Nuclear Renaissance

Yes, It Is. An Opportunity, But Challenges Remain

Prof M Sai Baba

PRF

https://prfworld.org

ABOUT US

Politeia Research Foundation, a non-profit initiative, reflects on global and public policy issues. The research foundation engages with plural worldviews and the exchange of ideas with inputs from a wide spectrum of scholars, practitioners and learners from multiple disciplines and diverse backgrounds. Besides researching international political, societal, security and economic issues, the foundation aspires to foster peacebuilding approaches to facilitate relevant conversations through publications, deliberative processes and related activities. The foundation, in its work, will uphold and value the liberty, equality, and dignity of the individual.

AUTHOR

Prof. M. Sai Baba

Prof. M. Sai Baba is an Honorary Visiting Professor in the School of Natural Sciences and Engineering at the National Institute of Advanced Studies (NIAS) in Bengaluru. An accomplished researcher, scientific administrator, and institutional builder. Made significant contributions to implementing several high-impact activities relevant to IGCAR and the DAE. He is an Outstanding Scientist and former Director of the RMG, IGCAR, Senior Professor at HBN. Served as Registrar and Director of the Centre for Professional Development and Training at Ramaiah University of Applied Sciences, Bengaluru. The views expressed here are personal

Prof M Sai Baba, “Nuclear Renaissance. Yes, It Is. An Opportunity, But Challenges Remain,” *Politeia Research Foundation Report*, September 16, 2026.

Nuclear Renaissance.
Yes, It Is. An Opportunity, But Challenges Remain

by **Prof M Sai Baba**

Recent developments have underscored for many countries the importance of robust nuclear energy programmes that can power the economy amid rapidly changing geopolitical dynamics. More specifically, there is considerable discussion about Small Modular Reactors (SMRs). In this context, this paper briefly maps available energy options for fostering economic development and notes a shift in the debate from 'why nuclear' to 'how much nuclear', with SMRs as buzzwords. This paper also identifies the opportunities and challenges confronting SMR development in India. In the process, the paper evaluates India's indigenous SMR programme and its prospects over the next decade.

Keywords: Development, Energy, India, Indigenous, Nuclear, SMR, Energy Security

Introduction

The world is witnessing renewed interest in nuclear energy, driven by growing demand for reliable, affordable, low-carbon electricity. This nuclear renaissance presents an important opportunity for developing countries such as India, where rising energy demand must be reconciled with the need to reduce dependence on fossil fuels. Nuclear power, with its ability to provide firm electricity at high capacity factors, can potentially complement renewable energy and progressively replace coal-based generation. Small Modular Reactors (SMRs) have emerged as a prominent element of this renewed interest, offering potential advantages in smaller unit size, distributed deployment, modular construction, and reduced financial exposure.

However, smaller reactors do not automatically reduce the cost of nuclear electricity. The commercial viability of SMRs remains uncertain, particularly because many costs associated with safety, licensing, security and supporting infrastructure do not scale proportionally with reactor capacity. The economic benefits of modularity will depend on standardisation, serial production, supply-chain development and achieving sufficient deployment volumes. Other challenges include site selection, transportation of factory-built modules, radioactive-waste management, nuclear-fuel security, skilled human resources and, importantly, public acceptance.

India has significant advantages in pursuing SMRs, including extensive experience with indigenous PHWR technology, an established nuclear supply chain and a large industrial base. Its emerging SMR programme, including the BSMR-200, SMR-55 and high-temperature gas-cooled reactor concepts, could support applications ranging from grid electricity to industrial captive power and hydrogen production. Yet translating this technological capability into a commercially viable SMR industry will require standardised designs, sustained orders, manufacturing capacity, appropriate regulation, private-sector participation and stronger academic-industry collaboration. The nuclear renaissance is therefore a significant opportunity for India. However, its success will depend less on technology alone than on effective implementation, economics and institutional coordination.

Economic Development and Energy Options

Energy is fundamental to quality of life: the availability, affordability, reliability, and cleanliness of energy services influence health, education, livelihoods, productivity, and economic development. Energy choices affect the quality of life of individuals and societies.[1] Energy availability is a fundamental enabler of human development. At low levels of energy access, increasing energy availability can substantially improve the HDI; beyond a certain level, however, additional energy consumption yields diminishing gains in human development.[2] The historical association between per-capita energy consumption and the HDI indicates that energy availability is an important enabler of human development, particularly at lower levels of development.

For developing countries, the challenge is no longer merely providing access to electricity but ensuring adequate, reliable and affordable energy to support economic activity and improve human well-being. Developing countries need more energy, but what kind of energy infrastructure can provide it at sufficient scale, reliability and cost?

The IEA's latest electricity analysis makes this point clear: as wind and solar generation increase, electricity systems need sufficient dispatchable capacity and long-duration storage to handle periods of low renewable output.[3]

Coal is likely to remain an important energy source for the next several decades, even as its share of global energy supply progressively declines. The pace of decline will depend on energy demand growth, the availability and cost of alternative technologies, grid reliability, energy-storage capabilities, and climate policy.[4]

India's industrial sector already has a large captive-power ecosystem, with about 82 GW of installed captive generating capacity, more than half of which is coal-based. This represents a potentially important but largely overlooked market for low-carbon firm power. For Indian exporters of products such as steel, aluminium, cement and fertilisers, this is much more immediately relevant. EU importers will ultimately have to pay for the embedded carbon emissions in covered imports (likely to be implemented as early as the end of 2026).[5]

The question for nuclear, especially "Small Modular Reactors (SMRs)", is therefore not simply whether they can supply electricity to the national grid, but whether appropriately sized reactors can economically replace coal-based captive generation at energy-intensive industrial sites.[6]

A Nuclear Renaissance: From Why Nuclear To How Much Nuclear

Nuclear power provides a potential low-carbon substitute for coal's traditional role as firm, high-capacity-factor electricity generation. Unlike variable renewable sources, nuclear plants can provide dispatchable electricity around the clock, making them particularly relevant to electricity systems in which coal generation must decline. At the same time, demand continues to increase.[7]

Nuclear faces challenges, including capital intensity, long construction times, the need for enhanced safety, environmental impact, and waste management. Above all, public acceptance is the most important. The world is, in a way, seeing a nuclear renaissance. The narrative has shifted from why nuclear to how much nuclear. SMR is the buzzword, and no forum discussing future energy scenarios goes without discussing SMRs. It is important to examine how many of the issues faced by large-sized nuclear reactors are addressed when reactor size is reduced. We also need to consider whether any additional factors emerge because of the smaller size.

Capital Intensive: A coal-fired power plant is relatively less capital-intensive but has large recurring expenditure. Every year, millions of tonnes of coal must be mined, transported, handled and burned. Fuel costs therefore persist throughout the plant's operating life. Nuclear power reverses this relationship. The initial investment is high, but the recurring fuel requirement is very small. Uranium contains vastly more energy per unit mass than coal; consequently, the cost of nuclear fuel and its transportation is a much smaller component of electricity costs.

SMRs are small nuclear reactors that can vary in size (up to 300 MWe). The potential role of small reactors has been a focus of discussion and R&D for several years.[8] SMRs incorporate the latest technological and safety features, and many companies and startups are exploring SMR projects. They all use nuclear fission reactions to generate heat that can be used directly or to produce electricity. SMRs are harnessing the operating experience from traditional large reactors.[9] Globally, more than 120 SMR designs are at different stages of development.[10] While countries such as the U.S., UK, Canada, Japan, and South Korea are actively developing their own designs, Russia and China connected their first SMRs to the grid in 2019 and 2021, respectively.

Small Need Not Always Be Cheap: The future of SMRs depends as much on economics and industrial organisation as on reactor technology. Reducing reactor size does not automatically lower the cost per megawatt. Small need not always be cheap. A 300-MW reactor does not necessarily cost one-third of a 900-MW reactor. Many systems – control, security, licensing, emergency preparedness, electrical infrastructure and other support systems – do not scale linearly with reactor capacity. Smaller reactors enable distributed investment and earlier revenue, encouraging private enterprise to enter the market.

Commercial viability is probably the most important unresolved issue for SMRs. The technological feasibility of several designs is increasingly credible, but the commercial proposition remains unproven at scale. The IAEA's Climate Change and Nuclear Power report says SMRs remain in an early stage of commercialisation, and that it remains uncertain whether economies of volume will compensate for the diseconomies of smaller scale. It also points out that many SMR companies currently operate like start-ups, creating additional investor risk.[11] 5–7% could certainly be a plausible carbon-cost impact for some products and an important economic argument for low-carbon industrial electricity.[12] Carbon pricing may improve the relative economics of SMRs. However, it is unlikely to make SMRs competitive with India's existing captive coal plants. Nuclear manufacturing and large-scale infrastructure capabilities could make serial production more achievable than in countries without an established nuclear supply chain. In that sense, India has an advantage. But that advantage will materialise only if India develops standardised designs and orders enough units to create economies of scale.

India's Indigenous SMR Programme

The Indian government has made SMRs central to its new Nuclear Energy Mission.[13] The objective is ambitious: India aims to increase its nuclear generation capacity to 100 GWe by

2047. The government has allocated ₹20,000 crore for the research, development and deployment of SMRs.[14] India is developing three principal indigenous concepts.

1. Bharat Small Modular Reactor (BSMR-200): A 220 MWe reactor derived from India's experience with PHWR technology. Capacity augmentation to about 300 MWe is also envisaged based on experience with the BSMR-200. The attraction of converting India's established PHWR experience into a smaller, potentially more deployable SMR is obvious. Building an SMR around a mature technological base could reduce some of the risks associated with adopting an entirely new reactor technology.

2. SMR-55: A smaller 55 MWe reactor. Potential applications include captive power and smaller industrial or remote needs.

3. High Temperature Gas-Cooled Reactor: A reactor with up to 5 MWth is being developed for applications including hydrogen production.

Many issues remain, and the Indian government is taking steps to address them.

Regulation and Licensing: India has begun addressing the legal and regulatory environment. The SHANTI Act gives the Atomic Energy Regulatory Board (AERB) statutory status and reforms the nuclear liability framework to enable wider participation. The government has also stated that existing AERB regulatory processes are generally technology-neutral, though technology-specific aspects will need review.[15]

Creating a Manufacturing Ecosystem: The real promise of SMRs lies not simply in building a smaller reactor but in building many identical reactors. This requires transforming India's nuclear supply chain. India would need manufacturing capacity for reactor vessels, steam generators, pumps, valves, control systems, instrumentation, electrical systems, and other safety-critical components. Quality assurance would need to be maintained consistently across mass production.

Modularity is not the same as Mass Production: The terms modular and factory-built are often used interchangeably in discussions of SMRs, but they should not be. A reactor can be modular without being mass-produced. The economic case strengthens only when the same reactor is manufactured repeatedly. Lloyd (et al)[16] discuss what is truly modular, what remains conventional construction, why factory manufacturing is crucial, transportation constraints, first-of-a-kind versus nth-of-a-kind economics, and whether India can realistically establish serial SMR manufacturing.

Site Selection: SMRs may require less land than large nuclear stations, but that does not mean they can be placed anywhere. Questions of emergency planning, security, water requirements, radioactive waste, transportation of nuclear material and proximity to population centres will remain. If a cluster of SMRs is planned for an identified site, land requirements will remain an issue.

Public Acceptance: Experience with nuclear projects worldwide shows that technical safety alone does not guarantee social acceptance. SMRs do not automatically avoid the public-perception problems associated with nuclear power. Recent OECD/NEA work specifically identifies public risk perception and risk communication as key SMR challenges.[17] A particularly important SMR challenge is that they are likely to be located closer to people. The

OECD/NEA has noted that SMR deployment may require different public-engagement approaches than those used for large reactors, particularly because siting and host-community preferences may differ.

Nuclear Fuel and Waste: SMRs do not eliminate the nuclear-fuel cycle. Depending on the technology selected, reactors may require conventional uranium fuel, enriched uranium or, for some advanced concepts, specialised fuels such as high-assay low-enriched uranium. Fuel security will therefore remain a strategic issue. Similarly, smaller reactors produce radioactive waste. The volume may be smaller per reactor, but a large fleet of SMRs would create a correspondingly large number of spent-fuel management and waste-handling requirements.[18]

Skilled Human Resources: A large SMR programme would require engineers, reactor physicists, nuclear safety specialists, regulators, welders, quality-control specialists, instrumentation engineers, cybersecurity experts and trained operators. NITI Aayog has specifically identified the need to build skilled personnel across engineering, design, testing, inspection, construction, erection and commissioning.[19] India has a strong nuclear workforce, but a commercial SMR industry would require substantially expanding this ecosystem beyond traditional government nuclear establishments. Higher education and technical institutions will therefore need to play an important role.

SMRs are often assumed to require proportionally fewer people because they are smaller. That assumption is not necessarily valid. A 220-MWe reactor does not require only one-third of the personnel of a 700-MWe reactor simply because it has one-third the capacity. If five independent SMRs are deployed at five different sites, each requires many of these functions. SMRs could require more workforce per MW unless multiple modules share common site infrastructure and support functions.

The Transportation Problem: Factory production introduces another cost that is sometimes underemphasised. If a reactor module is manufactured in a central facility, it must eventually be transported to the nuclear site. The larger the module, the more difficult transport becomes. The optimum SMR is not necessarily the reactor with the most factory fabrication. It is the reactor that balances factory production and transport.

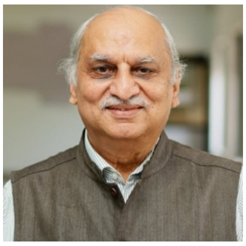
Dominance of Conventional Large Reactors: India in the Next Decade

IAEA[20] and IEA[21] data indicate that 81.7 GWe is under construction in 17 countries**,** with half of the capacity under construction in China**.** The data also indicate that nearly all reactors currently under construction are large. India ranks second, with 8 reactors and about 6 GWe under construction. Despite enormous publicity surrounding SMRs, the global nuclear construction pipeline remains overwhelmingly dominated by conventional large reactors**.**

The next decade will therefore be decisive. Demonstration projects must move beyond paper designs; regulatory procedures must evolve; supply chains must be strengthened; financing mechanisms must be developed; and the first units must generate credible data on cost, construction time, safety, and operational performance. Securing skilled personnel, earning public confidence, addressing concerns, and enhancing acceptance are crucial. The nuclear renaissance currently visible in construction statistics is primarily a renaissance of large reactors, not yet an SMR revolution.

India has an advantage in nuclear technology, as it is home-grown and has demonstrated indigenous capability. The way forward is to ensure effective implementation. A nuclear renaissance. Yes, it is. An opportunity, but challenges remain. Participation by academic institutes and support for MSMEs and startups would pave the way for realising the nuclear renaissance. We need better coordination and effective implementation.

*****



Prof. M. Sai Baba is an Honorary Visiting Professor in the School of Natural Sciences and Engineering at the National Institute of Advanced Studies (NIAS) in Bengaluru. An accomplished researcher, scientific administrator, and institutional builder. Made significant contributions to implementing several high-impact activities relevant to IGCAR and the DAE. He is an Outstanding Scientist and former Director of the RMG, IGCAR, Senior Professor at HBN. Served as Registrar and Director of the Centre for Professional Development and Training at Ramaiah University of Applied Sciences, Bengaluru. The views expressed here are personal.

References

[1] International Energy Agency, *"People Centred Transitions,"* in World Energy Outlook 2021 (Paris: IEA, 2021), https://www.iea.org/reports/world-energy-outlook-2021/people-centred-transitions ; also see Global Environment Facility, *The Challenge of Sustainability: An Action Agenda for the Global Environment(* Washington, DC: Global Environment Facility, 2002), https://documents1.worldbank.org/curated/en/195411468349836360/pdf/324740rev.pdf.

[2] Julia K. Steinberger, "Energising Human Development," *UNDP Human Development Reports*, 2016, https://hdr.undp.org/content/energising-human-development ; Amie Gaye, *Access to Energy and Human Development* (New York: United Nations Development Programme, Human Development Report Office, 2008) ; International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization, *Tracking SDG 7: The Energy Progress Report 2026* (Washington, DC: World Bank, 2026), https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2026.

[3] International Energy Agency, "Supply," in *Electricity 2025* (Paris: IEA, 2025), https://www.iea.org/reports/electricity-2025/supply

[4] International Energy Agency, *World Energy Outlook 2025* (Paris: IEA, 2025), https://www.iea.org/reports/world-energy-outlook-2025.

[5] European Commission, Directorate-General for Taxation and Customs Union, "CBAM Communication and News," accessedSeptember 8, 2026, https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism/cbam-communication-and-news_en

[6] Bureau of Energy Efficiency, "Bureau of Energy Efficiency (BEE)," Government of India, accessed September 8, 2026, https://beeindia.gov.in/

[7] International Energy Agency, *The Path to a New Era for Nuclear Energy* (Paris: IEA, 2025), https://www.iea.org/reports/the-path-to-a-new-era-for-nuclear-energy.

[8] U.S. Government Accountability Office, *Technology Assessment: Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts,* GAO-15-652 (Washington, DC: U.S. Government Accountability Office, July 2015).

[9] International Atomic Energy Agency. *Small Modular Reactors: Advances in SMR Developments 2024*. Non-serial Publications. Vienna: IAEA, 2024. https://doi.org/10.61092/iaea.3o4h-svum; International Atomic Energy Agency. *Technology Roadmap for Small Modular Reactor Deployment*. IAEA Nuclear Energy Series No. NR-T-1.18. Vienna: IAEA, 2021; International Atomic Energy Agency. *Deployment Indicators for Small Modular Reactors*. IAEA-TECDOC-1854. Vienna: IAEA, 2018

[10] NNN Newsroom, "Top SMR Developers in 2026, Ranked by What They've Actually Built," *Nuclear News Network*, August 5, 2026, https://www.nuclearnewsnetwork.com/news/top-smr-developers-2026.

[11] International Atomic Energy Agency, *Climate Change and Nuclear Power 2024: Financing Nuclear Energy in Low Carbon Transitions* (Vienna: International Atomic Energy Agency, 2024), https://www-pub.iaea.org/MTCD/Publications/PDF/PUB9048_web.pdf.

[12] CarbonNeeti Team, "Carbon Credit Price in India 2026: What Will CCCs Cost and How to Plan," *CarbonNeeti,* March 28, 2026, https://carbonneeti.com/blog/carbon-credit-price-india-2026.

[13] NITI Aayog, *The Role of Small Modular Reactors in the Energy Transition* (New Delhi: NITI Aayog, Government of India, 2023), https://www.niti.gov.in/sites/default/files/2023-05/The-Role-of-Small-Modular-Reactors-in-the-Energy-Transition-05162023.pdf

[14] Press Information Bureau, Government of India, "Parliament Question: Deployment of Small Modular Reactors (SMRs)," *Department of Atomic Energy,* March 12, 2026, https://www.pib.gov.in/PressReleasePage.aspx?PRID=2238907&lang=2&reg=3

[15] International Atomic Energy Agency, *Approach and Methodology for the Development of Regulatory Safety Requirements for the Design of Advanced Nuclear Power Reactors: Case Study on Small Modular Reactors*, IAEA-TECDOC-2010 (Vienna: International Atomic Energy Agency, 2022)

[16] C. A. Lloyd, T. Roulstone, and R. E. Lyons, "Transport, Constructability, and Economic Advantages of SMR Modularisation," *Progress in Nuclear Energy* 134 (2021): 103672, https://doi.org/10.1016/j.pnucene.2021.103672.

[17] Nuclear Energy Agency, *High-level Analysis of Radiological Protection Challenges Related to the Deployment of Small Modular Reactors,* NEA/WKP(2025)2 (Paris: OECD Publishing, 2026), https://doi.org/10.82155/99fz-y755

[18] International Atomic Energy Agency, *Considerations for the Back End of the Fuel Cycle of Small Modular Reactors: Proceedings of a Technical Meeting*, IAEA-TECDOC-2040 (Vienna: International Atomic Energy Agency, 2023).

[19] See n.14

[20] International Atomic Energy Agency, "Power Reactor Information System (PRIS)," accessed September 8, 2026, https://pris-stats.iaea.org

[21] International Energy Agency, "Technology: Nuclear," in *Global Energy Review 2026* (Paris: IEA, 2026), https://www.iea.org/reports/global-energy-review-2026/technology-nuclear