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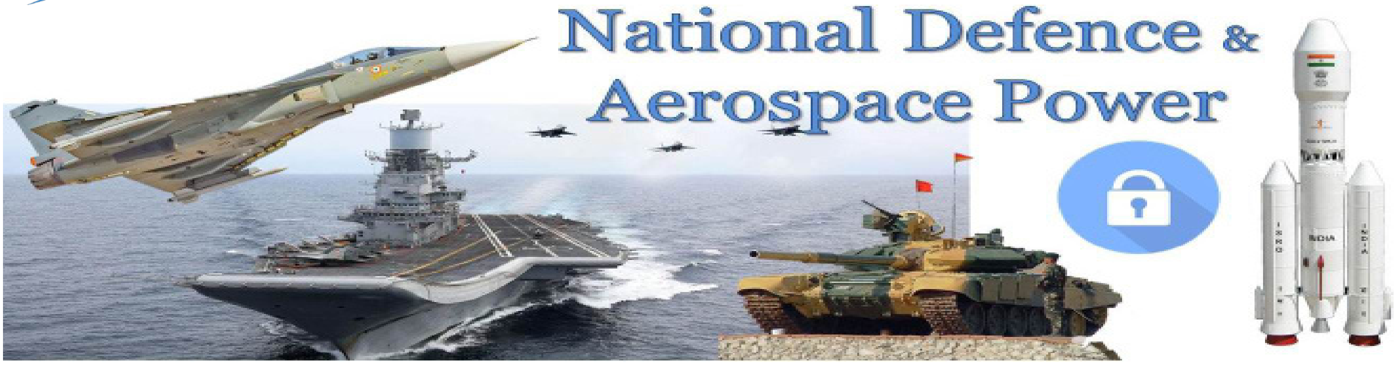

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ENSURING FUEL SECURITY FOR INDIA'S NUCLEAR ENERGY EXPANSION

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India has announced an ambitious nuclear energy expansion plan to scale up its nuclear capacity in phases, including 22 GW by 2032, 47 GW by 2037, and 67 GW by 2042, with a long-term vision of reaching 100 GW of nuclear power capacity by 2047.[1] Over the decades, India has demonstrated strong indigenous capabilities in the nuclear sector; thus, ambition is not the constraint; the real challenge lies in adhering to the timelines. To achieve these goals, India plans a "fleet mode" reactor expansion of the already matured domestic nuclear technology, like PHWR (Pressurised Heavy Water Reactor). It is also focusing on diversified nuclear reactor technologies, such as the indigenous Bharat Small Modular Reactor (BSMR), Bharat Small Reactor (BSR), and imported Light Water Reactor (LWR) technology. It indicates the horizontal expansion of nuclear reactors and the vertical expansion of nuclear technology in the coming years.

Though these plans for nuclear energy expansion are well known, the fuel requirement and security for these reactors have not attracted much attention. For years, India has remained dependent on foreign suppliers for uranium in various forms; this dependence will increase as the number of reactors grows in the coming years. India has introduced changes to the domestic nuclear legal framework with the Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Act, 2025; these changes are highly favourable for securing India's fuel requirements via

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private participation and greater global technology cooperation through graded liability. Therefore, if India is to pursue large-scale nuclear expansion, it will need to significantly augment uranium supplies through international agreements, while also strengthening domestic capacity and capability of UCIL (Uranium Corporation of India Limited).

Against this backdrop, the brief aims to highlight the critical importance of uranium in achieving India's 100 GW nuclear power target by 2047, analyse India's future uranium requirements, domestic uranium availability, and the challenges faced by UCIL, as well as international nuclear fuel cooperation.

India's Nuclear Energy Expansion Plans

Currently, nuclear energy accounts for 3.1 per cent of India's total electricity generation.[2] The total operational nuclear power capacity stands at 8,780 MW (excluding Rajasthan Atomic Power Station-1). The total capacity of eight under-construction nuclear power projects is about 6,600 MW.[3] In addition, administrative approval and financial sanction have been granted for "fleet mode" expansion of 10 PHWRs of 700 MW (totalling 7,000 MW),[4] which are already underway with the pre-project activities Phase (Table 1).[5] Fleet mode is the bulk approval and construction of nuclear reactors of the same design. Taken together, this brings the near-term planned capacity close to 22,380 MW (22.38 GW), meeting the government's target of achieving about 22 GW by 2031–32 (Table 1).

On April 06, 2026, India's indigenously designed and built Prototype Fast Breeder Reactor (PFBR) successfully attained "first criticality." Criticality is the state in a nuclear reactor where each fission event produces enough neutrons to sustain a continuous, self- sustaining nuclear fission chain reaction; that means neutron production equals neutron loss.[6] This PFBR achievement is part of India's three-stage nuclear power programme, a long-term strategy to maximise limited uranium resources and utilise abundant thorium to ensure energy security.

However, its underlying principle is the full utilisation of spent nuclear fuel (SNF) through reprocessing and breeding, enabling the generation of additional fissile material (Pu-239 and U-233). These fissile materials are bred from fertile materials (U-238 and Th-232) and can be recycled multiple times, generating more fuel than initially consumed and the establishment of a "closed fuel cycle."[7] India has adopted the world's most "forward-looking strategy," in

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which each stage will produce fuel to feed into the next stage.[8]

But even after the successful completion of all three stages, India will still require natural uranium in the first stage to run its PHWR reactors to initiate fuel cycles, though its overall dependence on fuel will decline due to the shift toward plutonium and thorium-based fuels.

Table 1: India's Operational, Under-Construction, and Pre-Project Phase Nuclear Power Plants

Operational Nuclear Power Plants		
Location & State	Project	Total Capacity (MW)
Tarapur, Maharashtra	TAPS-Units-1&2(2x160 MW BWRs); Units-3&4 (2x540; PHWRs)	1,400MW
Rawatbhata Rajasthan	RAPS-Units 1to7 (RAPS-1 100 MW; RAPS-2 200 MW; RAPS-3to6,4x220MW; RAPS-7, 700MW; PHWRs)	1,780MW (excluding RAPS-1)
Kalpakkam, Tamil Nadu	MAPS-Units-1&2 (2x220 MW; PHWRs)	440MW
Narora, Uttar Pradesh	NAPS-Units-1&2 (2x220 MW; PHWRs)	440MW
Kakrapar, Gujarat	KAPP- Units-1to4 (KAPP 1&2, 2x220 MW; KAPP-3&4, 2x700 MW; PHWRs)	1,840MW
Kaiga, Karnataka	KGS- Unit-1 to 4 (4x220 MW; PHWRs)	880MW
Kudankulam, Tamil Nadu	KNPP- Unit-1&2 (2x1000 MW; VVER)	2,000MW
	Total Capacity of Operational Nuclear Power Plants is	**8,780MW**

Under-Construction Nuclear Power Plants		
Location & State	Project	Total Capacity (MW)
Rawatbhata, Rajasthan	RAPS-Units-8 (700 MW; PHWR)	700MW
Gorakhpur, Haryana	GHAVP-1&2 (2x700 MW; PHWRs)	1,400MW
Kudankulam, Tamil Nadu	KKNPP– 3to6 (4x1000 MW; VVER)	4,000MW
Kalpakkam, Tamil Nadu	PFBR	500MW
	Total capacity of under-construction nuclear power plants is	**6,600MW**

Nuclear Plants under the pre-project activities Phase (Financial Sanction Granted)		
Location & State	Project	Total Capacity (MW)
Chutka, Madhya Pradesh	Chutka -1&2 (2 X 700; PHWRs)	1,400MW
Kaiga, Karnataka	KGS- Unit- 5&6 (2 X 700; PHWRs)	1,400MW
Mahi Banswara, Rajasthan	Mahi Banswara – 1to4 (4 X 700; PHWRs)	2,800MW
Gorakhpur, Haryana	GHAVP - 3&4 (2 X 700; PHWRs)	1,400MW
	Total Capacity of Pre-Project Nuclear Power Plants is	**7,000MW**

(TAPS-Tarapur Atomic Power Station, RAPS-Rajasthan Atomic Power Station, MAPS-Madras Atomic Power Station, NAPS-Narora Atomic Power Station, KAPP-Kakrapar Atomic Power Project, KGS-Kaiga Generating Station, KNPP-Kudankulam Nuclear Power Plant, GHAVP-Gorakhpur Haryana Anu Vidyut Pariyojana, PFBR -Prototype Fast Breeder Reactor, VVER-Vodo-Vodyanoi Energetichesky Reactor, BWR-Boiling Water Reactor)[9]

India's Uranium Requirements

In India, any discussion of nuclear energy expansion cannot overlook critical areas like uranium availability from domestic and imported resources. Uranium remains the primary fuel for nuclear power plants. The Department of Atomic Energy (DAE) estimates that a PHWR 220 MW reactor requires approximately 45 tonnes of Uranium Dioxide (UO_2) annually, while 540 MW and 700 MW reactors require about 100 tonnes and 125 tonnes of UO_2, respectively.[10] In parallel, a 1000 MW LWR roughly requires 27 tonnes of Low-Enriched Uranium (LEU) per annum.[11]

The Nuclear Power Corporation of India Limited (NPCIL) is presently operating 24 commercial nuclear power reactors (excluding Rajasthan Atomic Power Station-1). At present, the total PHWR reactor fleet generates about 6,460 MW, of which approximately 2,400 MW is produced using domestic fuel.[12] The domestic fuel requirements for eight reactors outside the International Atomic Energy Agency (IAEA) safeguards are fulfilled by the UCIL. It is the sole Central Public Sector Undertaking (CPSU) under the DAE responsible for uranium mining and processing. Over time, UCIL has played a crucial role in supplying uranium to the NPCIL.[13] Beyond this, the LWR currently generates 2,320 MW of nuclear power, which is fuelled by imported uranium from Russia.[14] To meet the fuel requirements of 14 operating reactors under IAEA safeguards, India has been importing around 800 tonnes of Uranium annually.[15]

It is estimated that, to operate the future PHWR fleet, India may have to import approximately 5,400 tonnes of uranium oxide per annum (TPA) of uranium to generate 27,160 MW (27.16 GW) of power.[16] UCIL is expected to meet up to 30 per cent of the annual demand, while the remaining share will need to be consistently imported or maintained through strategic stockpiling.[17] For the period 2025 to 2033, the projected requirement for imported natural uranium to support operational and planned PHWRs and LWRs under safeguards is estimated at around 9,000 metric tonne units (MTU).[18] [19]

Domestic Uranium Reserves in India

As of now, the Atomic Minerals Directorate for Exploration and Research (AMD) has identified cumulative in-situ uranium resources totalling approximately 4,33,800 tonnes of in-situ U_3O_8 resource in 47 uranium deposits across India.[20] Net uranium availability is toned to account for mining and milling losses of around 50 per cent,[21] which means that India's uranium availability to feed the nuclear power plant is 2,16,900 tonnes. Of this, 80,423 tonnes of U_3O_8 have been formally transferred to the UCIL.[22] Data indicate that 39.22 per cent of these reserves have already been extracted or depleted, leaving 60.78 per cent available for ongoing mining operations.[23] If no new deposits are incorporated, then at the current rate of uranium extraction, the existing reserves are projected to sustain production for roughly four decades.[24]

AMD continues extensive nationwide exploration to expand India's uranium reserve base in the coming years. Despite these efforts, mining will remain constrained due to low economic viability; therefore, not all deposits identified by AMD are mined and processed.[25] Additionally, factors like land acquisition challenges, environmental concerns, forest and wildlife protections, water availability and socio-political resistance continue to shape decisions on uranium extraction.[26]

Challenges for UCIL

First, India possesses uranium deposits that are comparable in quantity. But most deposits in India are low-grade (0.02–0.045 per cent, U_3O_8),[27] leading to higher production costs and substantial tailings generation. With this, UCIL is also dependent on imported, high-value mining and processing equipment, thereby increasing its financial and technological vulnerability. Additionally, depletion of reserves in upper levels of key mines such as Jaduguda, Narwapahar and Bagjata, along with ageing processing infrastructure, necessitates urgent modernisation and capacity renewal.[28]

Second, many uranium deposits in India are "deep-seated," extending beyond 600 meters in depth.[29] The "deep-seated minerals" mean such minerals that occur at a depth of more than 200 meters from the surface of the land with poor surface manifestations.[30] According to Section 6A of the Mines and Minerals Development and Regulation (MMDR) Act, 1957, a leased mining area can only be extended once by up to 10 per cent (or 30 per cent for composite licences) into nearby areas.[31] These limits on the extension of the area make uranium mining technically difficult and economically unviable, especially when ore bodies are fragmented across leased and non-leased areas. This will lead to inefficient extraction and potential loss of valuable resources. The government may consider revising relevant provisions of the MMDR Act to facilitate the extension of mining leases for contiguous areas for strategic minerals such as uranium.

Third, UCIL's project development is constrained by lengthy, multi-layered clearance processes involving agencies such as the Ministry of Environment, Forest and Climate Change, the Atomic Energy Regulatory Board, the Directorate General of Mines Safety, and State Pollution Control Boards. These procedural complexities are further compounded by coordination gaps between central and state authorities. It often leads to delays in mining lease approvals and project implementation.[32] To address this, the government may focus on operationalising a single-

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window clearance mechanism.[33] It may also enable integrated central–state approvals and parallel processing of consents to reduce delays and improve efficiency.[35]

Fourth, UCIL is the sole mining Public Sector Undertaking (PSU) under the DAE. The central government, through PSUs, undertake exploration activities for the discovery of uranium and mining activities. It is the need of the hour that the government allows domestic mining by private companies in Mine Developer cum Operator (MDO) mode.[34] MDO mode refers to a contractual model in which a private entity is appointed to develop, finance, and operate a mine on behalf of the government or a public-sector company. Under this arrangement, MDO undertakes activities such as mine planning, infrastructure creation, extraction, and sometimes processing, while the ownership of the mineral and the mining lease remains with the government entity.

The domestic public sector entity, National Thermal Power Corporation (NTPC), entered the nuclear energy sector with an ambitious target of 30 GW by 2047.[36] It is in joint venture with Anushakti Vidhyut Nigam Limited (ASHVINI), NPCIL and NTPC Parmanu Urja Nigam Limited (NPUNL) to achieve this target.[37] In parallel, to meet its future uranium fuel demands, it has signed a draft MOU with UCIL Limited to explore and acquire overseas uranium assets, which reflects a strategic effort to reduce market risks and limit import dependence.[38] This integrated approach will aim to ensure a stable, long-term uranium supply while strengthening India's mineral value chain to support the sustained expansion of its nuclear power programme.

But if UCIL fails to supply enough uranium or international supplies are disrupted, the immediate impact will be on reactor performance. Nuclear power plants cannot run at full capacity without a steady fuel supply, so load factors drop significantly, as seen in 2008, when reactors operated at nearly half capacity due to shortages.[39] Prolonged shortages can also delay expansion plans and undermine overall confidence in the reliability of nuclear energy.

International Cooperation and Uranium Import (Since 123 Agreement)

Since its independence, India has been engaged in the civil nuclear programme. After the peaceful nuclear explosion (PNE) in 1974, India's access to nuclear fuel and technology was restricted. The situation was complicated after its 1998 Pokhran-II tests, which intensified sanctions and kept it out in isolation from global nuclear commerce for years.

But the situation changed with the onset of 2008, with the India-United States (US)

Civil Nuclear Agreement (123 Agreement), which ended India's nuclear isolation and opened doors to civilian nuclear cooperation worldwide, including access to uranium.[40] The India-US 123 Agreement allowed the civilian nuclear trade without complementary inspections.[41]

Even after the 123 Agreement and additional protocol, liability concerns and the closed nuclear sector hindered India's full-scale nuclear cooperation. For years, foreign suppliers worried about unlimited operator liability under the Civil Liability for Nuclear Damage Act, 2010.

However, even after the 123 Agreement and additional protocol, liability concerns and the closed nuclear sector hindered India's full-scale nuclear cooperation. For years, foreign suppliers worried about unlimited operator liability under the Civil Liability for Nuclear Damage Act (CLNDA), 2010. To address this, India reformed its nuclear legal framework by effectively substituting the Atomic Energy Act (AEA), 1962, and the CLNDA with the new "SHANTI Act," which introduces a graded liability regime to attract investment and greater global collaboration.

This act also opened up the private sector under Clause 3 of the SHANTI Act. It allows the transportation and storage of nuclear fuel and spent fuel, as well as the import, export, acquisition, possession and use of nuclear fuel.[42] This marks a significant departure from the earlier regime under the AEA (1962), wherein such activities were largely confined to government entities. The SHANTI Act specifically enables these operations under strict governmental oversight and IAEA-aligned safeguards,[43] marking a major shift that broadens international nuclear commerce while balancing with India's sovereignty.

For years, India has maintained a uranium supply chain anchored in longstanding partnerships with Kazakhstan, Russia, Uzbekistan, and Canada, which have consistently met its import needs since the 2008 Nuclear Suppliers Group (NSG) waiver (Table 2). From 2008-09 to 2024-25, India's uranium imports in various forms total 18842.60 MTs under IAEA safeguards.[44] Further, India's long-term uranium supply outlook appears supported by international agreements and large-scale commercial contracts.

To ensure a stable uranium supply in the future, India has also strengthened its position by signing long-term agreements with its reliable partners. On March 02, 2026, India's DAE and Canadian Cameco Corporation signed a uranium supply agreement valued at approximately USD 2.6 billion.[45] Under this contract, deliveries are scheduled from 2027 to 2035, totalling around 22 million pounds[46] of uranium ore concentrate, equivalent to about 8300 MTU.[47] India's long-

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term engagement with Kazatomprom signals a deepening strategic partnership. It involves uranium assets valued at more than 50 per cent of Kazatomprom's total book value, approximately USD 4.2 billion.[48] Currently, India also has a long-term uranium supply agreement with Navoiyuran State Company, valid until 2026, under which 600 MTU has been supplied out of the contracted 1,100 MTU.

India's global nuclear fuel agreements reflect both the scale and reliability of future supply commitments. Such high-value transactions indicate confidence in India as a stable, long-term nuclear energy market. It also shows India's need for a robust and fuel procurement strategy.

In the coming years, Uranium will become increasingly central to India's energy needs, and it must simultaneously navigate vulnerabilities tied to global fuel supply chains. Although India's proactive uranium diplomacy reduces the likelihood of acute shortages, past delays in supply despite formal agreements highlight that energy security ultimately depends not just on contracts, but on stable, trust-based international partnerships and long-term institutional arrangements.

The growth of nuclear reactors worldwide also intensifies pressure on global uranium markets, where rising demand is projected to surge significantly by 2030 and could lead to price volatility.[49] Global geopolitical tensions and uncertainties can disrupt future uranium supply chains and could make it difficult to transport it from mining locations to the regions where it is required. [50]

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Table 2: Uranium supplies from various countries from 2008-09 to 2024-25

S. No.	Agency	Year	Quantity Received in MTU
1.	M/s. AREVA, France	2008-09	60.49*
		2009-10	239.38*
2.	M/S JSC NAC, Kazatomprom, Kazakhstan	2010-11	600*
		2011-12	350*
		2012-13	402.50*
		2013-14	460*
		2014-15	283.419*
		2016-17	999.807*
		2017-18	923.856*
		2017-18	1489.999*
		2018-19	392.753
		2018-19	2057.87*
		2019-20	1499.98*
		2020-21	999.82*
3.	M/S CAMECO Inc., Canada	2015-16	250.743*
		2016-17	1233.681*
		2017-18	989.452*
		2018-19	986.6012*
		2019-20	1001.291*
		2020-21	1000.479
4.	M/s PJSC TVEL Corporation, Russia	2009-10	150.33**
		2009-10	58.29@
		2010-11	179.79**
		2011-12	296.08**
		2012-13	59.43**
		2012-13	295.64**
		2013-14	296.31**
		2014-15	296.548**
		2015-16	303.787**
		2015-16	42.150@
		2016-17	187.334**
		2019-20	56.78**
5.	M/s. Navoiyuran State Company–Republic of Uzbekistan	2023-24	350
		2024-25	250

*In the form of Natural Uranium Ore Concentrate (UOC).

** In the form of Natural Uranium Di-oxide (UO_2) Pellets.

@ In the form of Enriched Uranium Di-oxide (UO_2) Pellets.

Source: The author has compiled this table from government websites and answers to parliamentary questions.[51]

Conclusion

India's nuclear energy trajectory in the coming years is set to expand significantly, driven by rising energy demand, climate commitments and a strategic push for clean baseload power. To support this growth, India has adopted a forward-looking approach by securing long-term uranium supply agreements with key international partners, including Kazakhstan, Canada, Russia, and Uzbekistan. At the same time, policy reforms such as the SHANTI Act allow private-sector participation in securing uranium import agreements under strict central government supervision and regulatory control. However, India's long-term nuclear sustainability cannot rely solely on imports. Expanding domestic uranium production will not only reduce strategic vulnerabilities but also complement international supply arrangements.

Enhancing domestic exploration, accelerating mine development, improving ore-processing efficiency, and addressing regulatory and logistical bottlenecks are key priorities. A balanced approach combining assured imports with robust indigenous production will enable India to meet its growing reactor fuel demands while maintaining energy security and strategic autonomy. Thus, capacity building in UCIL and scaling up domestic production must remain central to India's nuclear energy policy in the years ahead

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