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CENTRE FOR A
People-centric Energy Transition

Building Critical Mineral Resilience for Empowering and Aiding Nuclear Energy and Clean Energy Transition

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About the Ashoka Centre for a People-centric Energy Transition (ACPET)

ACPET is a research-focused, transdisciplinary centre within Ashoka University, India, established to drive a sustainable, equitable, and "people-centric" shift towards net-zero emissions. It bridges the knowledge gap in energy transition by collaborating with industry and government to create scalable solutions, covering areas like renewable energy, policy, and technology. For further information about ACPET, please visit: acpet.ashoka.edu.in

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The insights and exchanges during these deliberations greatly enriched our understanding of the policy, socio-economic, and strategic dimensions of critical minerals, strengthening the overall narrative and recommendations presented in this report.

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1. Executive Summary

This research report explores the intersection of critical minerals, nuclear energy expansion, and clean energy transition. Situated in the context on India's passing of Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Act - 2025, and the National Critical Mineral Mission (NCMM) launched the same year (2025), it brings forth the shared linkages between the two broad themes of nuclear energy expansion and critical mineral import dependency to suggest actionable policy outcomes towards India's twin goal of clean energy transition (2070), with a specific focus on India's ambitious nuclear expansion to reach 100 GW towards the larger goal of Viksit Bharat 2047.

Critical Minerals and Rare Earth Elements have emerged as fundamental pillars of economic and comprehensive national security in the 21st century. Their wide-ranging and diversified utility makes critical minerals strategic assets, indispensable for both clean energy systems and national defence capabilities. In the pursuit of the clean energy transition, particularly decarbonization and technological advancements, 'access to and control' have made them the linchpin of a country's sustainable socio-economic and defence necessities. Today, critical minerals are crucial strategic drivers, much like traditional energy resources such as oil and gas were in the 20th century.

There are evident shared linkages between critical minerals and nuclear energy: CRMs such as uranium, zirconium, hafnium, beryllium, and niobium play a vital role as constituents in nuclear power-energy systems. In the backdrop of the SHANTI Act, India too is expected to invest in these critical minerals through its PSUs. In light of India's aspirations to expand its nuclear power capacity to 100 gigawatts (GW) by 2047, representing a more than tenfold increase from the current installed capacity of 8.88 GW, a detailed assessment of critical mineral dependencies vis-à-vis nuclear energy merits scholarly and policy attention, especially because critical minerals for nuclear energy are a novel, understudied theme. Further, nuclear power is not only viewed as essential from the standpoint of clean energy transition but also embedded in the very goal of India's rapid embrace of Artificial Intelligence (AI) in its strategy of 'AI for All'. Nuclear energy is increasingly being viewed as a low-carbon power source for AI data centres that offer base-load power availability and grid stability to meet likely rising energy demands. Nuclear energy, particularly Small Modular Reactors (SMRS), is being looked at as a solution. India's nuclear energy expansion is heavily dependent on securing a stable and sufficient supply of uranium and its critical materials. Addressing this dependency requires a comprehensive strategy involving enhanced domestic production, diversified international procurement, advanced fuel cycle technologies, and robust international cooperation. The research report elucidates the intricate connections between critical mineral security, geopolitical dynamics, and India's energy future. As the world transitions toward clean energy and advanced technologies, critical minerals have become as strategically important as traditional energy resources. India's ambitious nuclear expansion, while essential for achieving its energy and climate goals, must navigate complex challenges related to mineral supply, infrastructure development, financial constraints, and human capital. Thus, a comprehensive approach to ensuring energy security and self-reliance in an increasingly resource-constrained and geopolitically competitive world remains a policy imperative.

Future research should focus on three priorities: a classified India-specific assessment of nuclear-related critical minerals against domestic requirements; a comparative study of QUAD nations' critical mineral strategies to identify actionable synergies; and a dedicated analysis of nuclear energy's role in meeting AI-driven data centre demand in India.

On policy, two actions are immediate. The Atomic Minerals Directorate for Exploration and Research under the Department of Atomic Energy, GoI, should pursue structured collaboration with select private players to build nuclear energy and critical mineral resilience through active handholding. Simultaneously, India's existing bilateral frameworks with the US, EU, and Australia should be explicitly extended to cover nuclear-linked critical minerals, converting diplomatic partnerships into supply chain outcomes.

2. Critical Minerals and Rare Earth Elements (RREs) in Comprehensive National Security (CNS)

Simply put, Critical Minerals or Critical Raw Materials (CRM) and Rare Earth Elements (RREs) are raw materials for economic security and, by extension, comprehensive national security. They are a subset of minerals considered crucial to industrial, engineering, and technological needs, without which nation-states cannot advance. Commonly identified as (to name a few) cobalt, graphite, manganese, and nickel, lithium, graphite, titanium and RREs such as neodymium, iridium, titanium, gallium and germanium; their applications range from electrical components to nuclear power reactors and EV batteries; and from metallurgy to aerospace and defence. They are strategic assets, forming the base for clean energy systems, advanced technologies, and national defence.

In recent times, the subject of critical minerals has gathered attention from the lens of the clean energy transition. Stakeholders, including governments, industries, public policy scholars and academia, are engaged in wide-ranging discourse about their contributions to a sustainable clean energy transition. In addition to clean energy contributions, critical minerals today have occupied the centre stage in evolving strategic and geopolitical discourse, mainly because of their inherent duality: being useful in civilian as well as military-defence purposes. Military operations in recent times have demonstrated and exposed the dependency of defence technology on critical minerals and REEs: precision-guided munitions; missiles, rockets, motors, jet engines, radars, drones, submarines, unmanned systems, battle tanks, optical technologies, etc. The entire spectrum of the conduct of modern warfare, from early warning, detection and targeting, benefits from critical minerals. Safe to say, without critical mineral resilience, even the most militarily powerful countries with state-of-the-art defence technologies and technologically advanced weapons would fail to produce any competitive advantage in warfare. There is indeed a "growing reliance on critical minerals for defence technologies emerging as a crucial issue for global security."[1] In 2024, the North Atlantic Treaty Alliance (NATO), a politico-military alliance responsible for guaranteeing the security of Europe and North America, published a list of 12 defence-critical raw materials essential

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[1] Vivoda, V., Matthews, R., & Andresen, J. (2025), "Securing defence critical minerals: Challenges and U.S. strategic responses in an evolving geopolitical landscape", *Comparative Strategy,* Vol. 44, No. 2, 281–315

and integral to the manufacture of advanced defence systems and equipment, even highlighted that their supply chain disruptions could affect the alliance's deterrence and defence."[2]

The 'critical' in critical minerals and RREs is that no single country enjoys self-sufficiency in them, and most countries, namely big and rising economies, are heavily dependent on sufficiently meeting their critical mineral needs to continue energy consumption in a clean and sustainable manner. The International Energy Agency (2021) forecasts that "...mineral demand for clean energy technologies will rise at least fourfold by 2040 to meet climate goals, with particularly high growth for minerals needed for electric vehicles…" Graphite, nickel, lithium, and rare earth minerals are expected to witness explosive demand under the scenario of meeting climate goals.[3]

As per the *Global Critical Minerals Outlook 2025, "*for a remarkable 19 out of 20 important strategic minerals, China is the leading refiner, with an average market share of 70%...."[4] Similarly, the same IEA data suggests that not only does China remain the most dominant country for many REEs, its global mining output, too, accounts for 60% of the total in 2024. In addition, China has also strengthened its share of being the world's single largest supplier of some of the CRM and REEs from 50% to 94%. [5] Further, "... in 2023, China accounted for about 69% of ore extraction for the world's REEs and was the top raw-ore producer of almost two-thirds (29) of the 50 minerals on the US Geological Survey (USGS) List."[6] Because no country enjoys true self-reliance in critical minerals, the race to secure

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[2] "NATO Releases list of 12 Defence-Critical Raw Materials", 11 December 2024, *NATO - News,* Available at URL: https://www.nato.int/en/news-and-events/articles/news/2024/12/11/nato-releases-list-of-12-defence-critical-raw-materials

[3] Rabah Arezki Frederick van der Ploeg, "The New Curse of Critical Minerals", *The Centre for Economic Policy Research (CEPR),* 15 October 2025, Available at URL: https://cepr.org/voxeu/columns/new-curse-critical-minerals

[4]Tae-Yoon Kim, Shobhan Dhir, Amrita Dasgupta, and Alessio Scanziani, " With New Export Controls on Critical Minerals, Supply Concentration Risks Become Reality", *International Energy Agency (IEA),* URL: https://www.iea.org/commentaries/with-new-export-controls-on-critical-minerals-supply-concentration-risks-become-reality

[5] ibid.

[6] As on 2026, the USGS has updated the list of CRM from 30 in 2025 to 60.

supply chains from geopolitical vulnerabilities will continue to make space for competition as well as cooperation, so far as global politics is concerned.

The problem is further compounded by the mismatch in the pace of critical minerals demand vis-à-vis their supply, often leading to the temptation of bringing in newer sources of supply through mining operations that are time-consuming and laden with inherent risks. Further, "... the gap between rapid technology adoption and slow resource development leaves governments and industry under constant pressure to secure new sources of supplies…"[7]. Albeit important, addressing these risks and planning requires long-term solutions. All major world economies today are engaged in devising national strategies to create robust critical mineral resilience.

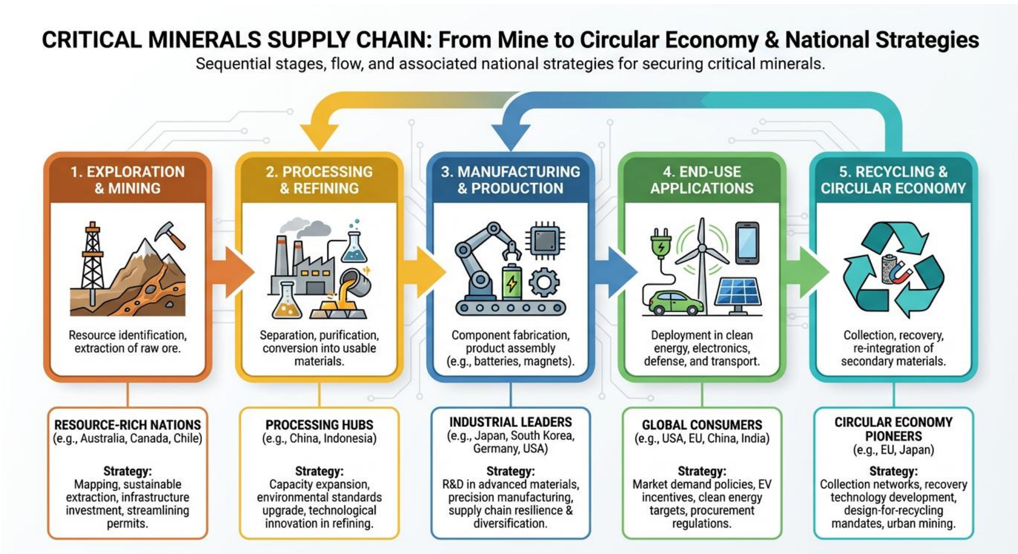

Figure 1. Infographic on Critical Minerals Strategies of Major Economies

** Disclaimer: The Author has used generative AI to design the above Infographic, 26 March 2026.*

[7] Chaitanya Gupta, "Critical Minerals Explained: Why They Matter for Geopolitics, Clean Energy & Tech", *Belfer Centre for Science and International Affairs,* 30 October 2025, Available at https://www.belfercenter.org/explainer-what-are-critical-minerals

Table 1. Global Strategies for Securing Critical Minerals by Major Economies

S. No	Countries	Critical Minerals and Clean Energy Transition
1.	**China**	Yes, dominant player + investments in Belt & Road Initiative
2.	**USA**	Yes, lacks a strong domestic supply – aims to diversify
3.	**UK**	Yes, released a 10-year strategy focusing on international collaboration and CRM security
4.	**EU**	Yes, passed – Critical Raw Materials Act – 2024, aiming to increase domestic capacity + diversification
5.	**Canada**	Yes, released their foundational strategy in 2022
6.	**Australia**	Yes, recently released a critical mineral strategy for 2030
7.	**Japan**	Yes, G-7 Action plan (5-point plan)
8.	**South Korea**	Yes, officially released in 2023, aims to reduce import dependence on specific countries.
10.	**Russia**	Yes – minerals resource base and self-sufficiency by 2050
11.	**France**	Yes, reduce dependence and secure supply chains

Each of the nations listed above is prioritising critical minerals as a matter of national and economic security, transitioning from individual domestic efforts to broad international strategies. In short, critical minerals and REEs are strategic assets and will continue to remain as strategic necessities that will drive any country's national economic and security imperatives. The focus of the current study is limited only to exploring linkages between critical minerals and the clean energy transition. It looks at drawing and analysing linkages of critical minerals with the dimension of energy, specifically, nuclear energy and clean energy transition.

3. Critical Minerals and Clean Energy Transition

The UN Secretary-General's Initiative on Critical Energy Transition Minerals (2024) highlighted in a report that demand for critical minerals is set to almost triple by 2030, driven primarily by the pace of transition from fossil fuels to renewable energy in the wake of reducing global carbon dioxide emissions to net zero by 2050. The report stresses that the "race to net zero cannot trample over the poor' and the renewables revolution must be guided towards justice"[8]. He laid out seven actionable guidelines and recommendations to ensure that clean energy transition can also accompany sustainable development and be inclusive of equity and justice. The Secretary General's report reiterated the indispensable role critical minerals would continue to play in Member States' strategies in achieving net zero emissions, especially post their endorsements of the same.

It is certain that arising out of the necessities of saving the planet, most of the energy hungry economies are compelled to make choices that direct the growth and development of their economy in an energy sustainable manner. This is reiterated further by the recently concluded, the COP-28 Conference (2023) of the UNFCCC) that led to the conclusion of agreement between the State Parties to phase down coal-based power generation and increase renewable energy installed capacity by three times by the year 2030, "… signalling the beginning of the end of the fossil fuel era by laying the ground for a swift, just and equitable transition…"[9] The UAE consensus signed reflected the shared commitment of 135 signatory countries "work together to triple the world's installed renewable energy generation capacity to at least 11,000 GW by 2030"[10]

[8] UN Secretary General's Initiative on Critical Minerals, "Resourcing The Energy Transition Principles To Guide Critical Energy Transition Minerals Towards Equity and Justice" *Report,* September 2024, Available at https://www.un.org/sites/un2.un.org/files/report_sg_panel_on_critical_energy_transition_minerals_11_sept_2024.pdf

[9] Nidhi Srivastava, Atul Kumar, Critical minerals for energy transition: The emerging regime complex, The Extractive Industries and Society, Volume 20, 2024

[10] UAE Consensus- COP -28 UAE - *Global Renewables and Energy Efficiency Pledge,* https://www.cop28.com/en/global-renewables-and-energy-efficiency-pledge

4. Critical Minerals and Nuclear Energy: Drawing Linkages for India

As one of the world's emerging economies, India is undergoing a revolution of clean energy transition on multiple levels, including the shift to de-carbonization, premised on sustainability and a people-centric approach. India's own national commitments include achieving "...at least 50% of its cumulative installed power capacity sourced from non-fossil fuels, while simultaneously reducing CO2 emissions by 1 billion tonnes and lowering carbon intensity to below 45% by the year 2030…."[11]Critical minerals and Rare Earth Elements (RREs) remain at the heart of this larger objective of clean energy transition as they are the key components driving the systems and technologies required for clean energy transition. The Government of India's National Critical Mineral Mission (NCMM), launched in 2025, highlighted the linkages and necessity of critical mineral resilience for solar energy, wind power, shift to electric transportation and energy storage. While the linkages between nuclear energy expansion and critical minerals resilience are not directly drawn, there remains an acknowledgment albeit implicit that, "...domestic production and sourcing of the minerals for nuclear (and defence) is paramount…"[12] In-fact, the NCMM's recent report (2025) has listed Indian Rare Earth Ltd (IREL) as one of the key Public Sector Undertakings (PSUs) expected to be investing in critical minerals. It is important to reiterate that the IREL (India) Limited, under the Department of Atomic Energy, works in mining and processing of RREs and contributes to the domestic supply of critical minerals. Thus, there are evident shared linkages between India's critical mineral mission and nuclear energy. Further, critical minerals such as uranium, zirconium, hafnium, beryllium and niobium play a vital role as constituents in nuclear power-energy systems.

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[11] Report - National Critical Mineral Mission, *Ministry of Mines,* 2025 and Ministry of Mines Notification, F. No. 28/15/2024-CMM-Part(1), National Critical Mineral Mission (NCMM) Available at https://mines.gov.in/admin/storage/ckeditor/NCMM_Notification_(1)_1751518157.pdf

[12] Ibid.

5. The SHANTI Act

With the passage of Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (hereafter, SHANTI Act 2025), India plans to expand its nuclear power generation capacity of 100 GW by 2047 for energy security and self-reliance in the energy sector. The goal of capacity expansion is anticipated to be achieved by a combination of existing reactors in addition to bringing in "..two new fleets of 10 reactors each of indigenous 700 MW PHWRs and two (02) FBRs each of 500 MW (with the use of indigenous fuel)…"[13] Further, India's roadmap to nuclear energy expansion also includes the design, development, and establishment of Small Modular Reactors (SMRs) by Bhabha Atomic Research Centre (BARC), with expected deployment by 2033. Funding for the R&D of these indigenous SMRs is already allocated under the Nuclear Energy Mission (NEM). Speaking at Rajya Sabha, the current Minister of State (MoS) for the Department of Atomic Energy in India, Shri Jitendra Singh, highlighted the rise in India's installed nuclear capacity "...from 4,780 MW in 2014 to 8,780 MW, expected to reach 22,380 MW by the 2031–2032…[14]" He further ensured that the fast-track goal of expansion of nuclear energy to triple the installed nuclear capacity will be supported by a combination of steps, including policy reforms, financial reforms, and private sector participation, including fuel security assurance.[15]

These emerging and recent developments suggest that nuclear power is now viewed as more integrated into India's clean energy strategy as a base load source of electricity, contributing to the national commitment towards net-zero emissions by 2070 and as a part of India's aspiration of attaining a sustainable growth rate equal to 9% by 2047. It is envisaged that more than 80% of electricity installed capacity and about 2/3rd of electricity generation in 2047 will be met from non-fossil fuel sources. Renewable energy, thus, will have a crucial role to play in the journey to achieve India's climate commitments. Nuclear energy in that mix would play a key role in India's renewable energy strategy, which is "…more than 10 times

[13] "Parliament Question: Domestic Power Generation", Department of Atomic Energy (DAE), *Press Information Bureau (PIB),* 04 February 2026, Available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2223250&reg=3&lang=1

[14] "India to triple nuclear power capacity by 2032: Union Minister Jitendra Singh", *DD News,* 12 February 2026, Available at https://ddnews.gov.in/en/india-to-triple-nuclear-power-capacity-by-2032union-minister-jitendra-singh/

[15] ibid.

expansion of the existing capacity in 22 years, that is an average capacity addition of approximately 4.14 GW per year."[16]

The SHANTI Act was passed in December 2025. Before that, in the previous year's Union Budget, "Rs 20,000 crore were allocated for a Nuclear Energy Mission (NEM) to research and develop Small Modular Reactors (SMRs); with a target of operationalising at least five indigenously developed SMRs by 2033".[17] Interestingly, in a related development in January 2026, the Ministry of Power put forward a draft National Electricity Policy (NEP) for review that categorically identified nuclear power as "…clean, reliable, and sustainable energy source with significant potential for India's long-term energy security"[18]. However, the current contribution of nuclear energy sits at 3% to the total electricity generated in India as per diversified government and secondary sources. (See Figure 2)

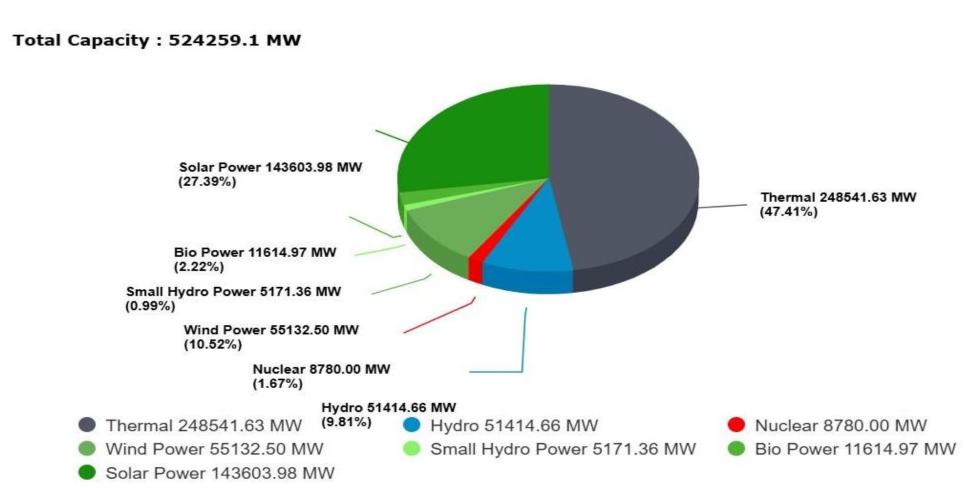

Figure 2. Share of Nuclear Power in Total Electricity as on 25 March 2026 (Ministry of Power, GoI)

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[16] " Roadmap for Achieving the Goal of 100 GW of Nuclear Capacity by 2047", *Central Electricity Authority,* 25 June 2025, Available at https://cea.nic.in/wp-content/uploads/notification/2025/10/Roadmap_Final_30062025.pdf

[17] Union Budget- 2026-2027, Government of India, 1 February 2026.Available at https://www.indiabudget.gov.in/doc/budget_speech.pdf and "A Nuclear Energy Mission For Research & Development OF Small Modular Reactors (SMR) Will Be Set Up"- *Ministry of Finance,* 01 February 2025, Available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2098367&reg=3&lang=2#:~:text=Union%20Minister%20of%20Finance%20and,crore%20will%20be%20set%20up

[18] Draft National Electricity Policy- 2026, *Ministry of Power,* Available at https://powermin.gov.in/sites/default/files/Seeking_comments_on_Draft_National_Electricity_Policy_2026.pdf

Table 2. Reactor under Construction in India (2023)

Reactor Name	Model	Reactor Type	Gross Capacity	Construction Start
Kaiga 5	Horizontal Pressure Tube type	PHWR	700	2026-03-01
Kaiga 6	Horizontal Pressure Tube type	PHWR	700	2026-03-01
Kudankulam 3	VVER V-412	PWR	1000	2017-06-29
Kudankulam 4	VVER V-412	PWR	1000	2017-10-23
Kudankulam 5	VVER V-412	PWR	1000	2021-06-29
Kudankulam 6	VVER V-412	PWR	1000	2021-12-20
PFBR	Prototype	FBR	500	2004-10-23
Rajasthan 8	Horizontal Pressure Tube type	PHWR	700	2011-09-30

Source: World Nuclear Association, 2023.

6. Nuclear Energy for AI and Clean Energy Transition

Countries are adapting AI into their everyday functioning of governance, from designing to the delivery of public goods, including digital public infrastructure. As a result, data centres are likely to occupy centre stage in policy thinking. While seemingly unrelated, the future of India's energy landscape and data centres is connected. As per a McKinsey analysis, "…the power demand for data centres is expected to reach 1,400 terawatt-hours by 2030, equivalent to 4% of total global power demand…"[19]. AI and non-AI workloads would be the key drivers of global data centre capacity demand growth, and an important challenge in the scaling of data centres remains securing adequate power in an environmentally efficient manner.

Nuclear energy is increasingly being viewed as a low-carbon power source for AI data centres that offer base load power availability and grid stability to meet likely rising energy demands. Nuclear energy, particularly SMRS, is being looked at as a solution. Furthermore, Goldman Sachs research has also estimated that "… 40% of the increase in power demand from data centres will be met by renewables, including nuclear capacity that's targeted for AI…"[20]. Clearly, AI-driven governance and development would likely put demand pressure on power, especially sustainable power solutions. The biggest tech giants, such as Amazon, Google, and Microsoft, have already begun investing in nuclear energy to secure energy independence. However, nuclear energy has its own set of challenges, despite presenting itself as a compelling option. Amazon is already investing in SMRs as a flexible and cost-efficient option - "…in collaboration with Energy Northwest, is developing four SMRs in Washington state to have an initial capacity of 320 megawatts (MW), with the potential to expand to 960 MW…."[21]. Google, on the other hand, has partnered with Kairos Power, a startup at the forefront of Molten Salt Reactors (MSR) technology, "planning six or seven of these reactors by 2030, aiming for a total capacity of 500 MW".[22] Microsoft has partnered

[19] "Scaling Bigger, Faster, Cheaper Data Centres with Smarter Designs", *McKinsey.com* 01 August 2025, Available at https://www.mckinsey.com/industries/private-capital/our-insights/scaling-bigger-faster-cheaper-data-centers-with-smarter-designs

[20] "How AI Is Transforming Data Centers and Ramping Up Power Demand", *Goldman Sachs,* 29 August 2025, Available at https://www.goldmansachs.com/insights/articles/how-ai-is-transforming-data-centers-and-ramping-up-power-demand

[21] "The Nuclear Bet: How Tech Giants Are Turning to Nuclear Energy to Power AI Growth", *Amaris Consulting,* 24 February 2025, Available at https://amaris.com/insights/viewpoint/nuclear-energy-to-power-ai-growth/

[22] Ibid.

with the existing nuclear power plant company Constellation Energy to revive a decommissioned reactor at the Three Mile Island (TMI) to ensure a steady supply of energy. Electricity demand for AI is expected to double by 2030. The rise of AI and the global transition towards clean energy are reshaping the global economic and security landscape.

The Director General of the International Atomic Energy Agency (IAEA), in his speech addressing the first International Symposium on Artificial Intelligence and Nuclear Energy, reiterated that, "…the AI revolution… was always going to choose nuclear energy as a partner; it was an inevitable partnership, the only question was when…"[23]. Indeed, as highlighted, global data centre energy consumption that currently exceeds 400 TWh annually, is further projected to reach 1,000 TWh by 2030. The SMRs offer a strategic solution for powering this digital expansion with clean energy. Not only does their modular design allow for phased deployment that scales directly with AI cluster growth, but their compact footprint and advanced safety systems enable operation in proximity to industrial zones, allowing technology companies to bypass grid constraints and reduce transmission losses. In middle power countries such as India, where AI adoption will take place at a massive scale, including digitalisation, SMRs may prove to be sustainable. This aspect is not lost on India's evolving policymaking; the SHANTI Act takes note of these shared linkages between nuclear energy, the anticipated growth of AI, other emerging technologies such as deep tech and frontier technologies such as High-Performance Computing, large-scale data-driven research, and indigenous semiconductor fabrication.

AI and nuclear energy will be the constituents driving the comprehensive development of India. The effects of the SHANTI Act go beyond the domain of traditional peaceful uses of nuclear energy, such as electricity generation, medical, agriculture, and industrial applications. Its preambular paragraphs have elucidated on the utilisation of nuclear energy to enable and accelerate the growth and development of AI in supporting 'future-ready applications', including advanced materials research, space technologies, and even industrial automation. Thus, while the goal of nuclear energy for electricity and the increase of nuclear energy share towards India's energy mix remains the same, the

[23] "International Symposium on Artificial Intelligence and Nuclear Energy", 03 December 2025, Available at https://www.iaea.org/newscenter/statements/the-atom-and-the-algorithm-nuclear-energy-and-ai-are-converging-to-shape-the-future

application and deployment of nuclear energy science and technologies have become diversified[24].

Further, India will expect a rapid surge in the number of Global Capability Centres and data hubs, creating a massive spike in electricity requirements for advanced computing. To meet this demand while delivering on the national pledge to reach net-zero by 2070 remains a herculean task. A Deloitte report suggests, "…data centre capacity of India is expected to increase six-fold from around 1.5 Gigawatt (GW) in 2025 to 8-10 GW by 2030. As a direct result of it, the electricity consumption from the sector is also estimated to rise from 10-15 terawatt hours (TWh) in 2024 to 40-45 TWh by 2030…"[25]. This means fast expansion would imply a rise in India's total electricity demand from around 0.8% currently to as much as 2.5–3% by the end of the decade[26].

India embracing AI includes a balance between rapid innovation with social inclusion, which comes at the investment of $1.2 billion dollars in AI infrastructure for startups and data centres. Official sources cite it as the "…world's third most competitive nation owing to India's rapid growth in the global AI landscape…."[27]. India's "AI for All" strategy, which focuses on delivering better public services and governance, would require potentially double the energy consumption soon. India intends AI's impact to reach every citizen and enhance public services through faster, data-driven governance. Nuclear energy, given its potential, will have to be a part of the solution. Thus, the integration of SMRs into the country's energy strategy is being proposed as a sustainable solution that would provide reliable, carbon-free power necessary to support India's expanding digital infrastructure.

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[24] SHANTI ACT- 2025

[25] "India's Data Centre Capacity Estimated to Increase Six-Fold, to Put More Pressure on State Grids", *The Wire,* 06 February 2025, Available at https://thewire.in/energy/indias-data-centre-capacity-estimated-to-increase-six-fold-to-put-more-pressure-on-state-grids

[26] Ibid.

[27] "Transforming India with AI", *PIB Press Release,* 30 December 2025, Available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2209737&reg=3&lang=1

7. Nuclear Energy Expansion and Critical Mineral Dependency

As India prepares to navigate the nuclear energy mission of taking India's installed nuclear energy capacity from 8180 MW as of 30 January 2025 to 22,480 MW by 2031-32, including the expected addition of at least five Bharat Small Modular Reactors (BSM- 200) to come up by 2033, the critical minerals dimension indirectly figures in India's nuclear power strategy. The SHANTI Act does not directly highlight the requirement of critical minerals and REEs for nuclear energy expansion. However, the journey of India's nuclear energy expansion will remain intertwined with India's preparedness in critical minerals and rare earth elements. This shared linkage is acknowledged in the Report - "Roadmap for Achieving the Goal of 100 GW of Nuclear Capacity by 2027", released in 2025 by the Ministry of Power. The report points to some issues that require attention, such as "manufacturing of components and access to critical minerals"[28], that are likely to become increasingly pressing, such as lead times, financial issues, privatisation and public perceptions, shortage of personnel and uranium insufficiency, to name a few.

7.1. Critical Mineral Dependency

Thus, for the effective implementation of the SHANTI Act, in addition to sustaining India's nuclear self-sufficiency, attention to critical minerals is deemed important even by relevant domestic stakeholders. The tables below elucidate the global supply chain vulnerabilities of critical minerals.

[28]Op. cit 16

Table 3. Global Supply of the Critical Raw Materials (2023): A Study by the European Union (EU)

Sl. No.	Material	Stage*	Main Global Supplier	Share	Sl. No.	Material	Stage *	Main Global Supplier	Share
1	Aluminium	E	Australia	28%	27	magnesium	P	China	91%
2	antimony	E	China	56%	28	manganese	P	S. Africa	29%
3	arsenic	P	China	44%	29	natural graphite	E	China	67%
4	baryte	E	China	44%	30	neodymium	P	China	85%
5	beryllium	E	USA	88%	31	niobium	P	Brazil	92%
6	bismuth	P	China	70%	32	nickel	P	China	33%
7	boron	E	Türkiye	48%	33	palladium	P	Russia	40%
8	cerium	P	China	85%	34	phosphate rock	E	China	48%
9	cobalt	E	DRC	63%	35	phosphorus	P	China	74%
10	coking coal	E	China	53%	36	platinum	P	S. Africa	71%
11	copper	E	Chile	28%	37	praseodymium	P	China	85%
12	Dysprosium	P	China	100%	38	rhodium	P	S. Africa	81%
13	erbium	P	China	100%	39	ruthenium	P	S. Africa	94%

14	europium	P	China	100%	40	samarium	P	China	85%
15	feldspar	E	Türkiye	32%	41	scandium	P	China	67%
16	fluorspar	E	China	56%	42	silicon metal	P	China	76%
17	Gadolinium	P	China	100%	43	strontium	E	Spain	31%
18	Gallium	P	China	94%	44	tantalum	E	DRC	35%
19	Germanium	P	China	83%	45	terbium	P	China	100%
20	Hafnium	P	France	49%	46	thulium	P	China	100%
21	Helium	P	USA	56%	47	titanium metal	P	China	43%
22	holmium	P	China	100%	48	tungsten	P	China	86%
23	Iridium	P	S. Africa	93%	49	vanadium	E	China	62%
24	Lanthanum	P	China	85%	50	ytterbium	P	China	100%
25	Lithium	P	Australia	53%	51	yttrium	P	China	100%

Source: European Commission Study on Critical Raw Materials for EU 2023 – Final Report
**Critical Minerals for Nuclear Energy are highlighted*
**E = Extraction stage P = Processing stage*

Table 3 elucidates how India remains dependent on imports of critical minerals for nuclear energy.

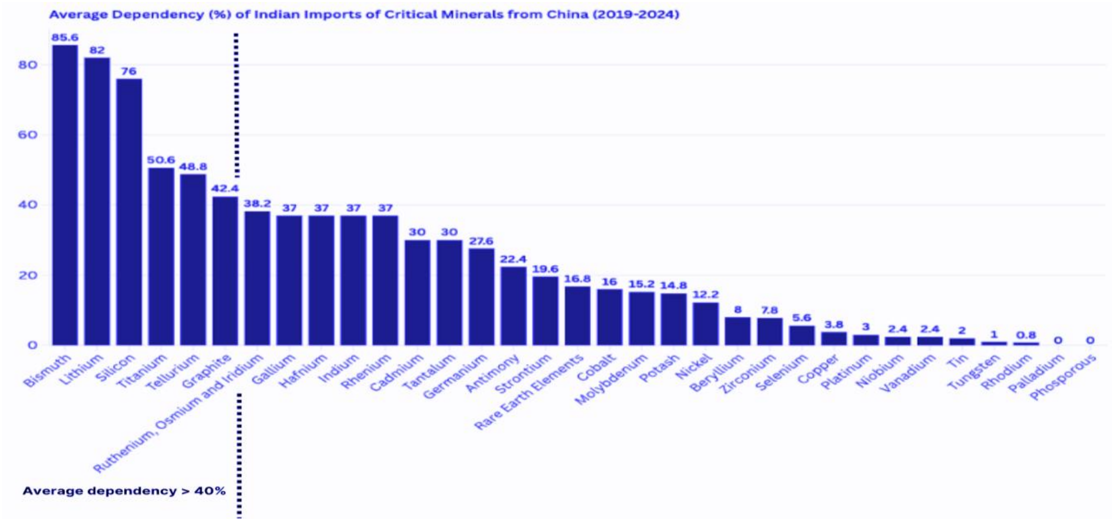

Figure 3. India’s Critical Mineral Dependency on China

Source: Assessing the Nature of India's Critical Minerals Vulnerabilities vis-à-vis China, Takshashila Discussion Document 2024-24

India’s dependency on CM reserves is widely acknowledged - “100 percent dependent on imports for critical minerals such as lithium, cobalt and nickel…”[29]. To close this supply gap, in 2019, Khanij Bidesh India Limited (KABIL) was established under the Ministry of Mines to ensure supply-side assurance of critical minerals, with a mandate to “identify, explore, acquire, develop, mine, process, procure strategic minerals outside”[30]. KABIL signed agreements with state-owned enterprises of Australia, Argentina and Chile for cooperation in critical minerals. India’s evolving threefold critical mineral strategy, including domestic extraction, acquisition of overseas mining assets, and building of strategic stockpiles, aims to shed its total reliance on imports. Additional steps, such as relaxation of fiscal policies, eliminating customs duties, and manufacturing incentives for encouraging the refining and recycling of minerals from e-waste, are also part of India’s CRM sustainability strategy.

While this is good news, it begs the question: what more can be done to achieve self-sustainability? For India to go from 100% import dependency to having a self-sustaining critical minerals ecosystem will require continuous learning, unlearning, devising, and implementing strategies to ensure critical minerals resilience. The table below shows India’s current critical mineral vulnerability vis-à-vis nuclear energy:

[29] Sauhard Kaushal, “Developing all Stages of Critical Mineral Value Chain: Crucial for Viksit Bharat”, *Research and Information Systems (RIS),* 07 March 2025, Available at https://ris.org.in/en/node/4093

[30] Khanij Bidesh India Limited (KABIL), Official Website, Available at https://kabilindia.in/

Table 4. India's Critical Minerals for Nuclear Energy Dependency

S. No.	CRM Listed by National Critical Mission	Application in Nuclear Power/Energy	Domestic Sufficiency-Dependence
1.	**Beryllium**	Material for moderators and reflectors in nuclear reactors.	China is the second-largest producer of beryllium concentrates, holding a global share of 27.19% in 2022 (Takshashila Report)
2.	***Copper**	Electrical conductors, heat exchangers, cooling system components, motor windings in reactor auxiliary systems; grid-scale transmission	India is copper-deficient; ~95% of copper ore imported or processed from limited domestic mines; demand will surge with 100 GW build-out
3.	**Nickel**	Stainless steel (austenitic grades) for reactor pressure vessels, piping, steam generators; Inconel/nickel superalloys in high-temperature zones	India is 100 percent Import dependent
4.	**Graphite**	Graphite is essential for its use in nuclear reactors	China is the largest producer of Graphite, accounting for 67.21% of global production in 2022
5.	**Lithium**	It is also used in nuclear reactor coolants	China's dominance in lithium processing (58% of global refining capacity). (Takshashila Document)
6.	**Niobium**	Niobium also is used in the manufacturing of naval nuclear reactors	Current requirement is made through imports
7.	**Hafnium**	Utilised as neutron absorption in control rods in nuclear power plants	Ministry of Mines Report does not clarify import dependency, World Integrated Trade Solution (WITS) highlighted India imported 639,574 Kgs of Gallium, **hafnium**, indium, niobium, and rhenium. **Normally, all zirconium compounds have between 1.4-3% hafnium. IREL & KMML are involved in zirconium production*

Source: The above tabulated data is sourced by the author from diversified sources such as the Report of the Committee on Identification of Critical Minerals by the Ministry of Mines (2023), GoI, Takshashila Discussion Document, World Integrated Trade Solution (WITS), and International Atomic Energy Agency.

The table above shows that, other than zirconium, India is import-dependent on almost all the critical minerals for nuclear energy expansion. Thus, strategies to ensure their sustainable supply are paramount. The importance of this is accentuated by two factors. First, India cannot afford to reverse its progress towards its net 2070 commitments, especially in light of achieving many of its targets ahead of schedule. In 2025, "…India achieved the milestone of 50% of its cumulative electric power installed capacity from non-fossil fuel sources in June 2025, five years ahead of the 2030 target set under its Nationally Determined Commitment (NDC) to the Paris Agreement…"[31].

In addition, as of 25 March 2026, India approved a new set of NDCs from 2031–2035: to add 47% reduction to emissions intensity by 2035 as compared to 2005 levels, and target to achieve 60% of cumulative installed electricity capacity from non-fossil sources by 2035[32]. All this is aligned with the COP-26 vision of reaching 500 GW non-fossil energy capacity by 2030. Second, considering the above, nuclear will continue to play an important role in the clean energy transition journey for India. If that is the case, then critical mineral dependencies towards nuclear energy need to be addressed.

[31] "2025 Marks Highest-Ever Renewable Energy Expansion in India's Energy Transition Journey" , *Ministry of New and Renewable Energy,* Press Information Bureau, 29 December 2025.

[32] Upamanyu Das, Sehr Raheja ", India unveils new UN climate target: 47% emissions intensity cut by 2035, 60% non-fossil power capacity", *Down to Earth,* 25 March 2026, Available at https://www.downtoearth.org.in/climate-change/india-unveils-new-un-climate-target-47-emissions-intensity-cut-by-2035-60-non-fossil-power-capacity

8. Nuclear is a Part of the Solution, but with Hurdles

While nuclear energy provides steady, round-the-clock electricity with low greenhouse gas emissions and will continue to play a significant role in the expansion of India's renewable energy portfolio, especially towards grid stability and a reliable baseload supply, challenges ahead will need to be met. India's present nuclear capacity stands at 8.78 GW. With new reactors under development, the capacity is projected to rise to 22.38 GW by 2031–32. The government has further announced a long-term Nuclear Energy Mission with a vision of achieving 100 GW by 2047, aligning nuclear expansion with India's clean energy and energy security goals. India is aggressively expanding its indigenous nuclear power sector to support a rapidly growing economy and reach net-zero by 2070. However, a lot hinges on the effective implementation of the SHANTI Act, the core component of India's nuclear energy strategy. A combination of measures, including construction of SMRs, private participation, and utilisation of thorium reserves, is envisaged to add to the nuclear power capacity of 100 GW by 2047, a goal that requires a more-than-tenfold increase from the current 8.88 GW. Achieving this ambitious target presents several challenges across various domains, including regulatory frameworks, financing, project timelines, fuel management, human resources, supply chain, and public perception. The challenges are discussed below:

Lead Times and Delay in Execution: In July 2024, the Indian budget specified setting up Bharat Small Reactors. In 2024, Nuclear Power Corporation of India Limited (NPCIL) issued a request for proposals (RFP) from Indian energy users to finance and build a proposed fleet of Bharat Small Reactors. The initial deadline was 31 March 2025, which has been extended several times, most recently to 31 March 2026. Six companies at that time had submitted documents in response to the RFP: Hindalco Industries, Jindal Steel & Power, Tata Power, Reliance Industries, JSW Energy, and Adani Power. They identified 16 prospective sites across six states, including five in Gujarat, four in Madhya Pradesh, three in Odisha, two in Andhra Pradesh, and one each in Jharkhand and Chhattisgarh.

Further, the total time required for nuclear power plant construction, from state government consent to first criticality, is often 11 to 12 years, which is considerably longer than other power projects. To address this gap, SMRs are to be integrated in the strategy as they offer considerably reduced construction time, with parallel construction, in contrast to "the traditional brick-by-brick on-site construction of the reactor". [33]

Privatisation and Public Perception– With the SHANTI Act, India overturned the previous Atomic Energy Act of 1962, which restricted private sector participation. Amendments to this Act were necessary to facilitate private investment. However, the involvement of private participation has also raised doubts about safety by civil society representatives, such as "supporters of the radiation victims of the various operations along India's nuclear fuel cycle." Organizations including the National Alliance of Anti-nuclear Movements, People's Movement Against Nuclear Energy, Cheemeni Anti-nuclear People's Vigilance Forum, National Alliance of People's Movements, and Bhopal Group for Information and Action, have expressed concerns that involving private industries can result in compromises in design, operations, maintenance, and disposal of radioactive materials and equipment[34]. Further, public perception owing to safety concerns has historically often delayed the process of land acquisition.

Financial Issues & Short Supply of Domestic Vendors*:* Nuclear power projects are capital-intensive with long gestation periods, leading to high upfront costs and tariffs. Attracting favourable debt financing is challenging due to perceived risks. The estimated incremental investment to reach 100 GW is approximately ₹19 lakh crore. In addition, as flagged by the 2047 roadmap*,* nuclear projects demand highly specialised equipment and advanced manufacturing owing to high complexity and stringent norms. There are currently very few domestic vendors, primarily for PHWR technology. Strengthening the supply chain and developing a broader vendor ecosystem are critical.

Shortage of Personnel*:* India, particularly, needs a large workforce with specialised education and training in engineering and nuclear science. Estimated peak manpower for operation, construction, and design will be 61,000, 120,000, and 5,500, respectively, by various target

[33] Clara A Lloyd, "Modular Manufacture and Construction of Small Nuclear Power Generation Systems", University of Cambridge, May 2019

[34] Snigdhendu Bhattacharya ,"India Speeds Up Civil Nuclear Sector Privatization", *Diplomat,* 11 December 2025, Available at https://thediplomat.com/2025/12/india-speeds-up-civil-nuclear-sector-privatization/

years, leading to significant recruitment and training challenges.

Uranium Insufficiency: India faces significant challenges regarding uranium dependency as it aims to expand its nuclear power capacity to 100 GW by 2047. The current domestic uranium resources are insufficient to meet the projected demand, necessitating a multi-pronged approach to fuel management, including domestic mining, acquisition of mines abroad, and diversification of imported fuel supplies. Meeting the 100 GW target by 2047 will require significant additional quantities of natural and enriched uranium, estimated at 8029 tonnes and 1045 tonnes annually, respectively. Thus, there lies a considerable gap between indigenous supply and future demand. Further, the cost of domestic uranium mining and processing in India is about three to four times more expensive than international prices, primarily due to the lower quality of ore found domestically.

9. Future Lessons

9.1. Securing Energy amidst Geopolitical Realities

While weaponisation of energy facilities and energy supplies may be an under-researched phenomenon in theory, ongoing military conflicts between Russia-Ukraine, and Iran-Israel and the US have demonstrated how sabotaging energy infrastructures will likely remain a tempting tactical counterforce option in the military strategies of countries. Not that these options were not available earlier, however, the blatant acknowledgement with which countries today have incorporated energy supply disruption as a part of their escalation-risk strategy is unfolding like never before. The blockage of the Strait of Hormuz, Black Sea, and Azov Sea in recent times has presented real-time multiplying challenges for energy security. Military conflicts, when protracted, do impact energy supply chains and hamper economic security, but sudden and unpredictable contingencies, such as in recent times, have exposed how fragile global security and India's national security really is. "While global energy markets can adjust to long-term risks, their responsiveness to sudden changes borne out of geopolitical instability remains fragile…"[35].

Five years ago, in 2021, the Suez Canal was obstructed for six days by a container ship. It was an accident that resulted in a loss of $89 million for the shipping company Maersk Line. A mere six-day blockage at one of the world's busiest and most critical shipping routes exposed global supply chain vulnerabilities. The problem was compounded as, "of Maersk's total loss of $89 million, the cost of holding container inventories was the largest expense at $76 million…", in addition to the environmental costs in terms of increased carbon dioxide emissions from the fleet [36]. This reveals the sudden contingencies that may arise out of geopolitical realities that would likely not only trigger an unexpected reorganization of the global energy landscape but also trigger risks and escalated costs for securing energy.

[35] Nguyen Khoi Tran, Hercules Haralambides, Theo Notteboom, Kevin Cullinane, "The costs of maritime supply chain disruptions: The case of the Suez Canal blockage by the 'Ever Given' megaship", International Journal of Production Economics, Volume 279, January 2025.

[36] Lee, R. G., & Powell, R. (2025), "Weaponisation of Energy Systems and Policy in the Age of Climate Change. Environmental Law Review, Vol. 27, No. (3), pp. 203-223.

In the case of the US-Israel-Iran crisis, it was evident that with the obstruction of critical maritime routes like the Strait of Hormuz, world markets were forced to recalibrate to seek alternative fuel sources. These sudden geopolitical triggers bear heavy implications for global energy markets, as the attack on major energy assets causes a substantial scale of disruption. Thus, the securing of energy supplies, development of indigenous capabilities and collaboration in capacities to assure energy security is the need of the hour. Such contingencies offer a timely reminder to assertively pursue energy transition and further diversify renewable energy portfolios. Most importantly, their lessons are to be studied to extrapolate into building critical mineral resilience for energy security.

10. Recommendations

10.1. Innovate Strategies for Diversification

Specifically, nuclear diversification of imported fuel supply and strategic stockpiling are crucial to mitigate geopolitical risks and ensure an uninterrupted fuel supply. There also remains a need to enhance domestic uranium production by encouraging private sector participation. While India is in the process of acquiring mines for critical minerals abroad, the process needs to be accelerated, and simultaneous international collaborations may be a prudent option.

10.2. The Need to Accelerate International-Multilateral CRM Collaboration

India launched the G20 Critical Minerals Framework as a voluntary, non-binding mechanism to secure global cooperation on critical minerals, driven by the need for sustainable, transparent, stable, and resilient critical mineral value chains. The G20 framework seeks to ensure that mineral-producing countries, particularly in the Global South, derive maximum benefit from their resources by moving beyond raw material exports and into higher-value segments of the supply chain. Many of these states have limited processing capacity, lack control over trade routes and markets, and face persistent geopolitical pressures that compound the problem. The G20 forum aims to reverse this pattern. However, operationalising the forum requires further work. This would also mean taking cognisance of local interests and balancing them with international demand. Further, the framework would also need to build international clout, especially since the US is not interested in backing the initiative. From a nuclear perspective, an assessment of non-fuel nuclear critical mineral needs is required, situated within the framework of the G20 Critical Minerals Partnership.

10.3. Accelerate QUAD’s Critical Mineral Initiative

At the Foreign Ministers’ meeting in July 2025, the leaders of four robust economies launched the Critical Mineral Initiative (CMI). The Joint Statement emphasised “…deep concerns about the abrupt constriction and future reliability of key supply chains, specifically for critical minerals”, including the use of non-market policies and practices for critical minerals and certain derivative products (such as nuclear-related critical minerals) and mineral processing technology. The countries underscored the importance of diversified and reliable global supply chains and reiterated strongly that reliance on any one country (China) for processing and refining critical minerals and derivative goods production exposes vulnerabilities and further harms economic and national security. The CMI did not outrightly highlight the non-fuel critical mineral angle, but from an Indian perspective, cooperation and collaboration may be sought on the critical minerals specific to nuclear energy. There is merit in addressing the supply chain dependencies of nuclear-related CRM, more so because these minerals are highly specialised and industrial supply cannot substantiate them. Vulnerability exists, and the four countries can jointly address the issue and collaborate on capacities, playing on each other's strengths. Since the Quad is a closed mini-lateral grouping, it may be prudent to discuss and expand the existing CMI agenda to address nuclear linkages without inviting much attention.

11. Takeaways for Future Research and Policy Consideration

11.1. Future Research Directions

1. Undertake an India-specific closed/ classified study on the assessment of nuclear-related critical minerals vis-à-vis their domestic requirement for domestic stakeholders.
2. Conduct the assessment of critical mineral strategies of QUAD countries – the US, Japan, Australia to find synergies for actionable policy outcomes.
3. Examine the challenges and opportunities linked to the use of nuclear energy for AI (energy demand from data centres), specific to India.

11.2. Possible Policy Takeaways

1. Explore structured collaboration between India's Atomic Minerals Directorate for Exploration and Research under the Department of Atomic Energy (having the mandate to identify, evaluate, and augment the mineral resources of critical elements) and select private players with a view to handholding them and contributing to anticipated nuclear energy and CRM resilience.
2. Leverage existing critical mineral partnership frameworks such as US-India, EU-India, and Australia-India to advance CRM for nuclear linkage.

12. Conclusion

This policy report has argued that for India, the intersection of its assertive goal of nuclear energy expansion and its critical mineral dependency represents a defining pivot for the country's comprehensive national security, in which the goal of sustainable energy security is intertwined. While the foundational pillars for a sustainable future, in the form of the SHANTI Act (2025) and the National Critical Mineral Mission (NCMM), have been established to collectively anchor India's comprehensive clean energy strategy, more needs to be done. As India navigates its dual goals of reaching 100 GW nuclear capacity by 2047 and achieving net-zero emissions by 2070, it needs to address the shared linkages between nuclear energy and critical mineral dependency. This should be viewed in the light that nuclear power is no longer only a tool for grid decarbonization; in fact, it has emerged as a potentially indispensable, low-carbon partner to power the burgeoning AI revolution. The promise of nuclear energy is also tied to the very realisation of unleashing the promise of AI-driven socio-economic progress of the nation. Nuclear power is increasingly being viewed as a solution for the massive baseload demands of expanding digital data centres.

However, translating this vision into a sustainable reality requires addressing, in real time, geopolitical and supply chain vulnerabilities. India remains profoundly import-dependent on nearly all critical raw materials and rare earth elements essential for nuclear systems, such as uranium, hafnium, beryllium, and niobium, in a global market overwhelmingly dominated by China's refining and mining monopolies. Furthermore, the path to 2047 is steepened by an estimated ₹19 lakh crore incremental investment requirement, widening deficits in both natural and enriched uranium fuel supplies, and civil society apprehensions regarding private sector participation and safety.

While India has demonstrated remarkable climate leadership by hitting its 50% non-fossil capacity target five years ahead of schedule, true self-reliance in sustainable clean energy cannot be decoupled from resource security. To prevent critical mineral bottlenecks from stalling India's clean energy momentum, tied to the objective of Viksit Bharat- 2047, India must execute a highly coordinated, multi-pronged strategy, inclusive of accelerating domestic mining, empowering key PSUs like IREL, expanding a specialized domestic vendor ecosystem, and forging resilient international procurement alliances. Through a comprehensive, secure, and resource-backed approach, India can successfully fuel its digital expansion, safeguard its national security, and fulfil its promise of a sustainable, Viksit Bharat-2047 and secure its commitment to achieving net-zero greenhouse gas emissions by 2070.

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