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Greenwheel Insights

Small Modular Reactors (SMRs): Over-hyped and under-evidenced

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Executive Summary

- Small Modular Reactors (SMRs) **are scaled-down versions of traditional nuclear reactors**, but with more varied design concepts, and **which may be manufactured and assembled in modules**.

- **Proponents claim they may be quicker and cheaper to build** than large-scale reactors, and **use less land and water, produce less waste, and operate more flexibly and safely**.

- For these reasons **interest is growing in the potential for SMRs to deliver quick, cheap, low carbon, firm power** for different applications – particularly data centres.

- However, **investors should be aware that their prospects may be substantially overhyped**, at least over the medium-term.

- **The technology is nascent, with few units built and operating**, mainly in Russia and China. Other designs are under construction, **with several others aiming for commissioning in the early 2030s**. **Investors should be cautious when examining these claims.**

- Evidence suggests **the construction time and cost per unit capacity may not be less than large-scale nuclear for early installations**.

- **Whether construction time and costs can reduce will depend on achieving economies of scale and learning through growing deployment**, **but this is highly contingent** on successful value demonstration of early units, the characteristics of individual SMR designs and their developers, and the environment they seek to build and operate SMRs in.

- **Even in countries with conducive policy and incentives, regulatory processes may be a significant barrier**. Pre-construction licencing alone may exceed a decade in some potential key markets. **The supply chain may also present constraints**.

- **Competition from other electricity supply technologies may also restrict growth**, although some significant niches may emerge over time, such as relatively small/off-grid applications where stability and low-carbon is important, land or renewable resources are limited, connection to other grids is infeasible, and cost is not the priority.

- **Claims around land and water use, waste generation and safety are complex**, and generally **difficult to verify** without real-world demonstration.

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Preface: The Investor Need

"SMRs are a technology that has attracted a lot of attention from investors, especially in the USA where there are growing concerns about the ability of electricity supply to keep pace with accelerating demand.

Some see SMRs as the key to unlocking this problem, but several open questions remain. This Greenwheel Insights paper examines the status of SMRs, their characteristics, and how they could develop. It shows that although SMRs might be a promising opportunity, they are far from a panacea to near-term electricity supply challenges."

Michel Sznajer
Portfolio Manager, Ecofin Global Renewable Strategies

What are Small Modular Reactors (SMRs), and their potential benefits?

Small Modular Reactors (SMRs) are scaled-down versions of traditional nuclear fission reactors, but with more varied design concepts. They have **a power output capacity up to 300 MW**, rather than the 1-2 GW typical of traditional large-scale reactors.[1]

Their modularity primarily comes from nature of their manufacture and construction, but also their deployment. Multiple SMRs may be installed together for greater total electricity or heat output, either at initial installation or over time.

Proponents claim SMRs will have a range of benefits over large-scale nuclear, including flexibility in application, as summarised in Figure 1 and Figure 2, below.

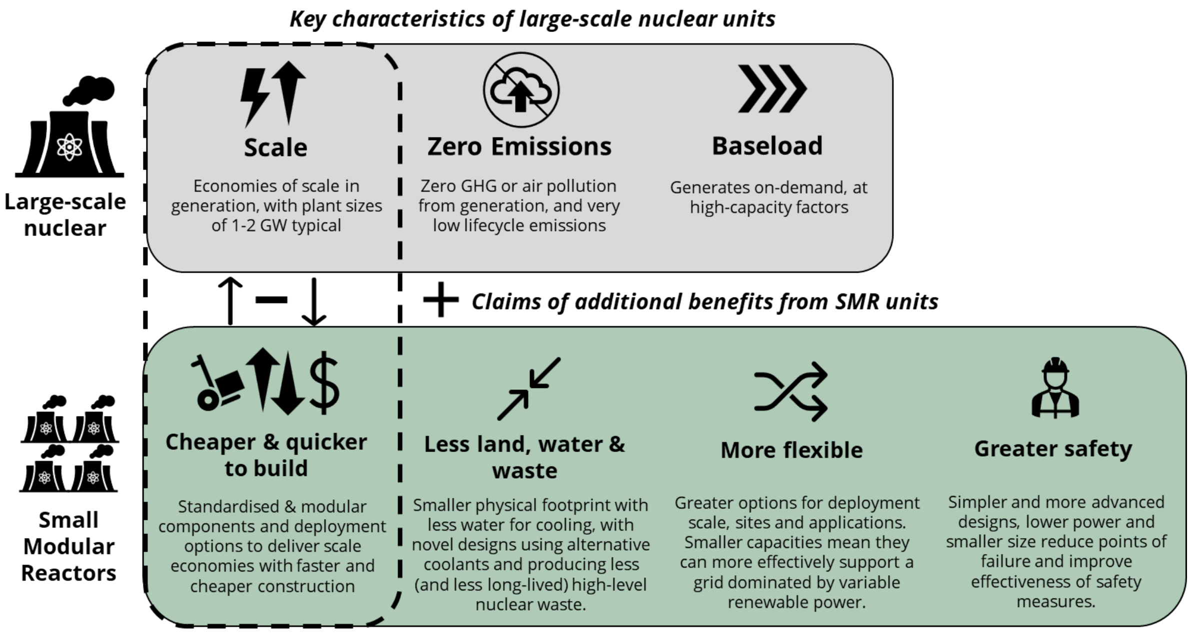


Figure 1 – Key characteristics of large-scale nuclear units and claims of additional benefits from SMRs. Graphic created by Greenwheel.

[1] Units under 50 or 100 MW are sometimes called microreactors (definitions vary), but all units under 300MW are considered here as SMRs.

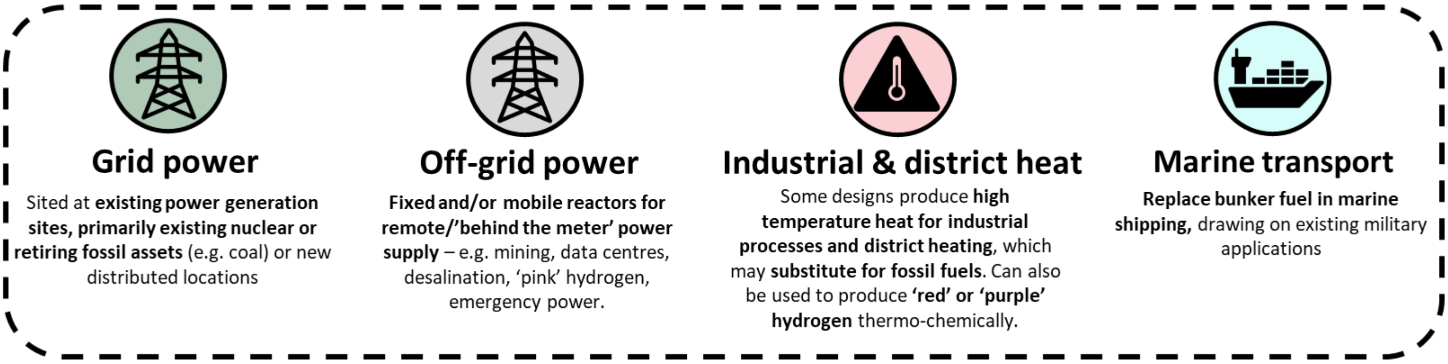


Figure 2 - Potential SMR applications. Graphic created by Greenwheel.

These promised characteristics have led to a recent surge in interest for SMRs, particularly among emerging sources of electricity demand such as data centres for Artificial Intelligence (AI) applications, which require substantial supplies of reliable, low-carbon and low-cost electricity, that can be built quickly.

Under the IEA's Net Zero Emissions by 2050 (NZE) scenario, global nuclear electricity capacity grows by ~2.5x to 2050, to over 1,000 GW. **Over 50% growth is projected even under current policies.** Under all scenarios, **a minority of this growth comes from SMRs**. Under current policies SMRs account for just 6% of total nuclear capacity by 2050, rising to 19% under a Net Zero scenario.[i]

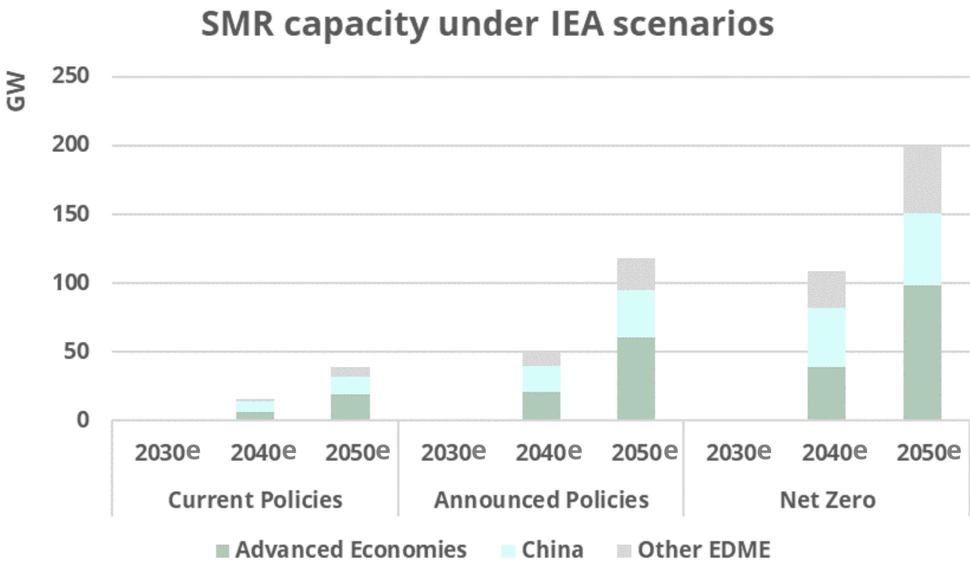


Figure 3 - SMR capacity under IEA Scenarios (Data source: IEA, 2025). Graphic created by Greenwheel. Forecasts and estimates are based upon subjective assumptions about circumstances and events that may not yet have taken place and may never do so.

However, **under all scenarios this would represent very significant growth for a nascent industry**. **Investors, developers and policymakers currently have active plans for around 25 GW of SMR capacity**, largely to power data centres.[i]

However, the successful development and deployment of SMRs is highly uncertain and contingent on several factors including support from policy makers and regulators, demand and support from investors and consumers, and on the ability of developers to successfully demonstrate the benefits of the technology.

How mature is the technology?

There are at least 84 identified SMR designs at different stages of development, employing different concepts, each with different advantages and disadvantages (Figure 4).[ii] **The majority are intended for fixed, land-based applications**, or mixed applications (i.e. fixed or mobile, including marine). The remaining few are intended exclusively for mobile or marine applications.[iii] **Designs are relatively evenly distributed between the four key reactor types** (see Figure 4).

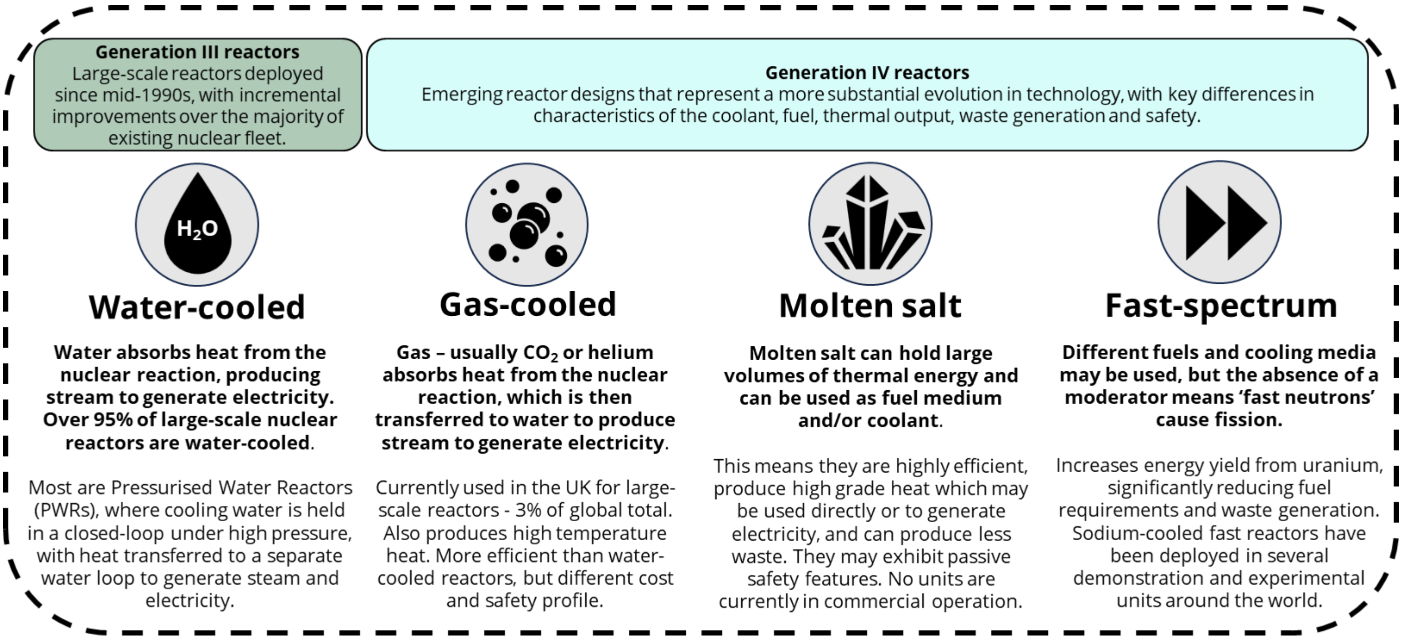


Figure 4 - Types of nuclear reactor. Data sources: IAEA (2025a); IAEA (2025b); IAEA (2025c); IAEA (2025d); WNA (2021) Graphic created by Greenwheel.

Four designs are in operation, with two in commercial applications – in China and Russia. A second reactor in China, and one in Japan, are operational for experimental and demonstration purposes. **Five further units are under construction, with three – in Argentina, Russia and the USA – for commercial application** (Figure 5).

Most of the units operating or under construction draw heavily on the existing nuclear ecosystem. Most are water- or gas-cooled, and most use ceramic uranium dioxide pellets as fuel, are built on existing nuclear (or related) sites, and are designed, developed and/or funded by government bodies and resources.

Of a total 84 SMR designs, 75 remain in the conceptual or design stages. Of these, **around a third are at the 'detailed design' stage** – i.e. a largely completed design and construction schedule are available, manufacturing, procurement and commissioning specifications are completed.[ii] **Around half of these are from developers based in the USA**. Around half are based on traditional water-cooled designs, with the remainder largely molten salt or gas-cooled designs.

Operating	RUSSIA KLT-40S	CHINA HTR-PM	CHINA HTR-10	JAPAN HTTR
Size* & Type	32 MWe	200 MWe	2.5 MWe	10 MWe
Application				***Not defined*** *(experimental)*
Commissioning**	**2020** (construction began 2006)	**2022** (construction began 2012)	**2003** (construction began 1995)	**1998** (construction began in 1991; offline 2011-2021; 2023-)
Description	A **modified version of the KLT-40 reactor used by the Russian icebreaker fleet**, this **floating, mobile reactor is used to provide power and heat to the isolated town of Pevek on the East Siberian Sea**. Publicly funded, owned and operated by Rosenergoatom.	Developed by Tsinghua University's Institute of Nuclear and New Energy Technology (INET) and constructed by China National Nuclear Corporation (CNNC). **Operated by China Huaneng Group as the Shidaowan Nuclear Power Plant**, on the Shandong coast.	Developed by Tsinghua University's Institute of Nuclear and New Energy Technology (INET). **Demonstration unit for HTR-PM reactor**.	Fully **financed by the Japanese government as an experimental unit**. Built at a research site of the Japanese Atomic Energy Agency on the Ibaraki Prefecture coast, with construction led by Toshiba, Hitachi, Fuji Electric and Mitsubishi Heavy Industries (MHI). New project to demonstrate hydrogen production by 2030 using process heat.

Under Construction	BREST	ACP-100	CAREM	RITM-200N	KP-FHR
Size* & Type	300 MWe	300 MWe	25 MWe	55 MWe	140 MWe
Application					
Planned Commissioning*	**2030** (construction began 2021)	**2030** (construction began 2021)	**>2028** (construction began 2014)	**2028** (construction began 2024)	**2027** (construction began 2024)
Description	**Funded by the Russian government and developed by and sited at the Siberian Chemical Combine site in Seversk** on the bank of the River Tom (owned by Rosatom). Forms part of the pilot-demonstration energy complex (PDEC), focused on demonstrating new technologies for the production and recycling of nuclear fuel.	**Funded and developed by China National Nuclear Corporation** (CNNC) **on the site of the existing Changjiang Nuclear Power Plant on the Hainan Province coast**. Also known as Longlong One.	**Fully financed by the Argentinian government**, and **under construction on the nationally-owned nuclear site of Atucha**, on the Parana river. The Comisión Nacional De Energia Atómica (CNEA) is the primary designer and developer, with Nucleoelectrica Argentina SA (both nationally-owned organisations) providing construction and technical assistance.	A **modified version of the RITM-200 reactor used by the Russian icebreaker fleet. Funded by the Russian government**, developed and constructed by a subsidiary of ROSATOM in the Russian Far East region of Yakutia. **ROSATOM has an agreement to provide power to the Russian mining company Seligdar**, for gold mining operations from 2028.	**Developed by Kairos Power**, a private company founded in 2016. First unit (Hermes 1) under construction Tennessee, to demonstrate heat output. Second unit (Hermes 2) intended to demonstrate electricity output granted construction permit in 2024. **Signed PPA with Google in 2024 for 500 MW capacity over 2030-2035, to power data centres**.

Commercial/semi-commercial operation   **Demonstration/Experimental operation**

Figure 5 – SMRs in operation and under construction. Data source: IAEA (2024), but adjusted using more recent public information where required. Notes: * = electrical capacity. **Broad definition taken (e.g. first criticality; connection to grid. Graphic created by Greenwheel.

Reactors yet to reach detailed design are highly varied in reactor concepts, size, application, fuel characteristics, and country of origin, although many of these designs are not under active development.[iii] Figure 6 illustrates the country base of the SMRs at the detailed design stages (left panel), and those at the basic or conceptual design stages (right panel).

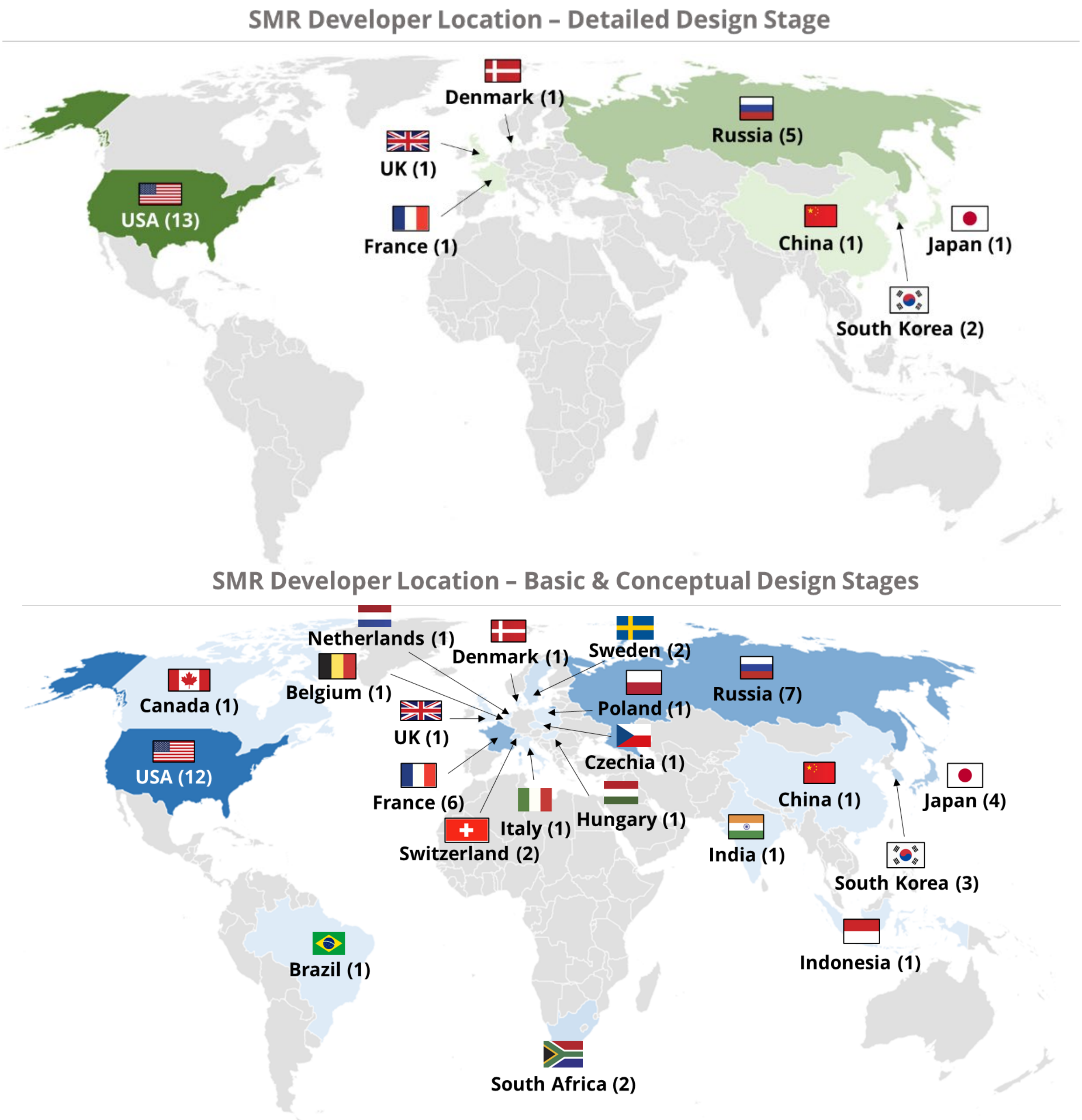


Figure 6 - Geographic distribution of SMR developers at different design stages. Data Source: IAEA (2024). Graphic created by Greenwheel.

Although few SMR designs have been built or are under construction, several other designs claim to be nearing the construction stage. Figure 7 highlights and describes the most prominent examples.

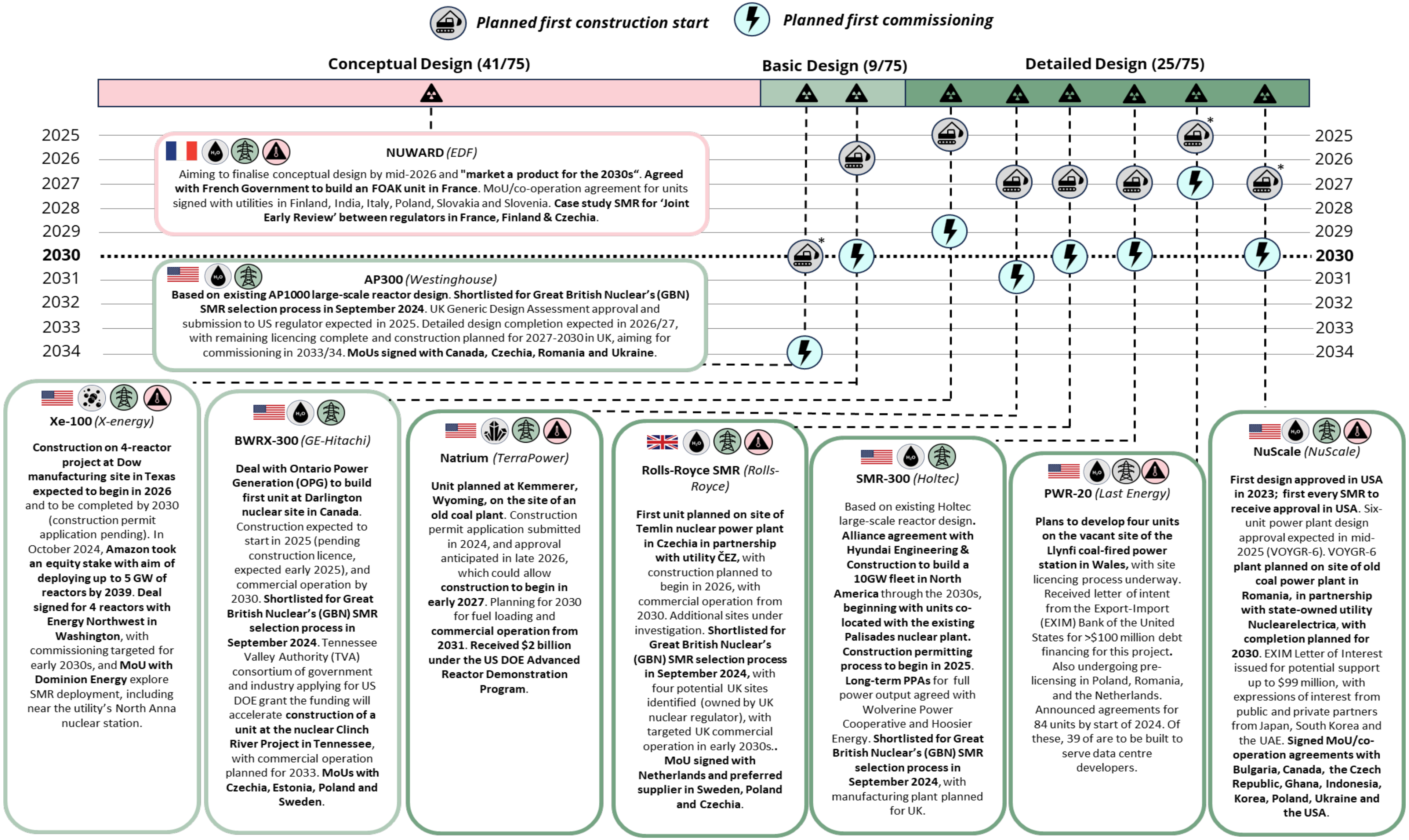


Figure 7 – Planned construction starts and planned first commissioning for key SMR designs in development. Information sources include: IAEA (2024); GBN (2025); WNN (2024) * = Estimated based on planned first commissioning date. Graphic created by Greenwheel. Forecasts and estimates are based upon subjective assumptions about circumstances and events that may not yet have taken place and may never do so.

Most of these designs are from US developers, build upon the existing nuclear ecosystem, and are focused on early deployment in the USA, Canada, UK, Czechia and Romania to provide power to the grid. Most are water-based reactors and so can share much the same value chain, and in some cases based on existing nuclear sites – although some plan to use retired coal power sites. **Although many of these designs are aiming for construction and commissioning of their first projects within the next ~5 years, there are reasons to be cautious that this is achievable in many cases** (discussed below).

Although data centre operators account for a significant proportion of the demand SMR deployment under discussion, they are largely focused on a small number of designs, are in relatively early stages, or have not made details available. For example, in late 2024 Oracle announced they plan to deploy three SMRs to power a new data centre campus but have not released further details, while Meta released a request for proposals for up to 4 GW of large-scale and SMR capacity, but have not yet selected proposals to take forward.[i]

What evidence exists for their potential benefits?

Might they be faster and cheaper to build than traditional nuclear?

Since 2000, **new large-scale nuclear reactors have taken an average seven years to build, but a have commonly exceeded a decade, particularly in advanced economies** like the USA, EU and UK.[i] Total development time is significantly longer with pre-construction processes, such as technology and site listening (discussed below).

Longer timeframes in advanced economies are largely due to delays during construction induced by design modifications, regulatory hurdles, and supply chain constraints and disruptions. In many cases, these factors are driven by **a lack of recent experience in nuclear construction** (including in countries with existing nuclear fleets, meaning knowledge, skills and supply chains must be rebuilt)[i], **and the use of new or heavily modified reactor designs**.[i]

These delays often produce substantial cost overruns. For example, construction of the Flamanville 3 reactor in France which connected to the grid in December 2024, overran by 12 years and cost treble the original estimate (reaching nearly $15 billion,[iv] or $11,000/kW capacity). In the UK, Hinkley Point C began construction in 2017 with commissioning planned for 2025. Commissioning is now likely to be at least 2029, while expected costs have doubled (to around £34 billion, or $16,000/kW; in 2015 prices).[i] Overall, across all projects for which data is available, **nuclear power projects have on average cost more than double their original estimates**.[v]

Construction time and costs have been lower in countries using more standardised reactors designs built in series, and with more recent activity in nuclear build-out – such as China, the UAE and South Korea.[i]

This suggests that SMRs, with standardised designs produced in series, ***may have the potential* for faster construction and capacity costs below large-scale reactors**. They are also **likely to require significantly lower total capital investment** per unit. While large-scale nuclear plants have commonly required capital investment far exceeding $10 billion, early SMR units may cost around $2-4 billion[i,vi] – similar to a large hydropower project.[i]

However, there is broad consensus that First-of-a-Kind (FOAK) and other early SMRs are not likely to be cheaper than new large-scale reactors on a capacity basis (Figure 8)**, and they may also not be significantly quicker to build**. This is mainly because early units are not able to take advantage of the potential for manufacturing scale economies Nth-of-a-kind (NOAK) units could enjoy, and so they remain civil nuclear construction projects, with the attendant constraints and problems large-scale projects for FOAK reactors in advanced economies have faced – but with much lower resulting unit capacity.

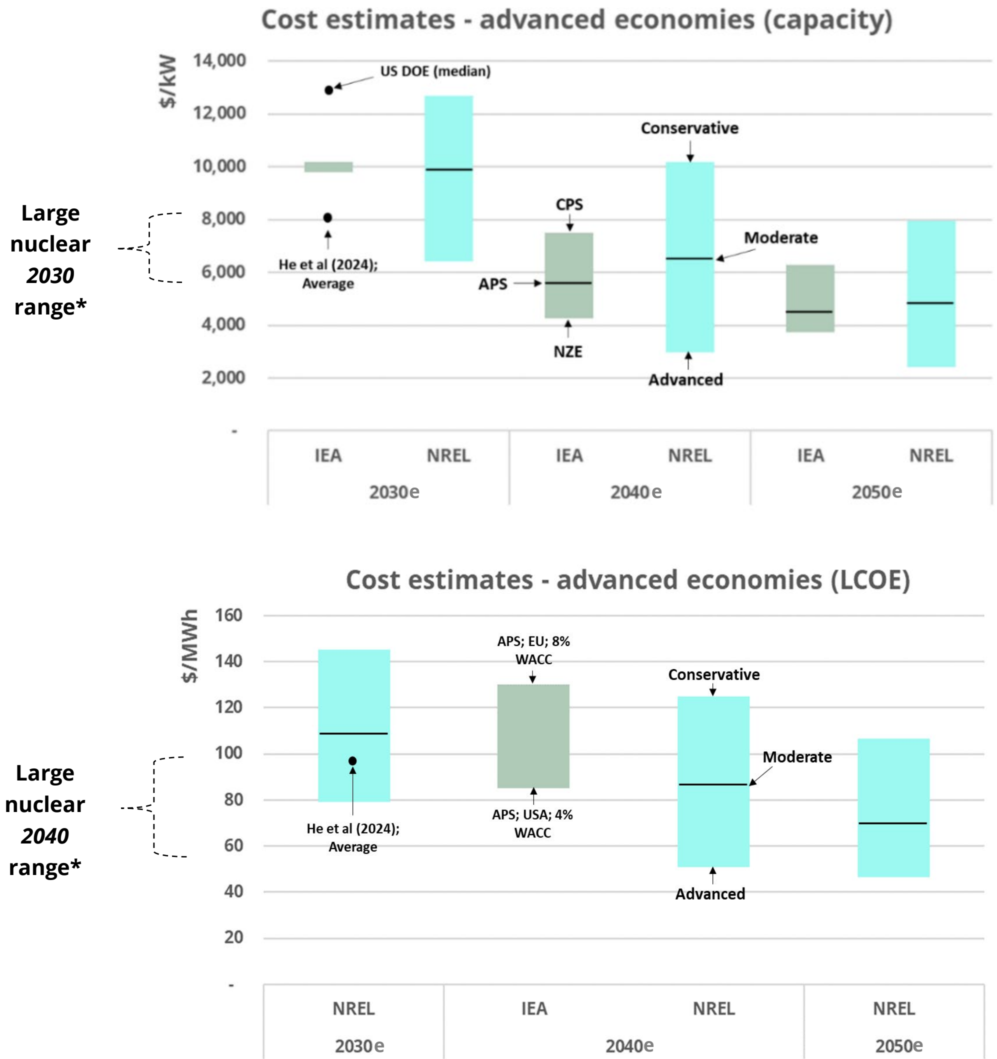


Figure 8 – Key SMR cost estimates for advanced economies. Data sources: IEA (2025); NREL (2025); US DOE (2024); Hee et al (2024). Notes: * = from IEA & NREL. Graphic created by Greenwheel. Forecasts and estimates are based upon subjective assumptions about circumstances and events that may not yet have taken place and may never do so.

The potentially high cost of FOAK and other early SMR units is supported by experience to date. Construction times and costs for many SMR units constructed, under construction or in advanced development have grown rapidly and substantially above original estimates, to values exceeding those experienced for recent large scale nuclear in advanced economies.[2,vii]

In Figure 8 **the IEA and NREL project SMR costs to decline over time, but to different degrees under scenarios with differing assumptions around the rate and scale of deployment and learning rates**. LCOE ranges are also significantly driven by assumptions around the weighted cost of capital (WACC), cost recovery periods and operational requirements (e.g. staffing levels). **Despite this, costs targeted by some leading developers are at or below the lower end of the estimates for 2050 under even the most optimistic scenarios**.[3,i]

Overall, SMR costs remain highly uncertain. **Future costs depend substantially on achieving a significant rate and scale of deployment**. However, **this is in turn dependent on the characteristics of different SMR designs and developers, and wider external factors** largely outside their control – as illustrated in Figure 9.

These factors may may interact to generate both positive and negative feedback loops. For example, growing deployment of an individual design may demonstrate its value proposition, and generate learning to further simplify or modularise, which can reduce costs to stimulate further deployment and value demonstration. Similarly, growing deployment can solidify supply chains and stimulate further policy support and regulatory learning. However, if FOAK units fail to demonstrate sufficient value (e.g. they come in significantly over time and budget), for example, further orders may not materialise, closing opportunities for further scale, learning and cost reductions.

Whether positive feedback loops can be induced to allow SMRs to achieve significant scale would likely require highly conducive technology and developer characteristics and external factors leading up to and during FOAK and other early deployment.

[2] For example, as of 2023 costs for the Nuscale, X-Energy and GE-Hitatch reactors have reached ~$21,500/kW, $18,000/kW and ~$12,500/kW respectively. These values are ~2.2x, ~4x and 4.3x estimates given just a few years earlier for each reactor, respectively, and may increase further once FOAK units have been built.

[3] For example, GE Hitachi, Moltex Energy and Westinghouse are targeting costs of $2,250/kW, %2,000/kW and $3,400/kW, respectively.

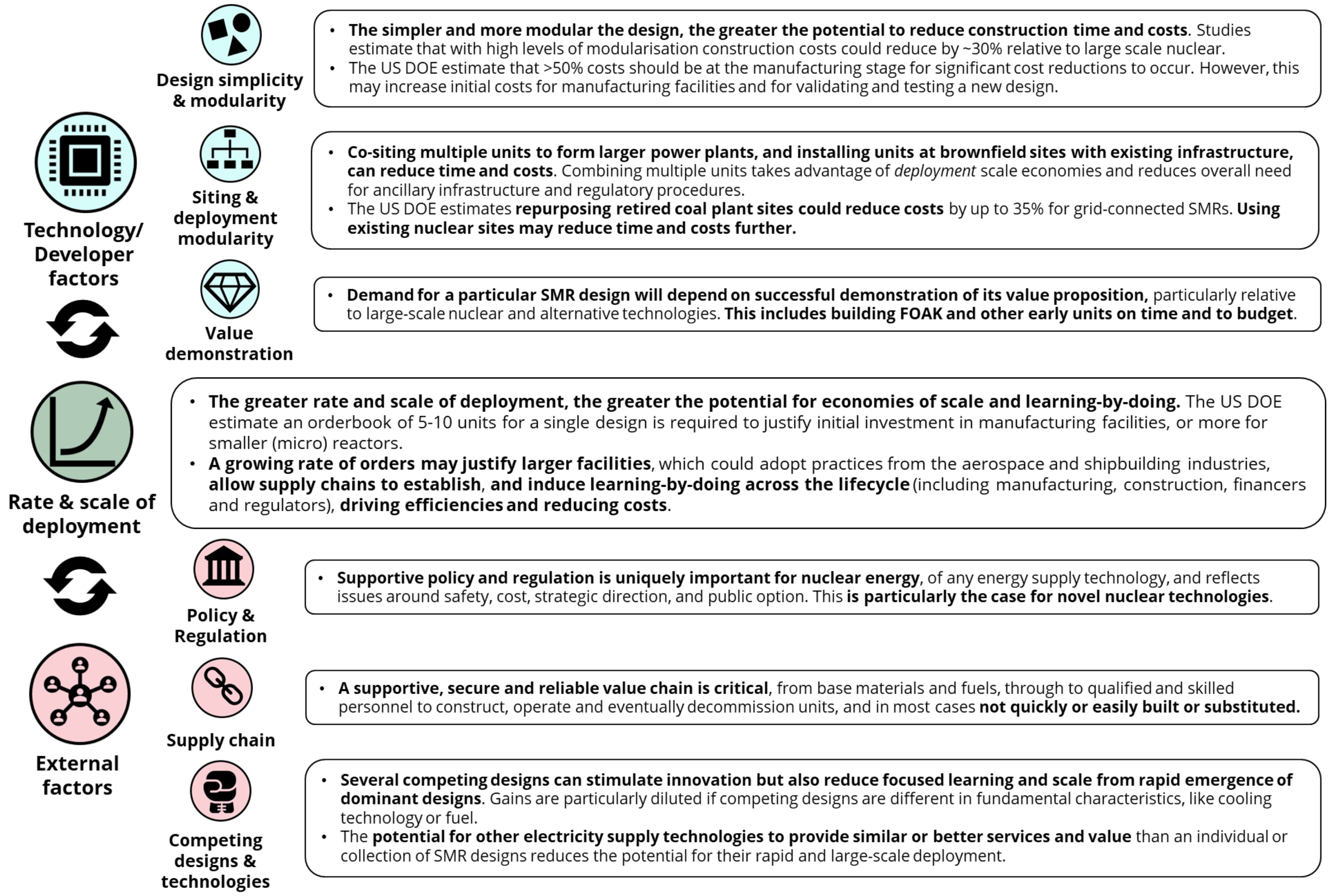


Figure 9 - Factors likely to determine the rate and scale of deployment of SMRs, and potential cost evolution. Data sources include: US DOE (2024); Mignacca & Locatellii (2020); IEEFA (2024). Graphic created by Greenwheel.

Might they use less land and water, and produce less waste?

Land

A typical large-scale nuclear plant requires a site of around 3 km^2.[viii] **SMRs may require smaller sites, both per unit and on a capacity basis**, although requirements may vary significantly. For example, according the their developers the X-energy Xe-100 may require less than 2 km^2 for 1 GW capacity, while the Rolls-Royce SMR may require significantly less than 0.5 km^2 for the same capacity.[4] **However, this is yet to be demonstrated in practice, and it is not yet clear what different regulators might allow**.

Water

Traditional large-scale, water-cooled reactors use water in two direct ways. The first is to absorb the heat from the nuclear reaction, which either turns the cooling water directly into steam to spin a turbine to generate electricity (a Boiling Water Reactor –

[4] According to the IAEA (2024), the Xe-100 plant requirements 130,900m^2 per 82.5 MW reactor, while the Rolls-Royce SMR requires 54,500m^2 per 470MW reactor.

BWR), or the cooling water heats under high pressure to remain liquid but passes through a heat exchanger to heat an external water loop, which instead boils into steam to pass through a turbine to generate electricity (a Pressurised Water Reactor - PWR).

Under both designs, **the water used in directly in the system remains in a closed loop and is not 'consumed'**. However, the steam generated to spin the turbine passes through a condenser to liquify it for re-use. **Recondensing steam for re-use requires and external water source to absorb and disperse the heat**, usually the ocean, a lake or river. **This water is either in turned into steam and released from cooling towers or taken in larger volumes and returned to the water body at higher temperatures** (which can be detrimental to aquatic ecosystems).[ix]

Large-scale reactors which release steam through cooling towers consume around 3,000 l/MWh on average. Those that return liquid water consume around half this on average but *use* much more. **These values are relatively high compared to other thermal generation technologies** and given the typically larger capacity of individual nuclear plants, they use and/or consume significantly more water on an absolute basis per plant compared to other power generation technologies.[x]

Most SMR designs at advanced stages are water-cooled. Although they may use less water per installation, **they are not likely to consume less water than equivalent large-scale reactors per unit of electricity generated** and may use more.[xi,xii]

Steam can also be re-condensed using ambient air, **known as 'dry-cooling'**. **This approach consumes no water, which also allows greater flexibility in location**. **However, dry cooling is much more expensive, less efficient** (particularly in warm environments), **and requires an estimated 5-7% of the electricity output of the reactor to run**.[ix,xiii] Very few commercial, large-scale water-cooled reactors use dry cooling, although some water-cooled SMR designs may be able to use it.[xiii]

The water consumed by new reactor designs like gas-cooled, molten salt or some fast reactors may be lower per unit of electricity generated, due to their higher thermal and electrical output, and the ability for this high-temperature 'waste' heat to be used for other purposes (Figure 2).[ix,xiii]

Waste

SMRs may generate different volumes of more complex waste that traditional large-scale reactors, although this may vary significantly by SMR design.[xiv,xv]

Due to their smaller cores, SMRs may experience more 'neutron leakage', which can increase generation of intermediate-level radioactive waste. However, the volume and characteristics of other forms of waste may vary substantially. For example, HALEU fuels may generate more depleted uranium waste in its fabrication, but less waste once used – although this waste may have higher radiotoxicity. Overall, **there remains relatively little information in the public domain on the likely waste characteristics of many SMR designs**.[xvi]

The use of novel coolants and/or moderators (e.g. molten salt) may require additional or alternative waste management. However, the **waste management technologies and technique for gas-cooled reactors have not yet been fully demonstrated, while those for molten salt and fast reactors remain largely at the basic research stage**.[xvi]

Might they be safer?

Measured in terms of attributable deaths across the value chain and total electricity generation, **nuclear power is one of the safest forms of power generation**.[xvii] **Despite this, although serious incidents are low probability, they can be high impact**.

SMRs may have three key safety advantages over traditional large-scale nuclear reactors (Figure 10).

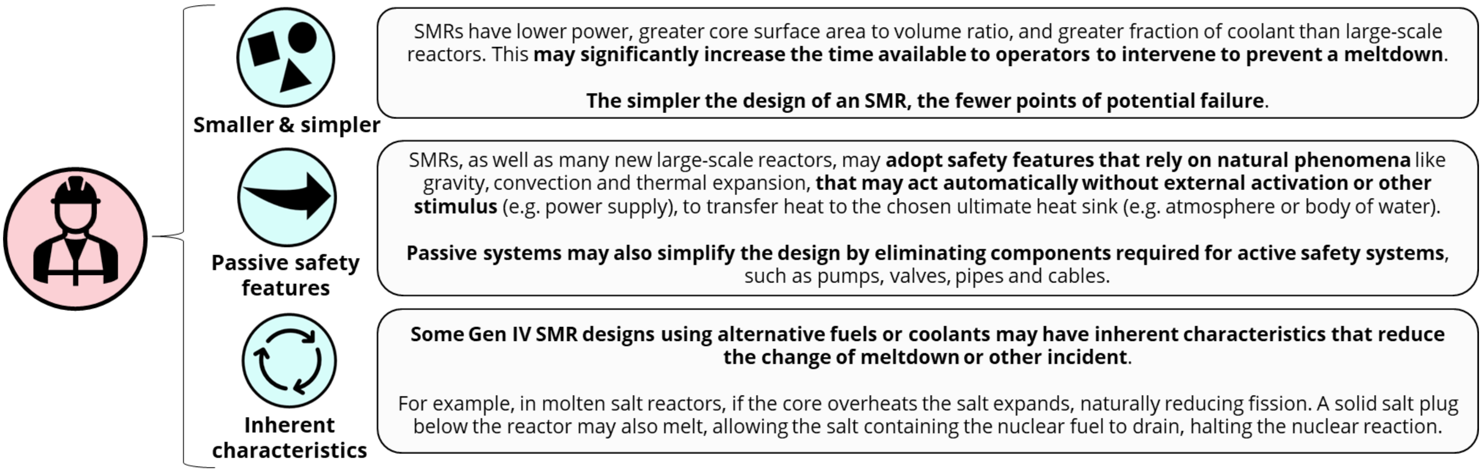


Figure 10 - Factors influencing the safety profile of SMRs relative to large-scale reactors. Information sources: EC (2025); WNA (2024); Lee (2024); IAEA (2025). Graphic created by Greenwheel.

While such features can help prevent incidents in case of failures or errors in reactor operation, they don't address the potential risk from natural disaster, attack or other malicious intent. By multiplying the number of nuclear sites, exposure to natural hazards or malicious intent may grow (including through greater transport of fuel and waste to and from these sites), and potentially limit the ability of off-site security personnel to respond. This is particularly the case for remote sites.[xviii] **There are concerns that such security factors have so far had relatively little attention**.[xix]

What other factors influence their prospects?

As illustrated by Figure 9, a range of factors external to the characteristics of SMRs themselves are crucial in determining their prospects for future growth.

Political and policy support

At COP28 in December 2023, more than 20 countries pledged to collectively triple global nuclear capacity by 2050. An additional 6 countries joined the pledge at COP29 in 2024.[i]

At present, **over 40 countries are planning to or are considering building new nuclear reactors**, including 10 that have no prior experience. **SMRs are explicitly planned in around 15 countries and are under discussion in a further 19 countries** (Figure 11).

Role of SMRs in countries with new nuclear capacity plans

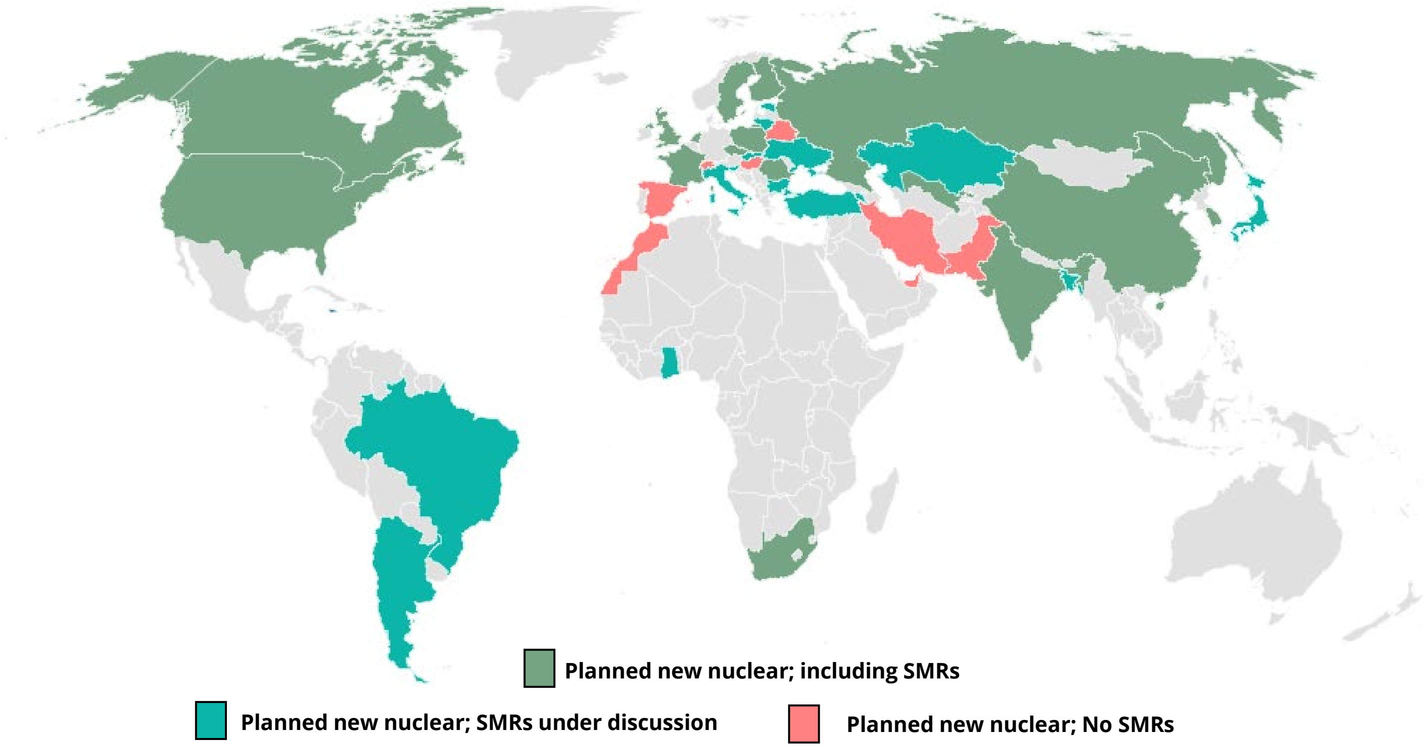


Figure 11 - Role of SMRs in countries with plans for new nuclear capacity. Data Source: IEA (2025). Graphic created by Greenwheel. Forecasts and estimates are based upon subjective assumptions about circumstances and events that may not yet have taken place and may never do so.

Given the relatively unique characteristics of nuclear power to date, particularly scale and safety and security concerns, **governments have often been involved in directing and financing its construction** (including through state-owned utilities). **Even where this has been less the case**, such as in the USA and Finland, **policy support has remained critical. This is likely to extend to SMRs**.

Figure 12 summarises policy frameworks in some key countries and regions where SMR development is explicitly supported by public policy.

United States

In November 2024, the **Federal government set a target to add 35 GW of new nuclear capacity by 2035, and 200 GW by 2050 – explicitly including SMRs**. **Several programmes and instruments are in place to help fund or otherwise support** for technology, project and supply chain development. At the time of writing, **these appear to have remained in place under the new administration**.

These include the $2.5 billion **Advanced Reactor Demonstration Program**; $900 million under the **Consolidated Appropriations Act**; loans and loan guarantees from the **DOE's Loan Programs Office**; investment and production tax credits under the **Inflation Reduction Act**; **potential installations at defence and other federal facilities**; **facilitating engagement** with and between local and international stakeholders; and proposed **action to tackle potential regulatory barriers**.

United Kingdom

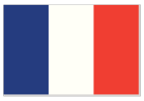
The 2022 British Energy Security Strategy **targets 8 new large-scale reactors and SMRs to achieve 24 GW total nuclear capacity by 2050**. In 2022, Great British Nuclear (an arm's length body of the Department for Energy Security & Net Zero, with statutory powers to facilitate the design, construction, commissioning and operation of nuclear energy generation projects), launched an **SMR Selection Competition**. SMR developers enter the competition, are shortlisted with **government contracts negotiated with an aim to reaching FID by 2029, and commissioning in the early 2030**. The **final decision on successful developers are due in Spring 2025**.

The government's **AI strategy includes development of data centres powered by renewables and SMRs**, with the government and UK Atomic Energy Authority (UKAEA) seeking a partner to develop new data centres in AI Growth Zones, with the first at the UKAEA's headquarters. **Changes to nuclear licencing procedures were made** in early 2025 **to facilitate SMR development**.

European Union

The EU recognises SMRs as a potentially important technology for meeting energy and climate objectives. In 2023, the Commission adopted **the European Net Zero Industry Act (NZIA), classifying SMR technologies as net-zero technologies**, and announced a Declaration on EU SMR 2030, signed by Commission and stakeholder representatives, confirming their **commitment to support R&D activities and skills development for SMRs in Europe**.

In February 2024, the Commission launched the **European Industrial Alliance on SMRs**, which **aims to facilitate and accelerate the development, demonstration, and deployment of the first SMRs projects in Europe in the early 2030s**. Across 8 working groups, it aims to support specific SMR projects and accelerate their deployment on the European market. To achieve these goals, the alliance will formulate a strategic action plan, together with technology roadmaps. **Several EU member states are also actively supporting SMRs.**



France

As part of the France 2030 National Investment Plan, the **French government will invest €1 billion in R&D for SMRs, and aim for first until commercial commissioning by 2035**. State-owned utility EDF is developing the NUWARD design, and has signed co-operation agreement with SMR developer Thorizon. The French Alternative Energies & Atomic Energy Commission has signed a partnership agreement with spin-off Blue Capsule. The **French government recently signed an SMR partnership letter of intent with India**.

Czechia

Since 2019, the **Czech Government has signed a series of MOUs with SMR developers** (see Figure 7). In March 2022, the Czech utility **CEZ earmarked land at its Temelin site to be used for the construction of the country's first SMR**. In 2023 CEZ identified the coal power plants at Dětmarovice and Tušimice as preferred locations for a second and third SMR, with commissioning targeted for second half of the 2030s. **In November 2023 the Czech SMR Roadmap was adopted**. The roadmap includes information on the various design options and **identifies 45 potential host sites**.

China

The 14th Five-Year Plan (2021-2025) **targets nuclear capacity of 70 GW by the end of 2025, and 200 GW by 2035 – including SMRs**. The country **has two SMRs in operation and one under construction** (Linglong One), using the ACP-100 design, aiming to be commissioned in 2026.

CNCC expects the **ACP-100 design to be in mass deployment by 2030, both domestically and for the export market**, with a focus on 'Belt and Road' Initiative partner countries.

Canada

This 2020 **SMR Action Plan contains 520 'actions' – almost all of which remain in progress or yet to begin**. The **Enabling Small Modular Reactors Program** which provides up to CAD 5 million of funding for R&D projects for SMRs. The **Canadian Nuclear Safety Commission's SMR Readiness Project aims to optimise readiness to license and regulate SMRs**, addressing over 50 actions from the SMR Action Plan.. GE **Hitachi deal with Ontario Power Generation (OPG) to build first SMR unit at Darlington nuclear site**, with **construction expected to start in 2025**.

India

India aims to grow its nuclear capacity from around 8 GW today, to around 22.5 GW by 2031, and at least 100 GW by 2047. In February the government announced the Nuclear Energy Mission for Viksit Bharat, and promised funding to develop at least five Indian-designed SMRs to be operational by 2033, as well as amendments to Indian legislation to encourage private sector participation. The **French government recently signed an SMR partnership letter of intent with India**.

Figure 12 - Policy frameworks in key countries and regions. Information sources include: IEA (2025) US DOE (2024); The White House (2024); GBN (2025); DSIT (2025); WNN (2024); WNN (2025); WNA (2025a); WNA (2025b); MITCR (2023); NBP (2024); NRCAN (2025) Graphic created by Greenwheel. Forecasts and estimates are based upon subjective assumptions about circumstances and events that may not yet have taken place and may never do so.

Nuclear regulation & processes

Existing nuclear regulatory procedures are centred on large-scale nuclear reactors of relatively similar designs (i.e. water-cooled). **This may present a significant barrier to the deployment of SMRs** – particularly Generation IV reactors. Figure 13 illustrates the broad steps a new nuclear reactor design must pass through before it reaches operation (although the specifics will vary by country).

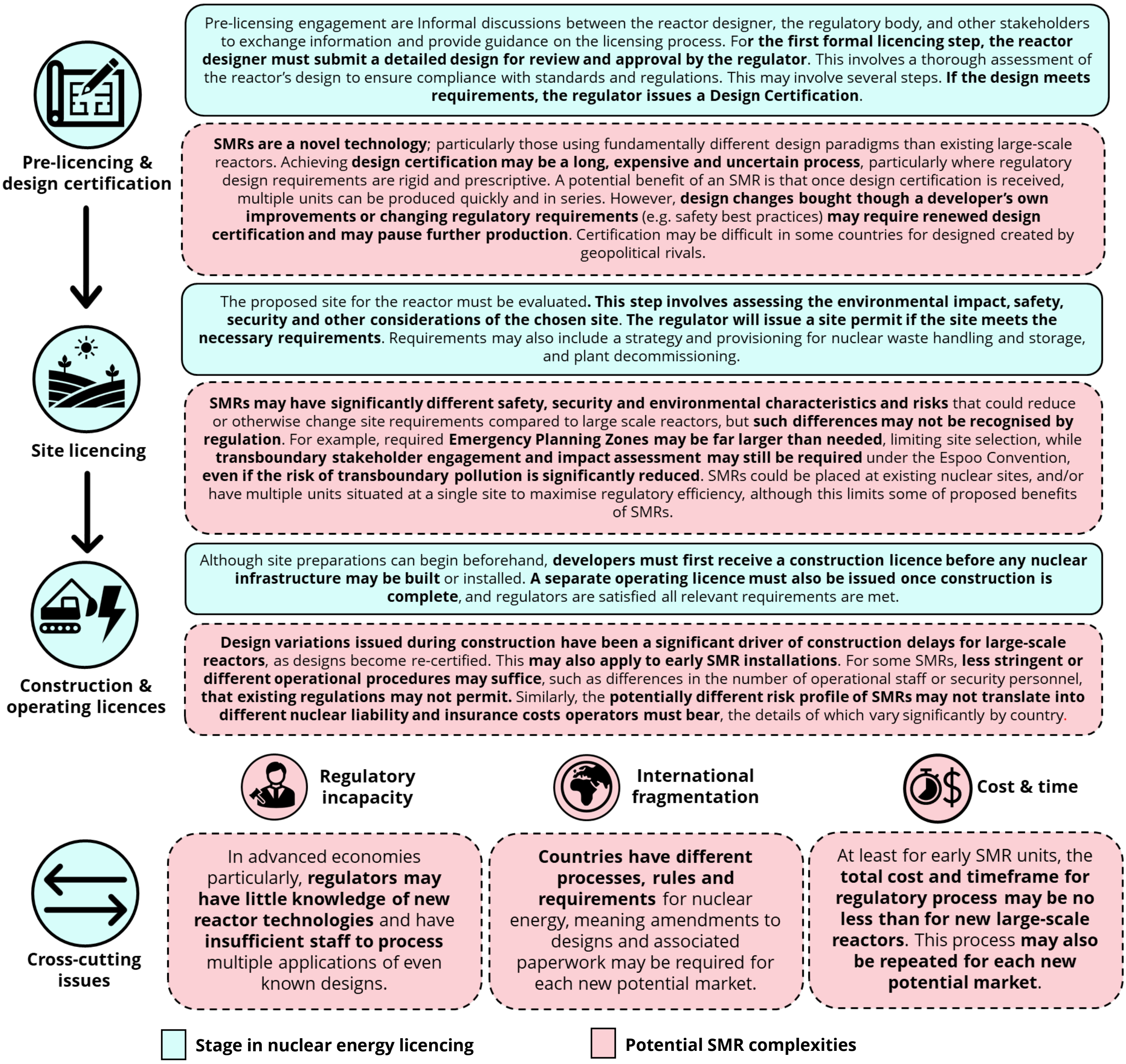


Figure 13 - Broad steps in nuclear power certification and potential difficulties faced by SMRs. Information sources include: IEA (2025); Sam et al (2023); OECD (2021) Graphic created by Greenwheel.

The range of potential issues illustrated in Figure 13 mean that **the time between submitting a new SMR for design certification to receiving a construction licence in that same jurisdiction could comfortably exceed a decade** in the USA and UK, for example.[5]

Once a specific design has received approval this step would not need to be repeated for a given jurisdiction, but remaining licencing steps could still take several years, and any design modifications may require re-approval.

Regulatory barriers to SMR deployment have been recognised, with several countries beginning to take action to tackle them. For example, in November 2024 the US nuclear regulator proposed a number of changes to the licencing framework, including moving to a probabilistic rather than prescriptive risk assessment framework, and efficiencies for multiple plants of common design.[xx] In February 2025, the UK government announced changes to nuclear site restrictions, streamlined regulations with explicit recognition of SMRs, and a new Nuclear Regulatory Taskforce to identify further improvements and efficiencies.[xxi] **However, many of these changes are yet to be fully implemented, and their effect remains unclear**.

Some international collaborations are also under discussion or being trialled, but these also remain in the early stages, and their overall potential also remains unclear. For example, in May 2024 the US, UK and Canada agreed to co-operate to develop shared approaches for reviewing common technical safety issues to meet each country's regulatory requirements. This builds on an existing US-Canada test regulatory cooperation process using SMR designs under review in both the United States and Canada.,[xxii]

Additionally, some countries may choose to deny licences to SMR designs developed in countries seen as geopolitical or otherwise strategic rivals, primarily on safety and security grounds.

Financing

Due to their scale, capital intensity and long lead times, in most countries, large-scale nuclear has largely financed through the State, either directly, through state-owned utilities, or indirectly using concessionary finance or supportive tariff structures (e.g. contracts-for-difference). **The smaller size, lower cost per unit and potentially shorter lead times means that SMRs could mean a greater role for commercial investors**, as with large offshore wind or hydropower projects.[i]

However, most SMR designs already built, under construction or at advanced stages so far have had or been promised some form of public financial support, either in the form of direct investment in the case of those already built or under

[5] In the UK, a new nuclear power station takes around five years to receive Generic Design Approval, while the recent Sizewell C site licencing took four years to secure (EA, 2022; Sizewell C, 2024)

construction, or in the form of grants or loan guarantees for those in advanced stages of development (see Figures 5 and 7).

A significant proportion of the currently planned 25 GW of SMR capacity are being supported through long-term power purchase agreements (PPAs), either from utilities or direct offtakers such as data centres. PPAs with offtakers with strong credit ratings helps developers receive financing but minimises the risk to the offtakers of directly investing in developing and operating an SMR.[i]

Over time, if SMRs become successfully demonstrated and deployed, public financial support may shrink and **commercial investors may become more directly involved and lower the cost of capital they offer, particularly if offtakers are secured through PPAs or other novel structures**. However, the WACC available to SMR developers may remain above that historically available to many large-scale nuclear projects, which in most cases have able to receive capital at costs approaching the low rates available to their Sovereign backers.[i]

Value chain

Fuels

As with existing large-scale reactors, most SMR designs use uranium as the primary fuel, regardless of the specific type of the reactor or fuel medium (e.g. pellets, molten salt). **Uranium supply has four key steps**. Uranium is first mined and milled into yellow cake, then converted to uranium hexafluoride (UF_6), when undergoes enrichment to increase the concentration of the fissile uranium-235 isotope for use in nuclear reactors.

As illustrated in Figure 14, **each of these steps is highly concentrated**. **Just four countries account for nearly three-quarters of global uranium mining and milling** (Kazakhstan, Canada, Namibia and Australia).[i] **Just five plants account for all conversation activity** (one in each country represented), **and nearly all global enrichment capacity is owned by four companies**: China National Nuclear Corporation (CNNC), Russia's Rosatom, Urenco (a British-German-Dutch consortium) and France's Orano.[i]

Although **current and announced supply chain capacity is likely to be sufficient to satisfy demand for uranium fuel in its traditional form in the medium-term**, even with relatively rapid grow in nuclear power, **some countries have been to seek to diversify their supply to manage risks,** particularly through the development of conversion and enrichment capacity in advanced economies.[i]

Many SMRs using Generation IV reactor designs (e.g. molten salt) are being designed to use high-assay low-enriched uranium (HALEU) fuel, which despite its name is uranium enriched to a higher degree than for traditional nuclear fuel. **However, only Russia and China currently have capacity to produce HALEU at scale**.[xxiii]

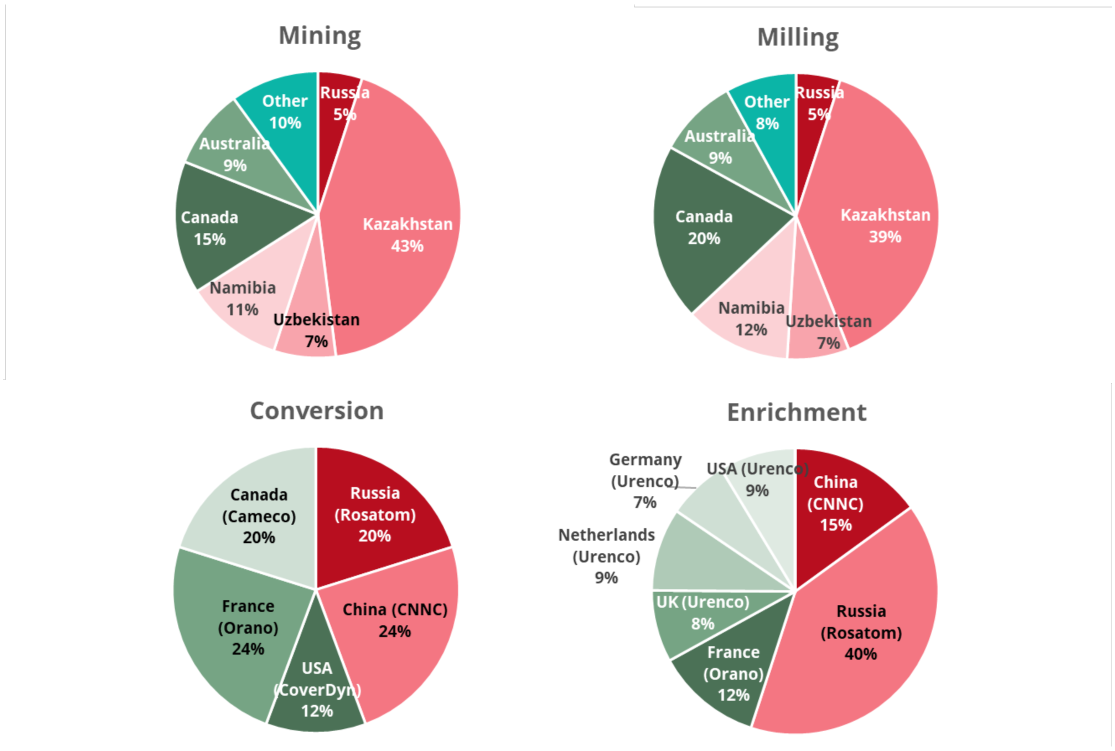


Figure 14 - Market share of the four main steps of uranium fuel supply, by country and company (where most relevant). Data sources: IEA (2025); WNA (2024a); WNA (2024b). Graphic created by Greenwheel.

Other countries, such as the USA and UK, have active strategies and public funding to develop domestic HALEU production capacity. The UK government has announced £300 million to establish domestic HALEU capacity by 2031, with £196 million allocated to Urenco in May 2024 to deliver Europe's first commercial-scale HALEU plant, alongside their existing enrichment capacity in England.[xxiv] The US Department of Energy has created a HALEU consortium and co-funded a demonstration production facility in Ohio.[i] **Over time it is expected that the HALEU supply chain would expand in response to commercial incentives, but this would require sufficient long-term demand**.

Following enrichment, the very final step fabrication into the final fuel form (e.g. pellets). **Fabrication capacity for traditional fuels (pellets) is relatively large and geographically diversified**.[xxv] However, **high-temperature designs such as molten-salt reactors use tristructural-isotropic (TRISO) fuel**, usually with HALEU fuel. **China has the only commercial scale TRISO fabrication plant, although commercial capacity is under development in the USA**.[xxv]

Components

Components for nuclear reactors are subject to strict specifications and quality standards. However, **the lack of nuclear build in advanced economies in recent years has reduced the number of suppliers with proven capability to deliver such components**. Such incapacity contributed to delays and cost overruns in recent nuclear projects. Many of these specifications and quality standards also differ between countries. [xxvi]

For SMRs, some specifications and standards may need to be updated or developed. This is particularly the case for SMRs using Generation IV reactor designs.[xxvi] **However, some SMR developers are planning to maximise the use of serially manufactured items** such as turbine sets, cooling equipment, pumps and values, that are widely used in industrial facilities **and are generally widely available**. In many cases, such equipment may be suitable for certification for use in nuclear applications.[xxvii]

However, this is not always the case. Some SMR designs (e.g. gas-cooled reactors) incorporate turbines usually used in gas power stations, which due to growing demand for new gas-fired capacity have growing lead times in some regions. In the USA, for example, lead times are currently 7-8 years.[xxviii]

Personnel

The reduced construction time claimed for SMRs is associated with reduced labour hours for construction of each unit, which could reduce further with increased modularisation (both in terms of manufacturing and deployment), and learning - although required **labour hours per unit capacity may remain higher than for large-scale reactors**.[xxix]

FOAK and other early units may remain predominantly construction rather than assembly projects, with potentially similar labour hour requirements. Similar skills to large-scale reactor construction are also likely to be required. **The growing lack of qualified personnel could present a significant bottleneck to SMR development, particularly if multiple units are to be constructed in parallel**.

Similarly, SMRs may require fewer staff per unit in operation, but more staff per unit capacity. Data varies, but large-scale reactors require around one person per MW capacity (across all areas of site operation). SMRs may require around 1.5 people per MW capacity, but this may reduce to <1 for sites with several SMR units deployed in parallel.[xxx] However, **this depends on the individual SMR design**, **and the degree to which regulators permit different standards from large-scale reactors**.[xxxi]

Competition with other technologies

Crucial to the prospects for SMRs are its ability to sufficiently deliver forms of value that competing electricity supply technologies cannot – including large-scale nuclear. **If claims from proponents are met, then SMRs could over time achieve substantial deployment** as projected in Figure 1, across the applications illustrated in Figure 2.

However, for many designs successfully demonstrating this greater value and achieving scale may prove difficult, as described above.

Early units are not likely to produce cheaper electricity than large-scale nuclear, most utility-scale renewables, and natural gas. As they may find it challenging to deliver rapid cost reductions**, they are not likely to significantly challenge other**

forms of grid power on this basis (Figure 15) – particularly as key renewable technologies are likely to continue to experience declining costs.

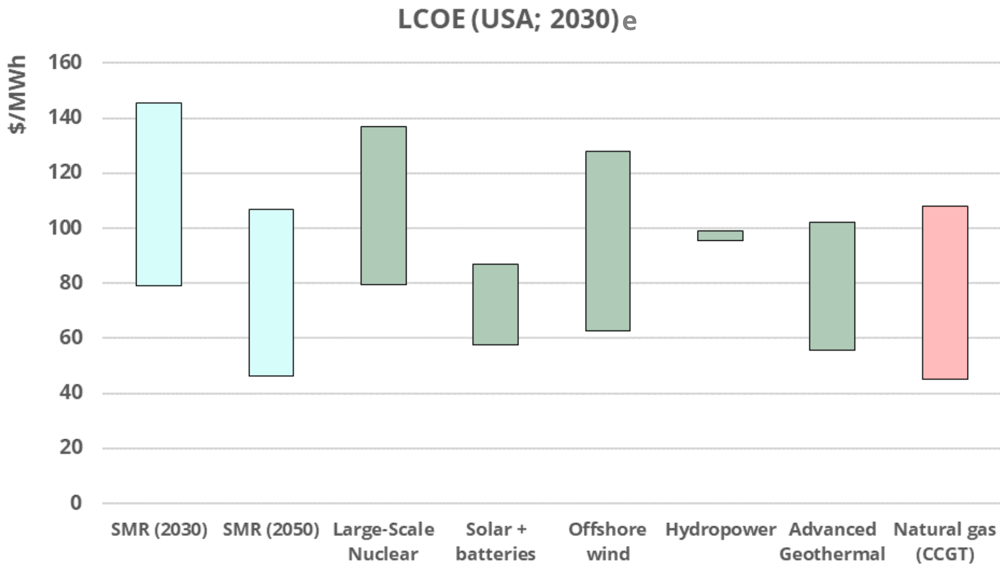


Figure 15 - Projected average LCOE range for key electricity generating technologies in the USA in 2030. Data Sources: Lazard (2024); NREL (2024). Graphic created by Greenwheel. Forecasts and estimates are based upon subjective assumptions about circumstances and events that may not yet have taken place and may never do so.

Despite this, **their potential to provide non-intermittent low-carbon power may provide value to the grid and support deployment**. **However, other solutions may also be able to serve this purpose**, including large-scale nuclear, hydropower, batteries, and geothermal. In some cases, large-scale nuclear or hydropower may be infeasible, for example to their capital intensity, lack of resource or political opposition. Although advanced geothermal technologies may have significant potential, they also remain relatively nascent.[xxxii] Batteries - either standalone utility scale installations or coupled directly with renewables - may be highly cost-effective in helping to balance intermittent renewable supply but may be limited in capacity. This limitation may be overcome in some instances when coupled with other solutions such as high degrees of interconnection with neighbouring grids or market incentives to encourage load shifting. **In instances where ensuring grid stability may come at the expense of full decarbonisation, gas power may instead be attractive**.

In general, **combinations of these solutions may reduce the available space for SMRs to compete on this basis in many instances, but some significant niche opportunities to supply grid power may remain**, such as on relatively small grids where land, renewable resources and gas supply is limited, and substantial interconnection to other grids is infeasible.

For these reasons, **the opportunity space for off-grid applications may be wider**, where a grid connection is not feasible or able to deliver sufficient, reliable and consistent power, a low-carbon solution remains important (or gas power is otherwise infeasible), and cost is not a priority consideration. **This may include some data centres**, **but not**

where developers are seeking to deploy SMRs primarily to avoid current grid connection queues, given the potential for long lead times for SMRs themselves.

SMRs may also face significant competition from alternatives to decarbonising industrial and other forms of heating, particularly from direct electrification, **although niche opportunities may emerge** where significant demand for low carbon power and heat are co-located, such as in some industrial clusters with few alternative options. **SMRs may be well suited to powering some forms of marine transport, but few SMR designs under development are intended for this**.

Endnotes

[i] IEA (2025)
[ii] IAEA (2024)
[iii] NEA (2024)
[iv] Enerdata (2024)
[v] Flyvbjerg & Gardner (2023)
[vi] US DOE (2024)
[vii] IEEFA (2024)
[viii] US DOE (n.d.)
[ix] Breakthrough Institute (2023)
[x] Jin et al (2019)
[xi] Kim et al (2024)
[xii] IAEA (2012)
[xiii] World Nuclear Association (2020)
[xiv] Krall et al (2022)
[xv] Kim et al (2024)
[xvi] CoRWM (2024)
[xvii] Our World in Data (2024)
[xviii] Evans et al (2021)
[xix] Pashby (2024)
[xx] Higgins et al (2024)
[xxi] DESNZ (2025)
[xxii] Nuclear News (2024)
[xxiii] World Nuclear Association (2023)
[xxiv] Nuclear Newswire (2024)
[xxv] World Nuclear Association (2021)
[xxvi] Ahmad & Usman (2025)
[xxvii] NHSI (2023)
[xxviii] Clark (2025)
[xxix] Stewart et al (2022)
[xxx] IAEA (2001)
[xxxi] OECD-NEA (2016)
[xxxii] IEA (2024)

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