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Small Modular Reactors: A Key Player in India's Path to Net-Zero

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As the world unites in its endeavor to combat the escalating climate change crisis and strives to achieve net-zero emissions, the spotlight is increasingly turning toward the burgeoning significance of Small Modular Nuclear Reactors (SMRs). These innovative nuclear technologies hold great promise as a vital component of India's collective response to the climate challenge. As nations strive to fulfill the United Nations Sustainable Development Goal 7, which aims to provide affordable, reliable, sustainable, and modern energy for all, it is clear that decarbonizing the power sector is essential. With 82% of the world's energy supply still reliant on fossil fuels, the transition to cleaner energy sources is paramount. Furthermore, the share of electricity in final energy consumption is expected to increase by 80-150% by 2050, emphasizing the importance of reliable, 24/7 low-carbon electricity resources.

Recent developments in Europe serve as a poignant reminder of the complexities of achieving a sustainable energy transition. Despite the growing adoption of solar and wind power, coal consumption has surged, underscoring the need for steadfast and low-carbon energy sources to maintain grid stability and ensure energy security. This phenomenon raises pertinent questions and emphasizes the imperative for innovative solutions. In this context, SMRs, a category of nuclear reactors characterized by their flexibility and scalability, are gaining prominence as a promising solution for India and various other nations grappling with analogous energy challenges. The potential of SMRs to provide a reliable, low-carbon energy source while addressing grid stability concerns is capturing the attention of policymakers, energy experts, and industry leaders worldwide.

The Challenges of Decarbonization

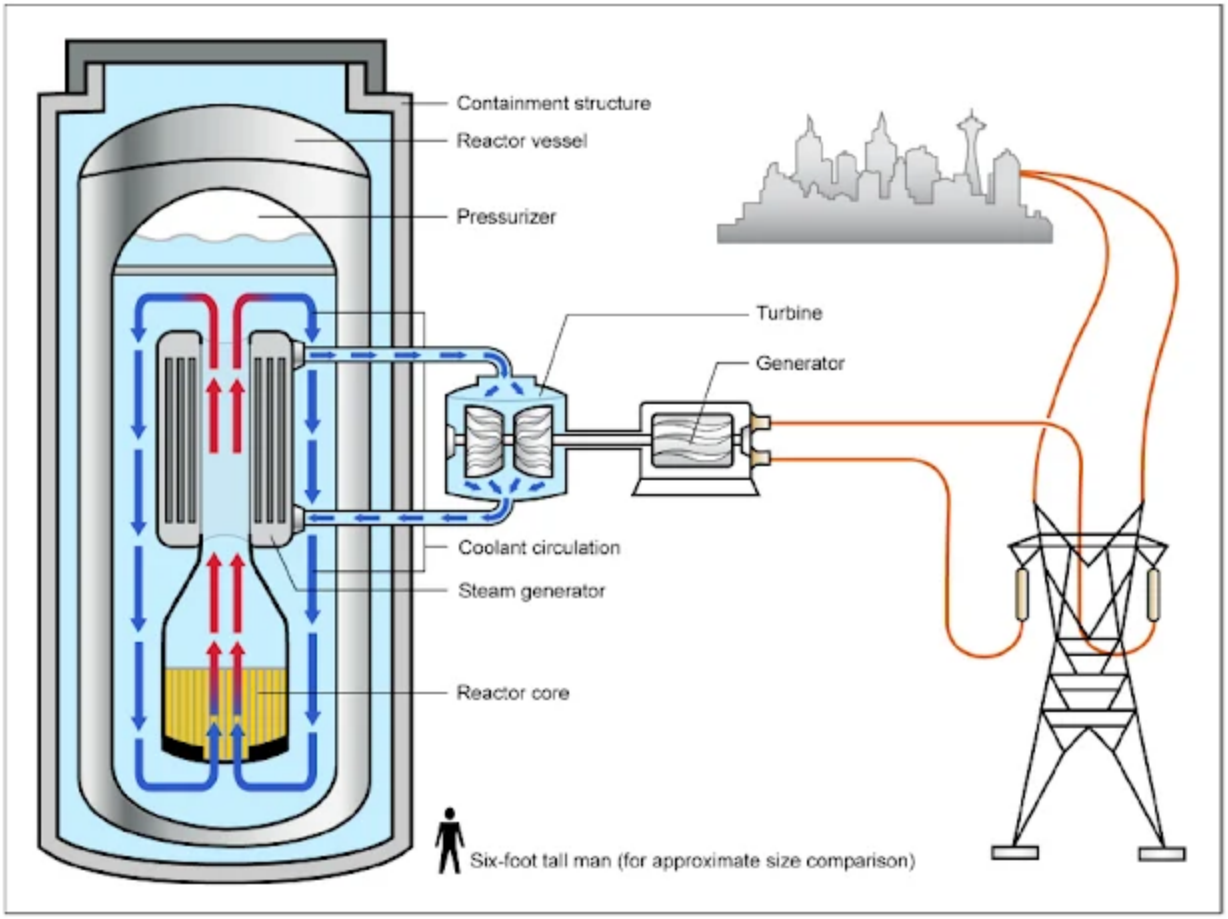
Transitioning from coal-fired power generation to clean energy sources presents significant challenges for all countries. Policymakers worldwide acknowledge that relying solely on solar and wind energy may not provide the reliable and affordable energy required to meet growing demand. Introducing at least one firm power-generating technology can enhance grid reliability and cost-effectiveness in decarbonized electricity systems with a substantial share of renewables.

The International Energy Agency (IEA) predicts a substantial surge in the demand for critical minerals such as lithium, nickel, cobalt, and rare earth elements, essential for clean-energy production, by up to 3.5 times by 2030. This surge poses global challenges, including the need for substantial capital investments to develop new mines and processing facilities. The environmental and social impacts associated with rapid mine and plant development in various regions worldwide and the concentration of mineral production in a few nations raise geopolitical and other risks.

Nuclear Power's Role

Nuclear power plants (NPPs) currently generate 10% of the world's electricity, significantly reducing natural gas demand and CO2 emissions. A reduction in nuclear power could make achieving net-zero emissions more challenging and expensive. NPPs are known for their efficient land use and lower grid integration costs compared to variable renewable energy sources, as they provide continuous power regardless of weather conditions. Nuclear power also offers valuable co-benefits, including high-skill job opportunities in technology, manufacturing, and operations.

However, conventional NPPs have often faced issues like time and cost overruns. In response, several countries are exploring the development of SMRs—nuclear reactors with a maximum capacity of 300 MW—as a complement to conventional NPPs. SMRs can be installed on decommissioned thermal power plant sites, utilizing existing infrastructure and minimizing the need for additional land acquisition or displacement of communities.



Source: GAO, based on Department of Energy documentation. | GAO-15-652

Image Attribute: Illustration of a light water small modular nuclear reactor / Source: This image is excerpted from a U.S. GAO report: GAO-15-652

Benefits of Small Modular Reactors (SMRs)

SMRs come equipped with a suite of advantages, most notably an enhanced safety profile that sets them apart from conventional Nuclear Power Plants (NPPs). These reactors are specifically designed to minimize the likelihood of core damage and mitigate the potential for radioactive contamination. Their built-in safety features include passive measures that act as an additional layer of defense, further reducing the risk of uncontrolled release of radioactive materials.

Another significant advantage lies in the reduced production of spent nuclear fuel by SMRs compared to their larger counterparts. This characteristic opens up opportunities for the deployment of SMRs in locations, such as brownfield sites, that may need to meet the stringent zoning requirements associated with conventional NPPs. With operational lifespans spanning 40 to 60 years and consistently high capacity factors, SMRs present an enticing and sustainable long-term energy solution, promising safety and reliability in a rapidly evolving energy landscape.

Exploring the Financial Aspects

When contemplating the implementation of SMRs, it is imperative to consider cost considerations. In the United States, the initial capital expenditure for SMRs is estimated at approximately $6,000 per megawatt (MW). However, it is worth noting that these costs are poised for a substantial decline post-2030, particularly as European SMR ventures commence operation by 2035. In the Indian context, established and well-regarded companies with a track record in manufacturing Nuclear Power Plants (NPPs), such as BHEL, L&T, and Godrej Industries, have the potential to play a pivotal role in driving down SMR costs. This could be achieved through the transfer of cutting-edge technology from international sources, a strategy that could also attract 'green' finance from entities like the Green Climate Fund and global investors. Such financial support mechanisms could serve to alleviate the fiscal burden on the government and facilitate the adoption of SMRs as a viable and sustainable energy solution in India.

Streamlined Regulation for Enhanced SMR Deployment

The need for efficient international regulatory frameworks becomes increasingly evident to accelerate SMR deployment and transition India toward net-zero emissions. This necessity is particularly pronounced when considering the transition from coal-based power generation to SMR installations at existing thermal power plant locations. Collaborative efforts among regulatory bodies and international organizations, such as the International Atomic Energy Agency (IAEA), are paramount to the harmonization of regulatory prerequisites. The goal here is to streamline approval processes, particularly for standardized SMR designs. By fostering this collaborative environment and enhancing regulatory efficiency, we can facilitate the swift and secure integration of SMRs into India's energy landscape, contributing significantly to the nation's sustainable energy goals.

India's Energy Transition

India's Central Electricity Authority (CEA) envisions a necessary expansion of coal-based thermal power capacity to reach 259,000 MW by 2032, all while experiencing substantial growth in variable renewable energy sources. As India solidifies its commitment to achieving net-zero emissions by 2070, the imperative for nuclear power to take on a more substantial role becomes evident. To navigate this transition successfully, private-sector investments channeled through robust public-private partnerships will be indispensable. These collaborative efforts are poised to be instrumental in the ambitious mission to decarbonize India's dynamic and evolving energy landscape, ensuring a sustainable future.

Evoking Legal and Regulatory Transformations

Amendments to the *Atomic Energy Act of 1962* must be underscored as a catalyst to empower the private sector in SMR designing, construction, and operation. Simultaneously, it remains paramount that the government maintains a steadfast grip on the oversight of nuclear fuel and waste management, a measure rooted in the utmost concern for safety and security within the nuclear sector.

To ensure the seamless and secure progression of nuclear power generation, the establishment of an independent regulatory body emerges as a crucial necessity. This body must possess the requisite expertise and capacity to diligently oversee every facet of this intricate process, thereby upholding the highest safety and operational efficiency standards.

In parallel, the Department of Atomic Energy (DAE) shoulders the responsibility of enhancing public perception and fostering trust. Achieving this pivotal goal demands a commitment to transparency, primarily through the disclosure of essential environmental and public health data tied to civilian reactors operating under the umbrella of international safeguards within India.

As the world collectively strives for the ambitious net-zero emissions target, India stands at a critical juncture where the integration of SMRs holds the promise of revolutionizing its energy landscape. India can unlock a sustainable and resilient energy future by navigating these necessary legal and regulatory transitions with precision and transparency.

FOR FURTHER READING

The Role of Small Modular Reactors in the Energy Transition

A Report by NITI Ayog (May 2023)

Link: https://doi.org/10.5281/zenodo.8405975

Small Modular Reactors (SMRs) are an advanced class of nuclear reactors featuring power generation capacities that span from less than 30 MWe to over 300 MWe. This comprehensive report from NITI Aayog delves into several critical aspects regarding SMRs in the context of the ongoing energy transition. It examines the evolution of SMR technology, the readiness of supply chains, efforts towards harmonizing SMR regulations, the international licensing process, and preparations for international safeguards. Additionally, the report emphasizes the necessity to minimize risks associated with SMR projects to attract private sector investments. Notably, the report underscores that SMRs have risen as the favored choice in nuclear energy when compared to larger reactors, primarily due to their lower inventory of atomic material per reactor, streamlined fabrication through standardization, rapid deployment capabilities even in challenging locations, and the ability to manage capital expenditures in stages by incorporating successive SMR modules.