Powering the transition: Why critical minerals will define India’s clean energy future

By Puneet Goel, Director, and Mayank Saraswat, Consultant, ICF

Executive summary

India’s clean energy ambitions are among the most consequential on the planet. With binding commitments to reach 500 GW of non-fossil electricity capacity by 2030, source half its electricity from renewables, cut economy-wide carbon intensity by 45% over 2005 levels, and achieve net-zero emissions by 2070, the country has charted an energy transition pathway that will reshape its industrial base.

What is less widely appreciated is that every gigawatt of solar capacity, every offshore wind turbine, every green-hydrogen electrolyser, and every EV battery pack embed a physical dependency on a narrow set of minerals—many of which India does not mine, process, or refine domestically.

“India’s energy transition is, at its foundation, a critical-minerals transition.”

Without a deliberate and accelerated strategy to secure upstream supply, build midstream processing capability, and diversify technology partnerships, the country’s headline climate targets risk being constrained not by policy ambition or renewable economics, but by the physical unavailability of the materials that make clean-energy hardware possible. This paper distils the strategic implications and identifies six actionable interventions to convert dependency into resilience.

©ICF

India's clean energy trajectory: Progress and ambition

India has already made significant strides toward its energy-transition targets. As of early 2025, the country has installed 259 GW of non-fossil-based electricity capacity, representing roughly 51.5% of total installed capacity—a milestone achieved five years ahead of schedule. Carbon intensity has already been reduced by 33% relative to 2005 levels.

Figure 1: India's key energy transition achievements to date

>50+
Non- fossil installed capacity (2025)

33%
Carbon intensity reduction vs. 2025

259 GW
Installed non-fossil capacity

3.22 Bn
Tonnes CO_2 from fossil fuels

However, total CO_2 emissions from fossil fuels remain at approximately 3.22 billion tonnes, underscoring the distance still to travel. The forward-looking targets are considerably more demanding.

Figure 2: India's 2030 clean energy targets

India's 2030 targets

500 GW
Non- fossil energy capacity target

50%
Electricity from renewables

45%
Carbon intensity cut vs. 2005

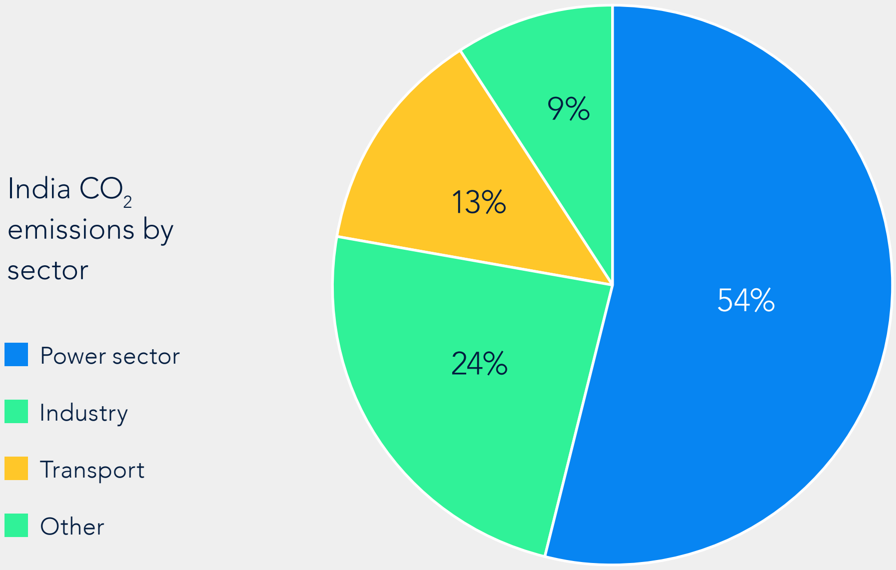
Net Zero
Emission target by 2070

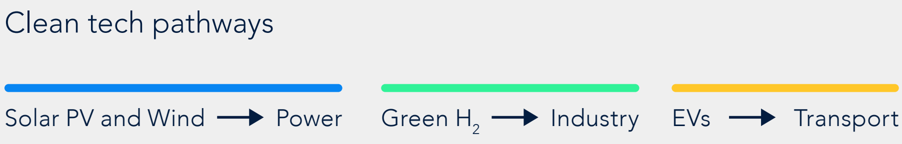
Reaching 500 GW requires near doubling the current non-fossil base in under five years. Each of the clean-energy technologies required to achieve these targets is mineral-intensive, and the scale of deployment envisaged translates directly into enormous mineral demand.

Emissions landscape and low-carbon technologies

India's CO_2 emission profile is dominated by the power sector at approximately 54%, followed by industry at 24%, transport at 13%, and other sectors at 9%. These proportions dictate the technology mix required for decarbonisation.

Figure 3: India's CO_2 emissions by sector and corresponding clean technology pathways





Source: IEA India CO_2 Report 2023

Solar PV and wind address the power sector; green hydrogen targets hard-to-abate industrial processes such as steel, cement, and ammonia production; and electric vehicles tackle transport emissions. Each pathway carries a distinct mineral fingerprint, and the aggregate demand across all three creates compounding pressure on a relatively small basket of elements.

Key insight: The simultaneity challenge

Unlike countries that electrified transport decades before scaling renewables, India is pursuing all technology pathways in parallel within a compressed timeline. This compression amplifies mineral demand peaks and shrinks the window available for building supply-chain resilience—making early action on mineral security not merely advisable but existentially important for the transition's credibility.

The 30 critical minerals: Backbone of India's missions

The Ministry of Mines identified 30 minerals as critical for India's economic and strategic security. The list includes lithium, cobalt, nickel, graphite, rare-earth elements, silicon, gallium, copper, platinum-group metals, and more. What is striking is the degree to which these minerals are directly embedded in the Government of India's flagship programmes:

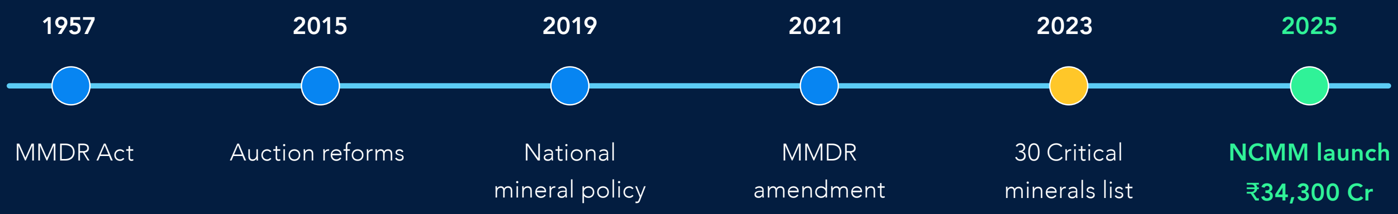
- **National Green Hydrogen Mission (NGHM):** relies on nickel, platinum-group metals, and zirconium for electrolysers.
- P**M-KUSUM and Solar Rooftop Missions:** require silicon, gallium, copper, and tin.
- **National Electric Mobility Mission Plan:** depends on lithium, cobalt, graphite, and nickel for batteries.
- **PLI Scheme for Advanced-Chemistry Cells:** draws on lithium, cobalt, nickel, graphite, molybdenum, and titanium.
- **Offshore Wind Policy 2023 (37 GW target):** predicated on rare earths—neodymium and dysprosium—for permanent-magnet generators.

In other words, every major clean-energy mission carries an implicit mineral procurement requirement that has, until recently, received far less policy attention than the gigawatt-level deployment targets themselves.

Evolution of India's critical minerals policy

India's policy framework for minerals has evolved substantially over the past decade, moving from a focus on domestic production transparency and competition to an explicit strategic approach to mineral security.

Figure 4: Evolution of India's critical minerals policy framework (1957–2025)



The most significant recent development is the launch of the National Critical Minerals Mission (NCMM) in 2025, representing the first time India has committed dedicated fiscal resources of this magnitude to a minerals-focused strategic programme.

Figure 5: National critical minerals mission 2025 — Structure and funding

Applicable to 24 minerals under MMDR Act, Part D | Mission period: 2024–25 to 2030–31

Total mission outlay

₹16,300 Cr (allocation) + ₹18,000 Cr (PSU) = ₹34,300 Cr

Domestic production

Overseas assets

Recycling and recovery

Trade and markets

Scientific research

Human resources

Fiscal incentives

The NCMM spans seven components: increasing domestic production, acquiring overseas assets, advancing recycling, building trade and market infrastructure, investing in scientific research, developing human resources, and designing financing and fiscal incentives. It applies to 24 minerals specified in Part D of the First Schedule of the Mines and Minerals (Development & Regulation) Act, 1957 (MMDR Act) and runs through 2030–31[1].

Mineral demand by technology

Solar photovoltaics

Solar PV sits at the core of India's clean-energy deployment. Core materials include silicon for solar cells, silver for cell metallisation, aluminium for frames, and copper for wiring. Critical thin-film technologies additionally require indium, gallium, tellurium, and selenium[2].

Wind energy

Wind turbines require large quantities of steel, copper, and aluminium as bulk materials. The critical mineral dimension arises from rare-earth elements—neodymium, dysprosium, praseodymium, and terbium-in permanent magnets of direct-drive generators, along with nickel, cobalt, manganese, and chromium in high-strength alloys.

Offshore wind installations are substantially more mineral-intensive than onshore counterparts. Given India's 2023 Offshore Wind Policy targeting 37 GW by 2030[3], the rare-earth requirement could represent a significant supply bottleneck if not addressed through diversified procurement and strategic stockpiling.

[1] https://mines.gov.in/admin/storage/ckeditor/24_pages__desktop_1752835254.pdf

[2] https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf

[3] https://www.pib.gov.in/PressReleasePage.aspx?PRID=1992732&reg=3&lang=2

Key insight:

For solar PV, per-megawatt mineral intensity is declining as cell efficiency improves. However, the explosive growth in deployment means absolute mineral demand continues to rise, particularly for copper, silicon, silver, and tellurium. India's solar ambitions are therefore constrained primarily by supply-chain security, not technology maturity.

Advanced PV technologies such as III–V semiconductors offer higher efficiencies (40%–50% at lab scale) but face India-specific barriers: prohibitive material costs, absence of domestic fabrication capability, constrained supply of gallium and indium, and a utility-scale market driven by cost per watt rather than peak efficiency.

Green hydrogen

Green hydrogen production relies on electrolysers whose mineral intensity varies with technology choice. Alkaline electrolysers sit at the lower end of critical-mineral demand. Proton-exchange membrane (PEM) electrolysers require platinum-group metals (iridium, platinum). Solid-oxide systems involve zirconium and rare-earth elements.

Battery Energy Storage Systems (BESS) and electric vehicles

Battery chemistry is the primary determinant of mineral dependency. NMC cathodes are the most mineral-intensive, requiring lithium, nickel, cobalt, and manganese. LFP eliminates cobalt and nickel but still requires lithium. Across all chemistries, graphite dominates anode requirements.

Grid-scale BESS capacity projections under both current-policy and net-zero scenarios indicate steep growth curves, compounding demand pressures created by the parallel expansion of India's EV fleet. India's PLI scheme for advanced-chemistry cell manufacturing will further concentrate mineral demand within national borders.

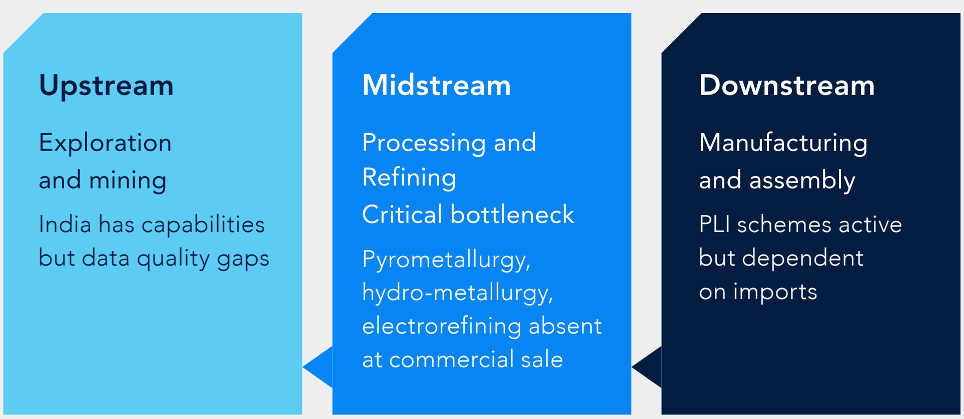
Strategic technology selection

The overall mineral intensity per megawatt decreases as India moves from solid oxide → PEM → alkaline technology. For NGHM targeting 5 MTPA of green hydrogen by 2030, prioritising alkaline electrolyser technology where technically feasible represents a meaningful mineral demand management lever.

Value chain gaps and global supply concentration

India's critical-mineral value chain has significant technology gaps in the midstream and downstream stages. While the country has capabilities in upstream exploration and mining, the processing, refining, and finished-product stages—pyrometallurgy, hydrometallurgy, solvent extraction, electrorefining, sintering, and metallothermic reduction—are either absent or operating below commercial scale.

Figure 6: India's critical mineral value chain — Where the technology gaps sit



The midstream processing bottleneck is India's most urgent gap — raw ore discovery alone cannot resolve import dependency.

Globally, supply chains for critical minerals are heavily concentrated. China dominates the processing of rare earths, graphite, cobalt, and lithium. The Democratic Republic of Congo accounts for a disproportionate share of cobalt mining. Australia and Chile lead in lithium extraction.

Recent events—including China's export controls on gallium, germanium, and antimony—have demonstrated that these are not theoretical risks but active and evolving threats to India's industrial planning. A truly resilient strategy must address the full value chain from exploration through to finished material, with particular urgency at the midstream processing stage.

India's import dependence: The scale of the challenge

India's import dependence for critical minerals is severe and, in many cases, total. The implications are stark: India's clean-energy hardware supply chain runs through a small number of countries, several of which are themselves facing rising domestic demand or pursuing strategic export restrictions.

Figure 7: India's critical mineral import dependency at a glance

Mineral	Import Share	Primary Sources
Silicon	100%	China, Malaysia, Norway
Lithium	100%	Ireland, Belgium, China
Cobalt	100%	Belgium, China, USA
Nickel	100%	China, Norway, Japan
Rare Earths	~95%	China (dominant)
Graphite	High	Madagascar, China
PGMs	100%	UK, UAE, South Africa

Source: India Mineral Yearbook 2024

Diversification is not a theoretical aspiration; it is a material prerequisite for achieving the 500 GW and net-zero targets. Key exposures include 100% import dependency for silicon, lithium, cobalt, nickel, and PGMs, and approximately 95% dependency on China for rare earth elements.

From dependency to leadership: Six strategic interventions

This analysis identifies six interventions that, taken together, would substantially de-risk India's critical-mineral supply chain and unlock the physical preconditions for achieving its clean-energy targets.

Figure 8: Six strategic interventions for India's critical minerals security

1. Exploration data quality

Move mineral blocks from G4 to G2/G1 bankable status. Fund analytical labs and trained mineralogists.

2. Pilot and demo facilities

Co-invest in in-country pilot plants for Indian ore processing. Make large-capital investment decisions bankable.

3. Extend policy incentives

PLI & capital subsidies for refining, beneficiation, and anode/cathode material production.

4. Single-window clearance

Mandate 5-year timelines. Create dedicated critical minerals approval authority.

5. Diversify tech partnerships

G2G and industry deals with Europe, Australia, Japan. Reduce single-supplier risk.

6. Formalise recycling

Reduce GST on battery scrap. Strengthen EPR audits. Incentivise black-mass processing ecosystem.

Detailed intervention notes

1. **Advance Exploration Data Quality:** Accelerate public funding to move mineral blocks from G4 (preliminary) to G2/G1 (bankable) status before auction and establish dedicated analytical laboratories with trained mineralogists. Without investment-grade geological data, private capital will not commit to domestic mining.
2. **Build Pilot and Demonstration Facilities:** Co-invest in in-country pilot plants for processing Indian ores. Bench-scale results are the only credible tool for making large-capital investment decisions bankable and for proving Indian ore grades can be processed economically.
3. **Extend Policy Incentives to Midstream:** Create PLI and capital-subsidy schemes that explicitly cover refining, beneficiation, and anode/cathode material production—not only cell assembly. The current policy architecture leaves the value chain's weakest link—midstream processing—without adequate support.
4. **Establish Single-Window Regulatory Clearance:** Reform the composite-licence-to-mining-lease pathway, mandate realistic 5 year timelines, and create a dedicated critical-minerals approval authority. Regulatory complexity is among the most cited deterrents for private-sector participation.

5. **Diversify Technology Partnerships:** Catalyse government-to-government and industry partnerships with European, Australian, and Japanese technology providers. Reducing dependency on any single supplier nation—particularly for processing technology—is essential for supply-chain resilience.
6. **Formalise the Recycling Ecosystem:** Reduce GST on battery scrap, strengthen Extended Producer Responsibility audits, and incentivise black-mass processing. Urban mining will become an increasingly important secondary supply source as India's first generation of EV batteries and solar panels reaches end-of-life.

Conclusions and inferences

The overarching inference from this analysis is that India's clean-energy transition and its critical-mineral strategy are inseparable. The country's climate commitments, industrial-policy ambitions under Make in India, and national-security interests all converge on the same imperative: building a sovereign, diversified, and technologically capable critical-minerals ecosystem.

Several specific conclusions emerge:

- India's progress on headline renewable-capacity targets has been impressive but the mineral supply chain underlying those targets is fragile, concentrated, and almost entirely import-dependent.
- The National Critical Minerals Mission provides a strong institutional and fiscal foundation, but its impact will depend on execution speed and on extending incentives into the underdeveloped midstream processing segment.
- Technology choices matter enormously: The mineral intensity of India's transition can be managed through deliberate selection of lower-intensity pathways (alkaline over PEM electrolysers, LFP over NMC batteries, crystalline-silicon over III–V solar) where performance trade-offs are acceptable.
- Global supply-chain concentration is a structural vulnerability that no single country can resolve alone; India must pursue bilateral resource partnerships, overseas asset acquisitions, and recycling in parallel.

Advisory and consulting organisations with deep energy-sector expertise can play a catalytic role in bridging the gap between policy intent and on-ground execution—through value-chain diagnostics, technology and capability assessments, investor landscape mapping, integrated asset due diligence, market intelligence, and risk-mitigation frameworks.

> "The critical-minerals challenge is the next frontier. Answering it in the affirmative will require the same urgency and scale of investment India has already demonstrated in deploying renewable capacity."

How ICF can support

ICF brings a unique combination of energy-sector depth, analytical rigour, and on-ground implementation experience to support India’s critical minerals agenda across the following service areas:

Service area	What ICF delivers
Value Chain Diagnostics	End-to-end mapping of supply chains to identify structural gaps, midstream bottlenecks, and import dependencies.
Technology and Capability Assessment	Evaluate local capabilities vs. global standards to spot gaps and suggest technology transfer, partnerships, and skill-building solutions.
Policy Design and Roadmapping	Develop actionable, time-bound strategies and targeted policy and incentive frameworks to strengthen domestic ecosystems.
Investor Landscape and Market Activation	Benchmark global investor expectations across incentives and ESG frameworks to enhance investment attractiveness.
Integrated Asset Due Diligence	Technical, financial, and ESG assessment of mining, processing, and manufacturing assets.
Market Intelligence and Strategic Monitoring	Track global prices, deal activity, policy changes, and technology trends to inform decisions.
Risk Assessment and Mitigation	Identify key geopolitical and operational risks, with actionable mitigation strategies.

Sources and references

IEA – The Role of Critical Minerals in Clean Energy Transitions (2023)

NITI Aayog – Critical Minerals Required for India's Net Zero Transition

Ministry of Mines, Government of India – Critical Minerals List (2023); India Mineral Yearbook 2024

Press Information Bureau – National Critical Minerals Mission (2025)

IEA – India CO_2 Emissions Report (2023)

©ICF

To find out more, contact:

Puneet Goel
Puneet.Goel@icf.com

Mayank Saraswat
Mayank.Saraswat@icf.com

icf.com

x.com/ICF
linkedin.com/company/icf-international
facebook.com/ThisIsICF
#thisisicf

ICF is a leading global solutions and technology provider. At ICF, business analysts and policy specialists work together with digital strategists, data scientists and creatives. We combine unmatched industry expertise with cutting-edge engagement capabilities to help organizations solve their most complex challenges. Since 1969, public and private sector clients have worked with ICF to navigate change and shape the future. Learn more at **icf.com**.

©ICF