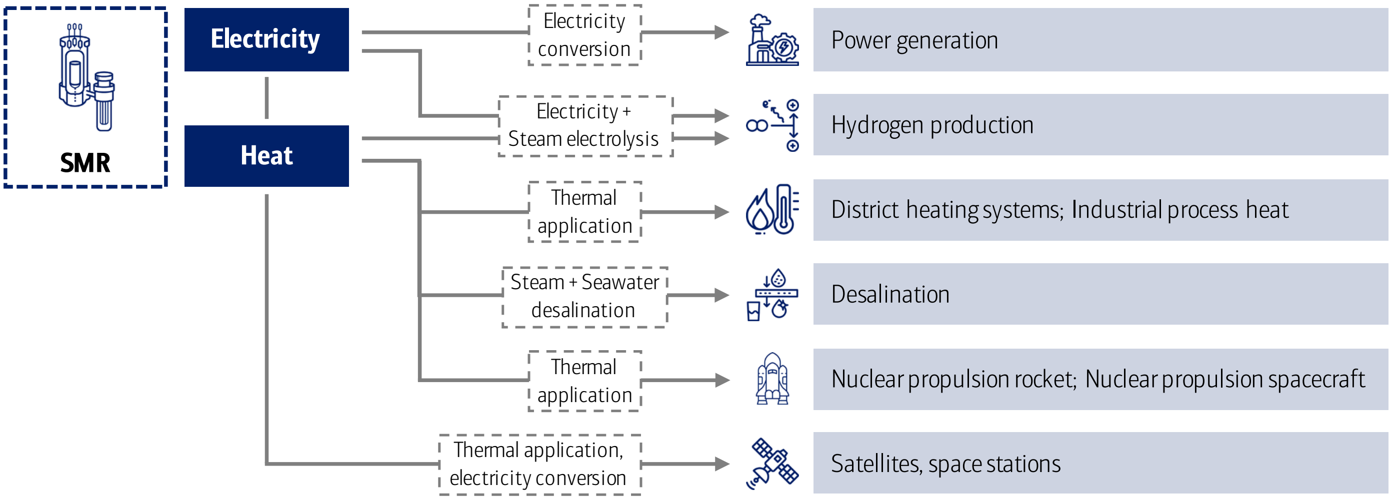
#3. What are they used for?

SMRs offer a wide range of applications, including: 1) **hydrogen production,** as they can provide the electricity needed for electrolysis (a process that uses electricity to split water into hydrogen oxygen); 2) **heat and desalination,** because of siting flexibility and reliability; and 3) **space and defense,** due to their compact size, modular design, and ability to provide reliable power for extended periods (Exhibit 2).

Exhibit 2: SMRs offer a wide range of applications, including hydrogen production, heat and desalination, and space and defense
SMR applications



Source: Industry data, BofA Global Research

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#4. What kind of SMRs are being developed?

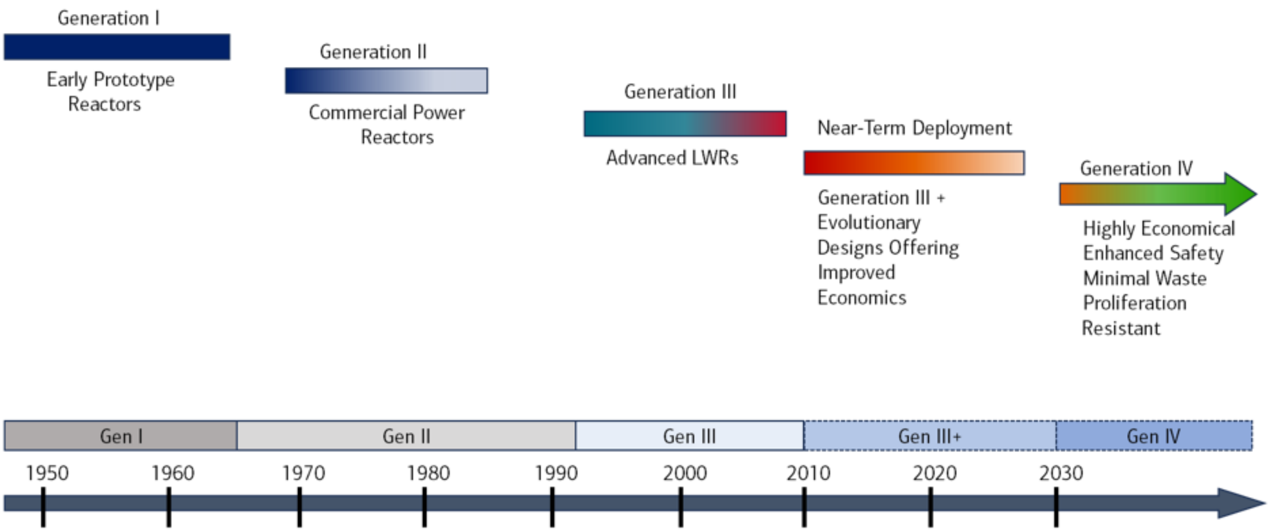
Interestingly, SMRs are classified as technology-agnostic, meaning they are not tied to or dependent on any particular technology. Therefore, they can be designed as light water reactors (LWRs), heavy water reactors, molten salt reactors, high-temperature gas-cooled reactors, liquid metal reactors, etc.

However, most commercial reactors, traditional or SMR, are designed to be pressurized water reactors (PWRs), or more specifically, LWRs. In fact, according to the International Atomic Energy Agency's Advanced Reactor Information System, in 2022, the PWR SMR type represented the largest among SMR projects under development, followed by lead-cooled fast reactor, sodium-cooled fast reactor, and molten fast reactor types.

Technological evolution

As illustrated in Exhibit 3, SMR technology has evolved over time, with early prototypes dating back to the 1950s. Currently, about 80 Gen 3.5 and Gen 4 designs are in development, aiming for commercialization by 2030. According to BofA Global Research, due to strict regulatory hurdles, Gen 3.5 designs—based on existing reactor types—are expected to reach the market earlier than Gen 4 models, which use alternative coolants like helium or sodium.

Exhibit 3: Gen 4 systems offer significant advances in sustainability, safety, reliability, and economics; expected to be deployable by 2030
SMR technology migration over time



Source: Industry data, BofA Global Research

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#5. What are the advantages of SMRs compared to traditional NPPs?

If commercialized, SMRs offer five major advantages over traditional, large-scale NPPs, which according to BofA Global Research, enables them to be more compelling options for versatile applications. These advantages are:

- **Better affordability:** SMRs offer better affordability, given lower upfront capital costs, compared to large NPPs. They can also be mostly built in factories, allowing for economies of scale via serial construction and potential cost reductions from learning-by-doing. Additionally, many SMRs require high-assay low-enriched uranium (HALEU), which allows for better efficiency in these smaller reactors with less fuel, aiding costs.

- **Enhanced safety:** SMRs are considered safer than large-scale traditional reactors due to simpler designs and smaller size. They rely on automatic controls to shut down or cool when needed, as they require less coolant and can ramp down very quickly. These passive safety features – features that rely on natural phenomena, such as gravity and natural circulation – mean there is very little human intervention needed from the operators. Additionally, their design lacks components such as valves, extra safety pumps, pipes, and cables, so there are fewer instruments that can fail, and if/when failure occurs, the root cause can be found promptly.

- **Modularization:** In this context, the term "modular" refers to the ability to fabricate major components for the NSSS in a factory environment before shipping them to the point of use. This permits shorter construction timeframes (<3 years for SMRs vs >6 years for large-scale NPPs), rapid scaling, and centralization of a skilled workforce. It also allows for incremental unit additions, as needs increase and transmission improves.

- **Smaller footprint:** SMRs' small size allows for more siting flexibility, with many options available at current nuclear plant sites or retired coal plant sites, according to a study from the US Department of Energy (DOE). Additionally, they can operate independently from the grid, which also contributes to flexibility.

- **Reduced CO_2 production:** Another key factor is the reliability that SMRs offer. They can produce base load zero carbon generation to the grid with minimal outages. Additionally, refueling can wait for longer periods (3-7 years), and can be staggered for each module so as not to lose the whole capacity.

#6. What are the challenges in developing and deploying SMRs?

BofA Global Research believes efforts to develop SMRs will face significant challenges. Among these are the design, licensing, development, and construction of first-of-a-kind (FOAK) technology; supply chain challenges; the availability of a skilled workforce; the availability of fuel; the development of methods for storing, and possibly recycling, spent fuel. We discuss these in detail below:

- **Underdeveloped supply chain:** One of the greatest barriers to SMR development is the underdeveloped supply chain. Currently, there is only one facility in the world that manufactures HALEU – a required component for many SMRs. And while the US has signed contracts and tried to incentivize domestic HALEU production, getting up to scale could take years, according to BofA Global Research.

- **Lack of a workforce:** The lack of a skilled workforce is also a big hurdle for SMR development. From 2012-2022, the number of students graduating with a bachelor's in nuclear engineering fell by 25%. Along with minimal entry, the workforce is aging, causing a shortage in workers, especially for utilities.

- **Regulations:** The regulation for SMRs through the Nuclear Regulatory Commission (NRC) has also slowed plans. Currently, there is only one approved design, but the firm behind the technology does not anticipate commercializing this model. And under current rules, NRC's approval processes are anticipated to take between five to 10 years (Exhibit 4).

- **Cost unpredictability:** The economics of SMRs are a bit complex. Proponents highlight potential cost and construction advantages (modular design); however, critics point to current cost unpredictability. SMRs often face cost overruns and delays in demonstration projects, raising concerns about their economic viability. This challenge is underscored by the fact that renewable energy technologies, like solar and wind, are becoming increasingly cost-competitive, potentially making SMRs less attractive economically.

Exhibit 4: The application process can range from 5-10 years
NRC application process for an SMR

Early End Date	Late End Date	Filing	Timeframe	Description
Year 0.5	Year 1	Pre-Application Activities	Up to 1 year	NRC engagement including proposal siting/design/regulation
Year 1.5	Year 3	Design Certification Application	1 - 2 years	Submission of design to NRC and NRC review for completion/compliance
Year 3.5	Year 7	Technical Review	2 - 4 years	Evaluation of safety, compliance, and impact; includes public comment
		Safety Evaluation	1 - 2 years	NRC evaluating safety findings of draft or final technical review; NRC approval or denial
Year 4.5	Year 9	Combined License Application	1 - 2 years	Submission of application for combined operating and construction license
Year 5	Year 10	NRC Approval	Up to 1 year	NRC evaluates combined license and issues approval; If denied application can be resubmitted

Source: NRC

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#7. What does the path forward look like for SMRs?

While BofA Global Research believes these challenges can be met, they also recognize that both the absolute price of electricity and the speed with which these units can enter service are of paramount importance. And as this technology evolves, projects are built, and operating experience is gained, the economics will improve.

Therefore, BofA Global Research views 2025 as an inflection point for solid order momentum of SMR foundries, prompted in part by policy directives. On May 23, 2025, President Donald Trump signed four executive orders aimed at accelerating the construction of NPPs in the US. Additionally, the US government has multiple policy supports to SMRs, including:

- **Advanced Reactor Demonstration Program (ARDP):** A US DOE program that supports and accelerates the demonstration of advanced nuclear reactors through cost-shared partnerships with US industry.
- **Microreactor Application Research Validation and Evaluation (MARVEL):** A sodium-potassium-cooled microreactor being developed by the US DOE, which will be located at the Transient Reactor Test Facility at Idaho National Laboratory.

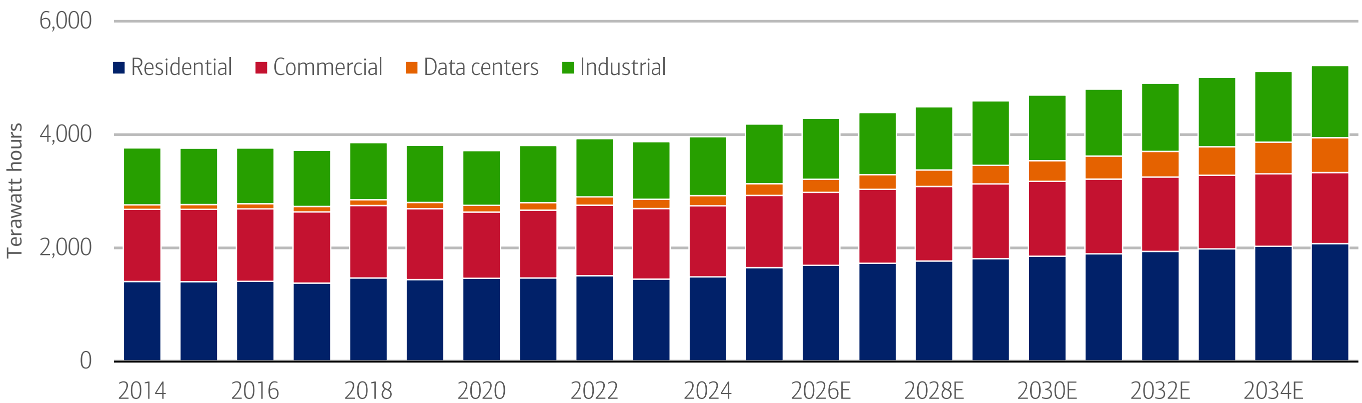
Increased demand for nuclear energy

Another factor that could drive SMR development? The global resurgence of nuclear energy.

In fact, US electrical demand grew at 0.5% CAGR (compound annual growth rate) over 2014-2024. As illustrated in Exhibit 5, BofA Global Research projects a 2.5% CAGR over 2024-2035, reflecting incremental demand from 1) building electrification; 2) data centers; 3) industrial demand; and 4) EV adoption. For more about US electrical demand and the power grid, see our recent publication: Power check: Watt's going on with the grid?.

Therefore, according to BofA Global Research, in the context of energy demand, advancements in technology like SMRs could likely reshape nuclear power supply chains over the next decade, given the major benefits over conventional powerplants.

Exhibit 5: BofA Global Research forecasts US electrical demand to grow at 2.5% CAGR over 2024-2035E
US electrical demand (in terawatt hours per year) 2014-2035E



Source: BofA Global Research estimates, US Energy Information Administration

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Disclosures