INDIA'S NUCLEAR POWER RENAISSANCE: PAVING THE WAY FOR A SUSTAINABLE ENERGY FUTURE

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ABSTRACT

India, a fast-growing economic powerhouse, is confronting an excessive rise in energy needs due to its growing population, urbanization and industrialization. To address these problems while also responding to environmental issues and reducing dependence on imported oil, India has launched an ambitious initiative to enhance its nuclear power generation capacity. The paper below discusses the current status of the Indian program for nuclear power, its rationale for expansion and the enormous challenges that must be overcome in order to ensure a sustainable nuclear future. It extensively examines how technology advances, international partnerships and strong policy frameworks are shaping India's direction in terms of utilizing nuclear power. It further investigates issues such as public acceptance, waste management, safety regulations, financing, and human resource development that are fundamental to ensure a successful implementation of this program and responsible use of atomic energy in this country. The article, therefore, provides useful hints on how India can attain secure sources of energy, reducing emissions by becoming a leading source of renewable energy globally among other countries.

INTRODUCTION

India is a country containing a massive population and has achieved significant development in industrializing and urbanizing the economy in the past few decades. This high energy demand has put a lot of pressure and stress on the prevailing energy formats in the country, hence the search for diversity as well as the sustainability of other formats of energy. For this reason, India has adopted nuclear power as an essential solution in a manner that enhances its capabilities to deliver sustainable electricity production.

The Problems in The Energy Sector Include the Following

Lack of domestic capital to finance energy infrastructures and energy import dependency: The erratic reform of the Indic energy sector has been a growing demand routine, partly due to the

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lack of capital within this nation for the achievement and provision of energy infrastructures. Per BP's Energy Outlook, 2019, India projected a growth in energy demand to rise substantially by 2037[1] from the level of 2017[2]. In its World Energy Utilities, World Energy has estimated that the change of the type of energy in the country to 2040 will be gradual and that fossil fuel may account for 79% of the energy demand in the year 2040 from 92% of the energy demand in the year 2017. Moreover, an analysis of the primary energy consumption of fossil fuels demonstrates that it could rise by 120% between 2017 and 2040. The nuclear programme in India can be traced back to the early 20th century, but the country got nuclear energy power just a few decades ago. Tarapur Atomic Power Station, located in India, was officially opened in 1969[3] and, hence, signalled the beginning of the use of this new generation nuclear power reactor for power generation in the country. Since then, the nation has progressively increased the bar of the nuclear power supply due to the merits of searching for new effective, safe and more reckoning-friendly ways for fulfilling the energy needs of the power-deficient nation by depending less on the fossil fuels imported from the other nations. Today's India is at a crossroads, and the country is all set to start a nuclear power renaissance that could change the energy map of the nation and place India at a vanguard in efficiently utilizing sustainable energy sources. Having set a goal of obtaining 63 GW of nuclear energy capacity by 2032 from the current 6 GW. 8 GW, India's nuclear power programme is all set for a transformation along the lines of new generation reactors, which are made possible by scientific innovations, global partnerships, and good governance. This long piece unravels multiple layers of India's nuclear power dreams and presents an analysis of the factors that will spur, hinder or enable efficient harnessing of this important resource in the future. This gives a systemic view of the technological, economic, social and environmental aspects of nuclear power in India, which is beneficial to policymakers, industrialists and academicians.

INDIA'S AMBITIOUS NUCLEAR POWER PROGRAM

Indian nuclear power plant and further development came up with a focused long-term vision and firm conviction of the nation to adopt nuclear power as one of the major components toward achieving energy security of the nation. The Indian government, under the Department of Atomic Energy (DAE), has planned for India to have 63 GW of nuclear power by 2032,

[1] https://world-nuclear.org/information-library/country-profiles/countries-g-n/india
[2] ibid
[3] https://www.nsenergybusiness.com/projects/tarapur-atomic-power-station-maharashtra/

which is a vast rise from 6. 8 GW.[4]

However, to accomplish this ambitious goal, India has to follow nuclear reactor projects in different phases of construction and planning. The Kudankulam Nuclear Power Plant KKNPP in Tamil Nadu, constructed jointly with Russia, is one of the examples of nuclear power facility development in India. The plant has two working VVER-1000 units, each providing one thousand MW, and two more ones, Units 3 and 4, under construction.

The other interesting site is the Badarpur Thermal Power Station in New Delhi, where two new units, the 2 × 500 MW Units, have been planned, Units 5 & 6 of KAPP in Gujarat, for a combined capacity of 1,400MW. An expansion is also happening at the Rajasthan Atomic Power Plant (RAPP) in Rajasthan, where Units 7 and 8 are currently in the planning phase.[5]

In addition, more nuclear power plants are being planned in India currently in partnership with other countries. The largest project of its kind planned in the country is the Jaitapur Nuclear Power Plant in Maharashtra, which is in collaboration with France's Electricite de France or EDF company and is scheduled to produce an estimated capacity of 9,900 MW through six reactors.

These ambitious projects, along with the continuous attempts to increase the service years of nuclear power plants, prove India's steadfastness in exploring the full capacity of nuclear energy as a strategic part of its energy portfolio.

DRIVERS OF NUCLEAR POWER GROWTH IN INDIA

Several important parameters indicate the expansion of nuclear power in India, which is becoming more and more feasible and suitable for the country. These drivers are the economic driver, the green driver, which is the environmental driver, the tech driver, and the biz driver, asserting the strategic value of nuclear power.

Energy Security and Self-Sufficiency

Another core reason that India has plans for the development of nuclear power is the matter of energy security and independence. India is a fast-growing country, and its population and industrial growth are increasing day by day; thus, its energy requirements are also on the rise.

[4] https://en.wikipedia.org/wiki/India%27s_three-stage_nuclear_power_programme
[5] Draft National Electricity Plan | Volume II |December,2016

However, one major problem is the fact that the country relies on the importation of fossil energy sources, mainly oil and natural gas, which can be a sensitive issue as far as energy security and the consequences of international price movements are concerned.

The need to address this challenge is, however, provided for by nuclear power, which is available domestically and can be independently harnessed using India's natural resources. Thorium, which is a natural nuclear fuel, is used in modern THTR types of reactors[6], and India has a good stock of thorium instead of depending upon the import of uranium.

Thus, through nuclear capacity addition, India will be able to achieve energy diversification and decrease its dependence on imported fossil fuels, thereby increasing the country's energy security against fluctuations and uncertainties in the global political and energy markets.

Environmental Sustainability and Climate Change Mitigation

The country's desire to embrace environmentally friendly measures and manage the effects of climate change is another factor that is fostering the development of nuclear power in India. India, being a signatory country to the Paris Agreement[7], has promised to bring down its greenhouse gas (GHG) emissions and move to a low-carbon economy.

The efficiency of nuclear power plants in the generation of power is much higher in comparison to fossil fuel-based power plants, as nuclear power plants do not emit greenhouse gases during their operation. This characteristic makes nuclear power an important source that India can rely on while adopting energy power to meet the growing energy demands without affecting climate change tremendously.

Furthermore, the incorporation of nuclear energy in India could also help the country in its plan of diversifying energy sources, where the existing capacity of renewable energy sources like solar and wind power is being worked upon.

Technological Advancements and Indigenous Capabilities

The following paper explores India's total nuclear power intention in light of the country's technological development and its capacity to indigenously manufacture nuclear energy equipment. Over the years, India has managed to embrace and master nuclear reactor

[6] https://www.theiet.org/media/8809/nuclear-reactor-types.pdf
[7] Nuclear Power and The Paris Agreement

technologies, especially pressurized heavy water reactors (PHWRs) and fast breeder reactors (FBR).

Early this year, there was a successful commissioning of the Prototype Fast Breeder Reactor[8] (PFBR) Kalpakkam Tamil Nadu successfully; this is part of the Indian three-stage nuclear power program to harness thorium in India's nuclear fuel cycle. Such an indigenous technological capability will enable India to grow and expand to other horizons of the nuclear power business in the future.

Also, India is trying to concentrate more on technologies of newer generation nuclear reactors and SMRs or Generation IV reactors. These modern technologies have enhanced safety measures, better efficiency, and more versatility, providing a solid foundation for India's nuclear power.

International Collaborations and Technology Transfer

India has drawn a lot of benefits from international relations, particularly in its nuclear power project, through cooperation and the sale of technology. The Civil Nuclear Agreement[9] signed between India and the United States of America in 2008 changed the dynamics of India's nuclear policy to an extent. Since then, India has been isolated at the international level in the field of civil nuclear cooperation.

Since then, India has entered into strategic civil nuclear cooperation with many nations, such as Russia, France, the UK and Canada. These accords have created the possibility of buying and sharing uranium resources, along with techniques in civil nuclear technologies, which helps India capitalize on international experience and foster the expansion of nuclear power in India.

Cooperative international relations also play a significant role in building modern nuclear power plants in India in association with Russia. The Kudankulam Nuclear Power Plant is a prime example, as the proposed Jaitapur Nuclear Power Plant in association with French Electricitée de France EDF.

These collaborations not only give a possibility to obtain modern technologies but also contribute to the formation of capacities, the improvement of the skill level, and the

[8] Fast Breeder Reactor - PIB
[9] Baru Sanjay | An Agreement was called a Deal | The Hindu |04 December,2021

augmentation of the expertise within the Indian AP, which creates the basis for the subsequent nuclear self-sufficiency.

CHALLENGES AND OPPORTUNITIES

Even though India holds many opportunities to develop nuclear power to gain energy security, climate change solutions, and economic growth, there are many faceted problems that must be solved to avoid dangerous consequences and guarantee further nuclear energy development. These challenges cover a wide range of factors and fronts, including public acceptance of biogas, proper management of waste, safety issues, finance, and the development of human resources.

Public Acceptance and Risk Perception

Another critically important problem concerning the development of nuclear power in India is the social acceptance of nuclear power and points of concern regarding the impacts of using nuclear power. The instances of big nuclear catastrophes like Chornobyl and Fukushima contributed to the pessimistic feeling of the people about the nuclear power potential and its safety, accompanied by the fears related to the hazards of nuclear power stations.

Addressing these concerns pertains to the following strategies, namely: public engagement, sharing of information, and sensitization on factors involving the local people. Governments have to advance clear and detailed discussions on questions, fears, and uncertainties and enhance the knowledge of opportunities and threats of nuclear power. However, sound safety measures, adequate drills, and tight regulatory controls and laws need to be implemented to ensure people's confidence in handling these nuclear facilities.

Radioactive Waste Management

The disposal of radioactive waste produced by nuclear power stations is a major global problem today, and the same is the case with India. The storage and disposal of radioactive waste, especially spent nuclear fuel, if not properly handled, may pose great threatening risks to the environment and human health.

India needs to work out effective disposal programmes for radioactive wastes, both in the short term and in the long term. This may require commitment to innovative techniques for waste, recycling, and volume reduction, as well as the feasibility of deep geological solutions for the isolation of high-level radioactive waste.

He also pointed out that the strategies in waste management should also comprise the management of transported and handling of radioactive wastes to moderate the amplified hazards and pessimistic environmental consequences. International organizations and organizations from other countries can be partnered due to the exchange of knowledge and practices that are necessary in this field.

Safety Regulations and Emergency Preparedness

Of course, to maintain the standards and norms of nuclear safety, India needs to follow strict, well-defined nuclear regulatory norms in order to achieve nuclear globalization. The country has to have an effective and autonomous nuclear regulatory organization, like AERB[10], that must not only have the powers to enforce strict safety measures and standards, conduct inspections frequently, as well as issue licenses and clearances for the facilities involved in nuclear power.

Furthermore, effective general protection measures that have to do with Preparedness for Emergencies should be established and implemented with new protocols and measures to be taken in case of a nuclear accident or occurrence of an incident. Such measures should entail the cooperation of the government, rescue services, and residents in preventing severe outcomes of a nuclear occurrence and in preserving people's and the environment's well-being.

The staff safety competence, as well as the available specialized training and the implementation of the latest safety technologies and characteristics in the reactor design, are the critical factors to ensure further high safety performance and confidence of the population in the safety of nuclear power activity.

Financing and Economic Competitiveness

Nuclear power plants are capital-intensive and are characterized by long construction periods, which makes them very sensitive to the issue of financing. These are some of the financial challenges that South Africa must overcome in order to carry out efficient nuclear power expansion plans as a country.

Some of the measures may include searching for new financing models, using Public-Private Partnerships, FDI, and IFI. India could also adopt favourable policies and reforms to enhance nuclear power's appeal since it can be costly when compared to other renewable energy

[10] Atomic Energy Regulatory Board

sources; there could be the implementation of a 'carbon price' or subsidy for carbon-free energy.

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OPPORTUNITIES AND POTENTIAL BENEFITS

Nevertheless, there are some advantages and possibilities linked to nuclear power in India as it can represent one of the ways towards sustainable goals in India and the development of India, and it at the same time may create a possibility for India to become the leader in the sphere of clean energy application.

Energy Security and Self-Sufficiency

Hence, hiding its nuclear power capacity, it is possible to state that the indicated country has several problems that will make sure of stable development in the sphere of energetic security and will not import fossils. It not only helps Bahrain avoid fluctuation and volatility within the global oil market, but it also benefits energy security and energy autonomy to the extent of producing adequate energy within Bahrain.

Environmental Benefits and Climate Change Mitigation

However, if the blanket is removed, nuclear power has one or maybe one big plus point over the other forms of power generation that India, which is becoming conscious about its carbon footprint, would like to note, and that is nuclear power as a carbon means of producing electrical power. The purpose of this paper would be to analyze the actual fact that nuclear power, together with the least GHG emissions such as conventional fossil fuel-based power generation, can help India and other countries to progress within the framework of the Paris Agreement, as well as to address the issues of climate change in the world.

Economic Development and Job Creation

The development of India's nuclear power sector can bring about the needed economic reform and employment openings. The building, utilization, and management of nuclear power plants involve a competent team of people in many fields, consequently creating employment methods and enhancing the economies of respective regions.

Furthermore, the advancement of the nuclear industry can also spur economic activities such as innovation, research, and development on nuclear power, as well as initiate the growth of supporting industries that, in turn, fortify the Indian economy and establish the country as a premier supplier of the modern energy technologies.

Technology Leadership and Innovation

Thus, India's approach towards ramping up its nuclear power profile offers the country a unique chance to globally assert itself as a technology innovator and nuclear industry hotspot. Embarking on emerging advanced reactor designs, small modular reactors, and next-generation fuel cycles will place India at the strategic corner of global civil nuclear research and development.

Such technological leadership could also help the country become energy-sufficient in the future, create new opportunities for cooperation and information exchange in the sphere of nuclear power, and possibly enter the export markets for nuclear technologies.

International Cooperation and Diplomacy

Therefore, the development of its nuclear power segment has broadened the field of interaction and the range of potential diplomatic relationships. This kind of partnership with various

countries through the signing of bilateral and multilateral cooperation agreements has boosted India's diplomatic relations and has paved the way for joint ventures in sharing technology, conducting research work and exchanging ideas and technology.

The above cooperation strategy can take India to the next level in the global system to enhance the country's foreign policy adopted through the utilization of nuclear technology for only peaceful purposes, as aimed through the non-proliferation regime. At the same time, the situation offers India a signal opportunity to leave its mark on the shaping of the NPT rules and become a participant in the creation of a just nuclear world order. If the Indian leadership harnesses the opportunities while overcoming the threats posed by nuclear energy and if India shows the importance of nuclear power around the world, the nation can have the energy security it requires while minimizing its carbon footprint without limiting economic progress.

THE GOVERNMENT OF INDIA HAS GIVEN NUCLEAR POWER THE STATUS OF PRIORITY SOURCE AS A PART OF ITS CUMULATIVE DEVELOPMENT PLAN WITH PREDOMINANCE IN THE SOUTH ASIAN MARKET. INDIA'S NUCLEAR DOCTRINE IS CENTRED AROUND THREE MAIN PILLARS:

Credible Minimum Deterrence[11]

Indeed, India's strategy is somehow to retain a minimal nuclear arsenal that will deter an attack but does not lead to warfare.

No First Use[12]

India is the sixth largest and, along with Russia, Great Britain, France, and China, is one of the responsible nuclear weapon states which, in contrast to Pakistan, pledged not to use nuclear weapons in a conflict first, It is considered as one that has the effect of reducing tension and the risk of an unplanned confrontation.

Civilian Control[13]

The decision on the use of nuclear weapons lies in the domain of the political leadership- NCA and, further, not in the military domain.

[11] https://cdn.visionias.in/value_added_material/Indias-Nuclear-Doctrine.pdf
[12] https://cdn.visionias.in/value_added_material/Indias-Nuclear-Doctrine.pdf
[13] https://cdn.visionias.in/value_added_material/Indias-Nuclear-Doctrine.pdf

INDIA'S DOCTRINE IS ALSO GUIDED BY

Non-use against Non-Nuclear States

India reiterates its policy of no first use of nuclear weapons, which means India will not use nuclear weapons against states that do not possess them.

Universal Disarmament

To secure itself from a nuclear threat, it has, as a fact, not excluded the possession of nuclear weapons while at the same time advocating for total and complete eradication of nuclear arms.

The main flaw in India's nuclear policy is that it has not clearly defined its position on the framework under which India will respond with nuclear weapons. Still, some skeptics dare suppose that it is, on the whole, weaker in confrontation with an adversary who has not declared the 'No-First-Use' policy.

CONCLUSION

Thus, India's continuing efforts to enhance Nuclear Power Generation capacity is indeed an appreciable step towards building the requisite sustainable energy framework. Therefore, it can be seen that as a country that has the third highest population and which has developed economically rather fast, India has had its energy requirements go considerably high and nuclear power is a solution that can be implemented to cater to needs and at the same time keeping greenhouse gases and the use of fossil fuel to a minimum.

Israel's policy of the Nuclear Power Programme and the Nuclear Energy Policy shows that the government has an interest in reactivating the nuclear industry and the prospect that has frustrated its development in the past future. Policies that obligate corporations to participate in risky nuclear projects as well as find ways to support advanced reactor technologies, advanced safety measures towards nuclear energy, nuclear capability personnel, and improvement of nuclear power generation will take India a long way.

Nevertheless, it is important to dispel people's fears and doubts concerning the safety of the nuclear industry and problems connected with the disposal of nuclear waste by means of open dialogue and adherence to international norms and standards. Therefore, the benchmarks for involving the locals, developing partnerships between the private sector and government agencies, and global cooperation will be critical in sustaining India's nuclear power

renaissance.

In addition, combining nuclear power with other forms of renewable electricity, such as solar and wind electricity, is a viable way of creating a balanced and stable electricity supply that does not have the flaws of some sources of renewable electricity.

Being in the development process, India needs a reliable source of electric power, and nuclear power is one of the safest ways to cut CO2 emissions and become independent from oil and gas, sharing the economic benefits. With a proper strategy mapped out in the long term, India positioned itself among the leaders of the nuclear world, holding the key to the possibility of achieving great benefits from nuclear technology, using it responsibly, and protecting the people of the country and the environment.