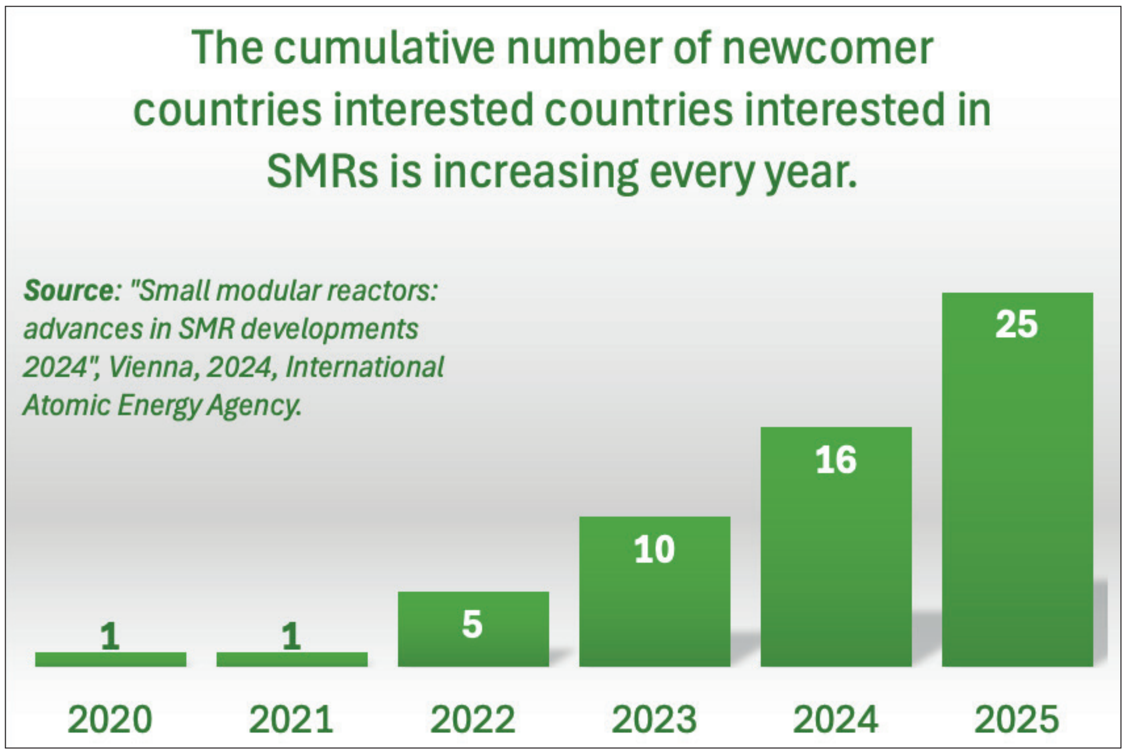
A new nuclear wave: small is beautiful

Small modular reactors (SMRs) are gaining global momentum thanks to their flexibility, enhanced safety, and ease of installation. Currently, there is a significant wave of projects under design or construction, as the technology gears up to play a crucial role in decarbonisation – particularly in powering data centres and the maritime industry. **Joseph Jacobelli** explores.



What are Small modular reactors (SMRs)? In nuclear power, reactors are broadly classified by capacity: 700 MW or more for large conventional reactors, up to 300 MW for SMRs, and up to 10 MW for modular micro reactors (MMRs), according to the International Atomic Energy Agency (IAEA). Advantages of SMRs over larger plants include that they can be assembled in a factory, the installation is simpler, they have increased safety features, their fuel requirements are reduced and their deployment is more flexible, including off-grid and remote areas, highlights the IAEA. The agency notes that the global decarbonisation momentum positions SMRs uniquely due to their smaller size and lower upfront costs.

Widespread innovation across numerous countries has led to nearly 70 SMR designs at various stages of development and deployment. These SMRs range in several key technological buckets, including land-based water-cooled (14), marine-based water-cooled (6), gas-cooled (14), MMRs (13), molten salt (11), and liquid-metal fast-neutron (10) . These technologies are detailed in the IAEA's report: 'Small modular reactors: advances in SMR developments 2024'.

Recent years have seen a global surge in interest and development of SMRs, as highlighted by the IAEA report. In Canada, construction of the GE Hitachi BWRX-300 reactor is scheduled to start in 2025, with grid connection anticipated by late 2028, marking North America's first commercial SMR project. France is pushing SMR advancements through its France Relance 2030 funds, backing projects such as EDF-NUWARD and nine other designs. Japan is discussing six SMR designs and intends to use its operational High Temperature Engineering Test Reactor for hydrogen production. South Korea has approved the SMART technology and is developing the innovative i-SMR, with a new partnership with Canada for potential deployment. In the UK, Rolls-Royce is working on a 470 MW Pressurized Water Reactor. The US has multiple SMR designs underway, including those by NuScale, Westinghouse, and Holtec, alongside microreactors and Generation IV technologies that emphasise sustainability, economic viability, safety, and reliability.

Additionally, several countries are exploring marine-based SMRs for floating nuclear power plants, with notable projects from Seaborg Technologies (Denmark), KEPCO (South Korea), Russia, and China.

Numerous recent developments underscore this momentum. France's EDF announced a cooperation agreement with Italy's ENEA. In the US, Constellation Energy is seeking federal funding for SMRs at its Nine Mile Point plant, and NANO Nuclear Inc recently acquired Ultra Safe Nuclear Corp's MMR technology. The UK is also considering the BWRX-300 SMR from GE-Hitachi Nuclear Energy , which has completed the first phase of the UK design assessment process and advanced to the next phase.

Two notable applications are driving the recent surge in SMR development: data centres and artificial intelligence (AI), and maritime shipping.

The world is experiencing a significant surge in data centre investments, driven by digitalisation and AI. Data centres impact electricity systems in two main ways: they require substantial generation capacity and strain grid networks. The sharp rise in demand from data centre investments must be met with additional generation, predominantly from clean energy sources. In the US, data centre power demand rose from 58 TWh in 2014 to 176 TWh in 2023 and could reach 580 TWh by 2028, a 229.6 per cent increase, according to the Lawrence Berkeley National Laboratory. Data centres are often built away from major load centres, putting pressure on grids, typically due to land price considerations. SMRs are an ideal solution for powering data centres, which typically require 10 to 100 MW, according to the International Energy Agency.

Several projects are underway to harness SMRs for powering data centres. In the US, Energy Northwest is exploring an SMR project with Amazon and X-energy, aiming to build four advanced SMRs generating around 320 MW, with the potential to expand to 12 reactors. Additionally, Google said in late 2024 a deal to procure up to 500 MW from SMRs, to be deployed by Kairos Power between 2030 and 2035.

In the UK, Prime Minister Keir Starmer announced the establishment of 'AI Growth Zones' to support AI data centres, beginning in Culham, Oxfordshire. These zones will collaborate with the private sector to explore renewable energy solutions, including SMRs, to sustainably power AI development.

The global marine shipping sector is highly carbon-intensive and accounts for about 3 per cent of global CO_2 emissions, making it particularly challenging to decarbonise. Numerous solutions are being explored by hundreds of companies and stakeholders, including renewable energy, hybrid systems, fuel cells, larger batteries, ammonia, biogas, biofuels, green hydrogen, green methanol, and SMRs.

The concept of nuclear propulsion is not new; it is widely used by the navies of various countries. A report by Lloyd's Register suggests that SMRs could revolutionise the maritime industry by providing safer, more reliable, and emissions-free shipping solutions. However, the report acknowledges that widespread adoption faces hurdles such as regulatory uncertainty and the need for strong social acceptance. International standards and goal-based regulations are currently being developed to facilitate broader implementation. One notable example is Norway's programme to utilise Generation IV SMRs.

The Norwegian NuProShip project, spearheaded by shipbuilder VARD and backed by various maritime organisations, has concluded its first phase of assessing nuclear power for commercial shipping, evaluating 99 different reactor technologies. Following this initial review, three promising SMR designs have been chosen for further development in the second phase. These include Kairos Power's (US) fluoride high-temperature molten salt reactor using tri-structural isotropic (TRISO) fuel particles, Ultra Safe Nuclear Corp's (US) helium-cooled gas reactor also employing TRISO fuel particles, and Blykalla's (Sweden) lead-cooled reactor concept utilising uranium oxide as fuel. The initiative aims to create a commercially viable, zero-emission technology for deep-sea ships that meets the needs of all stakeholders and requires no subsidies post-development.

While the investment momentum in SMR technologies is undeniable, several significant challenges remain. Achieving a competitive cost per MWh is crucial for economic viability. Regulatory barriers pose another major obstacle, as existing nuclear rules often cater to larger, traditional reactors, necessitating substantial adjustments for SMRs. Public resistance, driven by safety concerns, waste disposal issues, and fears of accidents, can also impede project progress. Environmental considerations extend beyond safe waste disposal to include potential impacts on local ecosystems during construction and operation. Additionally, technological hurdles such as ensuring reliability, efficiency, and cost-effective production must be overcome.

However, as the industry grows and matures, and proven technologies are deployed, the prospects for SMRs appear promising.

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