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IAEA
International Atomic Energy Agency

small modular reactors

Advances in SMR Developments

2024

INTERNATIONAL CONFERENCE ON SMALL MODULAR REACTORS AND THEIR APPLICATIONS
21–25 OCTOBER 2024

Small Modular Reactors: Advances in SMR Developments

2024

Nuclear energy has arrived at an important milestone. A new global consensus emerged from the 2023 United Nations Climate Change Conference (COP28) in Dubai. In the historic first Global Stocktake under the Paris Agreement approved at COP28, the 198 signatory countries to the UN Framework Convention on Climate Change included nuclear among the technologies whose deployment needed to be accelerated for net zero carbon emissions to be reached.

The shift in acceptance of nuclear reflects the realization that rapid, deep decarbonization, especially in hard to abate areas such as industry, will not be possible without a significant increase in nuclear capacity. To that end, more than 20 countries attending COP28 pledged to work towards tripling nuclear power capacity by 2050.

Advanced nuclear power technologies such as small modular reactors (SMRs) and microreactors, a subset of SMRs, have the potential to play a key role in the coming nuclear power expansion.

The high case scenario of the IAEA's latest projections sees nuclear electrical generating capacity in 2050 being two and a half times greater than today. A quarter of that new capacity is projected to come from SMRs.

SMRs have much going for them. They are well positioned to enable the decarbonization of electricity and industries through low carbon heat and hydrogen production. They are also well suited to replace fossil fuel generation in remote communities and industries. Some SMRs are also optimized to work flexibly alongside renewables and energy storage. Given their size and lower upfront costs, SMRs offer a new nuclear power option for countries and industries for which conventional large nuclear power reactors are not suitable. Technology companies are already striking deals with SMR producers as they look for ways to cleanly power their energy-hungry data centres. Developing countries are looking to SMRs as a more affordable option for smaller grids. This is spurring innovation across the nuclear power sector in several countries, with some 70 SMR designs at different active stages of development and deployment worldwide, according to the IAEA's Advanced Reactors Information System (ARIS) database.

To meet the needs of countries and industry, we must ensure timely demonstration and deployment of SMRs. International cooperation and collaboration are essential. The IAEA Platform on Small Modular Reactors and their Applications offers comprehensive support to Member States. Meanwhile, our Nuclear Harmonization and Standardization Initiative (NHSI) is helping to facilitate the development and deployment of safe and secure SMRs by working towards greater harmonization of regulatory approaches and industrial standardization.

This publication features the latest ARIS data and information and will provide further support to Member States considering advanced nuclear power technologies. Much is changing in the world of nuclear and of SMRs. The information here is key to good decision making that is crucial to providing sustainable development and prosperity for all. ■

Rafael Mariano Grossi
IAEA Director General

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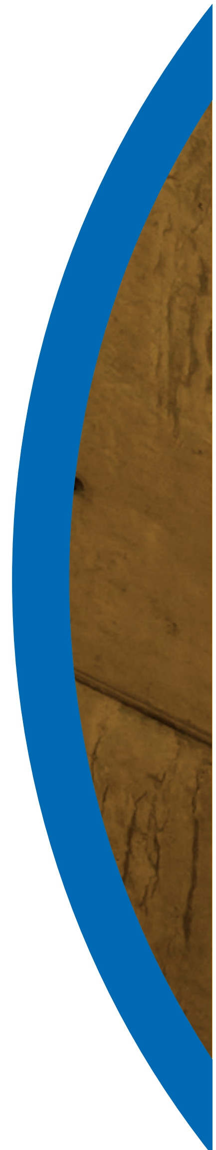
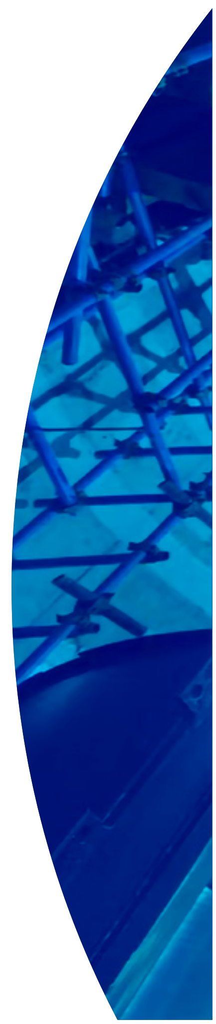
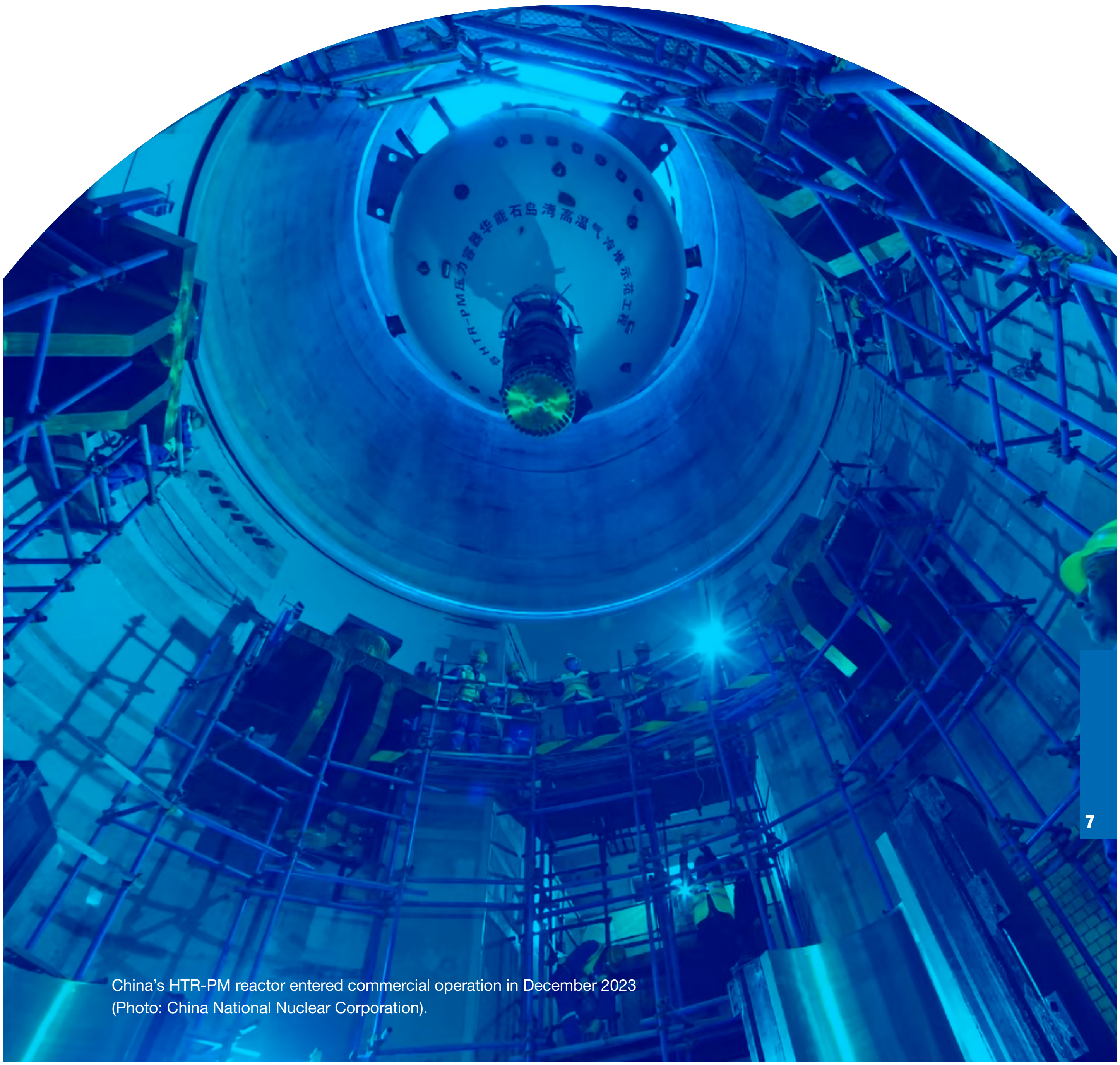
IAEA Director General Rafael Mariano Grossi at the opening of the Nuclear Energy Summit (Brussels, Belgium, March 2024).

Access the 2024 SMR catalogue.



Small Modular Reactors: A New Option for Nuclear Power





China's HTR-PM reactor entered commercial operation in December 2023 (Photo: China National Nuclear Corporation).

The urgent need to accelerate the deployment of nuclear energy to meet climate change goals was underscored in the first Global Stocktake under the Paris Agreement at the 2023 United Nations Climate Change Conference (COP28) in Dubai, United Arab Emirates, where more than 20 countries also pledged to triple global nuclear power capacity by 2050. But nuclear power—unique in generating low carbon electricity, heat and hydrogen at scale—is also key to meeting energy security and sustainable development goals. Advanced technologies such as small modular reactors (SMRs) and microreactors (MRs) can produce baseload and dispatchable electricity as well as other clean energy products needed to decarbonize sectors such as industry, transport and buildings as well as for seawater desalination. Some SMRs are also designed for flexible operation with variable renewable energy sources such as solar and wind, providing a platform for their wider deployment.

Global interest in SMRs is rising, with units already deployed in China and the Russian Federation and more than 68 active designs[1], according to the IAEA's Advanced Reactor Information System Database (ARIS), at different stages of development around the world, although not all of them are intended to become commercial reactors. SMRs typically have a power capacity of up to 300 MW(e) per unit and can be shop fabricated and transported as modules. Most SMR designs have advanced safety features and can be deployed as single or multi-module plants. They are being developed across various reactor technologies, including water cooled, gas cooled, liquid metal cooled and molten salt designs. Key drivers of SMR deployment include having flexible power generation, replacing aging fossil fired units and allowing a scaled deployment to ease financing.

SMRs are ideal for niche markets where large reactors may not be viable, such as areas that have small grids or are remote. Their modular design allows for shorter installation times and economies of serial production. Near-term deployable SMRs are expected to have safety performances comparable to or possibly better than existing reactor designs. Smaller footprints and flexible siting make SMRs suitable for regional or industrial clusters, including in embarking countries that are beginning their journeys towards introducing nuclear energy. Transportable systems are also being developed for remote sites or as marine plants for both electricity and industrial heat. SMRs are also envisioned for use in marine propulsion to decarbonize global shipping.

Despite significant advancements, some technical issues are still being addressed. For example, control room staffing, human factors engineering for multi-module plants, applicability of existing codes and standards, manufacturing approaches for novel components, fuel supply and fuel cycle back-end solutions still need attention. Moreover, regulatory discussions continue about potential deployment advantages, such as reduced emergency planning zones and operation of multiple modules from a single control room. Although SMRs promise lower upfront capital costs per unit, their overall economic competitiveness is yet to be proven.

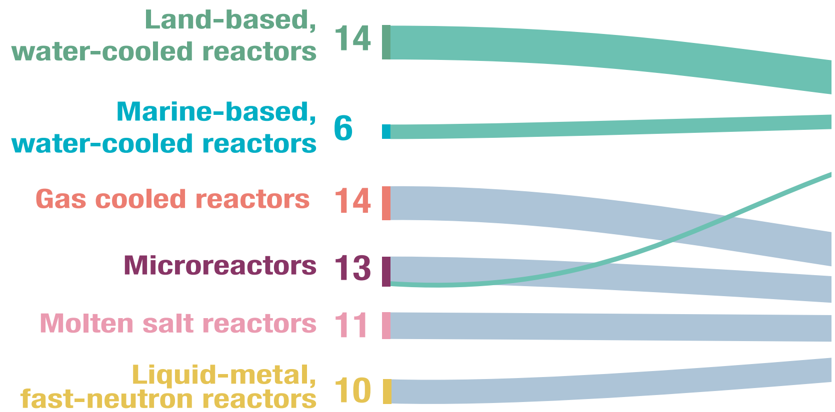
This publication explores SMR technologies under development, their potential growth trajectory, and the lifecycle of SMR development from concept to decommissioning. It also examines the unique global role the International Atomic Energy Agency (IAEA) plays in supporting the establishment of sustainable nuclear power programmes and in catalysing technology development and deployment in Member States, including through efforts such as the SMR Platform and the Nuclear Harmonization and Standardization Initiative (NHSI). Most data presented in this publication come from the 2024 update to the ARIS database. ■

1 Since 2012, the SMR catalogue has listed SMR designs, with the 2022 edition featuring eighty three designs. The 2024 edition only includes designs confirmed by their designers to the IAEA, also called "active designs".

The Advanced Reactor Information System (ARIS) is a web-based database developed by the IAEA to provide Member States with comprehensive and up-to-date information on advanced nuclear power plant designs, including SMRs. ARIS offers standardized reactor design descriptions derived from data supplied by various design organizations, covering reactors of all sizes and developmental stages—from near-term evolutionary designs to innovative concepts. The 2024 update of ARIS incorporates the latest advancements and trends in reactor technology development, including an e-booklet titled Advances in Small Modular Reactor Technology Developments (2024), which highlights the development of active SMR designs.

Access the Advanced Reactor Information System (ARIS).

Family of SMR Technologies



Land-based, water-cooled SMRs

These designs use light water reactor (LWR) and heavy water reactor (HWR) technologies to leverage mature technology prevalent in current large reactors. There are currently some 14 land-based, water-cooled SMR designs from nine Member States, including integral pressurized water reactors (PWRs), compact PWRs, loop-type PWRs, boiling water reactors (BWRs) and pool-type PWRs for district heating — all parts of the water cooled reactor (WCR) family. The integral PWR CAREM is under construction in Argentina, and first criticality is targeted for 2028. Construction began on another SMR, the ACP100 in China, in 2021; this reactor should start commercial operation by 2026. Additional designs for near-term deployment include the RITM-200N (the Russian Federation); the NuScale VOYGR, the Westinghouse AP300 and the GE-Hitachi BWRX-300 (the United States of America (USA)); the Rolls-Royce SMR (the United Kingdom (UK)); and the EDF-NUWARD (France).

Marine-based, water-cooled SMRs

There are currently six marine-based SMR concepts for deployment; these designs are barge-mounted floating power units, offering flexible deployment options. Notable among them are two units of the KLT-40S type, and these PWRs have been operational since 2020 on the Akademik Lomonosov floating nuclear power plant (NPP) in Pevek, Russian Federation. Other countries advancing marine-based, water-cooled SMRs include China, the Republic of Korea and the USA.

Gas cooled SMRs

There are currently 14 high-temperature, gas-cooled (GCR or HTGR) type SMRs under development or in operation, providing high-temperature heat (≥ 750°C) for efficient electricity generation, industrial applications and cogeneration. Highlights include the high-temperature reactor–pebble-bed module (HTR-PM), which is located in China, was connected to the grid in December 2021 and has operated full power since 2022. Two other HTGR test reactors (one in Japan and one in China) have also been operational for over 20 years.

Liquid metal-cooled, fast-neutron SMRs

Ten SMR designs use fast neutrons with liquid metal coolants, including sodium, pure lead, and lead-bismuth eutectic. Significant advances include the BREST-OD-300, a lead-cooled, fast-neutron reactor that is under construction in Seversk, Russian Federation. Other designs under development include a lead-cooled fast reactor by Newcleo, based in France, and a sodium-cooled fast reactor by Oklo in the USA.

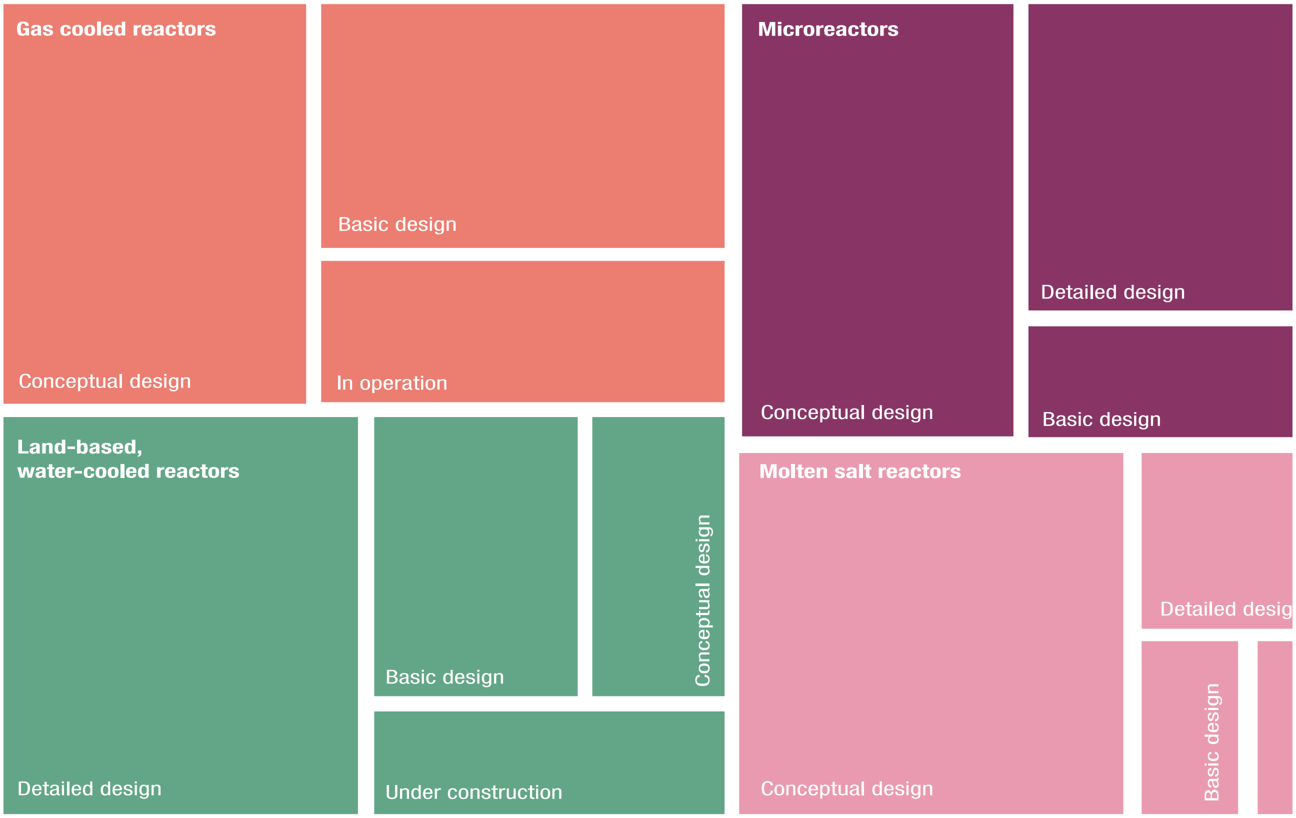
Molten salt SMRs

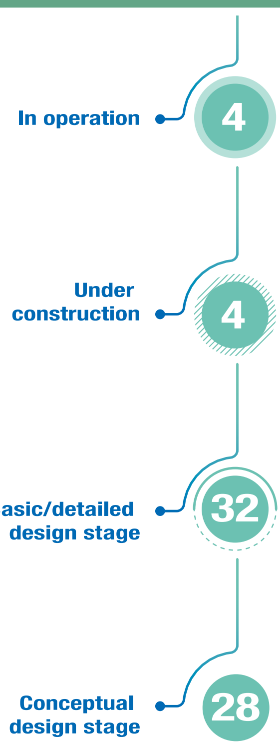
Eleven SMR designs use molten salt fuel and coolant technologies, one of the six Generation IV designs. Molten salt reactors (MSRs) offer enhanced safety, low-pressure single-phase coolant systems, high efficiency, and flexible fuel cycles. Designs are in design stages in Canada, Denmark, France, the Kingdom of the Netherlands, the UK and the USA. One design has just entered the construction stage in the USA.

Microreactors

These reactors are small SMRs generating typically up to 30 MW(th) and use various coolants, including light water, helium, molten salt, and liquid metal (heat pipe cooling systems have also been proposed). Several designs are undergoing licensing in Canada and the USA for near-term deployment. Microreactors target niche markets such as micro-grids, remote areas, disaster recovery, and critical service restoration. Thirteen designs are currently under development.

Family of SMR technologies. Among the 68 active designs, 22 are water cooled reactors (WCRs) and 46 are not WCRs (N-WCRs).





Recent SMR Highlights

In addition to countries that have deployed or are developing SMR designs, a number of other countries have included SMRs in their technology considerations or continue to monitor developments, including embarking or newcomer countries such as Estonia, Ghana, Indonesia, Jordan, Kenya, the Philippines, Poland, Saudi Arabia, Sudan, Uganda and Zambia, and countries that are expanding their nuclear power programmes such as Bulgaria, the Czech Republic, Romania and South Africa. ■

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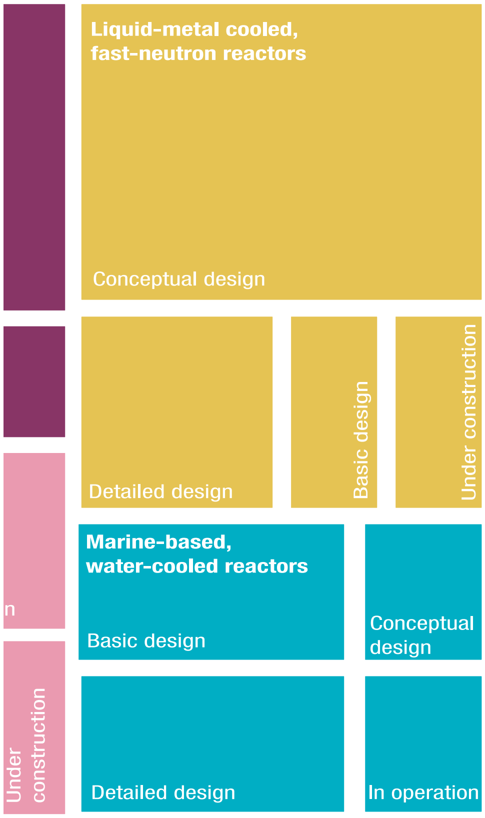
Most SMR designs are in the basic/detailed design stage or conceptual design stage.

Access the 2024 SMR catalogue.



Status of Development of Active SMR Designs

SMRs in Operation

In 2024, two SMR NPPs are in operation, in addition to two high-temperature test reactors.

- In the **Russian Federation**, the Akademik Lomonosov floating NPP, with two KLT-40S reactors of 35 MW(e) each, was refuelled for the first time in 2023. This floating NPP has been in commercial operation since May 2020, supplying heat and power to the town of Pevek in the Chukotka region.
- In **China**, the demonstration HTR-PM at the Shidaowan site started commercial operation during December 2023. It generates 200 MW(e) at full power, from two reactors linked to a single power turbine. ■

SMRs under Construction

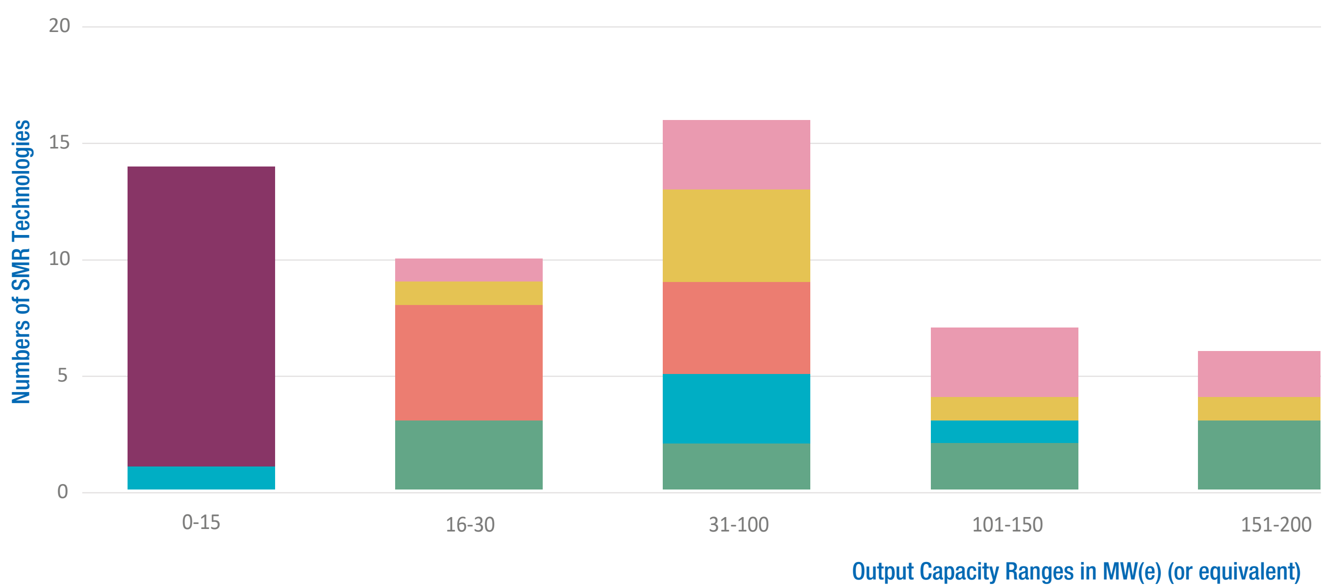
- In **Argentina**, the CAREM-25 prototype reactor is under construction with grid connection targeted for 2028.
- The ACP100 demonstration plant at Changjiang, Hainan province in **China**, has been under construction since 2021. The reactor core was installed during August 2023. This multi-purpose PWR unit, referred to as the Linglong One, is due to generate 125 MW(e) of electricity by 2026.
- In the **Russian Federation**, construction of the BREST-OD-300 reactor began in June 2021 in Seversk, Siberia. The 165-tonne steel reactor base plate was installed in 2024, marking the start of major installation work. The pilot demonstration reactor is expected to become operational in 2026 and generate 300 MW(e).
- Construction began during July 2024 on Kairos Power's Hermes Low-Power Demonstration Reactor in Oak Ridge, Tennessee, **USA**. This reactor is the first and only Generation IV reactor to receive a construction license from the U. S. Nuclear Regulatory Commission, and the first non-lightwater reactor permitted in the USA in over 50 years. The Hermes reactor will not generate electricity; instead, this fluoride salt-cooled, high-temperature reactor should demonstrate affordable heat production. ■

▲ This treemap compares the types of reactor designs and the stages of development. Note that most models are in the design stage.

Highlights Continued

Notable SMR Developments

- In **Canada**, construction of the GE Hitachi Nuclear Energy BWRX-300 reactor that uses natural circulation is planned to begin in 2025 at the Darlington site, and connection to the grid is expected by the end of 2028. This would be the first commercial SMR project to begin construction in North America.
- **France** is pursuing and encouraging developments of SMRs through the France Relance 2030 funds, including the EDF-NUWARD SMR (which is also a PWR) and nine other advanced designs: NAAREA (Nuclear Abundant Affordable Resourceful Energy for All), Newcleo, Jimmy Energy, Otrera, Calogena, Blue Capsule Technology, Hexana, Stellaria and Thorizon.
- In **Japan**, six SMR designs developed by private sector stakeholders are under discussion. The High Temperature Engineering Test Reactor (HTTR) at the Japan Atomic Energy Agency, with a thermal power of 30 MW, is operational and is planned to be utilized for a hydrogen production demonstration project.
- The **Republic of Korea** has two notable SMR designs. The first, called the System-integrated Modular Advanced Reactor (SMART) and developed by KAERI with Saudi Arabia, is a PWR capable of generating 100 MW(e). It was granted standard design approval in September 2024 by the regulatory body of the Republic of Korea while a new partnership with Canada has been announced, with a licensing application to be submitted for the potential deployment at Chalk River Laboratories in Canada. The second, called i-SMR, is an integral PWR designed to generate 170 MW(e) and is being developed by a national consortium.
- In the **United Kingdom**, Rolls-Royce is developing a PWR of 470 MW(e) capacity.
- Numerous SMR designs are under development in the **USA**. The licensing and demonstration of the NuScale VOYGR design, which could comprise six modules that generate 77 MW(e) each, has shifted from Idaho Falls, Idaho to other potential users in the USA and Europe, including Romania. Westinghouse has submitted a pre-application for design certification for its AP300 SMR, and Holtec International is developing its SMR-300. Generation



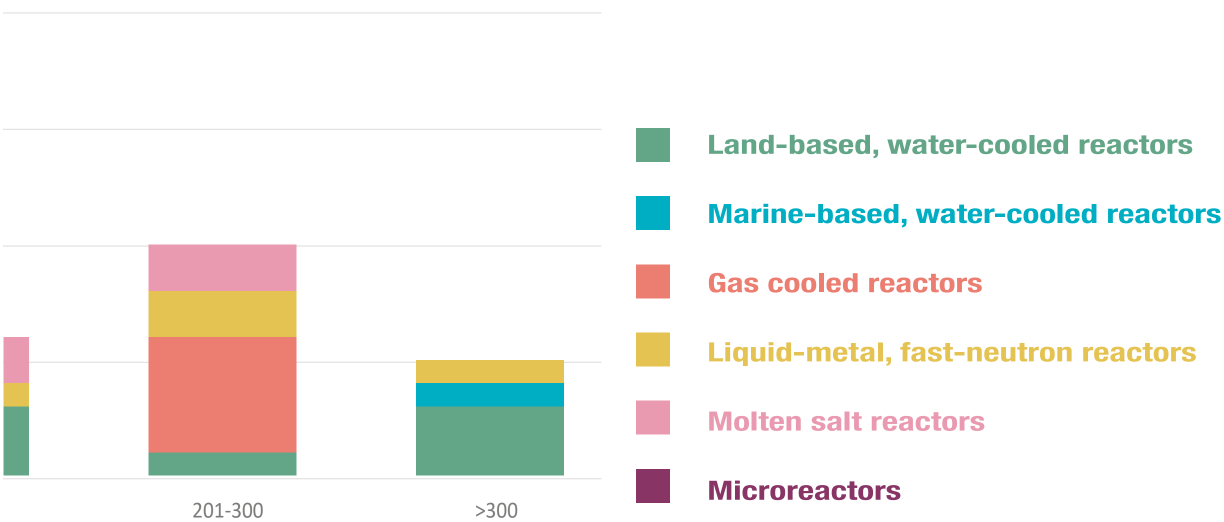
Types of SMRs in terms of their output capacity ranges (MW(e)).

IV reactor technologies include the X-energy Xe-100, which uses HTGR technology and the Oklo Aurora Powerhouse and Westinghouse eVinci microreactors. The Microreactors Applications, Research, Validation and Evaluation (MARVEL) project is also ongoing at the Idaho National Laboratory. ■

Notable Floating Nuclear Power Plant Developments

Several countries are engaged in the design development of marine-based SMRs for floating NPPs for on shore and offshore applications. A reactor design start-up company, Seaborg Technologies in **Denmark**, is developing a compact molten salt reactor to produce 100 MW(e). The KEPCO E&C (**Republic of Korea**) continues the development of BANDI, a PWR-based floating power unit to generate 60 MW(e). The **Russian Federation** has adopted the RITM-200M design (already used in icebreakers) for upcoming floating NPPs, while the China National Nuclear Corporation (**China**) is developing a floating design, the ACP100S. ■

Bow of an ice breaker going through ice.



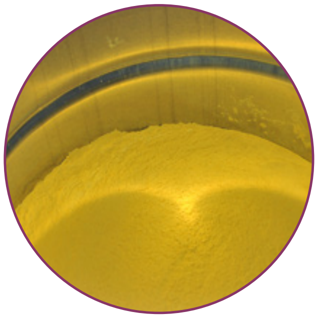
Nuclear Fuel Cycle Options for SMRs

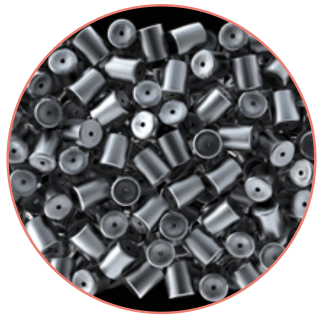
The designs of future SMRs and the operation of existing SMRs can benefit from the experience gained from existing power and research reactors (i.e. in fuel supply and spent fuel, waste and decommissioning management). Early life cycle planning ensures that SMRs remain sustainable by establishing the right infrastructure, building trust and confidence among stakeholders and preventing future liabilities.

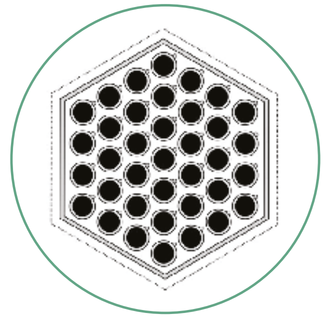
Many SMR design concepts and operational procedures are similar to those of large NPPs currently in operation (such as oxide fuel-based reactor technologies), enabling consistent implementation of nuclear fuel cycles. However, advanced SMR designs using new fuel concepts (such as metallic, carbide, nitride or particle fuels) will require the deployment and licensing of new industrial fuel cycle facilities to supply these fuels (which include enrichment, conversion/deconversion and fuel fabrication steps) and to manage them after irradiation as well as the waste generated by the SMRs (the management of which will include processing/reprocessing, predisposal and disposal steps). In parallel, new cask design and licensing will be necessary for the transportation of the radioactive materials (fresh fuels, spent fuels and waste) used in and generated by SMRs' nuclear fuel cycles. Hence, a lot of research, development and demonstration (RD&D) activities will be needed to support all these industrial developments in the next decades.

Fuel cycle choices are often determined by governments, which may impose restrictions on SMR vendors. Many SMR designs propose longer operation cycles between refuelling, raising issues regarding fuel and cladding performance at higher burnups, core maintainability, and spent fuel management (including storage, transport and recycling routes). Innovative fuel cycles include Th/U-233, reprocessed uranium (RepU), MOX and nitride, carbide, metallic, and transuranic (TRU) fuels; some of them require advanced reprocessing technologies such as pyro processing, which are still in research and development (R&D) stages.

Understanding the specific fuel cycle approaches of SMR designs is key. Knowledge of the fuel cycle helps in discussions about fuel supply requirements, spent fuel and waste management routes, final waste repository needs, and safeguards by design (SBD) implementation. Early planning can mitigate unforeseen technological, environmental and financial issues. ■







Material for SMR Fuels

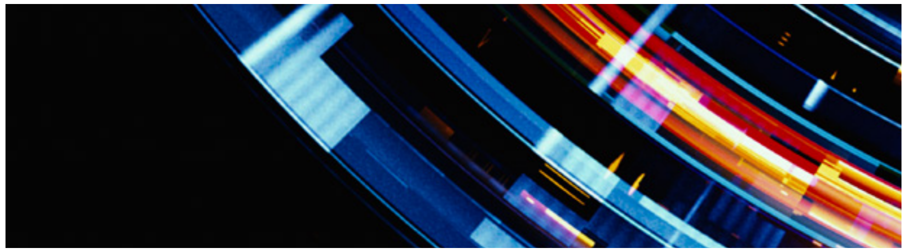
Many SMR designs require high assay low enriched uranium (HALEU) fuel to operate, between the 5% U-235 that powers most NPPs in operation and up to 20% U-235. HALEU is produced in the Russian Federation and the USA, mostly for use in research reactors and for possible use in operating light water reactors. The facility in the Russian Federation is currently the only one that manufactures HALEU on a commercial scale. Some countries are boosting their production capacity to ensure that sufficient HALEU supply becomes available for the market.

The Euratom Supply Agency estimates that, by 2035, the European Union (EU) will need between 700 kg and a ton of HALEU each year to keep its research reactors in operation. This estimate does not include any future demand from advanced reactors used for power generation. Euratom has recommended that the EU develop its own capacity to produce HALEU fuel due to concerns over the future security of supplies. However, the licensing, building, securing and operation of such facilities requires significant investment, and European producers say they still need to see the business case for that investment. European companies could start producing HALEU in as little as five years, and there are plans for the expansion of an existing plant in France. In addition, the construction of new facilities in the UK and the USA is envisaged.

The US nuclear industry has stated that the deployment of some SMR designs could be delayed by years due to the lack of HALEU. Currently, nine out of ten advanced reactor designs funded by the Government of the USA will need HALEU fuel in the next decade. Projections by the U. S. Department of Energy (DOE) suggest that more than 40 000 kg of HALEU will be needed in the USA by 2030, with that amount set to increase year after year as the new fleet of advanced reactors is put into operation.

Working to address this need, the DOE is investing in domestic HALEU production. It has set up a HALEU Consortium and has co-funded a demonstration production plant in Piketon, Ohio, USA. During June 2023, the Piketon facility was cleared to begin enrichment operations. To complement this, production is beginning on another type of HALEU fuel by down-blending government stockpiles of high enriched uranium. ■

Refuelling Cycles of SMRs



Land-based, water-cooled SMRs

Land-based, water-cooled SMRs, typically using existing LWR fuel designs with U-235 enrichment below 5%, usually have refuelling cycles of 18–24 months. These designs achieve average burnups over 45 GWd/tHM[2], with half the assemblies replaced each cycle to optimize fuel economics and to maximize discharge burnup. The aim for these SMRs is high-capacity factors (over 90%) and low operation and maintenance costs. They tend to be similar to existing large, water-cooled designs so that they utilize existing supply chains and leverage regulatory familiarity.

Marine-based, water-cooled SMRs

Marine-based, water-cooled designs use fuels with higher U-235 enrichment levels (close to 20%) to ensure long operation periods in remote areas (refuelling cycles up to 120 months). The first operational SMR, the PWR-type KLT-40S on the Akademik Lomonosov floating NPP, uses approximately 20% enriched fuel (a 30–36 month refuelling cycle), achieving an average 45.4 GWd/tHM discharge burnup. Refuelling occurs 14 days after shutdown, with fresh fuel loaded in all core positions. The RITM-200M optimized floating power unit can have a refuelling cycle up to 120 months and then can return to the country of origin with spent fuel for post-reactor maintenance and reprocessing.

Gas cooled SMRs

HTGR-type SMRs use inherently safe fuel and feature pebble-bed or prismatic core designs using tristructural isotropic (TRISO) coated particle fuel, with higher U-235 enrichment levels with UO2 or UCO particles. Particle fuel (TRISO coated) is made of particles covered in three layers of carbon and ceramic based materials that prevent the release of radioactive fission products. These particles can then be shaped into either billiard ball sized spheres placed in hexagonal graphite blocks called pebbles or cylindrical pellets. HTGR-type SMRs generally support sustainability with high thermal efficiency and burnup and can handle various advanced fuel cycles, though most start with an open cycle. China's two-unit pebble bed HTR-PMs adopt online refuelling or long refuelling cycles of 25–60 months. The design of the EM2 high-temperature, gas-cooled fast reactor (General Atomics Electromagnetic Systems, USA) should allow the reactor to operate for over 30 years without refuelling.

2 The fuel burnup (also known as fuel utilization) is a measure of how much energy is extracted from a primary nuclear fuel source, and is counted in gigawatt-days/metric ton of heavy metal (GWd/tHM).

Liquid metal-cooled, fast-neutron SMRs

Compared to water-cooled SMRs, liquid metal-cooled, fast-neutron SMRs have higher enrichment levels (14% to 20% U-235) and long fuel cycles up to 30 years. The BREST-OD-300 (under construction in the Russian Federation) will use a closed nuclear fuel cycle with mixed nitride fuel. The lead fast reactor (LFR; Westinghouse, USA) and the SEALER-55 (Blykalla, Sweden) have high-enrichment fuel and long-life core designs, with options for open or closed fuel cycles. The LFR-AS-200 (Newcleo, France) also uses a closed nuclear fuel cycle, relying on stockpiled MOX fuel from reprocessing.

Molten salt SMRs

Molten salt reactors differ significantly from solid-fuelled reactors, as they use fuel in a molten state, eliminating risks associated with fuel cladding failures. MSRs feature long fuel cycles up to 150 months and online refuelling. The IMSR400 design from Terrestrial Energy (USA) has a core unit that is replaced every seven years. The Waste Burner reactor (Copenhagen Atomics, Denmark) and the ThorCon reactor (Indonesia and USA) adopt various fuel compositions and enrichment levels, aiming for sustainability.

Spent Fuel and Radioactive Waste Management

Whether or not an SMR design is envisioned to use an open or closed fuel cycle as part of the refuelling strategy, effective spent nuclear fuel and radioactive waste management are crucial for the sustainable deployment of SMRs. Early consideration of spent fuel and radioactive waste management in SMR design, leveraging existing technologies and adapting to new fuel materials are key strategies. The specific approaches to spent fuel and radioactive waste management depend on the SMR design and a country's existing infrastructure and management plans. These plans could require adjustment or enhancement to accommodate the need for novel or additional waste management concepts and technologies.

Existing Technical Solutions

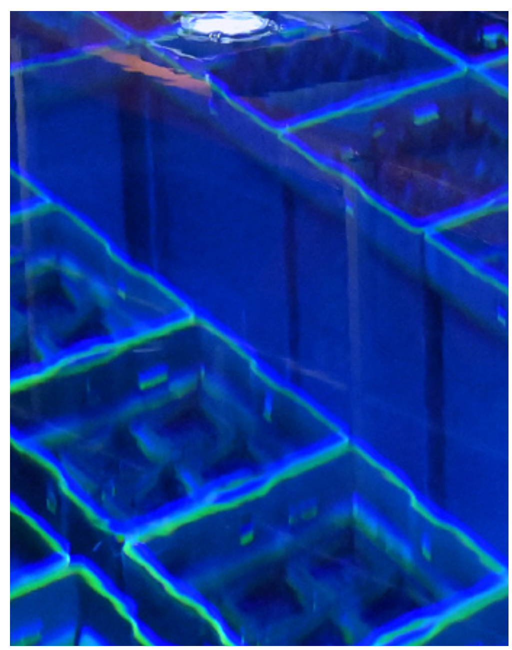
Current solutions for spent nuclear fuel and radioactive waste management include recycling (through processing or reprocessing), conditioning and disposal. The approach for the disposal of high level waste (HLW) including spent nuclear fuel declared as waste, which has international consensus, is in a mined deep geological repository (DGR). Advanced processes such as partitioning and transmutation can further reduce the impact of radioactive waste to be disposed of in a DGR. Many countries currently operate facilities to effectively manage and dispose of low level waste (LLW) and to a lesser extent intermediate level waste (ILW). ■

Early Consideration in SMR Design

Incorporating spent fuel and radioactive waste management early in the SMR design process can address fuel cycle uncertainties, reduce costs, enhance public acceptance and ensure all radioactive waste generated has an identified pathway to disposition. In addition, addressing these aspects at the design stage provides the greatest flexibility to leverage and optimize opportunities for reduction, reuse, and recycling thereby positively contributing to the overall sustainability of SMRs. Advances in computer codes and simulations help assess spent nuclear fuel and radioactive waste management during the design stages, though new fuel materials require experimental validation. Some SMRs, with features such as longer refuelling cycles (up to 30 years), propose using existing infrastructure for new spent nuclear fuel and radioactive waste streams. ■

Land-based, water-cooled SMRs

Land-based, water-cooled SMRs generally adopt spent nuclear fuel and radioactive waste management plans similar to advanced water cooled reactors. Advances in dry storage technologies, such as MPC-37 (Holtec International, USA; PWR fuel), support future spent nuclear fuel storage. Some SMR designs also incorporate systematic dose reduction during decommissioning; and designs, such as integral PWRs, reduce vessel embrittlement and activation of steel components.



Gas cooled SMRs

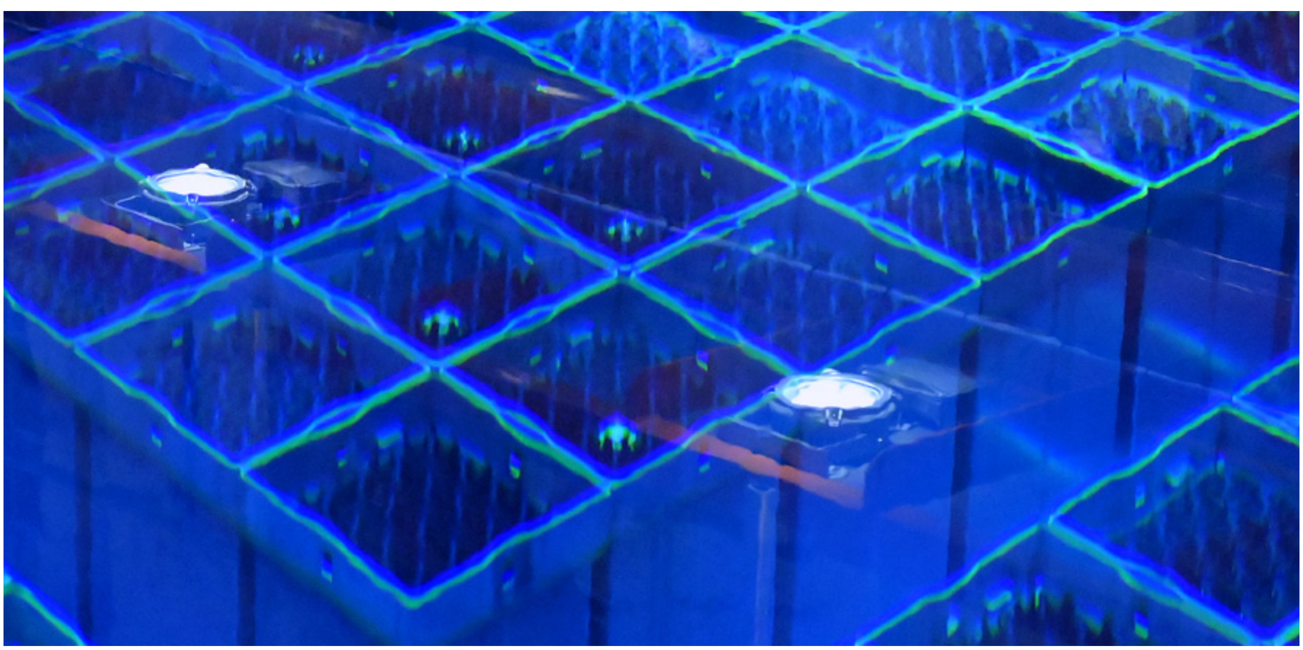
HTGRs produce less high level waste (HLW) per unit of energy, with lower plutonium content and heat generation. Their storage and disposal requirements depend on the volume, activity and decay heat of the waste. HTGRs have a dedicated waste handling system and use advanced packaging due to lower specific source terms. Options include reprocessing, separation and direct disposal, with no commercial scale implementation of either option yet. The solution for graphite still needs to be addressed.

Liquid metal-cooled, fast-neutron SMRs

These SMRs can substantially reduce the radiotoxicity of the high level waste generated and disposed in a DGR by burning long-lived plutonium and minor actinides. Designs, such as the sodium-cooled 4S SMR (Toshiba, Japan), focus on waste reduction during operation and decommissioning. Some designs, such as ARC-100 (ARC Clean Technology, Canada), plan long-term storage in containers suitable for disposal in a DGR.

Molten salt SMRs

Molten salt reactors actively remove and store gaseous fission products. Off-site reprocessing or conditioning of spent salt is envisaged, with residual waste transported to geological repositories. Actinides separated at reprocessing facilities are recycled, which could reduce the lifetime of waste to a few hundred years.



Market Trends and New SMR Users

The market for SMRs is developing quickly, fuelled by technological innovations, growing energy demands and an increasing focus on clean and dependable power. This section examines different facets of SMR market growth, such as financing, newcomer countries interested in SMRs, and the potential for applications beyond electricity generation. It also describes how emerging end-users, such as tech companies eager for clean electricity to power their data centres and artificial intelligence (AI) applications, are influencing the future direction of SMRs.

Understanding and managing costs and risks, securing affordable financing, building local infrastructure, enhancing global supply chains, and effectively communicating the benefits of SMRs will be essential for the successful deployment and contribution of SMRs to help meet global energy, climate and development goals in the coming years.

Cost and Cost Drivers

Like other electricity generation technologies, SMRs can be evaluated using the levelized cost of electricity (LCOE) metric, which represents the per-megawatt-hour cost of building and operating a plant over its lifetime. While a key challenge in SMR deployment is managing the high upfront capital expenditures (CAPEX) associated with construction, which significantly impacts LCOE, SMRs are designed for modular and standardized production of components, which can reduce construction times and costs. By adopting manufacturing practices from industries such as the aerospace and shipbuilding industries, it is expected that SMR developers can achieve cost reductions through learning and scale. A UK study suggests that with sufficient deployment — around 5 GW of SMR capacity — LCOE could reach parity with larger nuclear plants, assuming production of 10 SMR units annually.

In addition, some SMR designs offer flexibility in their operation through cogeneration (e.g. with district heating, desalination, or hydrogen production) and their capacity to do load following (or to adjust their output with demand). This allows SMRs to provide a service to grids, which is not valued by the LCOE metric, and they can still have a positive net present value regardless of their LCOEs. ■

Financing and Enabling Policies

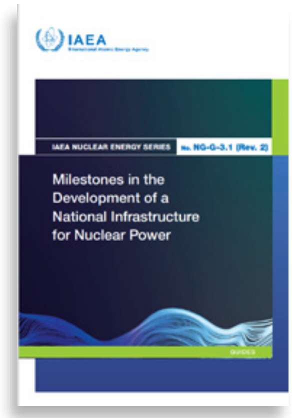
Securing financing for nuclear power projects, including SMRs, is complex due to their capital intensity, the long project lifetime, regulatory processes and country-specific risks. These factors make nuclear power projects less appealing to risk-adverse investors. However, SMRs' smaller sizes, reduced complexity and shorter construction times could improve their attractiveness to investors. The modular nature of SMRs allows for phased investments, offering flexibility in capacity expansion, which could further appeal to investors.

To facilitate the deployment of SMRs, governments need to create environments through policy that support nuclear energy within low carbon energy systems. Financing options for SMRs include public funding, corporate financing, project financing (with government backing for nuclear specific risks) and support from sustainability-linked financial mechanisms such as green and transition bonds, in addition to loans and loan guarantees from export credit agencies (ECAs) and multilateral development banks (MDBs) for international projects. Revenue models, such as power purchase agreements (PPAs), contracts for difference (CfD) and the regulated asset base (RAB) model could also be employed to secure income for SMR operators. ■

Economic Impacts

Nuclear power projects, including SMRs, contribute to long-term economic growth through direct, indirect and induced effects. They are also labour intensive and offer high-paying jobs. In addition to their direct impacts on national economies, SMRs provide a number of advantages such as replacing obsolete energy infrastructure and supporting local industries, hence contributing to the overall economic grow of a country. Countries with established nuclear industries and localized supply chains are likely to see significant economic benefits from SMR deployment. For instance, a study of five 300 MW(e) SMR projects in Canada projected a positive impact on GDP of CAN$17 billion, with government revenues increasing by CAN$5.4 billion over 65 years. Even in countries without significant manufacturing or construction activities for local participation in the projects, SMRs can positively impact the economy by contributing to grid reliability and resilience and affordable and predictable electricity production, which can stimulate broader economic activity through the income-consumption loop. ■

Newcomer Countries and the Milestones Approach



The journey towards nuclear power is a complex undertaking, and the IAEA Milestones Approach has emerged as a crucial framework for countries embarking on this intricate path including more than 25 nuclear newcomer countries that are exploring the possibility of deploying SMRs.

The IAEA Milestones Approach is a phased and comprehensive method designed to assist countries in developing their nuclear power programmes to the operational phase, a process that spans 10 to 15 years for large NPP projects. The revised IAEA Nuclear Energy Series No. NG-G-3.1 (Rev. 2), Milestones in the Development of a National Infrastructure for Nuclear Power — the guidance publication for the Milestones Approach — addresses aspects of infrastructure that can be implemented or considered differently in the context of SMR deployment, where appropriate. The publication has a separate annex describing the specific infrastructure considerations for SMRs.

Several countries looking to add nuclear power to their energy mixes are exploring the potential of SMRs. These include **Ghana**, **Kenya** and **Estonia**, which hosted the first IAEA Integrated Nuclear Infrastructure Review (INIR) focused on SMRs in 2023. **Italy** phased out nuclear power in the late 1980s; however, the Government aims to conduct a pre-feasibility study for the possible redeployment of nuclear energy, with SMRs and MRs as the reference technologies. **Jordan** is studying the use of SMRs for electricity and for a desalination project that would pump potable water generated at the Red Sea across the country to the capital Amman. In 2023, working with the IAEA SMR Platform, Jordan invited the IAEA to study its plans regarding nuclear power technology and safety, siting and licensing, nuclear desalination, nuclear law and stakeholder engagement. ■

"As the nuclear power landscape continues to evolve, so too must the assistance we provide. This latest update of the IAEA Milestones guidance comes at a pivotal moment when an increasing number of Member States are considering nuclear power for their energy mix to achieve their net zero pledges. SMRs will be a key part of the clean energy transition, and we must ensure that countries interested in this technology have a solid understanding of what is needed to successfully implement SMR projects."

Mikhail Chudakov,
IAEA Deputy Director General
and Head of the Department of Nuclear Energy

Access Milestones in the Development of a National Infrastructure for Nuclear Power.

Ghana

Ghana, one of the countries set to embrace nuclear power, is considering SMRs and has established the Ghana Nuclear Power Programme Organization (GNPPO) to coordinate preparatory activities. The country's 15-year roadmap, structured around the three-phases of the IAEA's Milestones Approach, envisions adding 700–1000 MW(e) of new nuclear capacity to the national grid by 2030. ■

Estonia

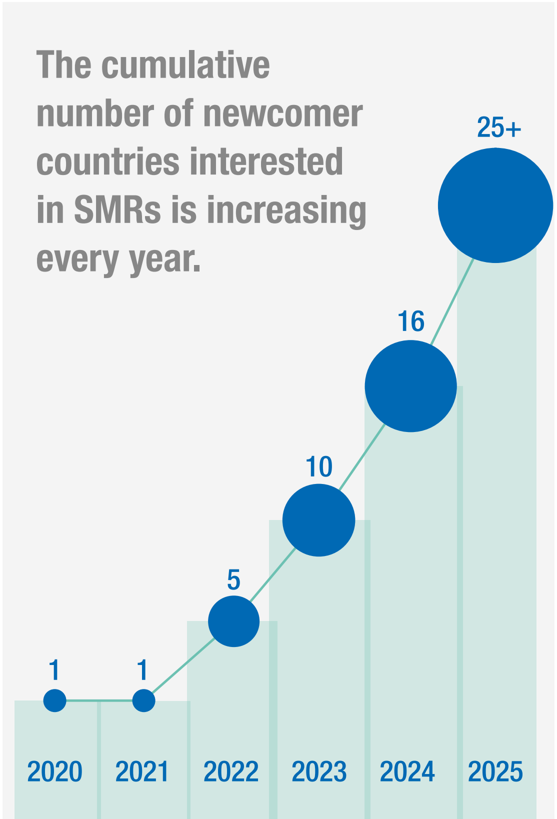
Estonia is also considering deploying SMRs as a reliable and low carbon energy option. Reelika Runnel, Coordinator of the Estonian Nuclear Energy Working Group, emphasized how the Milestones Approach gave Estonia a starting point: "It provides an overview of how much work is needed to establish a nuclear programme and encompasses all topics related to nuclear power. It reassures decision makers at the political level that they can make decisions based on the experiences of the IAEA, drawing on many Member States' experiences." Estonia sees limitations in accommodating large reactors in its relatively small electricity grid. ■

Issues with Starting up an SMR Programme

Some SMRs, particularly those using coolants other than water, could generate new forms of radioactive waste, and so countries planning to deploy SMRs need to plan to manage these new waste types. If new fuel types are employed, it will be important to establish a supply chain to secure the consistent availability of fuel. And safeguards approaches may need to be developed to address certain novel design features of SMRs, ensuring that robust nuclear material accountancy and control measures are not hindered.

Even for expanding countries with nuclear operating experience, when building new reactors after a long pause, it is beneficial to reassess the maturity of their existing infrastructure issues for the end of Phase 2 to see if there are disparities compared to the level that the IAEA

H.E. Nana Addo Dankwa Akufo-Addo, President of Ghana, at the Scientific Forum, Nuclear Innovations for Net Zero (the IAEA 67th General Conference, Vienna, Austria, September 2023).



“The Milestones Approach provides a very high-level roadmap and guidance on how to prepare. For a newcomer country, developing such a major infrastructure project is challenging. The Milestones Approach provides a comprehensive formal structure to develop it.”

Archibold Buah-Kwofie, Ghana Atomic Energy Commission (GAEC)

recommends before starting construction. Whenever gaps are identified, the IAEA can support expanding countries in areas such as supply chains, energy grids, human resources and other aspects of the broader infrastructure.

“Whether a big or small reactor, you will need the Milestones as guidance,” said Archibold Buah-Kwofie of the Ghana Atomic Energy Commission (GAEC). “The Government needs to decide and establish necessary laws and regulations, and an operator to finance and run the reactor is needed, just like for larger reactors. It is all there, and the Milestones Approach remains a useful tool for embarking countries”. ■

“The Milestones Approach is also fully applicable to SMRs. Even though the concept of SMRs differs from conventional reactors, the same set of regulations are applicable.”

Reelika Runnel, Coordinator of the Estonian Nuclear Energy Working Group

The IAEA tracks the interest of Member States in SMRs by how many of them contact the IAEA Nuclear Infrastructure Development Section. This section coordinates IAEA assistance to Member States considering or embarking on nuclear power programmes.

New End Users: Tech Companies Eye SMRs to Meet Clean Energy Needs

With electricity-consuming technology, such as data centres (which house the servers and computing equipment needed to store digital information), artificial intelligence (AI) and cryptocurrencies, set to grow in the coming years, major tech companies are actively looking to advanced nuclear technologies such as SMRs to provide low carbon, continuous power. This could result in a new pathway for the commercialization of SMRs and other advanced reactors.

In fact, data centres, AI and cryptocurrencies are driving an increase in electricity demand in several regions. They accounted for 2% of global electricity consumption in 2022, a figure that could double by 2026, according to the International Energy Agency (IEA). The combined electricity consumption of four companies alone — Amazon, Microsoft, Google and Meta — more than doubled between 2017 and 2021 to about 72 terawatt-hours (TWh).

In 2022, data centres consumed an estimated 460 TWh of electricity, according to the IEA. By 2026 that figure could increase to more than 1000 TWh — over one third of the total electricity generated by the world's NPPs last year and roughly equivalent to the electricity consumption of Japan.

In China, electricity demand from data centres is expected to double to 400 TWh by 2030 compared to 2020. In the northeast region of the USA, it is expected that data centres will increasingly drive electricity demand. The data centre market in Europe is also developing rapidly. Electricity demand from data centres in Ireland, for example, was 5.3 TWh in 2022, equivalent to 17% of the country's total electricity consumption. The IEA has stated that "at this pace, Ireland's data centres may double their electricity consumption by 2026, and with AI applications penetrating the market at a fast rate, we forecast the sector to reach a share of 32% of the country's total electricity demand in 2026".

As they seek to meet their rising power needs, major tech companies also want to decarbonize their operations, either because legislation requires them to do so or in order to meet their own sustainability goals. To achieve this, they are looking not only to variable renewable sources of electricity such as solar and wind energy but also to advanced nuclear technologies such as SMRs. A similar trend can be observed in other industries seeking clean, continuous power and heat, such as petrochemicals.

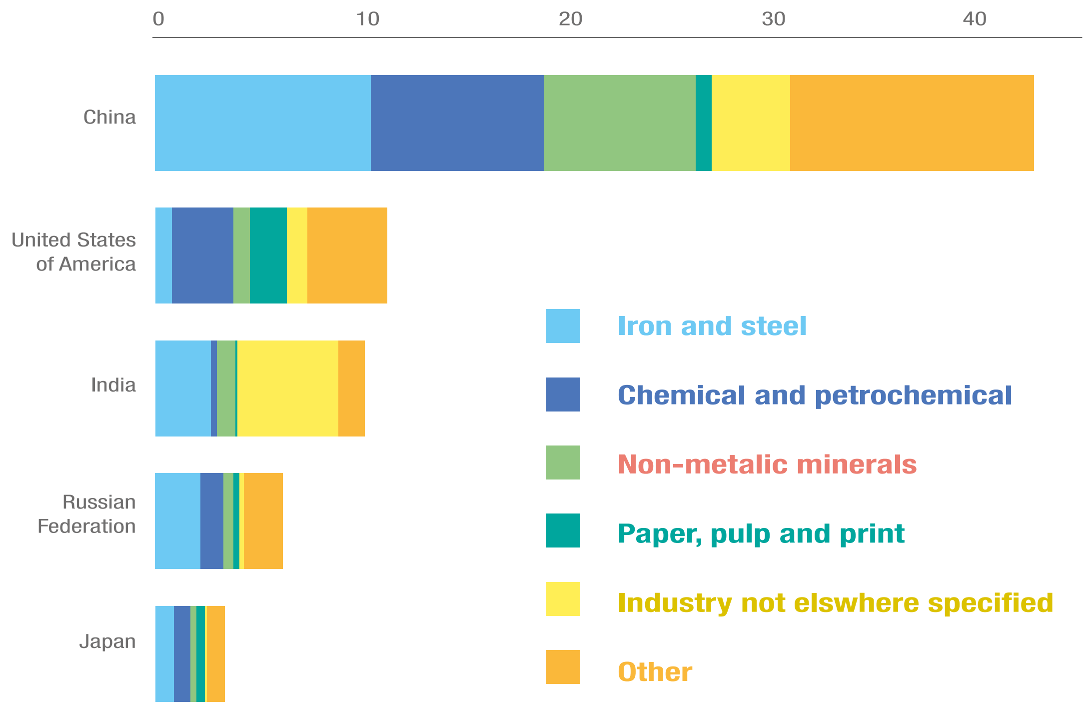
Searching for solutions to these emerging needs, both Google and Microsoft (USA) have recently released reports examining how advanced nuclear sources, along with other clean electricity sources, can support their business and sustainability goals. "We know that wind, solar and batteries will be critical in order to decarbonize our energy consumption. But we also need firm, dispatchable, carbon free electricity technologies to cost-effectively decarbonize our electricity consumption," said Devon Swezey, Senior Manager in Global Energy and Climate at Google.

In its recent policy brief on the use of advanced nuclear fission and fusion as a decarbonization tool, Microsoft cited a number of areas in which the company and other stakeholders can advocate for addressing such barriers. These include accelerating research and development, enabling programmes for testing new technologies and modelling them for integration with other low carbon sources, advancing regulatory approaches for safe and cost-effective deployment, and leveraging the power of digital technologies, including AI, in the management of new energy technologies and the grid.

Electricity end users such as tech companies need the kind of clean and firm power that advanced nuclear energy sources can provide. At the same time, they can help to overcome the barriers to deployment that stand in the way of these technologies coming to market. Moreover, as data centres, AI and cryptocurrency companies seek sources of clean and reliable baseload power to run their operations and achieve decarbonization targets, vendors of advanced nuclear technology are taking note. The result could be a new path for nuclear power deployment. Packaging nuclear in smaller ways — even micro scale — and modular could make it affordable for private industry while developing projects with purely private capital. ■

“In some regions, the pathway to advanced nuclear power deployment may very well pass through major corporate end users. SMRs and other advanced nuclear reactors are well suited to play a key role for these companies, providing the flexible and reliable low carbon energy they need to run their operations.”

Aline des Cloizeaux,
Director of the IAEA Division of Nuclear Power



Decarbonizing Beyond Electricity: SMRs for Non-Power Applications

Interest in applications of SMRs that do not involve electricity generation is growing, driven by environmental concerns, economic factors and energy security needs. SMRs, some of which can provide high temperature heat, can help decarbonize sectors for which electricity use is not an option, such as metal refining, chemical synthesis, cement and steel production, and heavy-duty transport. These sectors are energy intensive, as shown in the figure, and decarbonization will be needed to achieve net zero targets. SMRs can also produce hydrogen, potable water and heat for district heating uses.

Industry energy consumption by sub-sector (energy consumption in EJ) of top five countries by total final consumption, 2019 (courtesy of the International Energy Agency). Note: “Other” includes non-ferrous metals, transport equipment, machinery, mining and quarrying, food and tobacco, wood and wood products, construction, textile and leather.

Designs for Different Needs

Different SMR technologies cater to various industrial needs. Light water reactors, operating at lower temperatures, are ideal for district heating, desalination and hydrogen production; while higher temperature reactors, such as liquid metal, molten salt, and gas cooled reactors, are better suited for industries requiring intense heat, such as petroleum refining, steelmaking, synthetic fuel production and some hydrogen high-temperature production processes. Small modular reactors can also accommodate lower heat demand, as most of the heat demand in industry is on the order of tens of megawatts rather than hundreds. As heat is expensive and difficult to transport, SMRs offer a tailored solution to industry needs, possibly in combination with industrial clusters.

Cogeneration

Like companies in the tech sector, those in other industries, such as Dow Chemicals (USA), are looking to deploy SMRs to power their operations not only with decarbonized electricity but with high temperature heat.

Nuclear cogeneration, which combines electricity and heat production, offers several benefits. It can boost plant efficiency to over 80%, compared to approximately 33% for traditional reactors used solely for electricity. Cogeneration also allows for better energy use and reduces capital investment by avoiding unnecessary energy transformations, improving flexibility by enabling plants to switch between electricity and heat production, and reducing environmental impacts by minimizing waste heat and water usage.

District Heating

For district heating, nuclear reactors can supply steam or hot water at temperatures of 80–150°C, suitable for pipeline distribution within a 10–15 km range. Although large reactors have been used for district heating in some countries, SMRs are now being developed specifically for this purpose,

addressing challenges such as the distance between reactors and urban areas and the economic feasibility of such projects.

Desalination

Nuclear desalination has been proven to be both technically and economically viable, with large reactors already used for this purpose. Desalination requires significant energy, which SMRs can provide efficiently, making them attractive for regions with growing energy demands and limited water resources. In addition, using SMRs avoids large carbon emissions typically associated with desalination powered by fossil fuels.

Industrial Heat

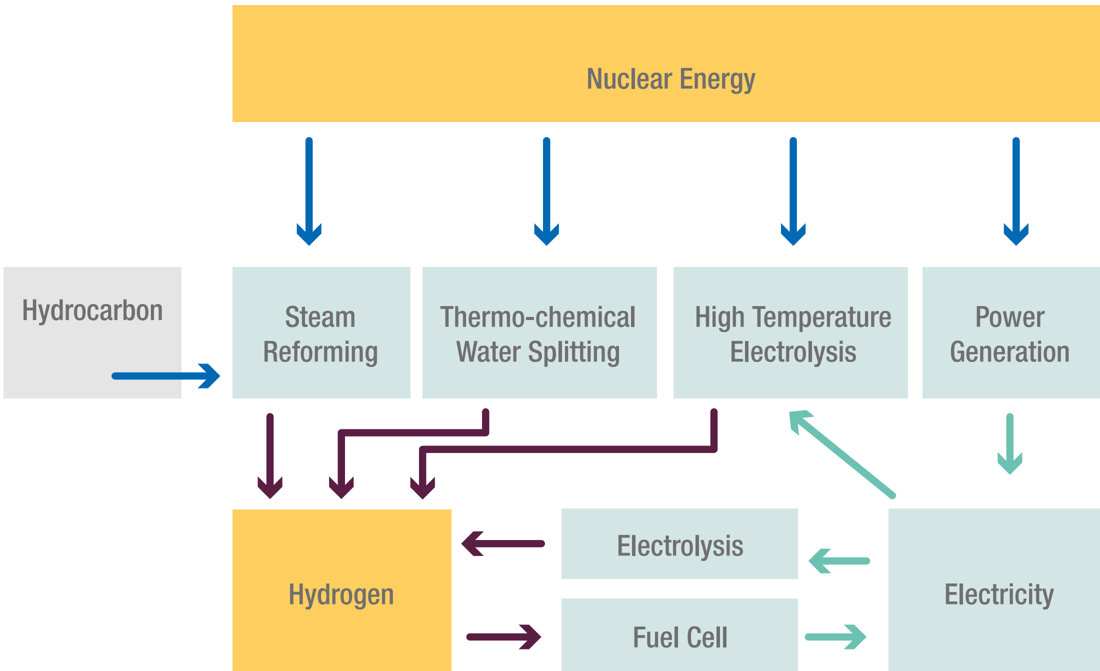
SMRs also offer advantages for industrial heat applications, such as providing zero-carbon hydrogen and heat to produce steel and fertilizers with no emissions. In addition, SMRs can provide zero emission energy to support intermediate steps to arrive at net zero, such as enhancing coal quality and supporting oil recovery. The proximity of the reactor to the industrial site is crucial for minimizing heat transport costs; and SMRs, with their potential for reduced emergency planning zones, are well-suited for co-location with industrial users. This proximity, combined with the potential reliability and flexibility of SMRs, makes them an attractive option for industries requiring continuous heat supply.

Hydrogen Production

In hydrogen production, SMRs can play a key role by providing both clean electricity and heat. Co-locating SMRs with hydrogen users reduces transportation costs, improving the overall economics of hydrogen production.

Hydrogen can be produced through two main types of electrolysis: low temperature electrolysis (LTE) and high temperature electrolysis (HTSE). While LTE requires only electricity, HTSE also needs heat, which increases hydrogen production efficiency. Specifically,

A modern desalination plant on the shores of Dubai, United Arab Emirates.



Schematic of alternative routes to hydrogen production with nuclear energy.

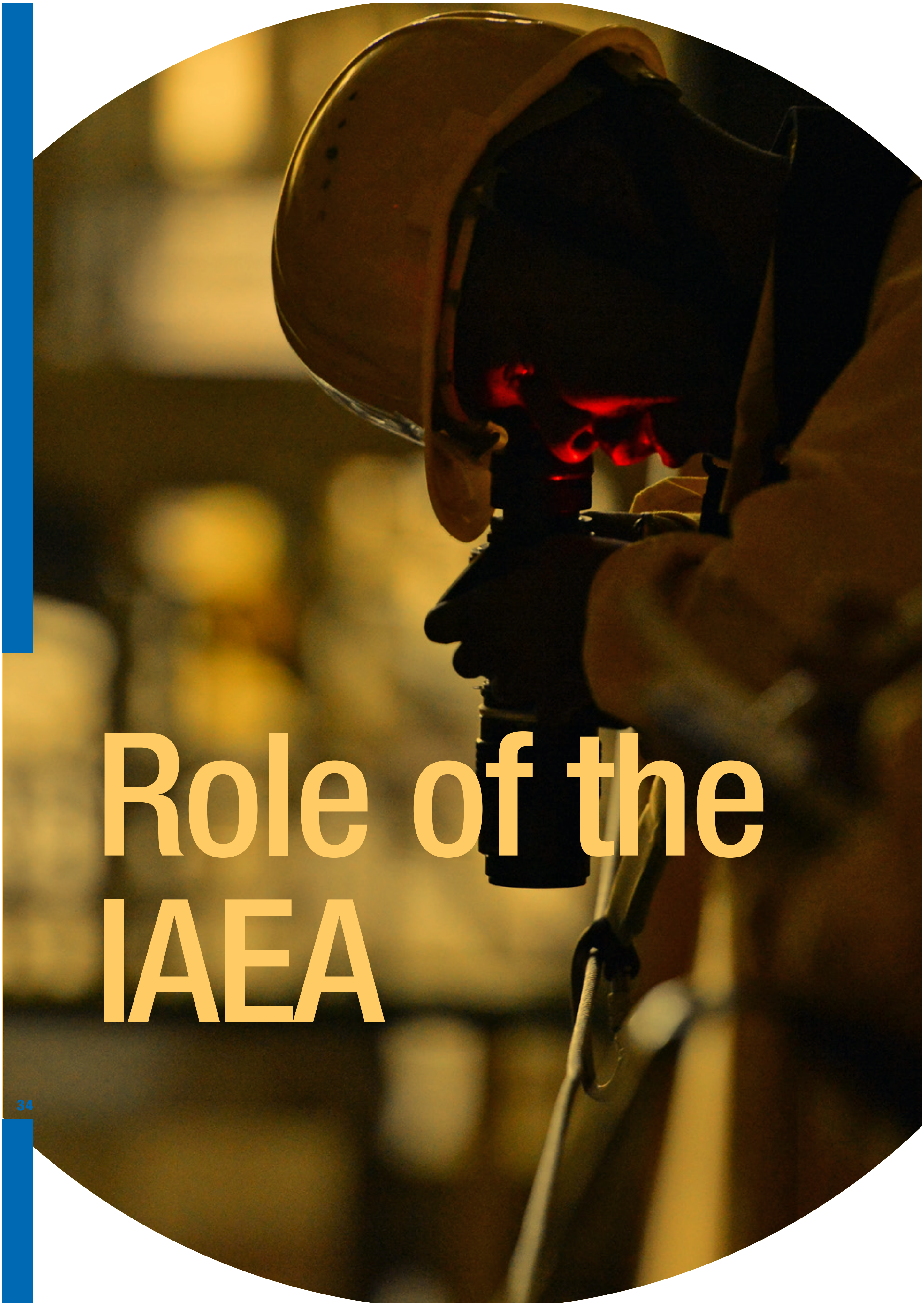
LTE consumes about 50–60 kWh per kilogram of hydrogen, whereas HTSE can consume as little as 40 kWh per kilogram, plus an additional 2–3 kWh per kilogram to generate the necessary heat.

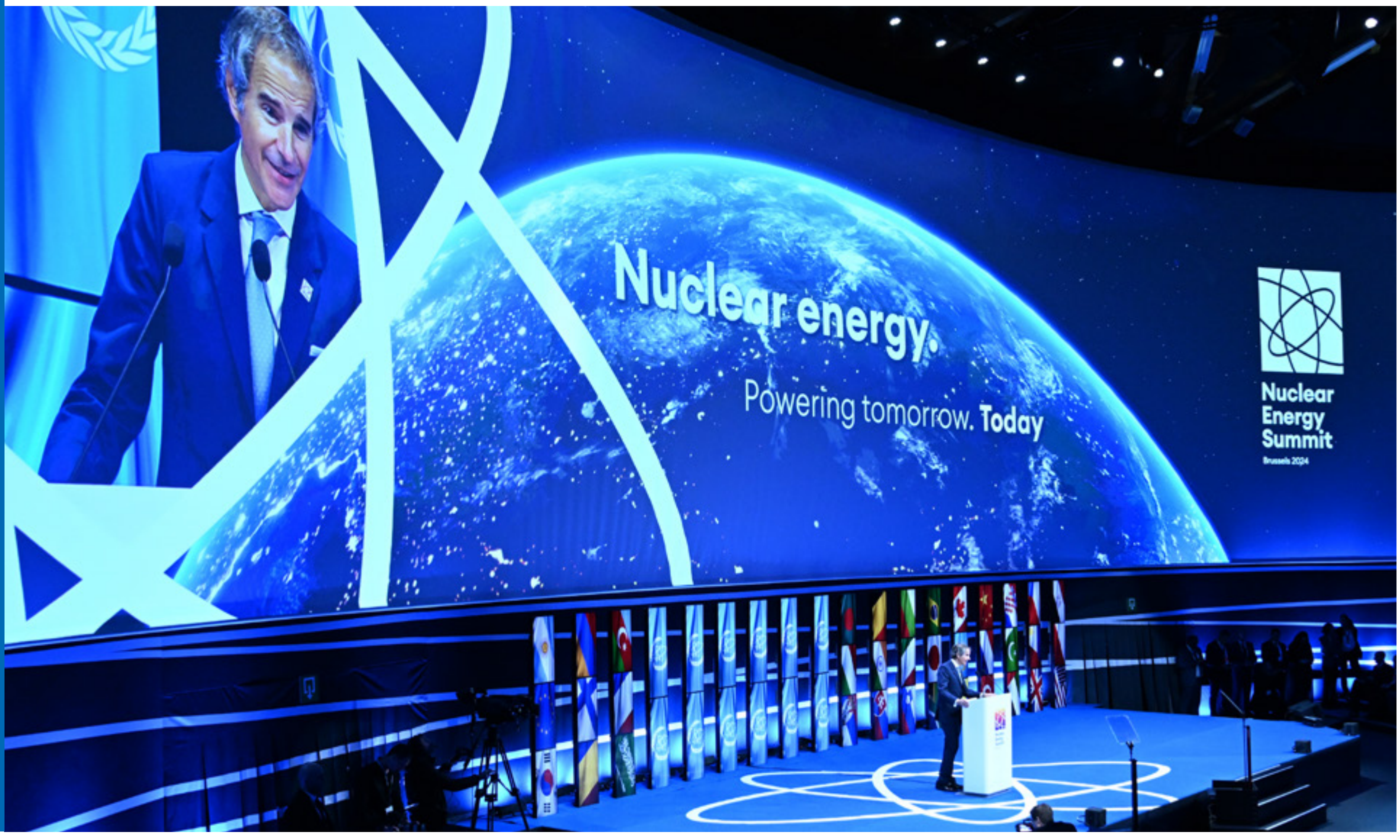
During HTSE, hydrogen is produced at temperatures of approximately 700–800°C, but the input steam required from nuclear energy sources is only 150–200°C with current commercial HTSE technology. This makes SMRs, including LWRs, suitable for efficiently providing the energy needed for current commercial HTSE. Thermochemical cycles, such as sulfur-iodine or copper-chlorine, offer even higher efficiency but require steam at higher temperatures, necessitating the use of SMRs capable of producing the required heat.

Hybrid Systems

SMRs can also support hybrid energy systems, where nuclear power is coupled with other forms of energy storage, such as heat or hydrogen, and intermittent electricity production from renewable sources. This flexibility enables SMRs to provide a broader range of services, beyond just electricity generation, making them valuable components of future energy systems. ■

Role of the IAEA

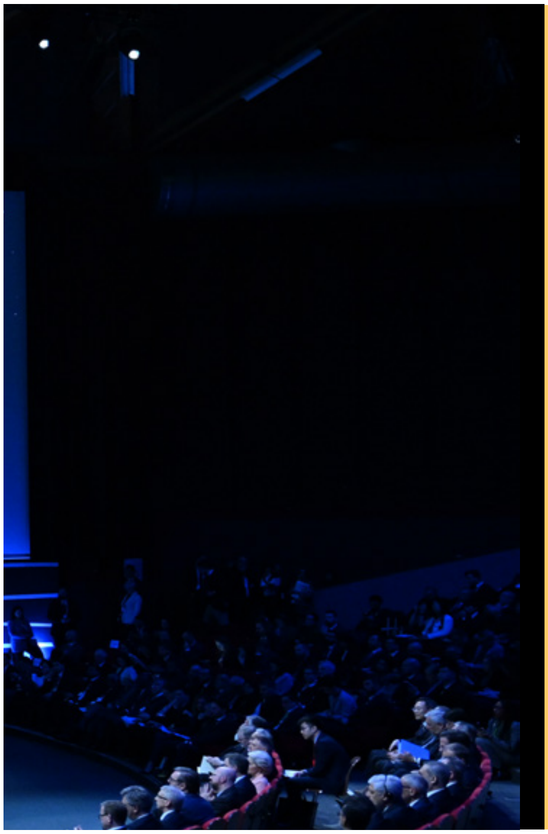


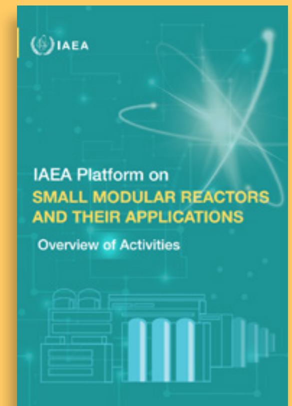


The IAEA is the world's centre for intergovernmental cooperation in the nuclear field and seeks to promote the safe, secure and peaceful use of nuclear science and technologies. The IAEA's mandate is inclusive of low, middle, and high income countries. Continuous engagement with both nuclear technology leaders and those that are new to the industry enables the IAEA to address issues unique to the nuclear community comprehensively—from promoting the peaceful uses of nuclear technology to serving as the international centre for nuclear cooperation and carrying out statutory responsibilities in nuclear safeguards and verification.

The IAEA's role in facilitating the timely deployment of safe and secure SMRs is multifaceted. Through its coordinated research projects, working groups, intergovernmental fora, technical meetings and publications, the IAEA fosters international collaboration on key aspects of SMR development and deployment, including high level requirements, regulatory frameworks and safety.

IAEA Director General Rafael Mariano Grossi delivered remarks at the opening of the Nuclear Energy Summit (Brussels, Belgium, March 2024).





The IAEA offers tailored guidance and services on infrastructure development including regulatory framework and human resource capacity building, which are crucial for countries considering SMR deployment — especially newcomers to the nuclear community. In addition to safety and security, the IAEA's work on safeguards helps ensure that the expansion of SMR technology aligns with non-proliferation objectives.

To effectively help Member States engage with the IAEA and access these various forms of assistance, the IAEA has established the **Platform on Small Modular Reactors and their Applications** — the IAEA SMR Platform. In addition to coordinating the IAEA's activities in this area, the SMR Platform provides access to expertise from across the IAEA, encompassing all aspects relevant to the development, deployment and oversight of SMRs and their applications. Engagement with the SMR Platform can help provide all parties with a clear understanding of specific requests and ensure that the assistance provided by the IAEA is targeted and effective. ■

Access the Platform on Small Modular Reactors and their Applications.

Access IAEA Platform on Small Modular Reactors and their Applications: Overview of Activities.

A Few Ways to Engage the IAEA

1

Technical Cooperation Programme: Member States can request assistance through the IAEA's Technical Cooperation Programme, which provides support in the form of expertise, training, and equipment to help countries develop and implement nuclear energy projects, including SMRs. This programme is tailored to the specific needs of each Member State and can cover various aspects of SMR deployment, such as feasibility studies, infrastructure development and capacity building.

2

Coordinated Research Projects: The IAEA organizes Coordinated Research Projects **(CRPs)** that bring together research institutions, industry partners, and experts from Member States to collaborate on specific topics related to SMRs. Participating in these CRPs can provide access to cutting-edge research, knowledge sharing and networking opportunities with leading experts in the field.

3

Technical Meetings and Workshops: The IAEA regularly organizes technical meetings, workshops, and conferences focused on various aspects of SMR deployment, such as safety, licensing and economics. Attending these events can provide valuable insights into best practices, emerging trends, and opportunities for collaboration with other Member States and industry partners.

4

SMR Regulators' Forum: For countries interested in the regulatory aspects of SMR deployment, engaging with the SMR Regulators' Forum can provide access to a network of regulatory authorities from around the world. This forum facilitates the sharing of experiences, best practices and approaches to licensing and oversight of SMRs.

5

Technical Safety Review Service (TSR): Member States and technology developers can request independent evaluations through the IAEA's Technical Safety Review Service, which provides expert assessments of nuclear facilities, including SMRs. This service is tailored to specific needs and can cover various aspects of nuclear safety, such as design safety, operational safety, and regulatory compliance. By participating in the TSR, Member States can enhance their nuclear safety infrastructure, ensure adherence to international safety standards, and gain valuable insights to support the safe deployment of SMRs.

6

Expert Missions and Peer Reviews: Member States can request expert missions and peer reviews from the IAEA to assess their readiness for SMR deployment and identify areas for improvement. These missions can cover various aspects of SMR deployment, such as infrastructure, regulatory frameworks and safety culture.

7

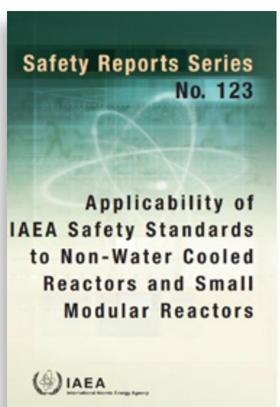
Training and Capacity Building: The IAEA offers a range of training courses and capacity building programmes related to SMRs, covering topics such as reactor technology, safety assessment and project management. Participating in these programmes can help Member States develop the necessary skills and expertise to successfully deploy SMRs.

8

Technical Publications and Guidance: The IAEA produces a wide range of technical publications and guidance documents related to SMRs, covering topics such as design, safety and licensing. Accessing these resources can provide valuable information and best practices to support SMR deployment.

A meeting during an SMR Regulators' Forum at the IAEA headquarters in Vienna, Austria.

SMR Regulators' Forum: For countries interested in the regulatory aspects of SMR deployment, engaging with the SMR Regulators' Forum can provide access to a network of regulatory authorities from around the world. This forum facilitates the sharing of experiences, good practices and approaches to licensing and oversight of SMRs.



The IAEA serves as the technical secretariat of the **SMR Regulators' Forum**, whose goal is to enhance nuclear safety by addressing common safety issues that could challenge regulatory reviews associated with SMRs and by facilitating robust and thorough regulatory decisions. Started in 2015, the forum has established three working groups: Licensing Issues, Design and Safety Analysis, and Manufacturing, Construction, Commissioning, and Operation. It has also been engaged as a working group lead for the Regulatory Track of the **Nuclear Harmonization and Standardization Initiative (NHSI)**.

Through its **Safeguards by Design Programme**, the IAEA works directly with Member State authorities, designers, equipment providers and prospective purchasers. This programme is a voluntary good practice programme, where the IAEA helps stakeholders allow for more informed design choices that optimize economic, operational, safety and security factors while also taking into consideration international safeguards.

Access Safety Reports Series No. 123, Applicability of IAEA Safety Standards to Non-Water Cooled Reactors and Small Modular Reactors.

Safeguards by Design

Decision to construct

	Conceptual design → Engineering design	Construction and commissioning → Operation
Mode of interaction:	Member State Support Programme engagement Bilateral engagement General outreach, workshops, etc.	Consultation with relevant IAEA Division of Operations, Department of Safeguards (per safeguards agreement)
IAEA participants:	Division of Concepts and Planning (Department of Safeguards), supported as needed by other Divisions	Relevant Division of Operations, supported as needed by other Divisions
Member State participants:	Led voluntarily by nuclear designer/vendor, supported as needed by Member State resources	Led by Member State authority, supported as needed by Member State resources
Outcome:	Preliminary Safeguards by Design report	New or modified safeguards approach

Safeguards by Design Programme. Currently, more than ten SMR designers are engaged with the IAEA's Safeguards by Design Programme. The designers are exploring different types of reactor technologies and represent a global cross section of the nuclear industry.

By engaging with Member States, industry and other international organizations, the IAEA contributes to creating an enabling environment for the sustainable deployment of SMRs, which supports the global transition to low carbon energy generation while maintaining high standards of nuclear safety and security.

The IAEA's distinctive convening authority enables it to bring together diverse stakeholders from across the global nuclear community. The IAEA regularly convenes Member States, regulatory bodies, industry representatives, research institutions and other international organizations to address the multifaceted challenges of SMR deployment. This collaborative environment not only facilitates the development and deployment of SMRs but also ensures that a wide range of perspectives are considered, leading to more robust and globally applicable solutions. The IAEA's ability to convene such diverse groups is unique and contributes significantly to supporting the deployment and integration of safe, secure and sustainable SMRs into the global energy landscape.

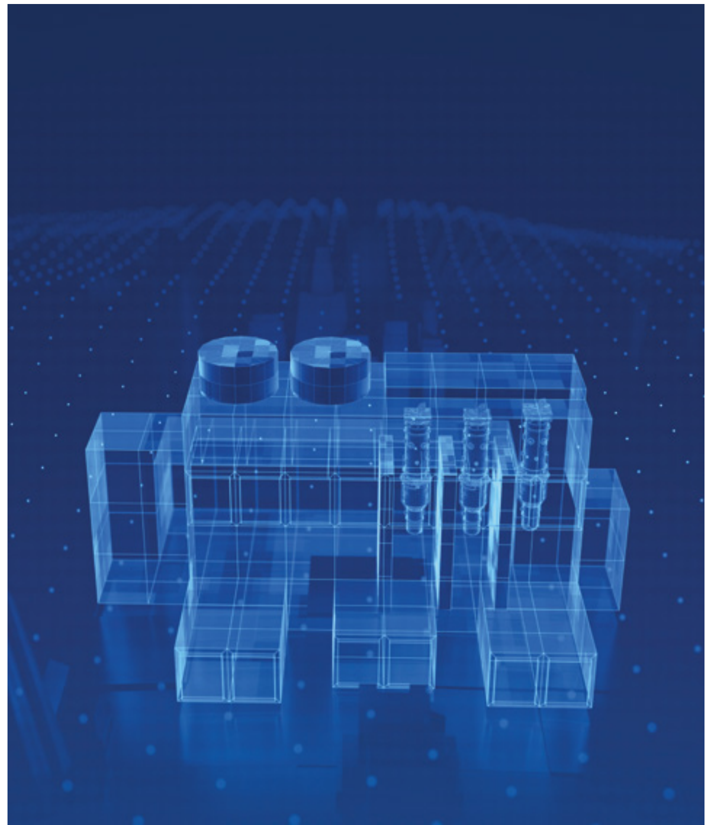
The IAEA plays a crucial role in coordinating and aligning the efforts of various international and regional organizations working towards harmonization in the nuclear field, particularly in the context of SMR deployment. **The Nuclear Harmonization and Standardization Initiative (NHSI)** brings together regulators, industry and other stakeholders to help facilitate the deployment of safe and secure SMRs through greater regulatory harmonization and industrial standardization.

IAEA Director General Rafael Mariano Grossi delivered remarks at the opening of the Nuclear Harmonization Standardization Initiative (NHSI) Wrap up session (IAEA headquarters in Vienna, Austria, June 2022).

IAEA

NUCLEAR
HARMONIZATION &
STANDARDIZATION
INITIATIVE

Through this initiative, the IAEA is bringing together top-level decision makers from governments, regulators, designers, technology holders, operators, non-traditional end users and other international organizations and associations to collaborate under one framework. With over 60 events held through the initiative, the IAEA is committed to delivering timely progress towards addressing common understandings of how to facilitate the near-term deployment of SMRs.



The IAEA plays a vital role in bridging the gap between the technical and policy aspects of SMR deployment, helping to ensure that the efforts of harmonizers are grounded in a common understanding of the broader societal and economic context. By engaging with policymakers, financial institutions and civil society organizations, the IAEA can provide a holistic perspective on SMR deployment and help to align the efforts of harmonizers with the needs and priorities of Member States and other stakeholders.

Through collaborative efforts with Member States and various international organizations, the IAEA provides technical assistance, establishes international safety standards and facilitates research and development across diverse fields such as energy, health and agriculture. The IAEA's near-universal membership and its affiliation with the United Nations position it as a neutral platform for addressing global nuclear challenges and opportunities. In this role, the IAEA works in concert with the international community, fostering partnerships and complementing the efforts of other organizations with the clear intention to collectively contribute to the safe, secure and peaceful utilization of nuclear technology worldwide. ■

Access the Advanced Reactor Information System (ARIS).

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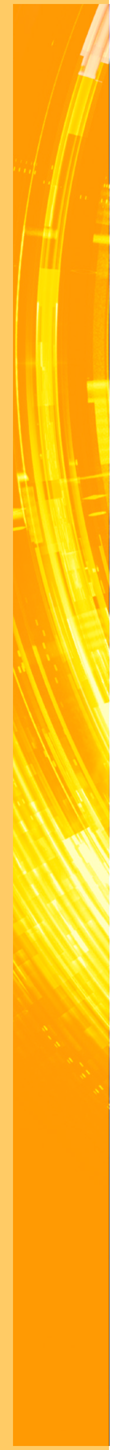

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Rafael Mariano Grossi
IAEA Director General

International Atomic Energy Agency
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