

INDIA'S QUEST FOR CIVIL NUCLEAR INNOVATIONS: POTENTIAL ROLE OF PRIVATE SECTOR AND INTERNATIONAL PARTNERSHIPS

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India's civil nuclear energy sector is undergoing a strategic transformation, as it gradually shifts its traditional state-dominated model to one that increasingly accommodates the private sector and foreign players. Long perceived as a closed domain, forced to develop in isolation after the Peaceful Nuclear Explosion (PNE) of 1974, India's trajectory saw a marked shift after the historic Civil Nuclear Agreement (CNA) with the United States (US). This milestone agreement legitimised India's position as a budding nuclear power and opened the doors to international civil nuclear partnerships, supporting domestic ambitions to achieve energy diversification and decarbonisation.

Under the incumbent dispensation holding power since 2014, policy developments such as the Nuclear Energy Mission 2025 and the proposed amendments to the Civil Liability for Nuclear Damage Act, 2010 (hereafter CLNDA), and the Atomic Energy Act, 1962, (hereafter AE Act), signal a shift that provides space to explore possible public-private partnership models.

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Rising domestic energy requirements have led to a changing state perspective, supporting innovation and indigenisation and aiding India's promise of a more diverse nuclear energy ecosystem.

These reforms aim to promote indigenous nuclear technologies like the Bharat Small Reactors (BSRs), along with an enhanced focus on Research and Development (R&D) and easing the inward flow of foreign participants. Ongoing efforts are being led by the partnership with the US, as increasing regulatory flexibility allows for a more inclusive nuclear innovation ecosystem.

This paper delves into understanding this aspect of 'inclusivity' in the Indian civil nuclear ecosystem, particularly by locating the private sector's and international partners' involvement. It analyses why the atomic energy landscape in India was historically devoid of a larger role of the private sector and what administrative-legal challenges it overcame to accommodate itself in the domain. Rising domestic energy requirements have led to a changing state perspective, supporting innovation and indigenisation and aiding India's promise of a more diverse nuclear energy ecosystem. The domestic discourse of 'self-reliance' continues to mould itself through changing circumstances. These changes, driven by international collaborations, are instrumental in helping India achieve its energy transition targets and decarbonisation goals, thereby positioning it as a key player in the global nuclear energy landscape. But do they supplement India's 'self-reliance' ambition, and to what extent (if they do), or do they instead reposition India's approach to nuclear energy? It is a discussion that remains to be addressed.

A HISTORICAL OVERVIEW OF NUCLEAR ENERGY GOVERNANCE IN INDIA: MAPPING ACTORS IN THE CIVIL NUCLEAR PROGRAMME

The foundational framework of India's civil nuclear programme was laid by the Nehru-Bhabha duo, building upon the legacy of pioneering scientists like C.V. Raman, Meghnad Saha, and S.N. Bose, who emerged from a vibrant scientific tradition rooted in Indian universities. For reasons that remain

unclear, even at this stage, the involvement of the industry in technology R&D was neither expected nor welcomed by the scientific community.¹ The most plausible explanation could be the widely agreed-upon belief that newly independent India was not ready for large-scale technological development. Thus, the nuclear programme remained under the network of government agencies, subsidiary universities, and research institutes.

Another plausible explanation for the distinct shape of the Indian civil nuclear ecosystem can be attributed to the structural factors in international politics at the time. Considering the project's strategic nature and the need to secure international confidence in its nuclear ambitions, India adopted a secretive, state-centric civil nuclear framework. Nehru's understanding of this approach stemmed from his belief that it was essential for India to protect its newly acquired nuclear materials and technical expertise from potential exploitation by the industrialised Western powers. This possible 'post-colonial' control could impact India's strategic atomic development and weaken its negotiating capability with them.² A secretive approach allowed the Western powers, such as the US, to demonstrate confidence in India's nuclear cooperation, as it ensured mutual security through their technical capabilities.³

This framework reflected the larger policy approach that the Nehru administration had, with its faith in 'state-centrality.' It involved giving the government exclusive control in sensitive domains (like space and nuclear), factoring in the situation for a newly independent and economically fragile India that would require international support to develop strategically

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1. R. Ramanna, "Development of Nuclear Energy in India 1947-73", in T.T. Poulse, ed., *Perspectives on India's Nuclear Policy* (New Delhi: Young Asia Publications 1978).
 2. George Perkovich, *India's Nuclear Bomb: The Impact on Global Proliferation* (London: University of California, Berkeley Press 1999).
 3. Ibid.

important sectors of the domestic economy. The aforementioned framework in the civil nuclear domain in India was primarily led by the Atomic Energy Act of 1948. This Act enabled the establishment of the Atomic Energy Commission (AEC), which would hold executive and financial powers over India's nuclear energy sector. Subsequent detailing of the nuclear administration was achieved by the Atomic Energy Act, 1962, denying any role to non-government entities in the operation of the civil nuclear power plants.

With the transition of political leadership to Indira Gandhi, India adopted a more assertive stance on its nuclear strategy, culminating in the 1974 nuclear test (codenamed Operation Smiling Buddha). Facing international isolation post-testing, the Indian atomic programme entered a period of indigenisation and standardisation.⁴ This situation also brought increased attention to the efficiency and administrative management of the domestic nuclear energy project. Debates arose on the nature of nuclear governance in India, where the ability of the AEC to administer the nuclear sector single-handedly was increasingly questioned. Policy-makers were raising concerns over the secrecy, as mentioned earlier, that followed the administrative approach of the AEC, and the necessity to separate the functions of production, administration, and regulation to effectively achieve the targeted nuclear share in the energy basket.⁵ The amendment to the AE Act in 1987 allowed the government to establish the Nuclear Power Corporation of India (NPCIL), a separate government-owned corporate entity to administer nuclear power plants in the country. Incorporation of the NPCIL also made the policy-makers believe it could resolve the funding issues, a primary reason that was thought to cause delays in achieving the nuclear energy targets. Experts also believed that the Department of Atomic Energy (DAE) should consider vertical disintegration of its functions by

4. PV Philipkuty, *Managing Supply Chains for Indian Nuclear Power Projects*, 15th INPRO Dialogue Forum: Sustainable Supply Chains for Advanced Nuclear Power Systems, IAEA Headquarters, Vienna, 2018.

5. Parliamentary Proceedings (1987) on Amendment of the Atomic Energy Act, 1962, www.rsdebates.nic.in.

involving other government agencies like the Geological Survey of India (GSI) in surveying and extraction activities. It would help the DAE to focus more on the R&D aspects of the nuclear energy programme, and would bring functional efficiency.⁶

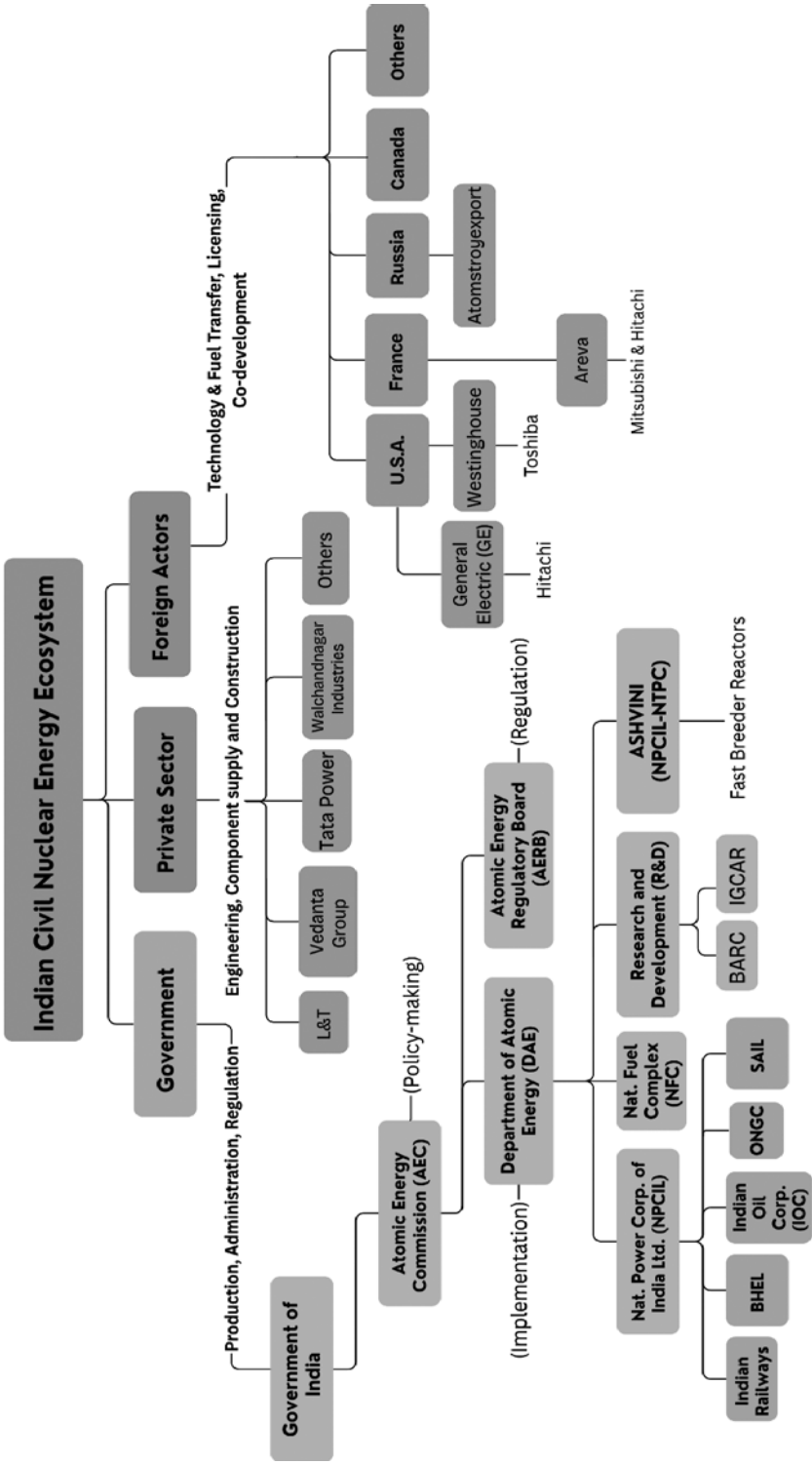
As the consolidation and commercialisation phase of the nuclear energy programme, set in motion by the late 20th century, Indian corporations like Larsen and Toubro (L&T) and Walchandnagar Industries gradually got involved in the engineering and equipment supply systems for the nuclear plants. They supplied critical components like heavy water production equipment and heat exchanger systems, and supported the aim of indigenising key elements of the nuclear programme. The Vajpayee government brought in a critical shift in the nuclear approach, with the strategic component of the atomic programme taking centre-stage (leading up to the 1998 nuclear tests codenamed Operation Shakti), and any discussion for diversifying the nuclear energy ecosystem left on the periphery. The attention would be brought back on the energy component only when the United Progressive Alliance (UPA) government under Manmohan Singh would bring in the historic civil nuclear deal with the US in 2005.

The nuclear deal with the US (the 123 Agreement) created a renewed space for private actors to be involved in India's nuclear landscape. The joint agreement made India internalise its domestic legal framework in the nuclear sector and question the existing structure. As the global atomic commerce slowly opened for India with the nuclear Non-Proliferation Treaty (NPT) exemption and the Nuclear Suppliers Group (NSG) waiver, engagement with foreign companies and location in the component export, reactor support, and fuel supplies became a possibility.⁷ As discussed below, the legal conundrums of the domestic nuclear sector created frustration amongst the American counterparts. International pressure and domestic ambition to scale production led to the implementation of

6. Ibid.

7. *Fact Sheet on the U.S.-India Civil Nuclear Cooperation Initiative*, Bureau of South and Central Asian Affairs, Archives of the Department of State, United States of America, October 15, 2008, <https://2001-2009.state.gov/p/sca/rls/fs/2008/109567.htm>.

Fig 1: India's Evolving Nuclear Energy Innovation Ecosystem



Source: Prepared by the author.

CLNDA, 2010, to institutionalise a nuclear liability policy. Despite these changes, differences remain with the international partners on the extent of the gap between the domestic framework and the global norms on nuclear liability.

Modi inherited a civil nuclear sector with immense potential for diversification, but with legal roadblocks, and one plagued by continuously missed production targets. His persona of an anti-nuclear dove, a regional leader who would rather support local farmers and their land rights over an atomic plant installation⁸, was soon transformed with his apparent support for nuclear commerce. He put forth the ambitious target of tripling the country's nuclear power capacity by 2024 [from the 5,780 Mega Watt electric (MWe) capacity in 2014].⁹ The idea of indigenisation picked up pace, and was complemented through a range of international civil nuclear agreements with several major countries, including Australia, France, and Japan, while arranging domestic technology development agreements with Atomstroyexport (Russia) and Areva (France).¹⁰

The nuclear energy ecosystem saw a shift with the 2015 amendment to the Atomic Energy Act that expanded the definition of a 'government company' to include state-owned entities, other than NPCIL, to participate in developing nuclear energy projects. It led to the formation of the Anushakti Vidhyut Nigam (ASHVINI) joint venture between NPCIL and NTPC (National Thermal Power Corporation) to create the Chutka and Mahi Banswara Pressurised Heavy Water Reactors (PHWRs) of 700 MWe each.¹¹ Other government corporate entities like the NALCO (National Aluminium Company) and ONGC (Oil and Natural Gas Corporation) are also in discussions with the NPCIL for establishing a similar arrangement for developing PHWRs under various projects. Policy transformation has also

8. Jaideep Prabhu, "India's Nuclear Milestone", <http://www.dnaindia.com/>. October 5, 2013.

9. Ibid.

10. Aniruddh Mohan, "The Future of Nuclear Energy in India", ORF Occasional Paper, August 2016.

11. Rama T. Ponangi and Kaushik Deb, *The Potential for Public-Private Partnership in India's Nuclear Electricity Program* (Centre on Global Energy Policy, School of International and Public Affairs, Columbia University, March 13, 2024).

The current administration has pledged to pour INR 20,000 crore into specialised segments like the Small Modular Reactors (SMRs) that are believed to be the future of the nuclear energy landscape.

raised the interest of domestic corporate groups like Adani Power and Vedanta Group to reconsider their involvement in the country's nuclear energy programme, previously snubbed due to the complex legal roadblocks.¹²

In recent years, diversification in the nuclear energy landscape has made small yet promising changes. Current debates on the amendments of major

legal roadblocks like the CLNDA, 2010, and the AE Act, 1962, have raised hopes in the nuclear industry worldwide. Alongside this, the current administration has pledged to pour INR 20,000 crore into specialised segments like the Small Modular Reactors (SMRs) that are believed to be the future of the nuclear energy landscape. All of this encompasses the Nuclear Energy Mission for Viksit Bharat, an ambitious policy that aims to achieve 100 Giga Watt (GW) of nuclear energy by 2047.¹³ This policy creates ample opportunity for private players and foreign corporations to get involved in developing smaller and cheaper reactors with greater energy efficiency¹⁴, conditioned on the fact of the legal debates on their presence being amply resolved. The repeatedly raised legal conundrums, particularly around liability issues, continue to decelerate the potential diversification of India's nuclear energy landscape. Nevertheless, they also necessitate contemplating on the concerns raised on their involvement, making an

12. Gargi Shukla, "India's Nuclear Push: Private Sector Steps In, but Full Liberalisation Still Distant", *Outlook Business*, April 21, 2025, <https://www.outlookbusiness.com/in-depth/indias-nuclear-push-private-sector-steps-in-but-full-liberalisation-still-distant>.

13. "'Nuclear Mission' Announced in the Union Budget 2025-26 Will Mark a Transformative Shift in India's Energy Landscape and will Enable Nuclear Power to Emerge as a Major Source of Energy for India: Union Minister Dr. Jitendra Singh", Department of Atomic Energy, Government of India, PIB Press Release, February 5, 2025, <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2100108>.

14. "India Wants to Embrace Nuclear Power. To do it, it'll Need a Lot of Time and Money", *The Economic Times*, February 15, 2025.

informed judgement on diversification, and even questioning whether diversification is the ultimate solution to our persistently missed nuclear energy targets.

THE LEGAL CONUNDRUMS IN INDIA'S NUCLEAR INNOVATION ECOSYSTEM: STATE, INDUSTRY, AND INTERNATIONAL COOPERATION

From the inception of the nuclear energy programme in India, a realisation existed amongst the scientific community and policy-makers alike that acceptance of the project would only come when it

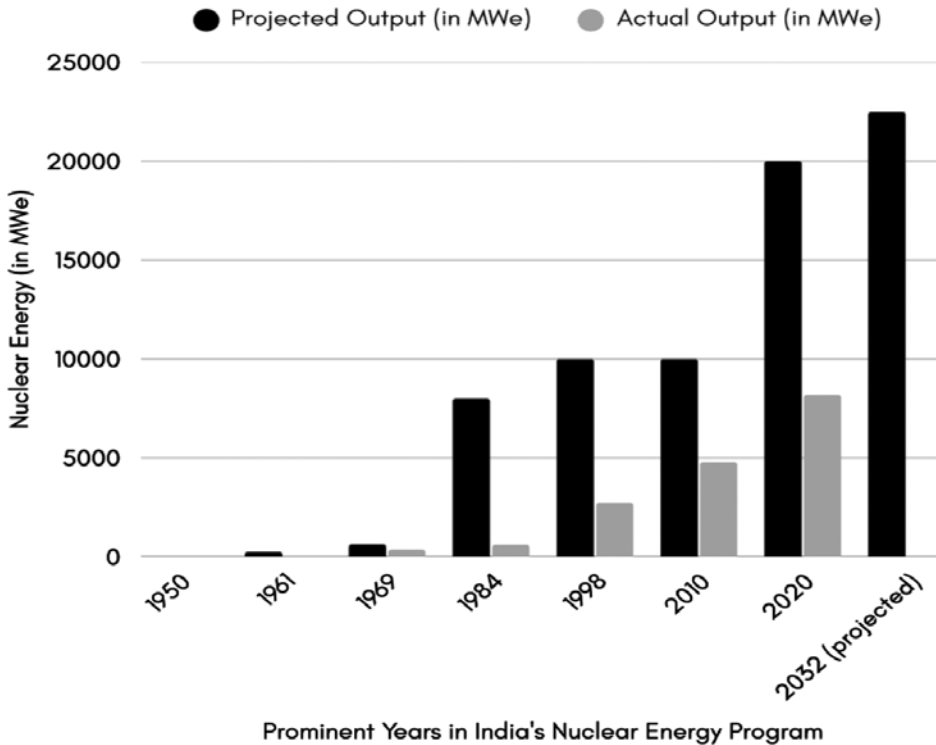
brought results of affordable energy options to the masses.¹⁵ To this end, making the nuclear option cost-competitive became essential by focussing on timely project completion and establishing a stable and diverse supply chain system. While the inception of the programme brought in indispensable support from countries like France and Canada, India gradually began to focus on developing indigenous nuclear programmes and support mechanisms that also involved gathering localised supplies for cost-effectiveness.¹⁶ Furthering this ambition, private sector agencies gradually began supporting the civil nuclear power plants. While a range of issues kept them away from the administration and management of the nuclear plants (as discussed earlier), they became a critical element in the localisation of supply equipment and component manufacturing. It now becomes imperative to examine the legal issues that kept the domestic nuclear energy sector aloof from the private dynamics.

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15. Ramanna, n. 1.

16. Philipkutty, n. 4.

**Fig 2: India's Targeted Nuclear Energy Production Against Actual Output
(with initial targets consideration)**



Source: Prepared by the author from data from PIB press releases and output estimates made by the World Nuclear Association.

The legal framework that guides the Indian civil nuclear policy is led by the Atomic Energy Act of 1948 (AE Act), supported by the executive policy framework and administrative structure under the AEC. The AE Act, 1948, was legislated within a year of gaining independence, marking the project's inherently 'secretive' nature. Established on the borrowed framework of the British Atomic Energy Act (1946), the Indian version was considered more opaque. When questioned, Nehru's response aligned with the prevailing perception of the time, expressing the increasing complexity in any possible

bifurcation of the nuclear energy programme from its strategic counterpart. Thus, any secrecy in one component naturally created a spillover into the other.

The aforementioned opaqueness of the nuclear energy policy and the substantial government control meant that any private sector involvement was out of the question. The legal position on this was explicitly put out with the AE Act, 1962, Section 3 of which states that it grants the state exclusive powers to “produce, develop, use, and dispose atomic energy, research into the same, manufacture any radioactive substance, buy, acquire, store, transport any of the radioactive substance, along with safety provisions”¹⁷.

As mentioned earlier, gradual discussion on this government monopoly on the functions of production, administration and regulation raised concerns from policy-makers and experts alike, and the consolidation phase of the 1980s led to the establishment of the NPCIL that would shift this function to an independent government corporate entity. Nevertheless, as the nuclear industry opened up in the 21st century, the role and administration of NPCIL increasingly came under question, with its monopoly on production, administration and regulation. This monopoly affected the efficiency of nuclear operations and neutral regulatory mechanisms that would have otherwise created transparency and fair accountability. To this end, the 2016 regulations permitted the NPCIL to enter into joint ventures with other Public Sector Undertakings (PSUs), leading to the establishment of specialised ventures like the ASHVINI.¹⁸ Nevertheless, increasing private sector engagement in the nuclear domain raises questions on the monopolised nuclear ownership, regulations, and potential tweaks in their framework that could allow greater diversity in nuclear operations. Contemporary policy review debates continue to assess the feasibility of making calculated changes to this regime.

17. Lohitaksh Shively, “All About Atomic Energy Act 1962”, *Latest Laws*, February 12, 2021, <https://www.latestlaws.com/articles/all-about-atomic-energy-act-1962/>.

18. “India’s NTPC Sets up Nuclear Subsidiary”, *World Nuclear News (WNN)*, January 15, 2025, <https://www.world-nuclear-news.org/articles/indias-ntpc-sets-up-nuclear-subsidiary/>.

The 'Liability' Factor in the Legal Framework of the Civil Nuclear Domain and Its Impact on Private Dynamism

The AE Act of 1962, despite forming the basic framework of the domestic nuclear regulation, failed to consider the issue of liability and legal responsibility of the plant administrator in the case of a nuclear accident. This issue was further highlighted post-1980s with the Bhopal gas tragedy that brought forth the serious consequences of complacent regulations on operator liability. Reflecting on the international normative framework, it figured that their mandate was not comprehensive regarding the liability issue, as the conventional approach excluded the suppliers and merely focussed on the operators in nuclear accidents and civilian damages. This was visible in the domestic laws of the signatory countries and came from a series of codifications, leaving them uncontested for a significant time. These include: the Third Party Liability Convention in the Nuclear Energy Field (1960), the Vienna Convention on Civil Liability for Nuclear Damage (1977), and the Convention on Supplementary Compensation for Nuclear Damages (1977).¹⁹

The Chernobyl disaster brought forth the consequences of this lack of a legal normative system that could bring all the stakeholders under a comprehensive framework, and international norms and regulations that create practical guidelines. The gradual international build-up on this led to the establishment of the Convention on the Supplementary Compensation for Nuclear Damages (CSC), 1997, which expanded the ambit of the liability framework by establishing conducive guidelines to increase participation.²⁰

In India, the civil nuclear deal with the US raised the need for legal reinterpretations in the nuclear sector. The Manmohan Singh government of the day assured the Obama administration that it would create a conducive environment in India for American companies to participate in the nuclear

19. Payal D. Dave, "Test of India's Nuclear Liability Law: Civil Liability to Nuclear Damages Act 2010", *AIR POWER: Journal of Air Power and Space Studies*, vol. 18, no. 4, Winter 2023.

20. Convention on Supplementary Compensation for Nuclear Damages, Office of Legal Affairs, International Atomic Energy Agency (IAEA), https://www.iaea.org/sites/default/files/24/09/csc_factsheet.pdf.

project. Nevertheless, the US lawmakers soon experienced frustration with the slow development of the bilateral nuclear cooperation and blamed this on the lack of a clear liability regulation framework in India.²¹ This pressure and the need to participate in the international nuclear liability framework led to the CLNDA, 2010. The legislation provided a speedy compensation mechanism for victims of a nuclear accident by establishing a minimum national compensation amount.²² Subsequently, India acceded to the Convention on Supplementary Compensation for Nuclear Damages (CSC) in October 2010.

However, the CLNDA, 2010, introduced its own challenges for industry participants, leading to a division among domain experts regarding its effectiveness in establishing an accurate liability standard. While the CLNDA framework was essential for some experts to develop the domestic liability regulation, most importantly, Section 17 (b) of the Act allowed the operators a 'right to recourse' to the supplier, which went beyond the international liability regime. This would extend the compensation responsibility to the suppliers in the case of defective supplies and substandard services,²³ forcing them to improve reactor service. Those favouring these changes have argued that the current legal insurance regime made little sense and went against the country's broader tort law. The current framework, thus, gave a 'no-risk ride' to the nuclear vendors in the entire nuclear industry.²⁴ Meanwhile, for most subject-matter experts, the CLNDA framework has upset many actors involved in nuclear commerce. Both domestic and international actors with potential interests in plant operation or administration have displayed frustration with specific provisions like the blanket compensation guaranteed to the victims by the mere occurrence of an accident (Article 4),

21. Jaideep Prabhu, "India's Nuclear Milestone", <http://www.dnaindia.com/>, October 5, 2013.

22. Diksha Munjal, "What are the Ambiguities in India's Nuclear Liability Laws?" *The Hindu*, April 27, 2023.

23. Mohit Abraham and MP Ram Mohan, "Don't Waver Now on Nuclear Liability", *The Hindu*, September 20, 2013.

24. Jaideep Prabhu, "Why India's Policy on N-Liability Reduces the Potential of the Civil Nuclear Deal with the US", <http://www.firstpost.com/>, November 12, 2015.

Major partner countries like the US, France, and Russia were upset with the legal developments in India that created a setback to their corporate involvement in the nuclear projects, and alienated private companies.

without the need to elaborate on faults.²⁵ Overall differences on the compensation issue bring forth the subtle distinction that exists between the possibility of a supplier incurring liability in case of an accident and using the same reason to absolve willful damage.²⁶

Another component of the liability framework that has divided experts is the liability capping on insurance. While for

some, the INR 1,500 crore margin of compensation was presumably 'low,' others pointed out the extension of the liability framework on the suppliers as a discrepancy to India's accession to the CSC framework that has been internationally accepted as a comprehensive nuclear liability framework.²⁷ It further goes against India's domestic legal stand on the matter, supported by cases like *Rattan Chand Hira Chand vs. Aksar Nawaz Jung* (1991) (which itself drew from the Indian Contracts Act, 1872), where the court upheld the idea of a contract to be illegal if it went against the established law or declared public policy.²⁸

Major partner countries like the US, France, and Russia were upset with the legal developments in India that created a setback to their corporate involvement in the nuclear projects, and alienated private companies like General Electric (GE) and Westinghouse from entering the Indian market.²⁹ Vague legal interpretation of certain sections like Article 45 of the CLNDA, which allows the government to waive liability from certain facilities in the case of insignificant nuclear material, created discrepancies. The Manmohan Singh government eventually utilised this section of the law to push for the NPCIL-Westinghouse deal (2013), which was delayed

25. Prabhu, n. 21.

26. Ibid.

27. Rakesh Sood, "Solving India's Nuclear Liability Conundrum", ORF India, January 22, 2015, <https://www.orfonline.org/research/solving-india-s-nuclear-liability-conundrum>.

28. Abraham and Rammohan, n. 23.

29. Prabhu, n. 21.

because of the disapproval of the American suppliers of the liability clause.³⁰ Similar external pressures have pushed for tweaks in the liability clause and have allowed for projects like the Mithivardi (Gujarat) and the Kovvada (Andhra Pradesh) to take off.³¹ Alternatively, vague understanding of other terminologies like what encompasses 'nuclear damage', creates the potential space to force other laws, such as the law of tort.³² Overall, while the law caps the liability for the operator under the CLNDA framework, it creates ambiguities about the suppliers' liability and blocks possible stimulation to nuclear commerce.

Contemporary efforts by the current administration to amend the nuclear laws have opened the debate on how corporate involvement in a sensitive domain like nuclear energy can be regulated, and finding a middle ground between civilian protection, legal flexibility, and responsible corporate participation.

Contemporary efforts by the current administration to amend the nuclear laws have opened the debate on how corporate involvement in a sensitive domain like nuclear energy can be regulated, and finding a middle ground among civilian protection, legal flexibility, and responsible corporate participation. Firstly, the amendment to the AE Act, 1962, could open up the nuclear energy sector to private ownership of up to 49 per cent, allowing the private companies to build, own, and operate nuclear power plants through a licensing mechanism established by the government.³³ This possibility would come through with case-by-case approval by the central government, allowing the private sector to invest and manufacture in the nuclear fuel segment. Secondly, the discussion on the civil liability law has been more heated. Among several possible changes that the government could table, one

30. Abraham and Rammohan, n. 23.

31. In addition to the comments made by then US Secretary of State John Kerry and Department of State lead Dick Stratford on the invariability of the Indian laws with international norms on liability; S. Nagesh Kumar, "In Nuclear Slowdown, Smaller is Better", *The Hindu*, September 7, 2013.

32. Diksha Munjal, "Ambiguities in the Nuclear Liability Law", *The Hindu*, June 17, 2025.

33. Sarita Chaganti Singh, <https://www.reuters.com/sustainability/boards-policy-regulation/india-considers-allowing-49-foreignstakes-nuclearpowerplants/>.

that has been broadly recognised and supported by the experts has been the capping of the compensation for liability to the value of the contract, which the operator could draw from the suppliers in the case of a nuclear accident.³⁴

The possibility of amending these critical legal roadblocks to diversify the Indian nuclear energy ecosystem is already attracting foreign firms like Westinghouse and GE-Hitachi to increase their presence in the Indian nuclear industry. Domestic players like Reliance Industries, Tata Power, Vedanta Ltd., and Adani Power are also in discussions with the government to pour approximately US\$ 26 billion in the nuclear energy sector to boost efficiency and further India's aspirations to establish a vibrant nuclear industry. Under the larger discourse of '*aatmanirbharta*' (self-reliance), these developments also create a parallel ambition to ensure that the conventionally held belief of the nuclear industry being 'largely self-sufficient' is not compromised. It is further strengthened by India's objective to expand its presence in third countries through collaborative projects (e.g., the Rooppur project in Bangladesh, in collaboration with Russia). Overall, this raises curiosity about the degree to which foreign collaborations catalyse nuclear energy development in the country, and to what extent their involvement should be encouraged without compromising budding domestic nuclear innovations.

FACTORING FOREIGN COLLABORATIONS AND THE ASPIRATIONS OF 'SELF-RELIANCE' IN THE NUCLEAR ENERGY LANDSCAPE

When early Indian scientists dreamed of nuclear developments in the country, they imagined India making strides in nuclear innovations, with gradual independence from foreign expertise.³⁵ While this objective was not achieved immediately, it remained in the scientific community's and policy-makers' consciousness. The first nuclear research reactor developed by India in 1956, named APSARA (Sanskrit for a 'celestial maiden'), was completely indigenous, except for the nuclear fuel the United Kingdom

34. "India Plans to Ease Nuclear Liability Laws to Attract Foreign Firms, Sources Say", <https://www.reuters.com/world/india/india-plans-ease-nuclear-liability-laws-attract-foreign-firms-sources-say-2025-04-18/>, April 19, 2025.

35. Cited in Homi Bhabha's letter to the chairman of Sir Dorabji Tata Trust (1944) in connection with the establishment of the Tata Institute of Fundamental Research (TIFR); Ramanna, n. 1.

(UK) provided. Similarly, the Canada-India Reactor Utility Services (CIRUS) reactor, developed in 1960 for radioisotope production, was designed with the support of Canada and the US, while India did the financing.

With the ambition to now turn to commercialising the nuclear project, India decided to establish the first commercial nuclear facility at Tarapur, Maharashtra. The dual-cycle Boiling Water Reactor (BWR) of 210 MWe capacity was almost entirely constructed abroad, contracted to the Kuljian Corporation, Philadelphia, and the Nuclear Utility Services, Washington, and aided under the United States Agency for International Development (USAID) programme. Along with supply and maintenance, the US continued to support the supply of enriched uranium until the 1974 nuclear test by India (becoming irregular henceforth).³⁶ Meanwhile, the Rajasthan Atomic Power Station (RAPS)-1 was approved in 1962, with a 200 MWe capacity, with Canadian aid, and with Canadian firms AECL, Montreal Engineering Company, and Ontario Hydro heading the planning and construction of the plant. RAPS-1 led the foundation for gradual involvement of the Indian private sector in plant maintenance and engineering supplies, with the initial fuel rods developed in India with Canadian equipment.³⁷ The Canadian collaboration would be fruitful in domestic capability-building, with Indian personnel receiving training for construction and maintenance. While RAPS-1 came close to completion, RAPS-2 was conceived with increased Indian involvement. This time around, the Indian private sector took the lead in making essential components for the reactor, including the dump tank, steel generators, and fuelling machines.³⁸

Thus, the initial desire for 'self-reliance' came from the aspirations of the indigenous scientific community that India must break away from foreign dependence, a reflection of its broader approach to the initial science and technology policy. This approach also came from the realisation that a young country like India would need massive energy to meet its industrial and

36. David Hart, *Nuclear Power in India: A Comparative Analysis* (London: George Allen and Unwin Publishers, 1983).

37. Ibid.

38. Ibid.

public demands, and nuclear energy appeared to be a promising domain for this requirement. This is reflected in the fact that about a quarter of India's research and development budget in the initial three decades since independence was invested in nuclear research.³⁹ India's scientific credentials allowed for foreign assistance to pour in and helped train Indian professionals in plant operation and maintenance aspects. The aspiration for 'self-reliance' became even more critical as the 1974 test pulled out foreign assistance that India received from its American and Canadian counterparts. As mentioned previously, the isolation period for India's nuclear programme raised several debates on efficient and economical plant operation, consolidating India's position as the first 'third-world' country to operate commercial nuclear power plants.⁴⁰

These achievements, however, did not reflect across the nuclear landscape and raised several problems throughout the operation. Post-1974 operations could not match the energy output of the plants with their intensive capital investments. Similarly, India could not achieve desirable success in supplementary requirements of nuclear plant operations like uranium fuel extraction or reprocessing fuel plants, weakening the credentials of claims of 'self-reliance' in the larger picture of nuclear energy generation. For example, the previously mentioned RAPS-2 plant gradually began incorporating Indian technology and personnel into its operation. But as indigenous manufacturers took over, delays in the supply of reactor core components became persistent, and the project faced setbacks in scheduled operation.⁴¹

The 1974 test set into motion a four-decade-long period of international isolation that pushed back India's aspirations to emerge as a unique nuclear force on the global stage. Western assistance was pulled out, significantly affecting individual plant efficiency and energy output objectives targeted by India. What remaining aid India received from the Russians, French and Chinese failed to achieve the projected targets.⁴² Continuous restructuring

39. Ibid.

40. Ibid.

41. Ibid.

42. Ibid.

of the nuclear ecosystem, along with persistently missed targets and project overruns, did not subdue the passion of the policy-makers, who continued to pour money into the nuclear programme without reducing budgetary allocations.⁴³ This dedication marked a milestone with the 1998 strategic atomic tests, as India faced a second round of international isolation until the civil nuclear deal with the United States came to its rescue.

The Civil Nuclear Deal and the Forthcoming 'Renaissance' in International Nuclear Participation

The 2008 civil nuclear deal with the US was arguably a milestone event in India's nuclear energy programme. The unique achievement of gaining an exemption from the NPT and a waiver from the NSG conditionalities positioned India's credentials as a responsible nuclear power globally. The deal marked an era of international nuclear cooperation for India, entering into nearly 20 individual nuclear deals with major nuclear countries worldwide. While there is sufficient mainstream discussion on the deal's significance, its impact on India's overall trajectory of diversification of the nuclear energy ecosystem is often overlooked.

The nuclear deal with the US set in motion a series of administrative and legal changes that India was forced to make to hold greater involvement in international nuclear commerce and compensate for decades of lost opportunities. Firstly, the deal pushed Indian policy-makers to evaluate and reform their domestic regulatory framework. The AE Act, 1962, and subsequently the CLNDA, 2010, faced debates on reconsideration because of the constant American pressure to open up the nuclear sector,⁴⁴ which prevented any diversification in the energy ecosystem. Opening up the nuclear domain gave India access to emerging technologies such as nuclear reactors,

43. Catherine Mei Ling Wong, *Energy, Risk and Governance: A Case of Nuclear Energy in India* (Luxembourg: Palgrave Macmillan Publishers, 2018).

44. Anil Sasi, "In Nuclear Energy Push, Government to Allow Private Operators, Limit Their Liability", *The Indian Express*, May 19, 2025, <https://indianexpress.com/article/india/in-nuclear-energy-push-govt-to-allow-private-operators-limit-their-liability-amendments-likely-in-monsoon-session-10014675/>.

While the US deal might have failed to actualise cooperation on plant operations, it has given several supplementary benefits to the Indian nuclear industry like enhancing the plant energy output to around 90 per cent, from the previous levels of 60 per cent.

fuel reprocessing, other supplementary technologies, and innovations like SMRs. These engagements have also gradually created spillovers into joint research and reactor development arrangements,⁴⁵ furthering the inherent ambition of achieving self-reliance in the nuclear programme.

Secondly, previously isolated international actors like Japan and South Korea have now turned their attention to India's nuclear industry. While the former entered the Indian market with the corporate involvement of Mitsubishi (stakeholder in Areva), Hitachi (through GE), etc., the latter engaged through ambitions to jointly engage in R&D to produce plant components.⁴⁶ This has increased the nuclear competency of the Indian nuclear industry by enhancing the reach and possible models of indigenisation, from which it can optimise its programme. Thirdly, this has directly impacted the domestic corporations, which previously were involved in supplies of engineering components and plant equipment, and are now showing interest in greater involvement. Corporations like the Vedanta Group and Adani Power have actively displayed interest in gaining the benefits of a potential shift in the liability regime,⁴⁷ and aim to contribute significantly to developing niche nuclear products like SMRs. This gradual shift comes from an inherent drive to achieve international standards, participate, and eventually, create, a global presence.

While the US deal might have failed to actualise cooperation on plant operations, it has given several supplementary benefits to the Indian nuclear

45. Abhishek Chakraborty, "India, US to Jointly Design, Manufacture Nuclear Reactors in India", NDTV News, March 31, 2025, <https://www.ndtv.com/world-news/india-us-to-jointly-design-manufacture-nuclear-reactors-in-india-8054762>.

46. Indrani Bagchi, "Japan Gives India Its Second Most Important Deal", *The Times of India*, December 13, 2015.

47. "India Plans to Ease Nuclear Liability Laws to Attract Foreign Firms, Sources Say", April 19, 2025, <https://www.reuters.com/world/india/india-plans-ease-nuclear-liability-laws-attract-foreign-firms-sources-say-2025-04-18/>.

industry like enhancing the plant energy output to around 90 per cent,⁴⁸ from the previous levels of 60 per cent. Along with this, India's engagement on subsidiary requirements like nuclear fuel has led to the country achieving a unique position globally, forging uranium contracts with Russia, Namibia, Kazakhstan, Argentina, etc. and striving for newer responsibilities in its capacity, like the recently announced LEU Bank for the International Atomic Energy Agency (IAEA) that is to be hosted by India to support nuclear fuel shortages.⁴⁹

This approach creates a middle path that India treads on, striving for a unique 'strategic autonomy' in the nuclear domain without isolating itself from the constantly evolving international nuclear commerce.

Contemporary developments along these lines, like the US Department of Energy's recent agreement to allow American companies to research and manufacture nuclear technologies like the SMR jointly, have displayed the possibility for India to gain expertise in niche nuclear technologies and eventually be efficient enough to export them. A similar arrangement has also been achieved with the French counterparts, which would focus on joint development of the SMR/ AMR (Advanced Modular Reactors) technologies.⁵⁰ In the former's case, Larsen and Toubro (L&T), a leading private actor in the Indian nuclear energy sector, has agreed establish a supply chain for

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48. "Nuclear Deals see Power Capacity hit 90% From 60% Five Years Ago", *Hindustan Times*, September 8, 2015.

49. Catherine Putz, "India Inks New Nuclear Deal with Kazakh", *The Diplomat*, July 9, 2015, <https://thediplomat.com/2015/07/india-inks-new-nuclear-deal-with-kazakhstan/>.

50. "India and France Sign SMR and AMR Partnership Letter of Intent", *World Nuclear News* (WNN), <https://www.world-nuclear-news.org/articles/india-and-france-aim-to-establish-smr-and-amr-partnership>.

thorium-based fuel, taking its involvement in the nuclear energy generation to the next stage.⁵¹

Policy-level measures like the Nuclear Energy Mission, 2025, have complemented this international outreach. This programme allocates INR 20,000 crore to the development of SMRs, focussing on developing at least five indigenously designed SMRs by 2033.⁵² Additional developments in Fast Breeder Reactors (FBRs) are significant, with India achieving criticality in its Kalpakkam plant, reducing nuclear energy waste to a minimum.⁵³ This has also supported India towards attaining the required plutonium reserves that would further strengthen it on the second stage of the 'three-stage nuclear cycle'⁵⁴ as envisioned by Bhabha. Effective and commercial thorium utilisation would only be possible once this stage has adequately matured.⁵⁵ Private sector involvement, therefore, not only allows India to hold niche technologies in the nuclear sector but also furthers the aspirations of the founding fathers of India's nuclear energy programme.

CONCLUSION

India's nuclear energy ecosystem is in a constant state of flux. While legislative changes on greater involvement of the private sector, both domestic and international, appear promising, the issues of ownership and liability for accidents require a truly comprehensive consensus. India's unique position as the first 'third-world' nation to have an independent nuclear programme comes with a larger realisation that, despite multiple

51. ET Infra Desk, "Commercial Nuclear Energy Now Part of L&T's Green Business Agenda", *The Economic Times*, June 17, 2025, <https://infra.economicstimes.indiatimes.com/news/construction/It-pioneers-nuclear-energy-commercialization-in-india-with-advanced-small-modular-reactors/121914203>.

52. "Nuclear Mission Announced in the Union Budget 2025-26 will Mark a Transformative Shift in India's Energy Landscape and Will Enable Nuclear Power to Emerge as a Major Source of Energy in India: Union Minister Dr. Jitendra Singh", Press Release, PIB, February 5, 2025.

53. Rajeshwari P. Rajagopalan, Sameer Patil, Shravishtha Ajaykumar, and Prateek Tripathi, "Nuclear Security Takes Priority Amid India's Push for Nuclear Power", *The Diplomat*, August 30, 2024, <https://thediplomat.com/2024/08/nuclear-security-takes-priority-amid-indias-renewed-push-for-nuclear-power/>

54. Ramanna, n. 1.

55. "Thorium-Based Nuclear Reactors", Press Information Bureau (PIB), Govt. of India, June 29, 2019, <https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1575801>.

supplementary reasons for the 'nuclear push,' the strategic nature of the programme remains primary. All along, policy-makers tread a thin line between diversification of the programme and increased risk of responsible liability ownership. The administration finds middle ground in innovative programmes like SMRs that appear to subdue the biggest concern in the nuclear industry, i.e. hefty project costs.

As India enters an era of joint ventures and potential corporate ownership, diversification of the atomic project gains newer dimensions. Recent developments, like the suggestions to establish a 'nuclear insurance pool' under a joint Public Sector Undertaking (PSU) mechanism led by the General Insurance Corporation of India (GICRE) and regulatory easing from the US Department of Energy for SMR technology transfer,⁵⁶ continue to showcase promising developments in the nuclear energy domain. Newer private actors continue to appear on the nuclear landscape, from component supply⁵⁷ to supplementary activities like heavy water assessment.⁵⁸ This involvement not only accelerates project completion, research, and maintenance operations but also the overall growth and confidence of the nuclear sector. The ultimate test of these diversification measures will be decided by how much they propel India's ambition to achieve 100 Giga Watt electric (GWe) nuclear energy by the centenary celebration of independence (2047). Only time will reflect whether concurrent policy decisions in the nuclear sector appear as a 'strategy'⁵⁹ or continue as a deferred dream of the nation.

56. The US Department of Energy recently permitted Holtec International to conditionally transfer SMR technology to Holtec Asia, as well as Tata Consulting Engineering Ltd. and Larson and Toubro (L&T), "Nuclear Push: Centre Eyes Key Changes to 1962 Law, Open up Atomic Energy Sector to Private Operators", Money Control, May 19, 2025.

57. "Azad Engineering is India's First Supplier of Parts for Nuclear Turbines", <http://www.ajaiashukla.com/2023/02/azad-engineering-is-indias-first.html/>., February 3, 2023.

58. Amitabh Sinha, "India's 1st Private Facility for Heavy Water Upgrade Opens", *The Indian Express*, July 29, 2025, <https://indianexpress.com/article/india/indias-1st-private-test-facility-for-heavy-water-upgrade-opens-10155958/>.

59. Inspired by Richard J Samuels' quote, "Only Time Makes Individual Policy Decisions Appear as a Strategy", in *Rich Nation Strong Army: National Security and Technological Transformation of Japan* (Cornell University Press, 1994).

