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Indo-French Nuclear Cooperation for India's Net-Zero Goals: A Descriptive Perspective

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Abstract

India, the third-largest carbon emitter in the world, must simultaneously meet its targets for net-zero carbon emissions by 2070 and ensure energy security. India has increasingly looked to nuclear energy as a dependable, low-carbon alternative after realising the limitations of renewable energy in supplying base-load power requirements. The development and importance of Indo-French nuclear cooperation in augmenting India's nuclear power capability and bolstering its clean energy transition are examined in this article. From early research agreements to more recent strategic alliances like the Jaitapur Nuclear Power Plant and partnerships on Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs), it charts the development of bilateral nuclear relations over time. The analysis emphasises how these collaborative initiatives lessen reliance on fossil fuels, diversify India's energy mix, and improve its energy security. The partnership's geopolitical significance in rebalancing regional power relations and bolstering India's strategic autonomy is also covered in the study. Notwithstanding popular opposition and infrastructure obstacles, Indo-French nuclear cooperation offers a viable method to increase India's capacity for clean energy, greatly advancing its climate and sustainable development objectives. According to the study's findings, nuclear power can be extremely important to India's search for dependable, scalable, and low-carbon energy sources if it is supported by international cooperation.

Keywords: - Nuclear Energy, Indo-French Partnership, Net-Zero Carbon Emission, Energy Security.

Introduction

India is the second most populous country in the world with 1.4 billion population and the third largest contributor in terms of carbon emissions after the United States and China. As environmental issues have risen on the international stage, New Delhi has placed climate change at the Centre of its development agenda. To reduce its climate footprint, India has been transitioning to low-emission energy sources and implementing policy frameworks to address and implement its energy transition toward a low-carbon economy. While India has robust renewable energy technologies and frameworks, there are many constraints of a nature-based supply. Therefore, India must diversify its energy basket and seek out alternatives such as nuclear energy to meet its growing needs.

India's national statement in COP 29 highlighted its "long-term low-emissions growth strategy with low carbon transition pathways in key economic sectors." Previously at COP26, Indian India committed to reaching net zero emissions by 2070 and at the G20 summit in Bali in 2022, India pledged that half of India's electricity would be generated by renewable energy by 2030. Further, India updated its Nationally Determined Contribution (NDC) and committed to using half of the power-installed capacity from non-fossil fuel-based energy resources and to achieve a 45 percent reduction in emissions intensity from its

2005 levels.

India formed its decarbonization strategy through climate commitments and prioritizing reliable, net-carbon, emission-neutral technologies which include non-conventional sources of energy like nuclear energy. India aims to achieve its ultimate energy transition goal through multiple pathways of technology innovation, adoption, and deployment to diversify its energy basket. The country's total renewable power capacity is at 166 GW, of the total pie of 410 GW, placing India at fourth largest in terms of installed renewable energy capacity worldwide.

However, India faces difficulties scaling its renewable energy capacity further. The key limitation of renewable energy is its inability to support the smallest carbon footprints and the ability to generate carbon-free, reliable, and continuous power.

India is poised for multi-fold growth in nuclear power generation to match the needs of its sustained economic growth and to improve the standard of living for the masses. It plans to achieve this ambitious nuclear energy growth plan through a unique three-stage nuclear program designed by Homi J. Bhabha in 1950 to provide energy security to India. Stage one uses natural Uranium as a fuel to generate power and it releases Plutonium- 239 as a by- product, the stage two would use Plutonium -239 and Thorium as fuel to generate power, releasing Uranium-233 (U-233) as a by-product. India is presently at the second stage of its nuclear program. Stage three involves the development of Thorium-based U-233 fuelled breeder nuclear reactors that would use Thorium as fuel and release U-233 as a by-product, making it a closed-loop circulation of fuel. The primary objective behind this is to make use of India's large thorium reserves, that account for approximately twenty-five percent of the world's thorium reserves, ensuring India's energy self-sufficiency and independence. Additionally, the closed fuel cycle effectively and significantly reduces the radioactive nuclear waste, which remains a global environmental concern.

India's Nuclear Power Programme

The Indian nuclear power program is entirely state regulated and operated. In 2019, the Government of India gave the Department of Atomic Energy a budgetary allocation of USD
$1.31 billion, with a subsequent yearly increase of USD $1.31 billion for the next 10 years. While India's nuclear capacity accounts for just under two percent of its total installed power capacity at present, there are strong efforts towards expansion after the increased availability of uranium from imports and domestic markets. Furthermore, the signing of international civil nuclear cooperation agreements with the United States, France, Russia, Canada, Korea, United Kingdom, and Japan, amongst others, is further facilitating this transition. India's clean reputation in nuclear non-proliferation and its recognition as a responsible nuclear power have facilitated the signing of such cooperation agreements. Additionally, India's waiver from the Nuclear Suppliers Group that enables India's engagement in nuclear trade and technology without being a signatory to the Nuclear Non-Proliferation Treaty and its agreement with the global atomic body IAEA have aided in its exponential growth plans in the last decade. India, a signatory to the Paris Agreement and driven by its rapidly growing electricity needs, plans an eight-fold increase in nuclear capacity relative to current levels.

At present, India's nuclear energy capacity building has been slow but parallel to the development of renewable power generation capacity, which has received a huge impetus from the Government, policymakers, and the market.

For India to realize its climate commitments through low-emission energy pathways, its nuclear energy program will remain at the heart of its energy transition. This would certainly entail the completion of its twenty one nuclear power reactors at five nuclear power plants, for a round-the-clock power assurance to India's growing economy. India already has the right policy orientation for the diversification of its energy supply, but there is scope for an economic and technological stimulation to amplify the development of nuclear infrastructure, especially in case of SMRs. There is a great potential for technology collaborations and a need to attract international and national investment by private companies in India's nuclear power program.

Nuclear power and hydropower form the backbone of low-carbon electricity generation. Together, they provide three-quarters of global low-carbon generation. Over the past 50 years, the use of nuclear power has reduced carbon dioxide (CO_2) emissions by over 60 gigatonnes – nearly two years' worth of global energy-related emissions. However, in advanced economies, nuclear power has begun to fade, with plants closing and little new investment made, just when the world requires more low-carbon electricity. This report, Nuclear Power in a Clean Energy System, focuses on the role of nuclear power in advanced economies and the factors that put nuclear power at risk of future decline. Achieving the pace of CO_2 emissions reductions in line with the Paris Agreement is already a huge challenge, as shown in the Sustainable Development Scenario. It requires large increases in efficiency and renewable investment, as well as an increase in nuclear power. This study will make an attempt to identify even greater challenges of attempting to follow this path with nuclear power. The present study will focus on the following

objective:

1. To study the India's Energy Scenario.
2. To study the Indo-French nuclear cooperation and its impact of India's energy security.
3. To discuss the comparative performance of nuclear plants globally.

Review of Literature

Ramana and Ahmad (2016), critically examined India's intentions for nuclear expansion, contending that goals have always been too lofty in comparison to real capacity growth. India has experienced delays as a result of safety clearances, public opposition, and financial limitations, despite foreign cooperation, especially with France. The authors highlighted nuclear energy's currently small share in India's electricity mix and raise concerns about its economic feasibility in light of the declining cost of renewable energy. They do admit that, with effective implementation, it has the potential to produce low-carbon electricity. They propose giving least-cost decarbonisation paths with a greater emphasis on renewables priority and point out that high capital costs and liability issues discourage private participation. The study warns against relying too much on nuclear energy, even as Indo-French cooperation improves access to technologies.

Gupta and Basu (2019), Examined how nuclear energy contributes to India's energy security and make the case that it offers a dependable, steady supply that is essential for the development of industry. It is noted that Indo-French collaboration is crucial to introducing cutting-edge reactor technology and raising safety standards. Initiatives such as Jaitapur diversify India's energy supply while fortifying strategic alliances. Delays brought on by liability concerns, public opposition, and environmental clearances still exist, nevertheless. To increase acceptance, the authors suggest bolstering public communication and regulatory systems.

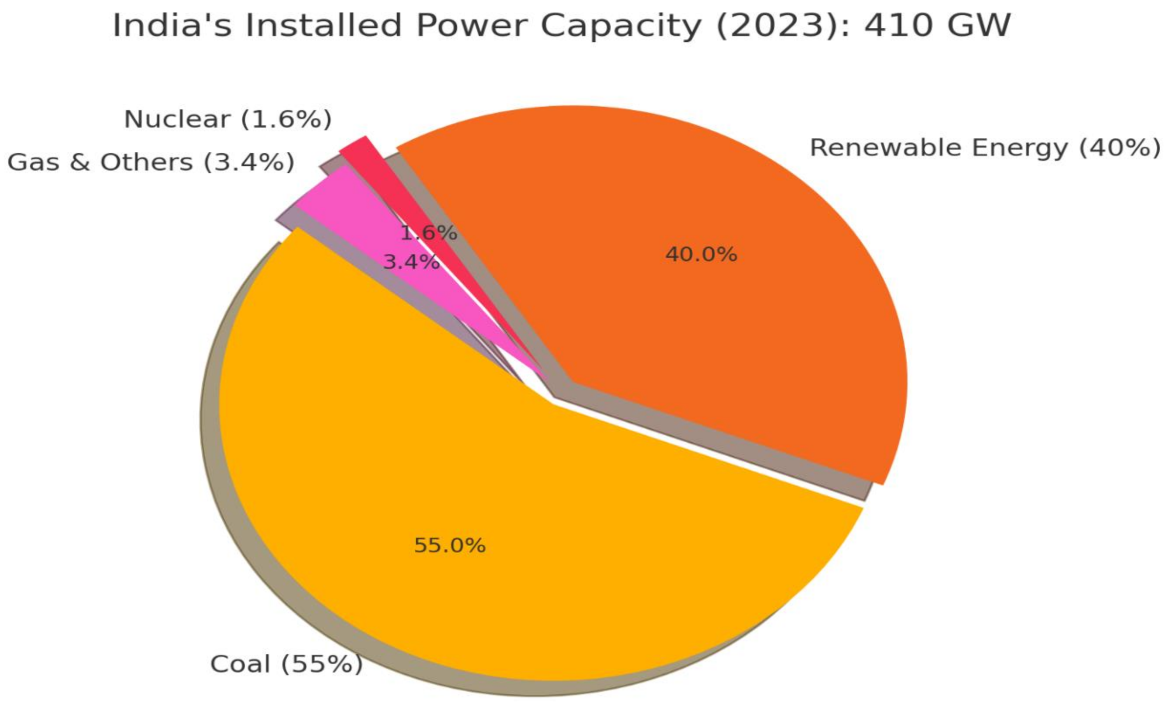
World Nuclear Association (2020), described India's three-phase nuclear program, emphasising the country's strategic goal of using its own thorium supplies to achieve energy independence. With France's cutting-edge EPR technology raising safety and efficiency requirements, Indo-French cooperation—particularly the Jaitapur project—is viewed as essential to increasing India's nuclear capability. In order to overcome the isolation of the nuclear commerce in the past, the research highlights the importance of international cooperation. Three major obstacles still exist: funding, waste management, and public opposition. The Association concluded that by supplying dependable, low-carbon base-load electricity, nuclear power can be used in conjunction with renewables to meet net-zero targets.

International Renewable Energy Agency (IRENA, 2021), recognized nuclear energy as a valuable addition to clean energy transitions, even while it prioritized renewable energy. It recommends policy stability and public acceptability tactics for deployment, arguing that SMRs are attractive for emerging economies because of their modularity and flexibility. Indo-French collaboration is seen as promoting the adoption of SMR by incorporating nuclear into a well-rounded approach with storage and renewable energy.

International Energy Agency (IEA, 2022), demonstrated how India is expected to contribute 25% of the rise in the world's energy needs over the next several decades. It implies that nuclear power is necessary for a steady base-load supply, even though renewable energy sources will predominate in new additions. Projects like Jaitapur and other Indo-French collaboration are important for increasing nuclear capability. Although funding, regulatory hold-ups, and public concerns continue to be obstacles, the research points out that nuclear energy improves energy security by reducing reliance on coal and foreign fuels. To unleash nuclear's potential for decarbonisation, the IEA suggests worldwide technical partnerships and legislative changes.

India’s Energy Scenario

India's rapidly developing economy and 1.4 billion people make it the world's third-largest energy consumer. Since 2000, the nation's energy consumption has doubled, and it is expected to continue to rise sharply over the next several decades. Fossil fuels now dominate India's energy mix; coal alone provides more than 70% of the country's electrical generation and over 55% of its total energy needs. India's climate pledges under the Paris Agreement are seriously threatened by this reliance on coal, which raises carbon emissions and degrades the ecosystem. India has set ambitious goals for renewable energy, but because solar and wind generation are intermittent and present storage and grid integration issues, it is unable to scale them up to satisfy base-load demands. India has over 410 GW of installed power capacity as of 2023, of which about 166 GW comes from renewable energy, ranking fourth in the world for installed renewable capacity. However, a steady, uninterrupted, and dependable energy supply—which is necessary for long-term economic growth—cannot be guaranteed by renewable sources alone.



(source: - Central Electricity Authority (CEA) Annual Report 2023)

The above diagram illustrates the composition of India’s total installed power capacity, which stands at approximately 410 GW as of 2023. It shows that coal remains the dominant source, accounting for 55% of the capacity, reflecting India’s heavy dependence on this fossil fuel due to its abundant domestic reserves and established power infrastructure. Renewable energy sources collectively contribute around 40%, comprising solar, wind, hydro, and other renewables, indicating significant progress towards clean energy targets. However, nuclear energy forms only 1.6% of the installed capacity, highlighting its current limited role despite being a crucial low-carbon, base-load power source for energy security and climate commitments. The remaining 3.4% comes from gas and other minor sources, which are used primarily for peaking power and operational flexibility. Overall, this diagram emphasises that while renewable energy has grown rapidly, coal continues to dominate, and nuclear power expansion remains essential for diversifying India’s energy mix and achieving its net-zero carbon emission targets by 2070.
Only approximately 1.6% of India's installed capacity and 3% of its electricity generation now comes from nuclear power, which saves an estimated 41 million tonnes of CO_2 emissions yearly. In recognition of the need to diversify its energy sources and lessen reliance on imports of fossil fuels, the Indian government has set the lofty goal of increasing nuclear capacity to 20 GW by 2032 and then to 100 GW by 2047. In order to attain long-term energy self-sufficiency, this expansion seeks to capitalise on India's distinctive three-stage nuclear program, which makes use of substantial native thorium sources. The Indian government has also implemented budgetary allotments and policy measures to support the growth of nuclear energy, including encouraging global partnerships to advance technological capabilities. In addition to giving access to cutting-edge nuclear technologies, alliances like the Indo-French nuclear cooperation also improve India's energy security by guaranteeing a varied, low-carbon energy mix. All things considered, the urgent need to strike a balance between quick economic expansion, environmental sustainability, energy security, and a steady supply of electricity for everyone defines

India's current energy situation. In this regard, nuclear energy becomes a viable option to supplement renewable energy sources and help the nation reach its 2070 net-zero carbon emission goals.

Nuclear Energy Partnership: Achieving India's Energy Transition for Zero Corban Target

Enhancing Nuclear Energy Partnership

France and India have also been working together on energy issues. The countries strive to reach carbon neutrality as soon as possible but no later than 2050 and 2070, respectively. India is party to the Paris Agreement and, Modi claims, was one of the first G20 countries to fulfil its obligations under the pact and is working with France on the global challenges of climate change. The two are strong proponents of nuclear energy as a sustainable alternative to fossil fuels, and both see solar energy and hydropower as areas of cooperation and growth. French company Engie has invested heavily in renewable energy projects in India, mostly solar. France is also sharing information on enhancing India's electrical grid, to meet India's urban center's demands, and to lay the groundwork for future joint energy projects.

Increasing Indo-French Nuclear Power Cooperation Following their recent meeting, Macron and Modi announced enhanced cooperation on a nuclear power plant in Jaitapur in western India. The collaboration, which began in 2018, will include a partnership on small and advanced modular reactors, staff training and the promotion of careers in the nuclear energy sector through internships and exchanges. The Jaitapur plant is slated to be the world's most powerful, capable of meeting the energy needs of 70 million Indian households. Although nuclear energy is an area of growth for India, a strong opposition exists and may limit the further expansion of nuclear energy capabilities. Elsewhere, India is one of only two non- European partners invited to cooperate on the Jules Horowitz Research Reactor (JHR) under construction at Cadarache in southern France. The reactor is scheduled to begin operations between 2026 and 2028. It will also be the premier site for materials testing and serve as an incubator for the next generation of reactor designs. An international consortium of European partners, including the European Commission and utility companies, plus the Indian and Japanese governments have been invited to join. India's energy needs are expected to more than double by 2050, according to BP's Energy Outlook, and the country's electricity generation by 2050 will be four to five times 2019 levels. This gives France a highly scalable partner in the energy sector, while India benefits from access to French nuclear expertise and, more broadly, European expertise on renewables. Both countries will use the collaboration to help meet two shared strategic goals, bolstering energy independence and combating climate change.

India's Union Budget 2025-26 has given a significant push toward nuclear energy as part of India's long-term energy transition strategy. The Government of India has set an ambitious target of 100 GW nuclear power capacity by 2047, reinforcing its commitment to energy security and sustainability. A crucial step in this direction is the Bharat Small Modular Reactors (BSMRs) – a compact 220 MW pressurized heavy water reactor based on India's reactor technology – which will be developed by private sector participation. This development aligns with the broader objective of Viksit Bharat, ensuring energy reliability and reducing dependency on fossil fuels.

Recognizing the importance of nuclear energy, On February 12, 2025, India and France agreed to jointly develop modern nuclear reactors, emphasizing that nuclear power is critical for energy security and transitioning to a low-carbon economy. Two countries signed the "Letter of Intent" on Small Modular Reactor (SMRs) and Advanced Modular Reactors (AMRs), confirmed by a joint statement issued after Indian Prime Minister Narendra Modi and his counterpart President Emmanuel Macron met in Paris. This bilateral meeting also renewed a memorandum of understanding(MoU) between India's Department of

Atomic Energy(DAE) and France's commissariat a "l'Énergie Atomique et aux Énergies Alternative" of France (CEA) to enhance cooperation with the Global Centre for Nuclear Energy Partnership (GCNEP), based in Haryana which aims to promote international collaboration in nuclear energy research and development and capacity building.
The Jaitapur project is envisioned as a six-unit EPR(European Pressurized Reactors) nuclear power plant in Maharashtra, India, with a total capacity of 9.6 GWe, making it the world's most powerful nuclear facility. Once operational, it will produce around 75 TWh of electricity annually, meeting the energy needs of 70 million Indian households while preventing the release of approximately 80 million tons of CO2.

About SMRs and AMRs

Small modular reactors(SMRs) are advanced next-generation nuclear reactors that are smaller, safer, and more flexible than conventional reactors. With a capacity of up to 300 MW(e) per unit, they can be factory-manufactured and transported for on-site installation, enabling rapid deployment of clean energy. Advanced Modular Reactors (AMRs) represent the next phase of nuclear innovation, integrating enhanced safety features, and greater adaptability to various energy needs.
Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs) represent the next generation of nuclear energy technologies, offering significant advantages over conventional large-scale nuclear reactors in terms of flexibility, safety, and economic feasibility. SMRs are defined as nuclear reactors with an electrical output of up to 300 MW per unit, designed to be factory-fabricated and modular, allowing for easier transportation, rapid on-site assembly, and scalable deployment based on local demand. This modularity not only reduces construction time and costs but also lowers financial risks associated with traditional nuclear plants that require massive upfront capital investments and long gestation periods. SMRs are designed with enhanced passive safety systems that rely on natural circulation and gravity-based mechanisms rather than external power sources, significantly reducing the risk of core damage and radioactive release during operational disruptions or natural disasters. Their compact size and advanced safety features make them particularly suitable for deployment in remote areas, small grids, or regions with limited transmission infrastructure, such as northeastern and Himalayan states in India where grid connectivity challenges persist.
Advanced Modular Reactors (AMRs) extend the technological innovation beyond SMRs by incorporating advanced fuel cycles, cooling technologies, and reactor designs that enable higher thermal efficiency, fuel utilisation, and waste reduction. AMRs include fast reactors, molten salt reactors, high-temperature gas-cooled reactors, and other Generation IV designs, many of which operate at higher temperatures, allowing for applications beyond electricity generation such as industrial heat supply, hydrogen production, and desalination. These reactors are designed to be inherently safe, with passive safety features and negative temperature coefficients that automatically reduce reactor activity during overheating scenarios. AMRs also utilise novel fuels such as thorium or high-assay low-enriched uranium (HALEU), increasing fuel availability and reducing proliferation risks associated with traditional enriched uranium. India's strategic advantage in thorium reserves aligns with AMR development, as thorium-based reactors such as molten salt reactors can utilise abundant domestic resources, ensuring long-term energy security.
Globally, SMRs are being considered as a critical technology to support decarbonisation efforts by providing dispatchable low-carbon power to complement intermittent renewables like solar and wind. Countries such as the United States, Canada, Russia, China, and France have advanced SMR projects at various stages of development and deployment. For instance, NuScale Power's SMR design in the US has

received Nuclear Regulatory Commission approval, while Russia has operational floating SMRs in Arctic regions. France's interest in collaborating with India on SMRs and AMRs reflects its strategic goal to maintain nuclear leadership and promote its reactor technologies globally. Indo-French cooperation in this field can accelerate India's clean energy transition by providing technical expertise, technology transfer, and investment in SMR and AMR projects. This partnership is evident in the recent Letter of Intent signed between India and France in February 2025, focusing on joint development of SMRs and AMRs for mutual energy security and climate goals.

From India's perspective, SMRs and AMRs align with its objectives of diversifying the energy mix, reducing dependence on coal, and achieving net-zero carbon emissions by 2070. The Government of India has recently announced the Bharat Small Modular Reactor (BSMR) initiative, targeting the development of indigenous 220 MW pressurised heavy water SMRs with private sector participation. This initiative aims to leverage India's existing PHWR technology while enhancing safety and economic competitiveness. Additionally, the government is considering amendments to the Atomic Energy Act, 1962, and the Nuclear Liability Act, 2010, to facilitate private investment and public-private partnerships in nuclear development. SMRs can be deployed as grid-connected or off-grid units, supporting industrial clusters, defence installations, and isolated regions with reliable low-carbon power. Their extended fuel cycles, requiring refuelling every 3–7 years compared to conventional reactors' 1–2 years, reduce operational disruptions and fuel supply chain vulnerabilities.

AMRs, particularly fast breeder reactors and molten salt reactors, support India's three-stage nuclear program aimed at utilising its vast thorium reserves. Fast breeder AMRs can close the nuclear fuel cycle by converting fertile materials into fissile fuel, significantly enhancing fuel utilisation and reducing nuclear waste. Molten salt AMRs offer enhanced safety with low-pressure operation and passive cooling mechanisms, minimising the risk of catastrophic failures. Moreover, AMRs operating at high temperatures can be integrated into industrial decarbonisation strategies, such as replacing fossil fuel-based steam production and enabling large-scale hydrogen production for clean fuel applications.

Despite their advantages, SMRs and AMRs face challenges such as high initial development costs, regulatory uncertainties, supply chain establishment, and public acceptance issues. International collaboration, as seen in Indo-French agreements, plays a crucial role in overcoming these barriers through shared R&D, harmonised safety standards, and financing mechanisms. In conclusion, SMRs and AMRs present transformative potential for India's energy sector by providing safe, scalable, and sustainable nuclear power solutions. Their deployment will not only strengthen India's energy security and support its net-zero targets but also position India as a global leader in advanced nuclear technologies, demonstrating the strategic and economic benefits of bilateral nuclear cooperation in addressing climate change and sustainable development goals.

Civil Nuclear Cooperation

The history of atomic energy cooperation between the two countries goes back to the early Cold War period. The cooperation was only realized in January 1951 when the two countries signed their first bilateral agreement for research and development of 'beryllium-moderated reactors'. Between 1966 and 1969, the two countries negotiated on breeder reactors- a plutonium-fueled, plutonium-breeding reactor technology, in which the French dominated. This agreement majorly impacted India's nuclear programme, by allowing India to have a civil justification for the acquired reactors and technology.

After India's first peaceful nuclear test in 1974, generated hostile reactions across the Western countries, France was the only Western country that congratulated India on achieving this "scientific feat". The nuclear test in 1974 proved costly for India's nuclear program as the US stopped supplying fuel reactors in the Tarapur Nuclear facility in Maharashtra, however, it was France, who replaced America as a fuel supplier to the Tarapur reactors.

In September 2008, a milestone was achieved in nuclear cooperation, after India received a Nuclear Suppliers Group (NSG) waiver for civil nuclear trade, France became the first country to sign a nuclear agreement. Later when NSG restricted enrichment and reprocessing technology for non-NPT signatories, France assured continued cooperation with India.

In 2010, India and France exchanged the instrument of ratification of the cooperation agreement, on the development of peaceful uses of nuclear energy signed in Paris on Sept. 30, 2008. The two countries intend to develop a multifaceted civil nuclear cooperation, covering a wide range of activities including nuclear power projects, fuel supply, research & development, nuclear safety, education and training.

India and France share a mutual commitment to peaceful nuclear energy which is evident in its Industrial Way Forward Agreement in 2018, on the Jaitapur Nuclear Power Plant Project (JNPP), in Maharashtra. In January 2025, a meeting of a special task force took place in the larger framework of the Indo-French Strategic Dialogue. Both sides agreed to work on establishing a partnership on low and medium-power modular reactors. Cooperation on JNPP and shared vision of developing small modular reactors and advanced modular reactors is considered to be instrumental in Indo-French relations in terms of energy security and environmental sustainability. Agreement on SMRs and AMRs would further advance the cooperative efforts on nuclear energy and deepen the ties between the two nations. India-France nuclear ties, rooted in middle power alignment, have persisted beyond the Cold War and continue to strengthen.

India's Energy Data

India relies heavily on fossil fuels, particularly coal (55% of energy needs), which accounts for more than 88% of its primary energy needs. This dependence poses risks related to supply chain stability and environmental sustainability. As part of the transition to clean energy mission, India aims to generate 100 GW of nuclear energy by 2047. Recently the government of India announced a project to launch a Nuclear Energy Mission with a budget outlay of Rs 20000 crore for research and development of SMRs.

India plans to operationalize a minimum of five SMRs which are to be developed within the country. The government is considering amendments to the Atomic Energy Act of 1962, and the Nuclear Liability Act, of 2010 to enable private sector participation in the research and development of nuclear energy. Private players in tandem with the government of India will collaborate to set up Bharat Small Reactors, Research and Development of Bharat Small Modular Reactors, and Research and Development of newer technology for nuclear energy.

As of now, nuclear power plants contribute 1.6% of India's total installed power capacity and approximately 3% of total electricity generation which helps save around 41 million tonnes of carbon dioxide emissions annually. India aims for a threefold increase in its installed nuclear capacity by 2031-32.

Reducing Dependence on Fossil Fuel

The Indian government has set an ambitious target to increase nuclear capacity, aiming at 20 GW by 2032 and 100 GW by 2047 and achieve 500 GW of non-fossil fuel capacity by 2030 as pledged at the COP26 summit in Glasgow in 2021. SMRs and AMRs would provide a reliable and scalable energy source to complement other renewables such as solar and wind.

The agreement would help address India's energy demand. India's energy demand is projected to grow rapidly, with the International Energy Agency estimating a doubling by 2040. India imports nearly 85% of its crude oil, and developing domestic nuclear power reduces its dependence on fossil fuels. Integrating SMRs and AMRs will diversify India's energy mix, reducing reliance on fossil fuels and enhancing energy security.

Demonstrating India's commitment to reducing greenhouse gas emissions and combating climate change. Successful implementation of projects like the Jaitapur Plant will significantly increase the share of clean energy in India's portfolio, serving as a model for sustainable energy development worldwide. The agreement emphasizes ongoing efforts related to the Jaitapur nuclear power plant project in Maharashtra, which, upon completion, is expected to be the world's largest nuclear power facility, significantly boosting India's nuclear energy capacity and helping India's target to achieve net zero emission by 2070.

One of the prominent challenges that India faces is pan-India electrification- challenges to accelerating access to energy is infrastructure – limited grid coverage in rural areas and the cost of grid connection for rural electrification. In areas lacking sufficient line transmission and grid capacity, SMRs can be installed into an existing grid or remotely off-grid, providing low-carbon power for industry and the population. Moreover, as compared to conventional plants – which require frequent refueling every 1 to 2 years, SMRs have reduced fuel requirements. Power plants based on SMRs may require less frequent refueling, every 3 to 7 years, making them more efficient and cost-effective.

Geopolitical Significance

India's collaboration with France in developing modern nuclear reactors holds immense geopolitical significance, influencing India's strategic autonomy and international standing. Historically, India's nuclear collaboration has been predominantly with Russia, exemplified by projects like the Kudankulam Nuclear Power Plant. However, the recent agreement with France signifies the strategic shift towards diversifying India's nuclear partnerships. This diversification reduces over-reliance on a single nation, thereby enhancing India's strategic autonomy and resilience in the global nuclear paradigm.

China's aggressive expansion in nuclear capabilities and nuclear technology exports- through road and belt initiative, and export reactors to Pakistan, pose a security threat to India. India's partnership with France serves as the counterbalance, ensuring regional power equilibrium. This progress not only deters potential adversaries but also showcases India's technological prowess, contributing to the balance of power in Asia.

By engaging with France- a nation recognized for its commitment to nuclear non-proliferation- India reinforces its dedication to peaceful nuclear development. This alignment enhances India's global image as a responsible nuclear power, facilitating smoother integration of international nuclear commerce and regulatory framework. The agreement strengthens India's case for Nuclear Supplier Group(NSG) membership, which is currently blocked by China. By deepening ties with France – a leading NSG member- India gained greater diplomatic leverage to push for full membership, allowing it to expand nuclear trade and technology access.

Way forward

The India-France nuclear agreement marks a strategic breakthrough in India's pursuit of energy security, sustainability and technological advancement. With France's expertise in nuclear technology and India's growing energy needs, this partnership is set to reshape India's power sector by accelerating the deployment of small modular reactors and advanced modular reactors. Agreement on cutting-edge technology such as SMRs and AMRs and renewed progression on the Jaitapur project between India and France will significantly reduce India's dependence on coal and curb carbon emissions. With India's energy demand projected to grow rapidly, nuclear power will play a critical role in diversifying its energy mix and achieving a net zero emissions target.

Furthermore, the agreement strengthens Indo-French diplomatic ties, enhances technological innovation and opens avenues for private-sector investment in India's nuclear industry. However, the success of this initiative hinges on policy reforms, regulatory clarity, and timely project execution. If implemented efficiently, this nuclear partnership has the potential to be a game changer, positioning India as a global leader and an inspiration for other developing countries in clean energy while ensuring stable, reliable, and long-term power supply for its growing population and economy.

Conclusion

The importance of Indo-French nuclear cooperation in enhancing India's energy security and reaching its net-zero carbon emission targets has been examined in this study. Nuclear energy is becoming a crucial and strategic part of India's energy transformation as it struggles to maintain both environmental sustainability and quick economic growth. Even while renewable energy sources like wind and solar have grown considerably, their sporadic nature makes it difficult for them to supply the steady base-load power needed for industrialisation and national electrification. Nuclear power provides dependable, low-carbon electricity in this situation, enhancing energy security and lowering reliance on imported fossil fuels.

The study emphasises how access to cutting-edge reactor technologies, safety procedures, and operational know-how has been made easier by Indo-French nuclear cooperation, as demonstrated by the Jaitapur Nuclear Power Project and recent agreements on Small Modular Reactors (SMRs) and Advanced Modular Reactors (AMRs). India's enormous market potential and critical thorium reserves, along with France's technological supremacy in nuclear energy, produce reciprocal advantages that promote innovation, capacity building, and geopolitical alignment. From early scientific cooperation in the 1950s to current partnerships, the history of Indo-French nuclear connections demonstrates the depth and tenacity of this bilateral relationship, which continues to support India's efforts to diversify its energy sources and fulfil its climate commitments.

The research does acknowledge the ongoing difficulties with nuclear growth, though, such as the high cost of capital, regulatory roadblocks, public resistance, safety worries, and waste disposal problems. To overcome these obstacles and increase public confidence in the safety and environmental sustainability of nuclear energy, legislative changes, clearer regulations, and increased public involvement are needed. Furthermore, to achieve the challenging goals outlined in India's nuclear development agenda, prompt project execution, cash mobilisation, and efficient private sector involvement are crucial.

To sum up, Indo-French nuclear cooperation is a key component of India's clean energy policy, offering not only financial and technological advantages but also enhancing its geopolitical position and strategic independence. Together with widespread renewable energy deployment and grid upgrading, nuclear energy integration provides India with a strong route to a secure, sustainable, and net-zero future. In order to establish India as a global leader in clean and cutting-edge nuclear technologies and to set an example for other developing countries striving for sustainable development and climate resilience, it will be crucial to strengthen this partnership through ongoing diplomatic engagement, cooperative research and development, and knowledge sharing.

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