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BRICS NUCLEAR PLATFORM

special report

advancements in small modular reactors

BRICS 2025 YOUTH ENERGY OUTLOOK

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BRICS NUCLEAR PLATFORM

Special Report

Advancements in Small Modular Reactors

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List of abbreviations and acronyms

ABWR	Advanced boiling water reactor
ACP100	Linglong One
ADVANCE	New program by ENEC to harness the latest advancements in nuclear energy
AGR	Advanced gas-cooled reactor
AHWR	Advanced heavy water reactor
AHWR-300-LEU AI	Advanced heavy water reactor with LEU-Th MOX fuel
BARC	Artificial Intelligence
BRICS	Bhabha Atomic Research Centre
BRIN	an acronym for a group of countries that includes Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Indonesia, Iran, and the United Arab Emirates.
BWR	National Research and Innovation Agency of Indonesia Boiling water reactor
BWRX-300	Boiling water SMR proposed by GE Hitachi Nuclear Energy
CAREM	First nuclear power reactor designed entirely in Argentina
CNNC	China National Nuclear Corporation
CNEN	National Nuclear Energy Commission of Brazil
COP21	2015 United Nations Climate Change Conference, Paris
COP28	2023 United Nations Climate Change Conference, Dubai
COP30	2025 United Nations Climate Change Conference, Belém
D2O	deuterium oxide, a form of water in which hydrogen atoms are all deuterium
DAE	Department of Atomic Energy of India
EMDCs	Emerging markets and developing countries
ENEC	Emirates Nuclear Energy Company
EPE	Energy Research Company of Brazil
EPR	European pressurized reactor or Evolutionary power reactor
ESBWR	Economic simplified boiling water reactor
ESG	an acronym for Environmental, Social and Governance that refers to a set of standards used to measure an organization's environmental and social impact
FANR	Federal Authority for Nuclear Regulation of UAE
FNPP	Floating nuclear power plant
FNR	Fast neutron reactor
FOAK	First-Of-A-Kind

General Electric Company	GE
Gigawatt	GW
High-assay low-enriched uranium HTGR Helium gas reactor	HALEU
High-temperature gas-cooled pebble-bed reactor	HTR-PM
High-Temperature Reactors	HTR
International Atomic Energy Authority	IAEA
International Uranium Enrichment Center	IUEC
Industrial Development Corporation of South Africa Limited	IDC
Idaho National Laboratory	INL
International project on innovative nuclear reactors and fuel cycles	INPRO
Indian rupee, official currency of India	INR
Independent Online	IOL
The Bandung Institute of Technology	ITB
Russian nuclear fission reactors originating from ship reactors	KLT-40S
Low-enriched uranium with uranium enriched up to 5%	LEU
Low-enriched uranium with uranium enriched between 5 and 10%	LEU+
Liquid lead/lead-bismuth reactor	LFR
Light water graphite reactor	LWGR
Light water reactor	LWR
Multilateral development banks	MDB
Ministry of Mines and Energy, Brazil	MME
Molybdenum	Mo
Memorandum of Understanding MOX Mixed oxide fuel	MoU
Molten salt reactor	MSR
Megawatt	MW
Megawatt electrical	MWe
New Development Bank	NDB
NuScale Power Module	NPM
Non-Proliferation Treaty	NPT
South African Nuclear Energy Corporation	NECSA
National Nuclear Energy Commission	NNEC
Nuclear power plant	NPP
The United States Nuclear Regulatory Commission	NRC
Pebble bed modular reactor	PBMR

List of abbreviations and acronyms

PHWR	Pressurized heavy water reactor
PuO2	Plutonium (IV) oxide
PWR	Pressurized water reactor
R&D	Research and development
RITM	Integrated generation III+ pressurized water reactor
RUB	Ruble, official currency of Russia
RUPTL	National Electricity Supply Plan of Indonesia
SAFARI-1	South African Fundamental Atomic Research Installation
SBD	Safeguards by Design
SMART	Korean small modular reactor
SMR	Small modular reactor
Th	Thorium
TRISO	Tristructural-isotropic fuel
TVEL	Nuclear fuel company of Rosatom, Russia
U	Uranium
UAE	United Arab Emirates
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nation
UO2	Uranium dioxide
USA, U.S.	United States of America
USD V	Dollar, official currency of the USA
VER	Russian-designed pressurized water reactors
ZAR	South African rand, official currency of South Africa
Zr	Zirconium

Executive summary

The growing interest in developing small modular reactor (SMR) technologies gives many countries the opportunity to include nuclear power in their energy mix because of its affordability and small size. This study focuses on the BRICS countries, which span the full spectrum of SMR development, from conceptual design to operational SMRs. BRICS countries are considering SMR technologies to some extent. Their energy development strategy documents include plans for introducing and developing this type of nuclear technology.

SMRs are advanced nuclear reactors with an electrical output of up to 300 megawatts (MW). They are flexible and scalable, and multiple SMRs can be deployed to meet the energy demands of countries at different stages of energy system development. SMRs are also being considered for use in remote locations and to complement variable renewable energy sources.
This technology is a versatile solution for decarbonizing a wide range of energy-intensive sectors. As well as generating electricity, they can provide heat for industrial processes, both of which are crucial for achieving net-zero targets. Furthermore, SMRs can be used to produce hydrogen, desalinate seawater and provide district heating. They also present a practical opportunity to repurpose retired coal-fired power plants and power new digital infrastructure, such as data centers and artificial intelligence.

Although the development of SMRs has been gaining significant political and financial backing around the world, particularly in the U.S., Canada, Russia and China, only four units have reached an advanced stage of deployment, either being operated or constructed. In Europe, there is growing momentum with key initiatives in France and the UK, while Central and Eastern European countries such as Poland, Romania, and the Czech Republic are developing national plans. Middle East and Central Asia countries step in active phase of planning SMR deployment, yet signing first contracts for several units and launching construction – Uzbekistan.

Opportunities of SMR development

SMRs are set to make a significant contribution to several of the UN's Sustainable Development Goals (SDGs). This potential was formally recognized at COP28, where SMRs were identified as a vital solution for achieving carbon neutrality and addressing climate change. This is due to the technology's many advantages. Firstly, SMRs tend to be simpler than conventional reactors, relying on passive and inherent safety systems. Secondly, integrating SMRs with renewable energy sources enables them to stabilize grids and reduce reliance on fossil fuels, thereby aligning with climate commitments. Thirdly, deploying SMRs can catalyze significant economic and social advancement. They can stimulate regional development, alleviate poverty, and enhance overall security by generating high-skilled employment opportunities during construction and operation and by ensuring a reliable energy supply for industrial growth. The shorter construction timelines and faster payback periods of SMRs make them a more attractive and lower-risk proposition for private investors. Finally, SMRs are being designed with advanced digital technologies to improve safety, efficiency and cost-effectiveness.

SMR designs and nuclear fuel

SMRs encompass a wide spectrum of technologies, fuel types and development stages. The majority of designs are still in the development phase, although a few have progressed from the conceptual stage to being licensed or operational. In order to enhance efficiency and sustainability, many SMR designs are adopting advanced nuclear fuels. One notable development is high-assay low-enriched uranium (HALEU). Other concepts, such as mixed oxide (MOX) and thorium-based fuels, promise to further diversify fuel supplies and improve resource utilization.

Prospects of the SMR development in BRICS countries

In the context of BRICS countries, Russia and China are the only countries with experience in operating their own SMR technologies. The national nuclear power development plans of India and Brazil consider the development of SMR technologies. Indonesia's program documents include plans to add nuclear capacity through the construction of both large and small modular reactors. The country is also developing its own technology.

Due to the growing interest in SMRs around the world, South Africa plans to resume the Pebble Bed Modular Reactor (PBMR) project. In addition, the country intends to implement a pilot project that will pave the way for the development of SMRs in the country. Egypt, as of 2025, has no plans to include SMRs in its energy mix, and Ethiopia is considering the technology as an option in the nearest future as it is planning to construct its first nuclear power plant. Iran's nuclear program gained renewed momentum following the signing of a memorandum of understanding with Russia, while the UAE is actively exploring the potential of this technology through including it in its policy program and establishing partnerships with many SMR developers.

Among BRICS partner nations, Uzbekistan has taken the most concrete step by signing a 2024 agreement with Russia, which includes the construction of two SMRs. Thailand and Malaysia are also exploring nuclear power, with SMRs under consideration for their future energy mixes. Nigeria has expressed interest in SMR development, though this has not yet been formalized in a strategic document.

On multilateral cooperation, BRICS energy ministers adopted the roadmap for BRICS energy cooperation 2025-2030 in May 2025. This document outlines collaboration within two pillars: sectoral cooperation, which is aligned with the priorities of the member states, and cross-cutting areas that must be considered within all sectoral initiatives.

At the same time, Multilateral Development Banks (MDBs) continue to play a crucial part in financing the energy transition. They can mobilize private capital for clean energy, especially in developing nations, by providing financial instruments such as loans, guarantees, and equity investment. Given its proven capacity to fund diverse and scalable projects, the New Development Bank (NDB) is particularly well-placed to include SMRs in its portfolio.

In addition to technology and financing, it is crucial to engage young people in the development and deployment of SMRs in BRICS countries. BRICS cooperation could facilitate this by organizing youth-focused innovation challenges, setting up nuclear incubators and providing cross-border training.

Challenges of the SMR development

The deployment of SMRs faces significant hurdles, including insufficient data on the full lifecycle of various technological pathways and a lack of large-scale operational data to validate modular construction and build investor confidence. Moreover, a new regulatory framework is required to address the specific safety and security issues associated with SMR technologies. Current regulatory standards need to be revised to allow for the licensing of land-based SMRs. Additionally, the global spread of SMRs poses significant non-proliferation risks, particularly in politically unstable regions with inadequate regulatory oversight. The dual-use nature of this technology amplifies these risks, highlighting the critical importance of the IAEA's role in safeguarding and verifying compliance.

Licensing frameworks for SMRs are being redesigned fundamentally, as traditional processes for large reactors are too slow and costly for modular deployment. One key trend facilitating this redesign is the international harmonization of regulatory standards, which enables faster design approval across multiple markets.

Concerning economic challenges for SMRs, it is their high capital intensity, which results in the Levelized Cost of Energy (LCOE) than conventional large reactors. A significant risk is that performance may not improve sufficiently during the transition from first-of-a-kind (FOAK) to nth-of-a-kind (NOAK) projects.

Conclusion and recommendations

SMRs are considered the next stage in nuclear development due to their potential to address many of the financial, safety, and deployment challenges that have long plagued the nuclear power industry.

Most BRICS nations are actively pursuing the integration of SMRs into their energy strategies, progressing from initial feasibility studies to formal cooperation agreements with technology vendors.

In this context, BRICS Young Expert Group has elaborated several recommendations on SMR development in BRICS countries:

- Harmonization of the regulatory frameworks.
- Collaborative supply chain development.
- Collaboration with the NDB for financing SMR projects.
- Building the expertise and skills of young nuclear professionals.

As the BRICS countries take on a more prominent role in shaping the global nuclear sector, it is crucial to foster dialogue. The BRICS Nuclear Platform, which promotes the best practices in nuclear energy and technology, may become a powerful mechanism for facilitating this necessary cooperation.

1. Introduction

General brief about reactor types and definition of SMRs

Nuclear reactors are intricate systems, coming in various types, each one characterized by its specific design and operational traits. Among the most frequently encountered types of nuclear reactors are Pressurized Water Reactors (PWRs), Boiling Water Reactors (BWRs), High-Temperature Reactors (HTRs), and Small Modular Reactors (SMRs). Each type boasts its unique strengths and weaknesses, which play a critical role in evaluating their suitability for various applications and in shaping energy security and energy policy planning. (Zarębski, P., 2023) Moreover, nuclear power reactor designs vary in scale, and they can be categorized based on their electrical output, as shown in Table 1.

Table 1. Categorization of nuclear power plants by electricity output (Butista, U.A., 2025)

Electrical Output (MWe)	Type of Nuclear Power Plant
below 10	Micro-Reactor
10 to 300	Small Modular Reactor
300 to 700	Medium-Sized Reactor
above 700	Large Reactor

SMRs are a category of advanced nuclear reactors that are smaller and can be factory-built. In this context, "small" usually refers to an electrical output of up to 300 megawatts (MW). This offers advantages in terms of flexibility and scalability, as multiple SMRs can be deployed to meet varying power demands. SMRs also have the potential to be used in remote locations or as a backup power source, complementing variable renewable energy sources like solar and wind. Economically, their mass factory production aims at overcoming the barriers of conventional nuclear power by reducing construction times, improving quality control, and allowing for phased investment, which lowers the initial financial risk. **(Guo, Y., et al., 2023)**

Modularization is the process by which SMRs are designed and assembled from building blocks, or modules. The fact that they can be built at one site and then transported to another enables simultaneous construction activities, improving productivity and significantly reducing plant construction time. This technique also aims to standardize components, reduce production costs due to modular mass production, and simplify on-site installation of pre-assembled modules. **(IAEA, 2022)**

In some SMR designs, such as those for light water reactors (LWRs), a module may consist of a complete nuclear steam supply system, including all primary components and associated instrumentation systems. Others may use traditional, yet integrated, components designed for easy field assembly, such as the instrumentation and control system module, which can be tested and partially commissioned in the factory, rather than, as is currently the case, where testing and commissioning can only be performed at the plant site. **(IAEA, 2022)**

Rising interest in SMR technologies

The rising international interest in SMRs is largely driven by their potential to advance energy transition strategies, expand access to clean, low-carbon power, and support broader ESG objectives. Table 2 shows the comparative summary of SMR technologies. Moreover, one of the key drivers is the electricity needs of developing countries because of their limited electrical grid systems, limited financial capacity, and rapidly growing energy demand. SMRs are also relevant for industrialized countries to be used in remote, isolated locations and open up new market opportunities in research and development. **(IAEA, 2024)**

Table 2. Comparative summary of SMR technologies (Hinov, N., 2025)

Reactor Type	Coolant	Example(s)
PWR	Pressurized Water	NPM, Rolls-Royce SMR, CNNC ACP-100
VVER	Pressurized Water	RITM-200N
BWR	Boiling Water	GE Hitachi BWRX-300
HTGR	Helium Gas	X-Energy Xe-100
MSR	Molten Salt	Saltfoss CMSR, Terrestrial Energy IMSR, Kairos Power KP-FHR
LFR	Liquid Lead/Lead- Bismuth	BREST-OD-300, Blykalla SEALER 55, newcleo LFR-AS-200, Westinghouse LFR
SFR	Liquid Sodium	TerraPower Natrium, ARC-100, Aalo-X

Based on IAEA PRIS database, only four SMRs are currently in operation or under construction in Russia and China – not including small reactors in nuclear submarines, aircraft carriers or, icebreakers or suspended projects. Argentina SMR (CAREM25) construction was suspended. Since PRIS database does not include the entire list of SMR construction, several more projects on different construction phases should be noted: three FNPPs (advanced stage) and one land-based NPP (early stage) are currently under construction in Russia, two units are in Uzbekistan (early stage), one unit in Canada (early stage).
SMR development is currently receiving significant political and financial support across multiple countries, notably the United States, Canada, Russia, and China. In Europe, key initiatives are also underway, particularly in France and the United Kingdom, the latter having established Great British Nuclear to coordinate SMR deployment through competitive selection. Central and Eastern European nations such as Poland, Romania, and the Czech Republic are actively progressing SMR plans, with some already identifying potential sites and initiating regulatory processes. At the EU level, the European Commission has launched the European Industrial Alliance on SMRs to foster accelerated development and deployment across member states. **(GRS, 2025)**

SMR applications

SMRs can have diverse applications across various sectors such as power generation, space power, submarine and icebreaker development, heavy oil extraction, and seawater desalination, hydrogen production and heating. Also, they provide a number of advantages such as reducing the load on the grid and supporting local industries, hence contributing to the overall economic growth of a country. An emerging application of advanced nuclear energy is powering data centers, AI (artificial intelligence), and other energy-intensive sectors with clean, reliable baseload electricity to support their decarbonization goals. **(Wang, Y., et al., 2024)**
Interest in the applications of SMRs that do not involve electricity generation is growing, driven by environmental concerns, economic factors and energy security needs. Some SMRs, including high-temperature gas-cooled reactors (HTGR), can help decarbonize sectors for which electricity and heat use is an integral part of the process, such as metal refining, chemical synthesis, cement and steel production, and heavy-duty transport. These sectors are energy-intensive, and decarbonization will be needed to achieve net-zero targets. SMRs can also produce hydrogen, potable water and heat for district heating uses. **(ARIS, 2024)**
The idea of transforming retired coal-fired power plants into nuclear plants and maximizing the use of idle infrastructure is gaining increasing attention worldwide, particularly with the advent of new SMR projects, which have energy capacities similar to coal-fired power units. In the U.S., of 237 sites analyzed to date, 157 demonstrate feasibility for the coal-to-nuclear (C2N) transition, representing a 15% to 35% reduction in CAPEX for the new technology, depending on the use of the existing thermal cycle **(U.S. Department of Energy, 2021)**.

Social-economic and other aspects

Considering the growing role of the BRICS countries in the development of nuclear technologies, this study will investigate the SMR technologies in the angle of these interconnected aspects in detail, analyzing the current developments and future prospects of SMR deployment in BRICS countries (Brazil, Russia, India, China, South Africa, Iran, Egypt, Indonesia, UAE, Ethiopia) and partner (Belarus, Bolivia, Kazakhstan, Cuba, Malaysia, Nigeria, Thailand, Uganda, Uzbekistan, Vietnam) countries. It will focus on the technical, regulatory, safety-related, and ESG dimensions of SMRs, with the aim of evaluating their contribution to a more secure, sustainable, and resilient global energy system.
These technological advances with the creation of new financing instruments, promoted within the framework of cooperation between BRICS countries, reinforce the relevance of SMRs as a strategic tool in the global energy transition. This not only points to diversifying national energy matrices, but also to promoting more equitable models of international cooperation in the development of advanced nuclear technologies.

2. Trends of the SMR Development

Socio-Economic Trends

ESG and Environmental Responsibility

SMRs are considered an innovative solution in the nuclear energy landscape, offering a variety of benefits in the field of ESG. **(Glucksberg N., Peters J., & Santoianni D., 2022)**

Considering ESG aspects of the SMR development, these technologies are expected to make significant contributions to achieve the SDGs: climate action (SDG 13), affordable and clean energy (SDG 7), industry, innovation and infrastructures (SDG 9), and clean water and sanitation **(SDG 6) (WNA, 2021)**. Their low water requirements make them well-suited for deployment in regions facing water scarcity, as they minimize both groundwater consumption and effluent discharge. At COP28, SMRs were highlighted as a key solution for achieving carbon neutrality and addressing climate change. In terms of ecological and social aspects, SMRs can replace decommissioned coal or large conventional nuclear plants, thereby preserving local employment, tax revenue, and enabling workforce reskilling into higher-wage, future-proof roles in the nuclear sector. **(Ibid)**

Social and energy security development

The deployment of SMRs can have significant economic benefits, both direct and indirect. Their construction and maintenance are labor-intensive, creating new jobs. SMRs also boost energy production, which can help local industries grow (IAEA, 2024). Furthermore, their modular and smaller design makes them ideal for remote areas, which are often underdeveloped due to their isolation from major infrastructure. Providing a reliable power source to these regions can spur industrial development and create more jobs. This can reduce poverty, attract more people, and consequently, improve energy security at the local, national, and even regional levels. Since SMRs may be deployed in regions without existing nuclear infrastructure, workforce development and knowledge transfer are vital **(IAEA, 2001; Small-Modular-Reactors.org, 2025)**.

The BRICS Youth Energy Outlook 2024 highlights the role of youth and green skills development in the energy transition, which aligns directly with the future workforce demands of SMR programs **(BRICS Youth Energy Agency, 2024)**.
Diversity and flexibility of applications

Currently, the design of SMRs is increasingly focused on "distributed energy" applications, demonstrating high flexibility and innovative potential. In terms of multi-applications, SMRs can not only meet users' electricity demand but also be widely used in various fields such as industrial process heat supply, seawater desalination, district heating, and hydrogen production, covering diverse energy scenarios and providing crucial support for the diversification of energy structures. In both land and marine applications, SMRs exhibit remarkable adaptability and mobility: they can serve as land-based distributed energy stations or as power sources for marine platforms or oceangoing vessels, supporting tasks such as deep-sea resource development, offshore operations, and long-distance navigation. Also, SMRs are the optimal solution to meet data centers' demand as they require a steady baseload power supply.

Political and Legal Trends

SMRs raise concerns regarding nuclear material security, especially if reactors are exported to countries with limited regulatory oversight. Safeguards must evolve to prevent diversion of fissile materials while still allowing for international trade in SMRs.

Licensing processes for SMRs are being redefined. Traditional licensing frameworks designed for large reactors are too slow and costly for modular deployment. A major trend is the harmonization of regulatory standards across jurisdictions, allowing reactor designs to be approved more quickly in multiple markets.

Technological Trends

Potential of modularity and factory manufacturing

The central advantage of SMRs is modularity: reactor units can be fabricated in factories and then transported to their deployment sites. This approach reduces construction time, cuts costs, and ensures greater quality control compared to building reactors entirely on-site **(WNA 2025; OECD-NEA, 2021)**.

Another benefit of modular construction is scalability. Countries or utilities can begin with a single unit and add additional modules as demand increases, making SMRs more adaptable to changing energy needs. **(Al-Salhabi, et al., 2024)**.

Although the single-reactor power limitations result in insufficient economies, making it difficult for their electricity generation costs to compete with large reactors, SMRs can still leverage their safety features and system flexibility to advance the comprehensive utilization of nuclear energy. By being deployed close to the end-users and adopting combined heat and power or pure heat supply modes to improve efficiency, their economic viability can be effectively enhanced.

Nuclear Fuel Cycle Innovations

Many SMR projects are exploring advanced nuclear fuels to improve efficiency and sustainability. High-Assay Low-Enriched Uranium is at the forefront of these efforts, as it enables longer operating cycles and reduces the need for frequent refueling (IEF, 2024). Other concepts include mixed oxide fuel and thorium-based fuels, which could further diversify supply chains and improve resource utilization.

In addition, several designs aim to close the fuel cycle through reprocessing and recycling, reducing long-lived waste and improving sustainability. For example, fast neutron SMRs have the potential to consume existing nuclear waste as fuel, addressing both energy supply and waste management challenges at once (OECD-NEA, 2021). These innovations strengthen the argument that SMRs can contribute not only to decarbonization but also to responsible long-term stewardship of nuclear resources.

Digitalization and Smart Operations

SMRs are being designed with advanced digital technologies that improve safety, efficiency, and cost-effectiveness. Automation, artificial intelligence, and digital twin models are increasingly being integrated to reduce human error, optimize operations, and minimize staffing requirements **(ATS Industrial Automation, 2024)**.

Digital twins, for example, allow engineers to simulate reactor conditions in real time, making it easier to predict maintenance needs and improve system reliability. Automation also enhances remote monitoring, enabling SMRs to be safely managed from centralized facilities, which is particularly useful in remote or off-grid locations **(INMM, 2023)**.

Finally, digitalization supports stronger cybersecurity frameworks. With more reliance on digital control systems, SMRs must be designed to resist cyber threats. **(INMM, 2023)**.

Overall, the technological trends in SMR development, ranging from modular construction and advanced fuel cycles to digital innovation, represent a major shift from the traditional nuclear paradigm. These features make SMRs more flexible, potentially more sustainable, and better adapted to modern energy systems. By combining innovative design with digital tools, SMRs could significantly expand the role of nuclear power in achieving a low-carbon future **(WNA, 2025; IEF, 2024)**.

Physical and Technical Safety

Safety opportunities

SMRs have the potential to achieve improvements in safety over existing NPPs through simplicity of design and use of inherent and passive safety characteristics in addition to active safety components. SMR designs bring forward opportunities to enhance, at the design stage, the robustness and independence of the Defence-in-Depth (DiD) levels as well as resilience to different types of hazards (SMR Regulators' Forum, 2023). In addition, the scale of SMRs enables different types of design provisions in comparison to large scale reactors, e.g., underground siting and containments submerged in water pools. SMRs' physical size and siting may necessitate different types of assessment analyses and provisions for the external and internal hazards **(SMR Regulators' Forum, 2023)**. The objectives of safety by design of SMRs is to inherently eliminate or minimize potential accident initiators, and to mitigate/counteract the remaining initiators within the design limits, by simplified and reliable passive systems.

SMRs mark an important advancement in nuclear safety, placing passive safety features at the center of their design. Their inherent resilience makes SMRs a promising pathway for expanding nuclear power, supporting a low-carbon energy future while reducing the risks traditionally associated with nuclear technology.

Financial opportunities

Nuclear energy projects are traditionally financed by governments due to the challenges like their large scale, capital intensity, long construction times, technical complexity and associated cost overruns and delays which can drive away the private sector. However, the emergence of SMRs heralds the prospect of smaller scale projects, short construction time and payback period which, in turn, might open the door for more private investment. **(IEA, 2025)**

3. SMR technologies globally

Small Modular Reactors vary widely by technology, fuel type, and readiness level. There are more than 80 SMR designs and concepts globally. Most of them are in various developmental stages and some are claimed as being near-term deployable.

Though most of the projects are still at the concept stage, some SMRs have advanced from conceptual designs to licensed projects and, in some cases, operational facilities. While particular attention is given to designs originating from BRICS countries (e.g.: China's ACP100 and Russia's RITM-200), the analysis also covers major international developments such the U.S.' NPM and GE-Hitachi BWRX 300, Argentina's CAREM, France's Newcleo, South Korea's SMART and i-SMR, and the UK's Rolls-Royce 5SMR which can be potential suppliers of SMR technologies to BRICS countries. This global perspective reflects the interconnected nature of nuclear innovation and the role that BRICS may play within broader international progress.

While full cost comparisons are limited due to FOAK (First-Of-A-Kind) deployment, SMRs are expected to have higher per-MW capital costs but lower total project risk due to smaller unit size, shorter construction times, and modularity. Other key differences include flexibility of deployment, applications, and passive safety features. This table visually captures global SMR technologies across all stages, clearly distinguishing conceptual, licensed, and operational projects. **(IAEA ARIS, 2025), (WNA, 2025)**

Table 3. Categorization of nuclear power plants by design status

Category	Design/ Facility	Country	Type/ Technology	Capacity (Mwe)	Deployment country	Year of FOAK commissioning
Conceptual, basic, or preliminary design	Rolls- Royce SMR	UK	PWR	470	UK, Czech Republic	2033
	Natrium	USA	Sodium-cooled fast reactor	345	USA	2030
	KRONOS MMR	USA	Helium-cooled HTGR	15	USA /Canada	
	ARC-100	USA	Sodium-cooled fast reactor	100	USA /Canada	2030/2035
	Xe-100	USA	HTGR	80	USA	2030+
	i-SMR	South Korea	PWR	170	South Korea	2035
	SMR-300	USA	PWR	300	USA	2030+
	Nuward	France	PWR	170 per module	France	2035
	AP300	USA	PWR	330		2033
	Newcleo	France	Lead-cooled fast reactor	200	France	2031
Licensed Designs	NPM	USA	PWR	77 per module		
	SMART	South Korea	Integral PWR	100		
	Aalo-X	USA	Sodium-cooled fast reactor	50 (10x5)	USA	2030
	Hermes	USA	Fluoride salt-cooled high-temperature reactor	10	USA	2030+
	Project Pele	USA	HTGR	5	USA	2026
	MSR-100	USA	MSR	80		
	RITM-400	Russia	PWR	155		
Under construction	ACP100 "Linglong One"	China	PWR	125	China	2026
	BREST- OD-300	Russia	lead-cooled fast neutron reactor	300	Russia	2028
	FNPP (RITM-200S)	Russia	PWR	53x2	Russia	2028
	RITM- 200N	Russia	PWR	53x2	Russia/ Uzbekistan	2031/2032
	BWRX 300	Canada	BWR	300	Canada	2030
	CAREM- 25	Argentina	Integral PWR	32	Argentina	Suspended
Operational Facilities	HTR-PM	China	Pebble-bed HTGR	210	China	2023
	RITM- 200S	Russia	PWR (icebreaker)	55	Russia	2020
	KLT-40S	Russia	Floating PWR	70 (2x35)	Russia	2020

SMRs vary vastly from standard large nuclear reactors (typically 1000-1600 MWe) in several categories: scale, flexibility in deployment and applications of each. The most notable trade-off is the one between cost efficiency (economies of scale) and flexibility of deployment. Large nuclear facilities take advantage of economies of scale (i.e saving in costs gained by an increased level of production) which offer a lower unit costs per kWe capital cost and established supply chains, however, they require substantially high upfront capital investment, long construction timelines and a robust grid infrastructure. Contrary, SMRs allow for modular deployment at a fraction of the construction timelines, scalability, and diversified applications (including district heating, hydrogen generation, and industrial process heat) making them suitable for emerging markets and remote regions. The table below summarizes key distinctions between SMRs and large nuclear reactors:

Table 4: SMRs vs. Large Reactors

Feature	SMRs	Large Nuclear Reactors
Capacity (MWe)	≤ 300	1000-1600
Capital Cost ($/kWe)	High	Low
Deployment Flexibility	High	Low
Safety features	Primary passive	Active and passive
Site Requirements	Small footprint, isolated deployment	Large footprint, grid-connected
Applications	Electricity, district heating, hydrogen, industrial process heat	Electricity, district heating, hydrogen, industrial process heat

Economics & Market Outlook

The IEA estimates that 40-200 GW of SMR capacity could be installed worldwide by 2050 under various scenarios. The main growth of the market is expected beyond 2030, after the successful implementation of the first FOAK and NOAK projects. Despite the promise of modularity, SMRs still face high FOAK costs. Typical FOAK overnight costs are USD 6,000–10,000/kW, higher than large-scale reactors, due to smaller economies of scale and extensive regulatory processes (IEA, 2025). However, once multiple units are deployed (NOAK), costs are targeted to fall below USD 5,000/kW (large-scale reactors – about USD 3,600/kW).

Studies indicate that the Levelized Cost of Energy (LCOE) for SMRs could reach USD 48–78/MWh with Production Tax Credit, competitive with "renewables + storage" in some contexts **(Abdusammi, et al., 2025)**. Cost competitiveness will depend on modular factory fabrication, regulatory harmonization, tax incentives and financing models.

Current CAPEX and LCOE estimates by technology providers are very preliminary and tend to be revised upwards as projects progress. Higher actual costs, delays and project failures of FOAKs can reduce the pace of NOAKs implementation dramatically. This may result in inability to achieve the benefits of economies of scale, standardization, process improvements due to moving up the learning curve, and, finally, to obtain the targeted cost reductions.

Overall, there are significant risks that during the transition from FOAK to NOAK, SMR projects' performance will not be able to improve significantly, and SMR will remain a niche solution for remote regions. According to other estimates, although FOAK deployment faces higher per-kWe costs, as serial production ramps up, cost competitiveness is expected to improve through learning curves and standardized manufacturing **(IAEA ARIS, 2024; WNA, 2024)**.

4. Nuclear fuel supply chain for SMRs

The nuclear fuel cycle corresponds to the sequence of industrial processes that extend from uranium mining to radioactive waste management, encompassing reactor operation and, in some cases, the reprocessing of spent fuel. In general, it is divided into three stages: front-end, in-core, and back-end. The table below visualizes the major differences of the nuclear fuel cycle of large-scale reactors and SMRs **(WNA, 2025)**.

Table 5. Comparison of SMRs vs Large-Scale Reactors in nuclear fuel cycle

Aspect	Capacity (MWe)	Capacity (MWe)
Fissile material	Natural, perfumed and reprocessed uranium, reprocessed plutonium	Natural, perfumed and reprocessed uranium in form of dioxide, reprocessed plutonium under investigation: uranium nitride, uranium boride, uranium silicide, and thorium
Enrichment	~3–5% U-235 (LEU)4	~3–5% U-235 (LEU), 5–10% (LEU+) or 10–19.75% (HALEU)
Cycle length	12–24 months	12–24 months 3–10 years (long-life cores); up to 30 years in sealed cores
Refueling	Regular refueling outages (from quarter to half of the core replaced with fresh fuel assemblies)	Modular, full core loading, or sealed core; fewer outages and greater logistical flexibility
Back-end strategy	Storage in pools/dry casks; reprocessing (in some countries)	Smaller absolute volume but higher waste density5; vendor take-back; fuel leasing; advanced recycling strategies
Examples	PWR (M310, CP1, CPR- 1000, EPR, VVER), BWR (ABWR, ESBWR)	PWR (RITM, CAREM-25, SMART, VOYGR, Rolls- Royce SMR, ACP100), BWR (BWRX-300)

The key difference in nuclear fuel cycles for light water SMRs from conventional LWRs is in the intention to the use the fuel with higher enrichment levels and operate the unit in relatively longer cycles in order to increase the unit capacity factor, consequently reducing the LCOE **(L. Carlson, J. Miller, & Zeyun Wu, 2022)**.

One of the most important stages in nuclear fuel production, as mentioned in the table above, is uranium enrichment. In addition to non-proliferation concerns arising from acquiring enrichment know-how, this process is capital-intensive and requires cutting-edge knowledge and expertise. This is why only a few States can afford carrying out the process, and the number of commercial uranium suppliers are limited (WNA, 2022). Currently, 40% and 17% of global uranium enrichment is conducted by Russia and China, respectively **(Thunder Said Energy, 2024)**.

4 Some countries are already investigating the feasibility of LEU+ fuel 5
For higher enrichment levels and higher burnups

So far, various proposals have been made for nuclear fuel supply assurance to the countries without nuclear fuel cycles. These proposals are as follows (IAEA, 2005):

1. Assurance of supply not involving ownership of facilities

   a) Supplier provides additional assurances of supply;
   b) Founding the international consortia of suppliers;
   c) IAEA related arrangements.

2. Conversion of existing national enrichment facilities in the supplier States into multinational facilities

3. Construction of new joint facilities.

BRICS States, relying on economic cooperation among themselves and leveraging existing capacities within BRICS, can opt for one of the proposed options as a solution for supplying nuclear fuel. Implementing these options, particularly the multilateral proposals within BRICS, is not far-fetched, as some members are already part of such initiatives. For example, Russia (BRICS country) and Kazakhstan (BRICS partner country) established the International Uranium Enrichment Centre (IUEC) in Angarsk in 2007. The aim of the project is to provide guaranteed access to uranium enrichment to the interested Parties without transferring the sensitive technology or restricting the development of national nuclear fuel cycle programs. Additionally, back in the same year, Russia proposed the creation of a guaranteed reserve of low enriched uranium (LEU) at the IUEC. This LEU Guaranteed Reserve would be controlled by the IAEA and could be used by its Member States that find themselves unable to procure LEU from the open market for political reasons. This proposal was approved by the IAEA and implemented in 2010 **(IAEA, 2016)**.

5. Prospects of the SMR development in BRICS countries

An overview on the development and deployment plans of SMRs in the BRICS countries and BRICS partner countries

Brazil

Brazil is actively exploring SMRs but has not committed to commercial deployment or announced large-scale construction funding. In recent parliamentary hearings, the National Nuclear Energy Commission (CNEN) has presented advancements in the regulatory framework to encompass new SMR safety licensing and the required coordination of scientific research and personnel training (CNEN, 2025). Amazul announced that it is preparing to propose a national project for Brazilian SMR (Amazul, 2023). State nuclear energy company Eletronuclear has included SMRs in its medium-term strategic plan for 2023–2027, emphasizing long-term interest amidst the absence of current construction projects (Eletronuclear, 2023). With support from the Ministry of Mines and Energy (MME) and the Energy Research Company (EPE), a Brazilian-American study was conducted with the Idaho National Laboratory (INL), published in February 2023, which analyzes the integration of SMRs into the energy system (EPE, n.d.). Brazil is considering increasing nuclear power plant capacity from 2 GW (2022) to 8-10 GW by 2050 (EPE, 2023). In a recent diplomatic visit to Russia, officials have initiated talks about the potential of developing SMR technology, mainly focused on energy delivery through floating (i.e. barge mounted) units, reinforcing international cooperation with other BRICS countries (WNN, 2025).

Russia

The Russian State Corporation Rosatom is one of the global leaders in the development of SMR technology. The flagship project in this area was the adaptation of the successful RITM-200 marine reactor unit into a land-based version, RITM-200N, with a capacity of 55 MW per module. On this basis, Rosatom is planning to build Russia's first small onshore nuclear power plant, consisting of two reactors, with a capacity of 110 MW in the village of Ust-Kuyga (Yakutia region), which is scheduled to be put into operation in 203 (Rosatom, 2023). At the same time, Russia is actively promoting its solutions on the international stage: Rosatom has started manufacturing a reactor for the first small nuclear power plant in Uzbekistan (six RITM-200N reactors) (Rosatom, 2025a), and in March 2025, an intergovernmental agreement was signed with Myanmar on the construction of 110 MW with the possibility of expansion to 330 MW (Rosatom, 2025b). Important operational experience was gained through the commissioning of the world's first floating nuclear power plant (FNPP), Akademik Lomonosov, in the Arctic city of Pevek (Chukotka region) with two KLT-40S reactors (total capacity 70 MW). This FNPP's main objective is to provide electricity to remote industrial areas of the city. Rosatom is also developing the RITM-200S reactor for the modernized floating power units that will supply power to the Baimsky Mining and Processing Plant in Chukotka region, and is planned to be operational in 2029 (Rosatom, 2022). In addition, Rosatom is developing optimized floating power units based on the RITM-200M reactor for mass production and export. Their fuel cycle would last up to 10 years, and its design life – up to 60 years (Rosatom, 2025c). Another project is the Shelf-M microreactors with a capacity of up to 35 MW and an electric capacity of 10 MW. The first plant based on this technology is expected to be operational by 2030. According to official reports of the State Corporation Rosatom, the development of SMR technologies is a national priority (Rosatom, 2023a). Thus, Russia has developed a full range of competitive SMR technologies some of which are already deployed both domestically for the development of the Arctic and the Northern Sea Route and internationally on the global market.

India

India is actively developing SMRs as part of its national energy strategy (Department of Atomic Energy, 2024). The government announced the launch of the national mission to develop five indigenous Bharat-SMRs with a capacity of 16-300 MW by 2033, allocating INR 20 trillion (~ USD 2,5 billion) for this purpose. The budget of the Department of Atomic Energy (DAE) has been increased by 170% since 2014, demonstrating the priority of such projects. Apart from energy sector decarbonization and reliable supply to remote areas, key factors include the need to utilize the world's largest thorium reserves (21% of global reserves). India is open to international cooperation, while maintaining a focus on developing its own technologies (Department of Atomic Energy, 2025). The Bhabha Atomic Research Centre (BARC) is developing a promising Advanced Heavy Water Reactor (AHWR) and its variants (including AHWR-300-LEU), with a capacity of 300 MW, passive security systems and the possibility of water desalination, which is part of a three-stage program for the development of the thorium fuel cycle (BARC, n.d.). Overall, India combines the development of its own technologies (such as AHWR and the thorium cycle) with the import of advanced solutions, positioning SMR as a key element in achieving zero emissions by 2070 (NPCIL, 2023).

China

China has emerged as a global leader in the development and deployment of SMR technology. The nation is actively pursuing two primary SMR projects to enhance its clean energy supply. The first is the ACP100 (Linglong One), developed by China National Nuclear Corporation (CNNC) (CNNC, n.d.). Its demonstration model is being constructed at the Changjiang Nuclear Power Plant (Hainan Island), with the first concrete poured in 2021. This is the first SMR in the world to pass the IAEA safety assessment in 2016. (CNNC, 2025). Moreover, CNNC offers an offshore version – ACP100s. The second flagship project is a modular design Gen-IV high-temperature gas-cooled reactor with spherical fuel pebbles (HTR-PM), developed by Tsinghua University in partnership with China Huaneng Group and CNNC. The pilot plant in Shidaowan was connected to the grid in December 2021 and entered commercial operation in December 2023. The equipment is mainly (93.4%) made in China. Additionally, the SMR technologies are being developed by China General Nuclear Power Corporation (CGN): ACPR100 (onshore NPP) and ACPR50S (offshore). These projects lay the foundation for strengthening China's position in the global nuclear energy market.

South Africa

South Africa is actively pursuing the development and deployment of SMR nuclear power plants to address its energy crisis and decarbonization goals. Both private and state-owned entities are involved, building upon South Africa's previous experience with pebble bed reactor technology. The Koeberg Nuclear Power Station is the only nuclear power plant in Africa, located in Cape Town on South Africa's west coast. It is owned and operated by the country's state-owned electricity utility, Eskom, and it has been in operation since the 1980s. South Africa is actively reviving its Pebble Bed Modular Reactor (PBMR) program and pursuing SMR deployment as a central part of its renewed nuclear energy strategy. This follows years of the PBMR project being placed on care and maintenance after development was halted in 2009. South African energy company Eskom is advancing plans to build a SMR with a capacity of 100 MW as part of a program to replace decommissioned coal-fired power plants. This decision will save up to 30% of capital costs through the use of existing infrastructure (NECSA, 2025). In October 2025, it was announced that NECSA was ready to step up as per the call by the Minister through its business strategy that included re-establishing the nuclear fuel, SMRs, and nuclear skills development. The new capacity of 5,2 GW allocated to nuclear opens the door for a robust nuclear build programme and makes a case for a sustainable nuclear industry that will complement the broader South African energy mix. (South African Government, 2025). It also has announced an ambitious plan to attract investments in the amount of ZAR 50 billion (USD 2.9 billion) for the development of research and pilot projects in the nuclear field, with a focus on SMR technology.

Egypt

Currently, there are no official plans to build an SMR in Egypt. Egypt's first nuclear power plant is the El-Dabaa Nuclear Power Plant, located on the Mediterranean coast in the Matruh province. The project is being constructed by Russia's Rosatom and will feature four VVER-1200 reactors, with operations expected to begin around mid-2029. The plant is a key part of Egypt's strategy to diversify its energy mix. The construction of the first unit began in July 2022, the second in November 2022, the third in May 2023, and the fourth in January 2024. It is planned that the plant will start generating electricity by 2026, and the full-scale operation of all four reactors should start by 2030.

Ethiopia

Although Ethiopia has not yet initiated domestic nuclear power production, it has demonstrated interest in nuclear science and technology, primarily for research and medical purposes. As part of the BRICS cooperation framework, Ethiopia is positioned to benefit from the technological advancements and capacity-building programs associated with SMRs. As of now, Ethiopia has no plans for SMR construction projects. In September 2025, the government revealed plans to build a nuclear power plant (Anadolu Ajansı, 2025) and signed an Action Plan with Russia to advance this initiative (Atommedia, 2025). Ethiopia has ratified international cooperation instruments and is working with the IAEA under its 2024–2028 Country Programme Framework to strengthen nuclear applications and regulatory capacity. In May 2024 at the 22nd INPRO Dialogue Forum on Successful Development and Sustainable Deployment of SMRs, Ethiopia noted that SMRs are being considered as an option within future planning and feasibility work (IAEA, 2024). The Government of Ethiopia is now working on diversifying its energy mix with other sources such as solar, wind, geothermal and nuclear.

Iran

SMRs could hold a special place in Iran's national energy strategy. Struggling with the severest energy crisis in decades (Shokri, Umud. 2025), the country could avail itself of the great potentials that SMRs offer for power generation. Development of SMRs in Iran has gained a new momentum by the recent memorandum of understanding signed with Russia's Rosatom. The document is believed to be a facilitator for contracts to be drawn up for the design and construction of SMRs in Iran (WNN, 2025). Prior to that, the possibility of deploying SMRs had been explored from different aspects by the Iranian Atomic Energy Organization through efforts such as holding seminars to review the process of selecting the most suitable SMR technologies for Iran (IAEO, 2021) and meeting with private sector actors to encourage them to invest in SMRs (IAEO, 2025). Apart from energy generating purposes, Iran has also recently announced its plan to build a mobile mini-reactor for seawater desalination (Azad News Agency, 2025).

Indonesia

SMR technologies are considered promising for Indonesia, an archipelago with a disparate energy system. Indonesia, with its vast maritime territory, is ideally suited for modular and floating nuclear power plants. Nuclear power is already included in the country's National Electricity Supply Plan (RUPTL) (Badan Pengawas Tenaga Nuklir, 2025). As of 2024, the Indonesian government is discussing nuclear energy development with companies from China, Russia, South Korea and the United States. According to National Research and Innovation Agency (BRIN), feasibility work is under way for nuclear power plants in the 2030s, including smaller units of 100–200 MW (typical SMR scale) to serve remote areas, aligned with Indonesia's net-zero emissions target for 2060. As for R&D, the BRIN and ITB (The Bandung Institute of Technology) are developing an Indonesian SMR technology – PeLUIt-40 – high-temperature gas-cooled reactor (HTGR) aiming to generate energy and support hydrogen production (Coelho, Z., 2024).

United Arab Emirates

The Emirates Nuclear Energy Company (ENEC) announced the launch of ENEC ADVANCE, a new program to harness the latest advancements in nuclear energy technologies. The program is provisioned to strengthen the UAE's position as a leading nation in delivering climate action by accelerating the global energy transition. The program will evaluate the latest technologies in the advanced, SMR and microreactor categories. ENEC has entered into strategic partnerships with leading international companies to promote SMR technologies. In May 2025, ENEC signed a memorandum with GE Vernova Hitachi Nuclear Energy to jointly evaluate the deployment of 300 MW BWRX-300 reactors, deepening the cooperation that began at COP28 in 2023. In parallel, ENEC has entered into an agreement with South Korea's Samsung C&T Corporation to implement international projects in civil nuclear energy. The Federal Authority for Nuclear Regulation (FANR) supports these efforts by implementing transformative projects to strengthen global security and position the UAE as 'the safest country in the world.' These strategic steps reinforce the UAE's position as a global leader in the peaceful use of nuclear energy and SMR technology.

Thailand

The main drivers for the development of SMR projects in Thailand are the need to diversify the energy balance and achieve carbon neutrality by 2050. The draft Power Development Plan for 2024-2037 notes that 47,251 MW of new capacity is planned to be built, of which 600 MW will be generated using SMRs (Public Debt Management Office of Thailand, 2024).

In June 2025, Korea Hydro & Nuclear Power signed a MoU with the Electricity Generating Authority of Thailand (EGAT) on cooperation in the field of SMRs and exploring their use in future projects. The agreement provides for the exchange of technical information related to SMRs, a joint review of options for introducing SMRs in Thailand, and cooperation in the field of personnel training through the organization of field trips and the exchange of personnel and technologies in the field of nuclear energy (WNN, 2025).

Uzbekistan

Among the partner countries, Uzbekistan has expressed the most notable interest in developing SMR technology. The main reasons for Uzbekistan's interest in developing its nuclear industry are its uranium reserves, the need to diversify its energy balance, and the need to meet its carbon neutrality targets.

Active cooperation between Uzbekistan and Russia on the construction of the SMR began in May 2024 when a protocol was signed amending the intergovernmental agreement on cooperation in the construction of a nuclear power plant in Uzbekistan dated 7 September 2018, extending its scope to include the construction of SMR, as well as a contract for the design, supply and construction of the SMR in Uzbekistan (Rosatom, 2025). In October 2025, a key stage of work on the construction of the SNPP in Uzbekistan was launched. The SNPP is being built in the Farish district of the Jizzakh region of Uzbekistan based on a Russian design (RITM-200N) (WNN, 2025). The project is planned to include two reactors, each with a capacity of 55 MW. The full launch of the SNPP is scheduled for no earlier than 2032. The Tashkent branch of MEPhI trains personnel for the nuclear industry, reflecting the potential for cooperation within BRICS in the area of personnel training.

In addition to Russia, Uzbekistan is also developing cooperation with China on the development of SMR technologies. In August 2024, Uzatom and CNNC signed a MoU and a roadmap for cooperation in the field of nuclear energy, which includes the development of SNPP projects (CNNC, 2024).

Malaysia

In July 2025, nuclear energy was included in the 13th Malaysia Plan (Economic Planning Unit, Prime Minister's Department of Malaysia, 2025). The document notes that nuclear power is expected to enter the national energy mix by 2031, providing low-carbon and clean electricity.

In August 2025, the Ministry of Energy Transition and Water Transformation (PETRA) announced that Malaysia is conducting a feasibility study on the development of nuclear energy, including the deployment of a SMR (WNN, 2025). In particular, the study of this possibility will focus on regions where the development of renewable energy sources faces particular challenges, especially in Peninsular Malaysia and Sabah. Part of the study will be devoted to issues of human capital development and the development of a regulatory framework to improve nuclear legislation.

In March 2025, the Ministry of Science, Technology and Innovation stated that Malaysia was considering developing cooperation with India and China on the import of technology for thorium reactors, including for the development of SMR technology (Bernama, 2025). In July 2025, Malaysia signed a MoU with the United States, which is one of the first steps towards further cooperation and accession to the 123 Agreement (US Department of State, 2025). In August 2025, it became known that Russia and Malaysia had begun working on an intergovernmental agreement on deliveries of FNPP.

Nigeria

The ambition to develop nuclear energy in Nigeria is linked to the need to expand access to stable electricity for the population and diversify the energy mix in order to achieve energy transition goals. Strategic planning documents mention plans to develop nuclear energy, but the deadlines for their implementation are not being met (Nigeria SEforALL Action Agenda, 2016). Nevertheless, during a speech at the IAEA General Conference in September 2025, the representative of Nigeria emphasized that the country remains engaged in exploring SMR options and looks forward to their full commercialization, while noting that deployment must be in line with IAEA Member States' obligations and without prejudice to their right to peaceful uses of nuclear energy (IAEA, 2025).

Adding nuclear energy and research on SMRs into the sectoral cooperation and cross-cutting areas of the Roadmap for BRICS energy cooperation 2025-2030

The roadmap for BRICS energy cooperation 2025-2030 was adopted at the Energy Ministers meeting in May 2025 (BRICS, 2025). This roadmap structures the members' cooperation in two fields sectoral cooperation, which reflects the priorities of BRICS countries in energy, and cross-cutting areas, which should be mainstreamed across joint activities under sectoral cooperation, such as capacity building, digitalization, and research. Current sectoral cooperation thematic areas include a wide spectrum of topics, ranging from renewable and bioenergy to fossil fuels and hydrogen. However, nuclear energy, and especially SMRs, remain beyond this framework. By including nuclear energy with a focus on SMR development, the roadmap could streamline policy and decision-making, enhance mutual investment and technology transfer, and facilitate relevant research among BRICS countries.

The role of the New Development Bank in the development of SMRs in BRICS countries

Multilateral Development Banks (MDBs) hold a crucial role in addressing energy transition issues. They can incentivize the flow of investment into clean energy projects by providing financial support, including loans, guarantees, equity investments and technical assistance, especially in developing countries (BBVA CIB, 2024). The adoption of the Paris Agreement at COP21 in 2015 was followed by a wave of joint commitments issued from MDBs in the form of goals, actions, initiatives, and voluntary principles aiming to increase finance for projects related to climate change and decarbonization (Rodriguez, Maria Elena, et al., 2024). Although nuclear energy is one of the major contributors to global decarbonization efforts, there has been a chronic disinterest of MDBs in financing nuclear projects. Drawbacks like safety and non-proliferation concerns, the enormous upfront capital requirements and prolonged, high-risk construction timelines and prioritizing other development goals like health, education or renewable energies (Coelho, Z., 2025) chiefly account for their uninvolved approach. However, the emergence of SMRs could, to a large part, mitigate these challenges. The recent shift in several major MDBs like the World Bank (World Nuclear News, 2025) and Asian Development Bank (Financial Times, 2025) towards reconsidering their policies to enable support for nuclear energy projects heralds new opportunities for nuclear power growth in developing countries under the auspices of MDBs.

The New Development Bank (NDB) is an MDB established by Brazil, Russia, India, China and South Africa (BRICS) in 2015 with the purpose of mobilizing resources for infrastructure and sustainable development projects in emerging markets and developing countries (EMDCs) (New Development Bank, 2023). The membership is not limited only to the BRICS members and open to members of the United Nations, in accordance with the provisions of the Articles of Agreement of the New Development Bank. Since its establishment in 2015, it has expanded and currently four new members including Bangladesh, United Arab Emirates, Egypt and Algeria have joined the bank (New Development Bank, 2025). One of the operation areas in the bank's General Strategy for 2022-2026 is dedicated to "Clean Energy and Energy Efficiency" (New Development Bank, 2023a). Some of the present projects in this area, which are financed by the Bank are as follows: Serentica Captive Renewable Energy Project (India), Brasilia Capital of Solar Lighting Project (Brazil), Beliy Porog Hydro Powerplant Project (Russia), IDC Renewable Energy Sector Development Project (South Africa) and Putian Pinghai Bay Offshore Wind Power Project (China) (New Development Bank, 2023c). As witnessed by these projects, the bank is efficiently competent to and capable of financing wide-ranging projects with varying degrees in scale and cost, to which SMR projects could also be added. In 2025 at the World Atomic Week held in Moscow, Russia, NDB's authorities declared the bank's willingness to include nuclear projects into its financing scope. Although there was no explicit reference to the SMRs projects, their financing falls under the bank's policy of supporting projects of scale in the field of clean energy. Therefore, explicitly including both large-scale NPP and SMR projects as one of the funding priorities in the new post-2026 General Strategy represents a unique turning point for the NDB to spearhead nuclear power development in the Global South countries through enabling capital for SMR deployment.

Youth perspectives and future energy roles

The success of SMR deployment in BRICS countries will depend not only on technology and financing but also on the engagement of younger generations. Surveys of youth attitudes toward nuclear energy show a divided picture: while many young people express concerns about safety and waste management, others see nuclear as an essential element to achieving carbon neutrality (IAEA, 2023; OECD NEA, 2022). Integrating nuclear education into university curricula, vocational training, and international exchange programs is critical for building the skilled workforce required for future SMR deployment. Initiatives such as the IAEA's Nuclear Energy for Climate youth program or this very BRICS Young Expert Group highlight the growing role of young professionals in shaping energy transitions.

Youth engagement in policy dialogues also ensures that SMR deployment aligns with broader sustainable development priorities, including just transition, energy equity, and intergenerational responsibility. BRICS cooperation could foster youth-led research, facilitate capacity building among young nuclear professionals working in the sector, provide opportunities for innovation challenges and cross-border training programs, thus positioning SMRs as not only a technological solution but also an attractive career opportunity for young people.

6. Challenges of the SMR development

"Success story" effect and pathfinding

The global SMR landscape features a multitude of technology routes, including light-water reactors, high-temperature gas-cooled reactors, molten salt reactors, and others. Each technology has its unique physical characteristics and safety systems, meaning that the success of a single project cannot validate all technologies. Each distinct technological pathway must complete the entire cycle from design and engineering demonstration to commercial deployment. This disperses resources and prolongs the overall technology maturation cycle.

FOAK engineering risks

The modular construction and factory fabrication model for SMRs itself has not yet been fully tested at a large scale. The reliability and economics of many key components, being FOAK equipment like fuels, steam generators (SGs), and pumps, carry significant risks. Also, the shift from on-site construction to factory manufacturing involves entirely new supply chains, quality assurance protocols, and module installation processes. Errors in any link could lead to delays and cost overruns.

Lack of long-term operational experience and demonstration projects

Currently, the majority of SMR designs are still on the drawing board or under construction. Very few SMRs have actually entered commercial operation and demonstrated reliable long-term performance. Without operational data validated through practice, it is difficult to build sufficient confidence for widespread deployment, mobilize funding or optimize the design and operational costs of subsequent units.

Social and security challenges

The deployment of SMR technology presents a complex array of interconnected safety, security and regulatory challenges that require a fundamental rethinking of large nuclear safeguards. While novel fuel designs and intrinsic safety features offer potential benefits in terms of reduced off-site contamination risks, they introduce new vulnerabilities related to automated operations, remote supervision systems, and concentrated safety infrastructure within compact footprints, making critical components more susceptible to simultaneous damage. Design considerations such as subterranean placement, which offer protection against external threats like aircraft impacts, introduce alternative hazards like flooding, whereas multi-unit configurations increase nuclear material inventories and associated security risks (SMR Regulators' Forum, 2023).

Non-proliferation concerns

Non-nuclear weapon countries must abide by the international non-proliferation rules largely originated from the Nuclear Weapons Non-Proliferation Treaty (NPT). Through implementation of the NPT safeguards agreements with its member states, the IAEA can verify that nuclear facilities are not misused and nuclear material not diverted from peaceful uses (IAEA, 2016). SMR designs, in particular, pose new challenges for IAEA safeguards because of their fuel types, coolants, and configurations (Virgili, N., 2020).

The following are noticeable examples of how the SMR designs could be problematic for the IAEA verification:

1. Low thermal signature emitted from SMRs, which is similar to other energy technologies, complicate remote sensing (such as satellite) for detecting reactor's operations;
2. Deployment in remote locations might limit access for inspection purposes;
3. Possibly sealed and long-life reactor core reducing the access to the core and therefore necessitating different types of monitoring, such as virtual access;
4. Possibly smaller size of fuels making concealment easier;
5. Vertical storage of spent fuels obstructing the direct-line visibility from above and reducing monitoring abilities (Whitlock, J, and J Sprinkle, 2012);
6. Reduced detectability due to their smaller size and portability (Joel, C., Saimum, O.S., and Amponfi, A., 2023);
7. Using fuels enriched higher than 20%, which could be more proliferation-prone in some SMRs, and the capability of converting Uranium to Plutonium-239 in special types of SMRs which are referred to as "Breeders" (Virgili, 2020).

These novel challenges call for more innovative ways to be taken by the IAEA. The concept of "Safeguards by Design" (SBD) which has already been developed by the IAEA could be of service to overcome the above-mentioned challenges. SBD implies the importance of considering the safeguards requisites during the designing phase, before constructing a nuclear facility, including SMRs. In this approach, the requirements for verification activities will be integrated into the SMR designs to make them more conducive for safeguards implementation, while also being customized in relation to specific SMR reactor type (Whitlock, J., 2025). Nonetheless, implementing SBD comes with challenges, such as the IAEA's lack of direct communication channels with facility designers, as well as gaps in the understanding of international safeguards requirements among designers and vendors (Cabañas, C., 2021).

Legal challenges
Current regulatory standards often require revision in order to be able to license land-based SMRs. Floating power units and types of reactors such as HTGR, MSR, LFR or SFR often require the development of separate regulatory documents. Many developing countries which are planning to develop or deploy SMRs lack standardized regulatory frameworks for nuclear licensing, leading to increased FOAK licensing risk, delays, and potential legal uncertainties.

Financial challenges
SMR technologies are of high capital intensity (per unit of output capacity), which might result in elevated costs of electricity supply. Despite the use of modular solutions in manufacturing, transportation and construction of SMRs, a significant share of capital investment per power unit will be accounted for by safety systems during its operation.

7. Conclusion and recommendations

This research has revealed that SMRs are considered the next stage technology in the development of nuclear power, offering a range of advantages to countries with limited resources and specific geographical locations where conventional large-scale NPPs cannot be a solution. However, there are certain challenges to their commercial deployment, including technical issues such as technological maturity and demonstration/validation, financial issues, and social, security, legal and environmental concerns. The latter include non-proliferation concerns and the complexity of regulatory approval and licensing.

Nevertheless, SMRs offer a wide range of opportunities, including technical ones, such as modularity and factory manufacturing, and the diversity and flexibility of applications. Financial opportunities include incentives for MDBs and the private sector to invest in nuclear energy, and the potential for modularity and factory manufacturing to reduce costs and shorten schedules. Social, security and legal opportunities include a surge in highly skilled and well-paid jobs and welfare in remote areas, as the deployment of SMRs can generate employment and provide energy to local populations, thus addressing energy justice.

Most BRICS countries are actively exploring the possibility of integrating SMRs into their energy strategies, from conducting feasibility studies to signing cooperation agreements with technology vendors. In this context, the world leaders' operational experience of Russia's RITM-200 and China's HTR-PM becomes a key advantage for the BRICS group. Therefore, further cooperation in SMR development within the BRICS framework is strategically important to leverage on proven technologies, create synergies that will help to reduce costs, accelerate joint R&D and establish common standards. Ultimately, this cooperation provides partner countries with access to reliable solutions for powering remote regions and decarbonizing hard-to-abate industrial sectors.

In this context, the BRICS Young Expert Group has elaborated several recommendations on SMR development in BRICS countries:

Harmonization of the regulatory framework. As the IAEA continues updating their guidelines and safeguards for SMRs, there is an opportunity for BRICS to develop its own complementary set of standards. Such BRICS-specific regulations could build upon the international baseline to address shared priorities and enable the creation of a harmonized regulatory environment for SMR deployment across member and partner states. This work could be facilitated by the BRICS Nuclear Platform and get additional impetus through the Roadmap for BRICS Energy Cooperation.

Collaboration with the NDB for financing SMR projects. As a multilateral development bank focused on sustainable infrastructure, the NDB's endorsement of nuclear project financing as part of its post-2026 General Strategy might open the door to creating viable funding models and consolidating common criteria, including ESG metrics, for SMR project assessment. This development is especially crucial for implementing SMR projects in NDB member countries with limited fiscal capacity.

Collaborative Supply Chain Development. The BRICS states and partner countries encompass nations with established nuclear energy programs alongside those newly embarking on the path of nuclear development. Given that the BRICS countries collectively possess a full nuclear supply chain, leveraging its collective potential could significantly enhance the resilience of supply while streamlining technical and procedural aspects.

Building the expertise and skills of young nuclear professionals. The implementation of ambitious technological plans in the BRICS countries largely depends on the young workforce committed to advancing innovation in the nuclear sector. Supporting thematic youth-led research, capacity building and practical training in partnership with key BRICS and global nuclear stakeholders will empower young people with necessary expertise and develop their technical skills, while also expanding their professional community for future collaboration.

Considering the increasing role of the BRICS countries in the global nuclear market, including the development of SMRs, it is crucial to create a space for constant dialogue and experience exchange. Such collaboration must be strengthened within the framework of multilateral initiatives that will address multiple issues related to the development and deployment of SMRs, including the financing of such projects by multilateral development banks. In this regard, the BRICS Nuclear Platform, which is aimed at introducing best practices and advanced approaches in the field of nuclear energy and non-energy technologies and promoting incentives for their development, could be an effective cooperation tool among the BRICS states and partner countries in the nuclear sector.

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