Bharat Cleantech Manufacturing Platform: Upstream Raw Materials and Critical Inputs

Accelerating an Aatmanirbhar, Green and Viksit Bharat

bharat CLIMATE FORUM

Council for International Economic Understanding

Dalberg

As India rapidly moves towards meeting its NDCs, indigenisation of cleantech manufacturing is critical for an *Aatmanirbhar* and *Viksit Bharat*

India has national targets and projections across renewable energy and e-mobility for 2030…

300 GW Solar
installed capacity[1]

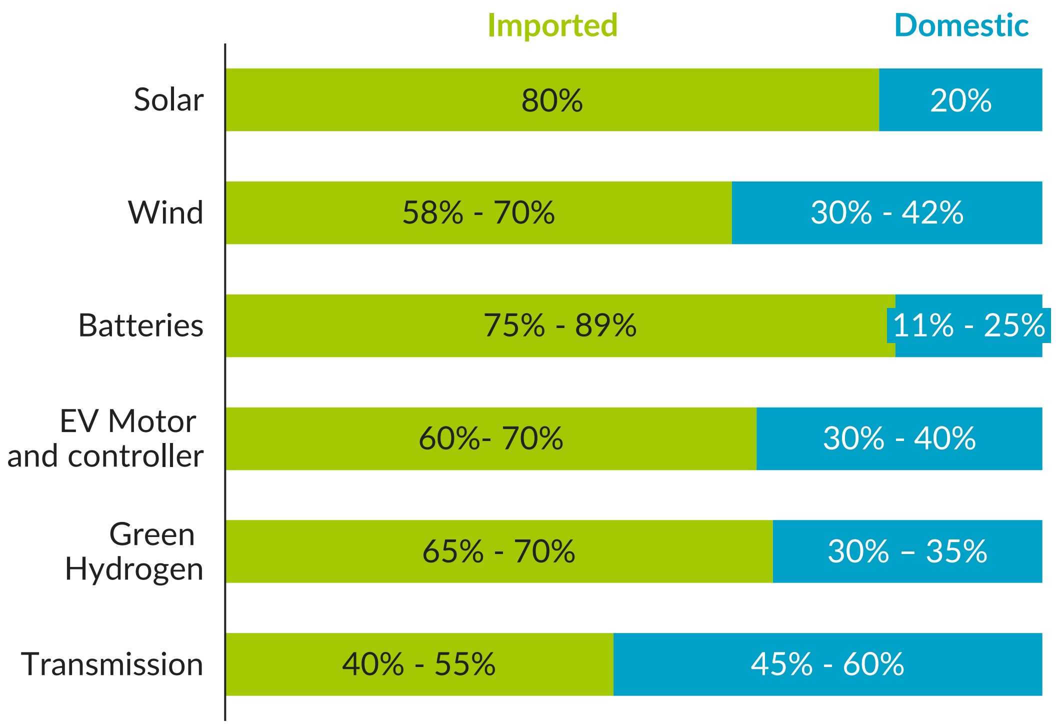
30% EV *sales penetration*[2]

100 GW Wind
installed capacity[3]

5 MTPA Green Hydrogen
production[4]

… but cleantech supply chains are heavily import-dependent and need to be indigenised for an Aatmanirbhar Bharat

Cleantech manufacturing import dependence across the value chain, 2023



Source: (1) MNRE; Solar capacity projection extrapolated from CEA's 2032 Solar capacity projections, assuming linear growth in capacity; (2) NITI Aayog ; (3) ET ; (4) MNRE - NGHM; MNRE, Ministry of Power; Economics Times; BNEF's installed and announced capacity; IEA, India – World Energy Investment 2024 – Analysis; NITI, India's Power Sector | Capacity & Generation Mix; PIB, India's Ethanol Push: A Path to Energy Security, CEEW, Strengthen India's Clean supply chain, 2024; Bain, India Electric Vehicle Report, 2023; Policy circle; Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future

The Platform could support the National Manufacturing Mission to target at least 50% indigenisation of cleantech manufacturing value chains by 2030 enabling net-zero ambition with indigenous production

The Platform's potential to accelerate development of incremental indigenous capacity can be observed across sectors

Sector-wise goals

	Solar	Wind	BESS	E-mobility	Green Hydrogen	Transmission
Installed capacity						
2030 targets	300 GW[1]	100 GW[2]	230-240 GWh[3]	30@30[4]	5 MTPA[6]	648,190[7] ckm
% value chain indigenisation*						
Current levels (est.)	~20%	~35%	~20%	~35%[5]	~35%	~55%
2030 target (Proposed)	~50%	~60%	~45%	~50%	~60%	~70%

May decline due to shifting and unstable demand of domestic components amid intensified global competition

Note: *Indigenisation is domestic value contribution across cleantech value chain from raw materials to end production for all components; : (1) MNRE; (2) ET; (3) Estimated requirements under National Electricity Plan (NEP) 2023 of CEA; (4) NITI Aayog ; (5) For EV Motors and controllers; (6) MNRE - NGHM (7) 2032 target from National Electricity Plan Volume II – Transmission of CEA

Source: MNRE, Ministry of Power; Economics Times; BNEF's installed and announced capacity; IEA, India – World Energy Investment 2024 – Analysis; NITI, India's Power Sector | Capacity & Generation Mix; PIB, India's Ethanol Push: A Path to Energy Security, NEP 2023 of CEA; EV Reporter, India's electric vehicle supply chain landscape | An overview, 2024

A detailed strategy and action plan for the focus sectors would be developed to achieve these goals and objectives and build the cleantech indigenisation pathways for these sectors

Sector-wise gaps would be identified and addressed with all stakeholders across each cross-cutting theme in alignment with the National Manufacturing Mission

Enablers:
Policy recommendations; Trade partnerships; Public and private stakeholder recommendations; Demand and supply drivers; Leveraging AI for Climate and cleantech manufacturing

Sectors

Solar | Wind | BESS | E-mobility | Green Hydrogen | Transmission

Cross-cutting themes

Demand & Market Architecture	*Drive demand and adoption of output, incl.* ***Quality Control Orders (QCOs)***	
R&D & Product Innovation	*Drive technology sharing, adoption and indigenous R&D*	
Upstream Raw Materials & Critical Inputs	*Streamline raw material sourcing (e.g. critical rare earth elements; bio-energy feedstock etc.)*	*Detailed ahead*
Capital Equipment & Infrastructure	*Address machinery sourcing & infrastructure requirements (e.g., grid connectivity)*	
Talent & Workforce	*Bridge skilling gaps for specialised and non-specialised workforce*	
Financing & Taxation	*Identify financial instruments and mechanisms to reduce the funding gap* *Identify levers to improve* ***Ease of Doing Business*** *to attract investments*	

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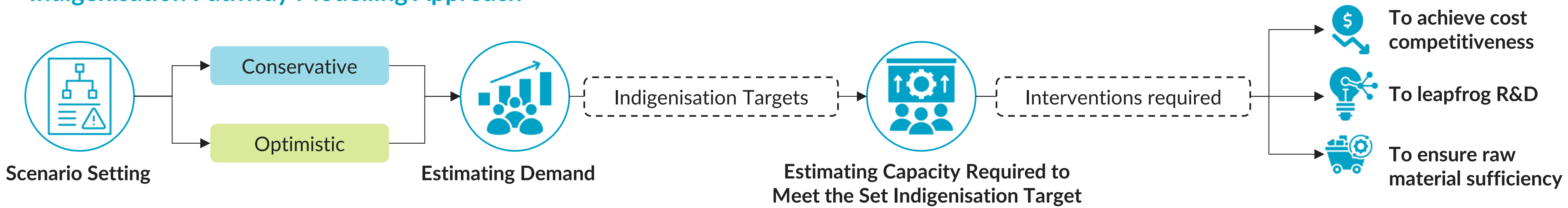
SECTION ONE

UPSTREAM INDIGENISATION PATHWAYS

The cleantech indigenisation pathways have been built on two demand scenarios – conservative and optimistic – to identify potential pathways and key enablers to achieve sectoral indigenisation targets (1/2)

Indigenisation Pathway Modelling Approach

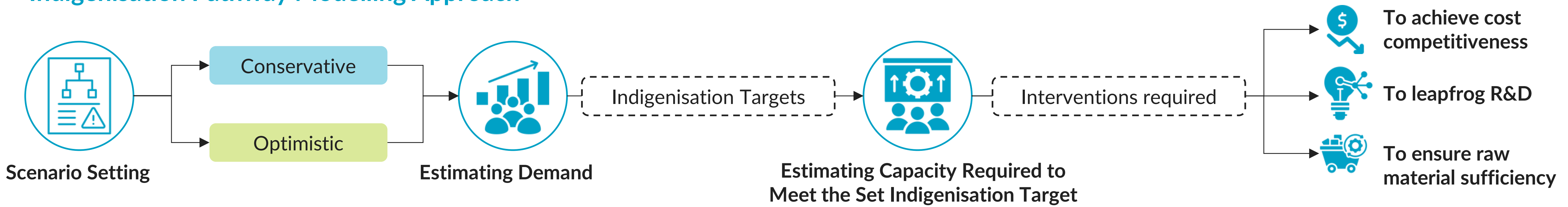


Scenario criteria	CONSERVATIVE SCENARIO			OPTIMISTIC SCENARIO		
	Solar	Wind	Battery	Solar	Wind	Battery
1 Government policy landscape		Upswing in tender activity, top states to meet RAP targets	Extension of ACC PLI and support for implementation		All states meet RAP targets; augmentation of grid at current pace	Extended support to battery manufacturers across value chain
2 Adoption Trajectory	Solar & hybrids meet **70%** of green H_2 energy demand **50%** off-grid & C&I adopt domestic modules	C&I levels expected to increase from current levels	**40 GWh** BESS by 2030 + additional for grid stability; **EV 30@30** to be achieved	Solar & hybrids meet **100%** of green H_2 energy demand **70%** of off-grid & C&I adopt domestic modules	Corporate shift to hybrid power accelerates to meet RE100 by 2030	Coverage of all additional VRE under 2-hour BESS; adoption of E2W/E3W beyond 30@30 goals
3 Export growth	**Africa**: Offer credit to 4 countries on use of Indian modules **US**: Deployment grows at 8% CAGR	**US/Europe/ME & Africa**: Existing share of 15% in global exports to these countries to be maintained		**Africa**: Offer credit to all countries on use of Indian modules **US**: Deployment grows at 10% CAGR	**US/Europe**: Existing share of 15% in global exports to be maintained **ME & Africa**: Increase in total share considered	

Source: MNRE, Physical progress; MNRE, Press release; : ISA, India EXIM bank ; PV Magazine, Industry experts (industry associations; Source: GWEC, Global Wind Report, 2025 report; Ministry of Heavy Industries, PM E-Drive Portal; CEA, National Electricity Plan Vol I; Company announcements; Industry experts; mec+ analysis; Dalberg analysis

The cleantech indigenisation pathways have been built on two demand scenarios – conservative and optimistic – to identify potential pathways and key enablers to achieve sectoral indigenisation targets (2/2)

Indigenisation Pathway Modelling Approach



Scenario criteria	CONSERVATIVE SCENARIO		OPTIMISTIC SCENARIO		
	E-mobility	Green Hydrogen	E-mobility	Green Hydrogen	Transmission
1 Government policy landscape	No additional subsidies on EVs beyond existing subsidies under PM E-DRIVE		Extension of subsidy schemes beyond 2026, especially for 2W, 3W, Bus and Trucks		*Demand for Transmission sector is **primarily government driven** and estimated to reach **6.5 lakh ckm by 2032***
2 Adoption Trajectory	Limited TCO[1] and product innovation – overall penetration[2] across vehicle segments expected to reach ~32% by 2030	Fertilizer sector – corresponds to tendered green ammonia capacity Refinery sector – 5% to 15% green H_2 blending in 2027-2030 for refiners with >50KTPA H2 consumption	Charging infra scale up, product innovation and financing mechanisms could enable ~48% penetration by 2030	Fertilizer sector - 100% import substitution of ammonia from 2027 Refinery sector – 5% to 30% green H_2 blending in 2027-2030 for refiners with >50KTPA H2 consumption	
3 Export growth		**EU, Japan, Singapore, South Korea, UK**: India could capture 10% of this market by 2030		**EU, Japan, Singapore, South Korea, UK**: India could capture 20% of this market	

(1) Total Cost of Ownership; (2) Penetration refers to % share of EVs in total annual vehicle sales; Sources: VAHAN Dashboard ; RMI, Niti Ayog, Harnessing Green Hydrogen, 2022; SECI, Clarification for setting up Production facilities for Green Hydrogen under SIGHT scheme, 2024; Bain, RMI, From Promise to Purchase: Unlocking India's Green Hydrogen Demand, 2025; MoP CEA, National Electricity Plan, Volume II – Transmission, 2024; Company announcements; Industry experts; Dalberg analysis

India could explore interventions in domestic refining capacity, circularity infrastructure and import diversification to streamline raw material sourcing for domestic cleantech manufacturing

Domestic mineral refining, Circularity and Import diversification are 3 key pathways for raw material sourcing that should be explored parallelly

Pathways for reducing India's critical mineral import dependance in the cleantech value chain

Sources of minerals and metals

	Description	Key Insights
A *Domestic mineral refining*	Establish **domestic refining capacities** and simultaneously develop global and domestic critical mineral deposits	• **Long lead time (~10 years)** for commercial-scale **domestic extraction**, output still needing refining • Domestic mineral refining capacities can **leverage overseas mining agreements** to source unrefined minerals till domestic mining comes online
B *Scaling circularity*	Enable metal recovery from end-of-life cleantech applications through **closed loop recycling**	• Parallel interventions would be required across **waste collection, refurbishment and recycling** • Critical to focus on **mineral recovery** beyond waste processing, to **meet demand for virgin minerals** • Enable **renewable-powered refining parks** with **zero-waste, circularity-by-design standards**
C *Stockpiling*	Develop a **strategic national mineral stockpile** for reliable access to critical raw materials	• Explore **stockpiling measures** to protect domestic manufacturers from price volatility and global supply shocks
D *Diversifying import partners*	Secure supply of raw materials by **partnering with alternate suppliers**	• **Identifying** other **potential import partners** to reduce dependence on China

All 4 pathways should be explored collectively to secure access to raw materials and reduce import dependence

Parallel efforts across Domestic refining and Circularity pathways can help India achieve atleast 50% self reliance in identified critical raw materials[1] for cleantech manufacturing, supported by a diversified import supply chain

While Circularity and Domestic refining capacity advancements could meet significant mineral demand across sectors by 2030, additional measures such as import diversification and stockpiling could safeguard remaining demand not met domestically

Potential for domestically meeting India's critical minerals demand across cleantech value chains

SOURCES OF MINERALS

	SOLAR	WIND	BATTERIES	E-MOBILITY	GREEN HYDROGEN	TRANSMISSION
	Potential kTPA[1] by 2030, (% of mineral demand)	Potential by 2030	Potential kTPA by 2030, (% of mineral demand)	Potential kTPA by 2030, (% of mineral demand)	Potential by 2030	Potential TPA by 2032 (% of mineral demand)
A	Total Polysilicon refining capacity required by 2030: **75-90 GW** for **50%** indigenisation	Total Concast S355 steel refining capacity required by 2030: **8 lakh tonne/year**	Targeted refining capacity by 2040: **Graphite:** 752 (80%) **Lithium:** 267 (80%) **Cobalt:** 143 (80%) **Nickel:** 32 (80%)	Total Rare Earth Oxide capacity (across Light and Heavy REO) required by 2030[2]: **8.5-11 kTPA (50-60%)**	Target Nickel, Zirconium and Titanium refining facilities: **Supporting 8-33 GW Electrolyser capacity**	Import copper concentrates because our domestic reserves are limited
B	R&D in early stages, currently low potential for reuse in solar in India	R&D in early stages, currently low potential for reuse in wind in India	**2 kTPA (2%) Lithium, 0.7 kTPA (6%) Nickel, and 3 kTPA (6%) Cobalt** can be recovered through end-of-life battery recycling	**~0.1 kTPA (~1%) REO** by 2030 and **~2 kTPA (~2-6%)** by 2040, can be recovered from EVs and consumer electronics recycling	**20% -50% of Platinum, Iridium and Titanium** required for PEM electrolysers can be recovered through recycling	**~0.16–0.20 lakh t/yr (40–50%) of Copper** required for Transmission sector can be met through recycling
C&D	Additional imports required to **meet polysilicon demand** worth **39-49 GW (76-95 kTPA)** unmet capacity	Additional imports required to meet **balsawood, glass fiber demand** and unmet capacity	Additional imports required to stockpile 25% of 2030 demand: **Graphite:** 60 **Cobalt:** 8 **Lithium:** 22	Additional imports required to stockpile 25% of 2030 demand **2-3.3 kTPA**	Imports required to secure Ni/Ti/Zr[3] ores for domestic refining	**~50–60%** of unmet demand must be bridged through concentrate/cathode imports

(1) Analysis based on one or more factors such as **cost contribution (e.g. Concast Steel)**, **weight (e.g, Copper)**, and/or **critical with import dependence (e.g. CRGO etc.)**; (2) Refers to Rare Earth Concentrate refining into Oxides; (3) Nickel/Titanium/Zirconium ; (4) Kilo Tonne Per Annum;
Sources: Dalberg analysis, Expert consultations

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Tapping this indigenisation potential by increasing domestic refining capacity, scaling circularity and adopting an "India plus many" approach, would need front-loaded investments and efforts pre-2030

Key interventions to reduce India's critical minerals import dependance across cleantech value chains

SOURCES OF MINERALS

A *Domestic mineral refining*

- **Build on recent composite license auctions** for Rare Earths, Graphite, etc., to **conduct additional auctions for domestic critical mineral blocks** to reduce exploration-to-output timelines for mining and refining
- **Double down on acquiring overseas mining assets in mineral rich countries** (e.g., KABIL[1] acquired mining rights in Argentina for Lithium extraction), expand scope to access multiple critical minerals, and facilitate investments in advanced mineral refining and purity enhancement technologies
- **Offer PLI-linked support and targeted fiscal incentives, on similar lines as PLI for Solar Modules[2]**, to accelerate private investment in domestic refining for critical minerals and key materials (e.g., Battery minerals[3], Rare Earth Oxides, Concast Steel for Wind turbines, etc.), and boost competitiveness viz. China

B *Scaling circularity*

- **Build on ₹1,500 Cr Critical Mineral Recycling incentive scheme under National Critical Minerals Mission (NCMM), and integrate dedicated incentives** to facilitate development of recycling and mineral recovery ecosystem for key critical mineral applications (e.g., EV motors, Catalysts and Electronics, Lithium-ion Batteries, etc.)
- **Provide capex investments to develop national waste collection infrastructure for critical mineral circularity** in cleantech, for e.g., creating 150+ battery waste collection and 350-600 vehicle scrappage centers by 2030
- **Scale material recovery systems via capex subsidies, and policy support to ease regulatory requirements**, facilitating recovery of critical minerals such as Rare Earth Oxides for EVs and Green Hydrogen Electrolysers, Battery minerals, PGM[4] for Electrolysers, Copper for transformers, switchgears in Transmission infrastructure, etc.

C&D *Stockpiling & diversifying import partners*

- **Leverage existing G2G[5] partnerships and platforms** (e.g., EU-India Trade and Tech Council), develop new partnerships with key global mineral suppliers (e.g., Australia, Brazil, Japan) to develop a diverse critical minerals supply
- **Leverage ₹500 Cr allocation under the NCMM to establish a strategic stockpiling framework** based on existing domestic (ISPRL) and global stockpiling models (Japan's JOGMEC), to mitigate supply shocks from China

(1) Khanij Bidesh India Ltd; (2) PLI for High Efficiency Solar PV Modules, supports integrated Polysilicon refining; (3) Lithium, Nickel, Cobalt; (4) Platinum Group Metals; (5) Government-to-Government.

A

Domestic Refining | Secure mining and extraction partnerships with mineral-rich nations and scale domestic refining to ensure access to cleantech raw materials by 2030

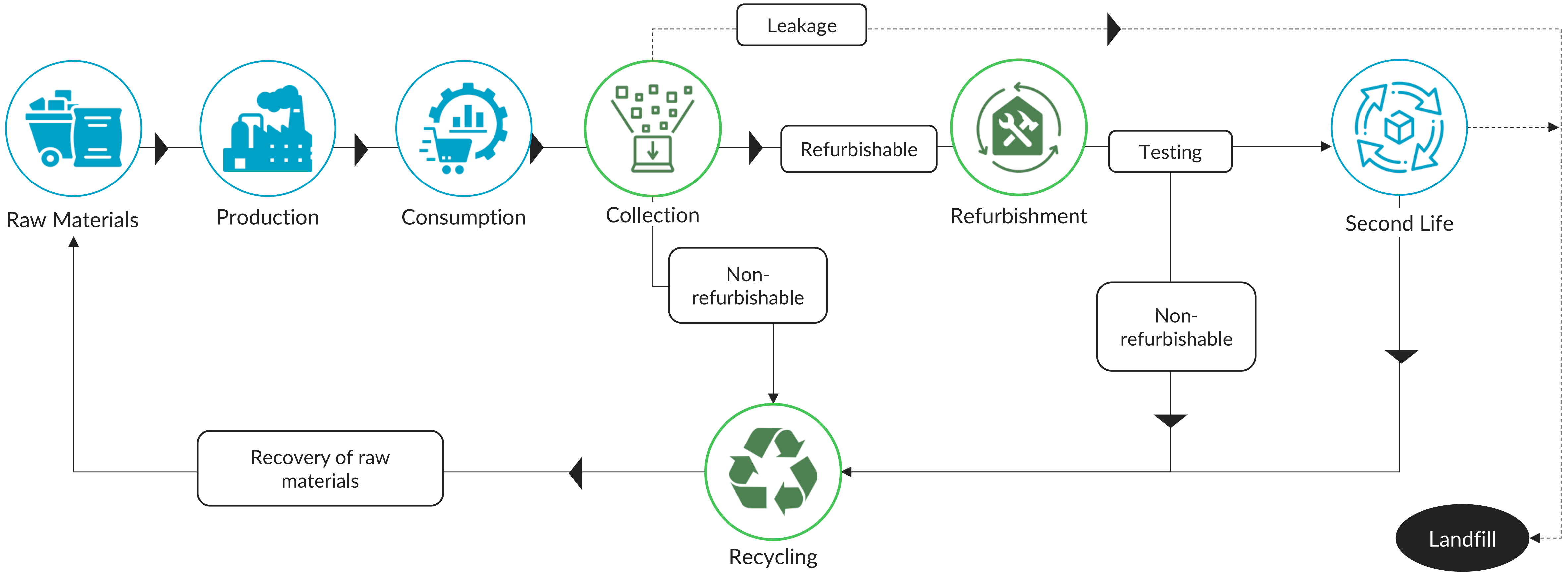
Key interventions to support development and scale-up of domestic refining capacity for select minerals[1] displaying policy tailwinds:

	Minerals	Current Policy/ Situation	Intervention	Investment by 2030
Solar	*Polysilicon*	• MNRE promotes upstream indigenisation of solar PV manufacturing – >80% of PLI outlay targeted at Polysilicon, Wafer, Cell, Module (PWCM)	• Facilitate incremental capex investment for 30-45 GW additional polysilicon refining capacity, over announced 45 GW capacity additions, via 25% capex subsidies and up to 25% interest subvention	**Cumulative Investment:** **INR 18,500 - 34,000 Cr** **Capex and Interest Support:** **INR 7,500-12,500 Cr**
Wind	*Concast Steel*	• India possesses the capability to produce S355 concast steel plates, but low demand and limited scale make domestic supply expensive compared to imported alternatives	• Drive incremental investment for improving existing and developing additional manufacturing facilities by offering 25% of requisite Capex as PLI support	**Cumulative Investment[7]:** **INR 10,000-15,000 Cr** **PLI Support:** **INR 5,000 Cr**
Battery	*Battery Minerals[2]*	• Exploring mining agreements with resource rich countries: E.g., COAL India working on a JV with YPF (Argentina PSU); KABIL[3] acquired mining rights in Argentina for Lithium and partnerships with key players in mineral refining (e.g., Australia) to gain access to overseas refining capacities • China's ~75% control of critical minerals supply lead to potential pricing and supply instability	• Provide 20% upfront capex subsidies & 20% interest subvention from 2026 to 2030 and 30% electricity price subsidy & import duty waiver on raw material inputs in 2030 for 423 kTPA domestic refining capacity for Graphite by 2030 and increase cost competitiveness • Initiate G2G[6] tech transfer partnerships with Japan, South Korea and Australia	**Cumulative Investment[8]:** **INR 75,000 Cr** **Subsidy and policy support:** **INR 16,300 Cr**
E-Mobility	*Rare Earth Oxide (REO)*	• Despite Oxide capacity announcements (by IREL[4] and GMDC[5], India is slated to meet only 26-47% of annual Rare Earth Oxide demand, domestically	• Provide 20% Capex Subsidies to support additional 3-5 kTPA capacity for Heavy and Light REOs to meet at least 50% REO demand domestically by 2030 • Secure low-cost Rare Earth Concentrates, facilitate tech transfer for Heavy REOs (Light REO: Australia, Brazil; Heavy REO: Australia, Myanmar)	**Cumulative Investment:** **INR 750-1,500 Cr** **Capex Subsidies:** **INR 120-260 Cr**

(1) Domestic refining for key Electrolyser minerals (Green Hydrogen) incentivized via interest subvention on capital equipment and has been covered in the Capex and Infrastructure note. Domestic refining facilities for Copper (key Transmission mineral) already exist.; (2) Lithium, Nickel, Cobalt; (3) Khanij Bidesh India Ltd; (4) Indian Rare Earths Ltd; (5) Gujarat Mineral Development Corporation Ltd; (6) Government-to-Government. (7) Concast steel is ~30% of total turbine weight i.e. 100 tonne/MW. PLI considered ~25% of capex to get breakeven in ~8 years, cost for setting up 1 plant of 1 lakh TPA capacity taken as ~INR 1,250 Cr; total 8 lakh TPA capacity required; (8) Upfront capex for Graphite refining only

Circularity | Circularity could hold significant mineral recovery potential for Battery, E-mobility, Green Hydrogen and Transmission sectors

Scaling circularity requires simultaneous efforts across key circularity pillars – collection, refurbishment and recycling, to meet raw material demand through recycling, and minimize wastage



B Circularity | Unlocking this potential would require strategic interventions by 2030, encompassing capex investments and targeted policy support across waste collection, and refurbishment and recycling

	COLLECTION	REFURBISHMENT AND RECYCLING
Battery	• Drive **INR 1,200-1,500 Cr cumulative capex investment** by 2030 to develop **160-180 battery waste collection centers**, enabling high waste collection rates • Integrate battery waste collection with existing and upcoming **Material Recovery Facilities**	• **Facilitate development of second-life battery certification regulations** under ICAT[1] and ARAI[2] to ensure safety and quality of refurbished batteries • **Offer upfront capex subsidies of INR 2,900-3,100 Cr** to support cumulative capex investment for battery refurbishment facilities required till 2040 • **Provide regulatory support** (exception approvals, subsidized land and working capital loans, deferred GST on capital equipment) **and upfront capex subsidies of INR 9,000-9,500 Cr,** for recycling startups meeting certain thresholds • **Extend policy support** (working capital loans) to support recycling scale up
E-Mobility	• INR 14,200-16,500 Cr cumulative capex investment[1] could be required by 2030 to develop **160-180 waste collection** and **~350-600 Vehicle Scrappage Centers**, enabling magnet waste collection from consumer electronics and EVs	• **Boost economic feasibility for recyclers** meeting threshold requirements, via price guarantee measures, 2-year GST deferrals on feedstock • **Scale magnet recycling capacity** by supporting **INR 4,400-4,700 Cr** investment in REO recovery capacity development **via INR 780-840 Cr capex subsidies**
Green Hydrogen		• **Leverage incentive schemes under National Critical Mineral Mission** (NCMM) to prioritize PGM[3] recycling for PEM[4] Electrolysers in India (from spent catalysts and electronics), which has proven recovery rates of 90–95% globally
Transmiss-ion	• Develop an **integrated national copper scrap collection and recycling system** to streamline recovery and boost India's copper recycling rate, which is currently limited by a fragmented setup	• Drive **INR 450-670 crores** capex investment in **copper recycling facilities** via **INR 80-120 crores capex subsidies,** required to meet 80% of copper needs in transmission sector through recycling • **Explore incentivization of private sector investments into recycling** through subsidies (upto 20%) under National Critical Mineral Mission

(1) International Centre for Automotive Technology; (2) Automotive Research Association of India; (3) Platinum Group Metals; (4) Polymer Electrolyte Membrane
Source: Dalberg Analysis

Stockpiling & Import diversification | Given China's dominance in mineral refining, diversification of India's raw material supply chain is critical to secure remaining critical mineral demand (not met domestically)

India could look to diversifying mineral supply chains by partnering with key global mineral refining hubs (e.g., Japan, US)

Potential import partnerships/sources for India

	Key materials	Global refining capacity, %	Potential partners
Solar	Polysilicon	86%, 5%, 5%, 3%	US, EU, Japan, South Korea
Solar	Metallurgical Grade Silicon	80%, 5%, 4%, 9%	Brazil, Norway, Germany
Wind	Balsawood[1]	90%, 10%	Ecuador Peru, Brazil, Papua New Guinea
Wind	Glassfiber[2]	70%, 30%	US, Germany, Japan, South Korea
Green Hydrogen	Molybdenum	45%, 10%, 45%	United States, Cananda, Russia
Green Hydrogen	Nickel	35%, 15%, 8%, 42%	Indonesia, Japan

	Key materials	Global refining capacity, %	Potential partners
E-Mobility	REO[2]	90%, 5%, 0%, 1%, 0%, 4%	US, Canada, Malaysia
Battery	Battery-grade Graphite	96%, 2%, 2%	Japan, US, Canada, Sweden, Germany
Battery	Cobalt Sulphate	78%, 8%, 12%	Finland, Japan, Indonesia, Canada
Battery	Lithium Carbonate	70%, 20%, 5%, 5%	Chile, Argentina, Australia
Transmission	CRGO[3]	23%, 43%, 11%, 23%	Russia, China, Japan
Transmission	Copper	57%, 21%, 11%, 11%	Chile, Australia

China | US | Chile | EU | Norway | Indonesia | Australia | Russia | Japan | Argentina | Finland | Brazil | Equador | Rest of the world

(1) Data limited to Ecuador's share of Global refining capacity; (2) Data limited to China's share of global capacity; (3) Cold Rolled Grain Oriented Steel; Sources: BloombergNEF China extends cleantech dominance over US, 2024; US Department of the Interior, USGS – Mineral Commodity Summaries, 2025; IEA, Global Critical Minerals Outlook, 2025; EIA, ILL Wind, 2024; MDPI, Growth and Yield Models for Balsa Wood Plantations in the Coastal Lowlands of Ecuador, 2019;Volza, CRGO Electrical Steel Exports from the world

Stockpiling & Import diversification | Leveraging existing MoUs with resource rich nations and stockpiling 25% of 2030 REO & Battery Minerals demand could safeguard India's cleantech manufacturing from global supply shocks

C&D

Stockpiling key battery and E-Mobility value chain raw materials could safeguard domestic manufacturing in the near term

Stockpiling
Battery
and
E-Mobility

*Establish national mineral stockpiles to ensure **continued access to minerals** during global supply constraints and **protection of domestic battery and E mobility manufacturing** against global mineral price fluctuation due to lack of domestic extraction and refining capacity*

Focus materials for stockpiling:

- **Battery:** **Battery-grade Graphite**, owing to China's stronghold on global refining (96%), **Cobalt Sulphate** and **Lithium Carbonate** due to lack of both domestic extraction and refining capacity for the minerals
- **E-Mobility:** **Stable** forms of elements, which serve as **raw materials for multiple applications,** and have a **longer shelf life** increasing the timeline for inventory refreshment

Secure 25% of 2030's annual raw material demand :

- **Battery:** Stockpiling targets of **90 kTPA, INR 50-60 Cr upfront capex investment required for developing storage Capacity**
- **E-Mobility:** Stockpiling targets of **2-3.3 kTPA, INR 5-10 Cr** investment required for development of **Rare Earth storage facility**

Leverage either of 2 existing models for stockpiling

- **ISPRL[1] (India)** – PSU-led acquisition of oil resources, government funded storage that is leased to private sector
- **JOGMEC[2] (Japan)** – Government mineral stockpile mandate supported by interest subvention for private sector

Diversifying key raw materials for Transmission could safeguard against global supply shocks and price fluctuations

Diversification
Solar,
Wind. and
Transmission

*Leverage existing and develop new bilateral and multilateral partnerships with key mineral refiners – **Japan**, **Australia**, **South Korea,** to overcome global supply shocks caused by concentration of mineral refining capacity*

Potential import partners, by material:

Silicon Wafers and Polysilicon	Steel and Glass Fibre	Copper	Sulphur Hexafluoride (SF6)
Germany, USA, Japan, South Korea	Japan, South Korea	Chile, Australia, DRC[3]	Russia, USA, Europe

(1) Indian Strategic Petroleum Reserves Limited (2) Japan Organization for Metals and Energy Security; (3) Democratic Republic of Congo

SECTION TWO

ANNEX:
SECTORAL UPSTREAM DEEP DIVES

SECTION TWO, SUB-SECTION A

SOLAR INDIGENISATION PATHWAYS

Increased indigenisation for wafers, cells and modules could lead to cumulative demand of up to **967 kT** of polysilicon between 2025- 2030, 86% of which might need to be imported from China

Polysilicon is currently imported in wafer or cell form, however, with upward integration, this could change. Current imports for raw materials are primarily critical minerals for thin film solar and for module frames and interconnects etc.

Critical minerals nearly entirely imported but not major demand component:

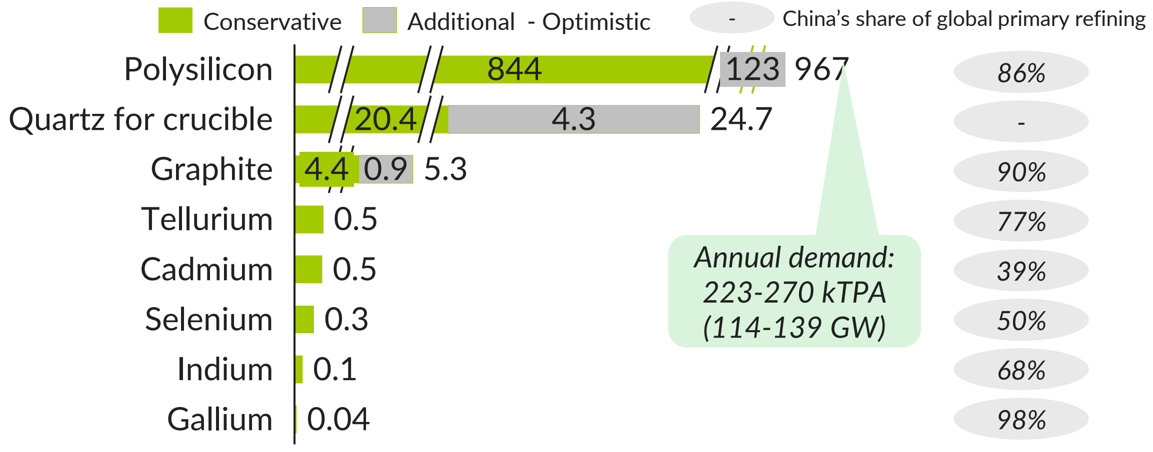
- Primarily used for **thin film modules**, 6-8% of PV demand till 2030
    - Mainly obtained through **co-refining of byproducts** during refining common ores like Bauxite, Copper, Zinc
    - India currently **lacks co-refining capacities** for domestic Bauxite, Copper, Zinc
- Estimated cumulative critical mineral import demand: **INR 507 Cr (USD 59 Mn) till 2030**
- **Import dependance** for **Quartz crucibles** (on China and North Carolina, USA) and **Graphite hot zones** (China, Madagascar, Germany, etc.) expected to continue for ingots, wafers production

Demand for other metals in solar value chain such as Aluminium largely imported despite domestic reserves:

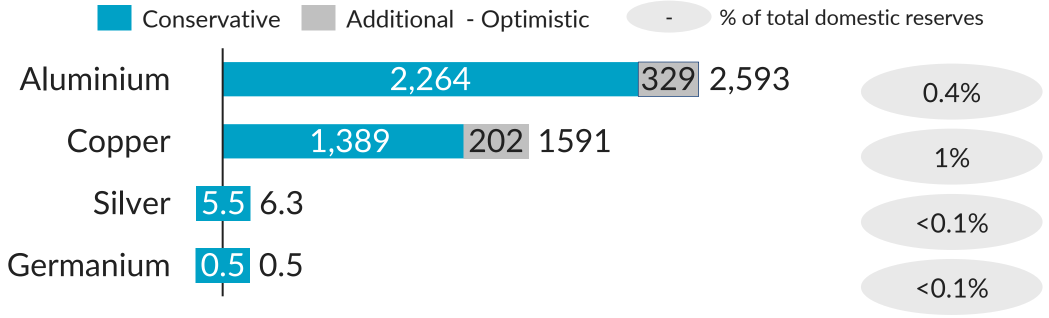
- India has 646 Mn Tons of Bauxite reserves, but **limited capacity for refining required grade of Aluminium** for solar frames leading to high import dependence
- **Silver** is primarily imported as silver paste for **interconnects and busbars** due to no domestic capacity for producing silver paste
- Germanium is primarily used in thin film solar

Cumulative demand 2025-2030, kT

Critical and major minerals in solar value chain



Key Metals in solar value chain



Sources: Polysilicon is obtained from quartz which was recently classified as a Major Mineral by the Ministry of Mines; Press Information Bureau, Ministry of Mines classifies Barytes, Felspar, Mica and Quartz as Major Minerals, 2025; BloombergNEF China extends cleantech dominance over US, 2024; US Department of the Interior, USGS – Mineral Commodity Summaries, 2025; Ministry of Commerce and Industry, Export Import Database; Estimated cumulative import demand based on current costs of imports

Total domestic polysilicon refining capacity of 75-90 GW is needed to achieve 50% indigenisation across solar value chain, requiring incremental investment of INR 18,500-34,000 Cr

Of the three potential pathways to reduce import dependence for polysilicon, two-thirds of the domestic demand could be met by increased domestic refining capacities by 2030

Pathways for reducing India's Polysilicon import dependance in the solar value chain

Sources of minerals and metals

Pathway	2030 Potential	Investment / Enabler
A *Domestic mineral refining capacities*	Total capacity required by 2030: 75-90 GW for 50% indigenisation	Incremental investment for **30-45 GW additional capacity[1]** - INR 18,500 – 34,000 Cr
B *Scaling circularity*	R&D in early stages, currently low potential for reuse in solar in India[2]	*To be estimated*
C *Diversifying import partners*	Additional imports required to meet polysilicon demand worth 39-49 GW (76-95 kTPA) unmet capacity	Leverage bi-lateral, multilateral G2G partnerships with other polysilicon producers - **Germany**, **USA**, **Japan**, **South Korea**

Key insights

- Domestic capacity could meet **two-thirds of 2030 annual** demand for polysilicon (worth 114-139 GW capacity)
- R&D in early stages on **module delamination** and **material purification** technologies to drive closed loop circularity for polysilicon
- The domestic polysilicon refining capacity would still require **imports of 185-222 kTPA metallurgical grade silicon** to meet **75-90 GW** domestic polysilicon capacity from producers such as Brazil, Norway, France, etc

(1) Additional capacity beyond currently announced 45GW capacity; (2) Solar panel recycling machines by Ecoprogetti are being commercialized in EU (Italy, Spain, Greece) and indicate potential for recovering 95% silicon (98.4% purity metallurgical grade), 100% aluminium, 99% of both copper and glass, and 98.5% plastic from solar panels
Sources: BloombergNEF China extends cleantech dominance over US, 2024; US Department of the Interior, USGS – Mineral Commodity Summaries, 2025; Expert consultations and Dalberg Analysis;

A Domestic refining | Strong potential to drive co-evolution of solar and semiconductor industry by setting up 75-90 GW domestic polysilicon refining capacity to achieve 50% indigenisation by 2030

Successful implementation of announced 50 GW of metallurgical grade silicon refining capacity could result in raw-material self sufficiency for 35-45% of polysilicon demand

Potential for domestic polysilicon and metallurgical grade silicon refining

- **Polysilicon:** MNRE promotes upstream indigenisation of solar PV manufacturing: **>80% of PLI outlay** targeted at Polysilicon, Wafer, Cell, Module (PWCM) and Wafer, Cell, Module (WCM) **integrated capacities**
- **Metallurgical grade silicon: 50 GW** (30 GW for raw materials and 20 GW integrated quartz to module) capacity has been announced by Indosol and Reliance Industries

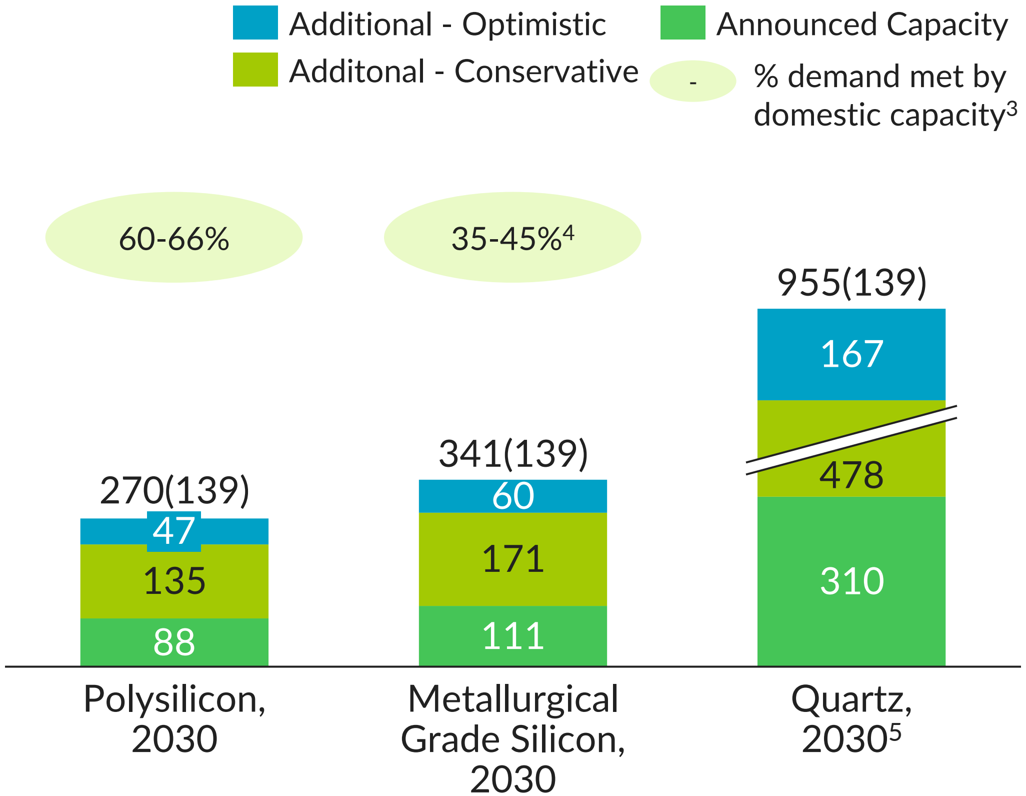
Co-evolution opportunity for polysilicon refining:

- **Rising semiconductor demand** has the potential to add an estimated additional polysilicon demand of **6-7 GW, of 10-12N polysilicon**
- Investing in polysilicon refining of 10N-12N[1] could support raw material sufficiency for both solar and semiconductor industries

Investment required:

- **INR 18,500 - 34,000 Cr** incremental[2] capex investment for 30-45 GW additional polysilicon refining capacity, over announced 45 GW

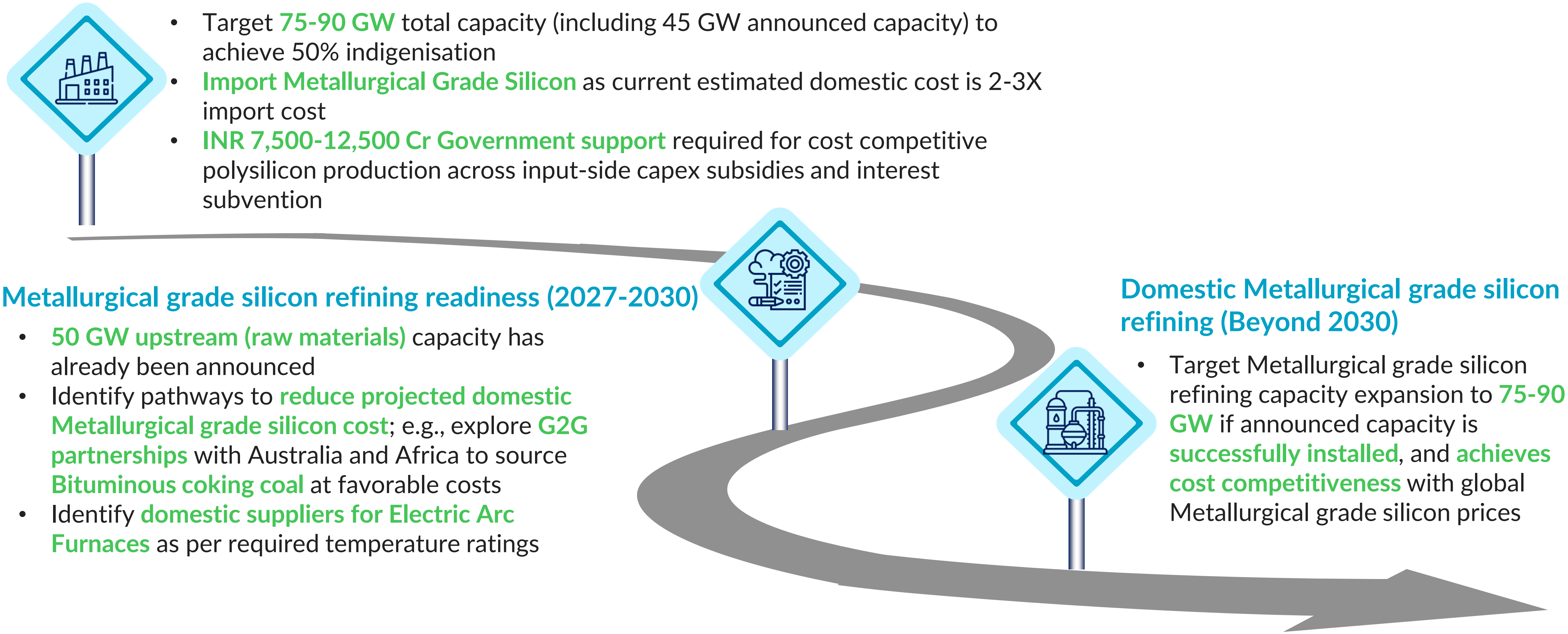
Annual demand for polysilicon, metallurgical grade silicon and quartz, including solar and semiconductor sectors, kTPA (GW)



(1) New solar cell technologies (e.g., TOPCon) require polysilicon purity levels similar to semiconductors (10-12N); (2) Incremental investment over 45 GW announced capacity; (3) Refers to 50 GW of upstream (raw material) capacity and 40 GW integrated module capacity; (4) Assuming announced capacities are implemented; (5) No clarity available on sourcing of Quartz; Source: Ministry of Mines and Indian Bureau of Mines, Indian Minerals Yearbook 2022 Mineral Reviews – Quartz and other Silica Metals; Expert consultations and Dalberg Analysis; IEA, Solar PV Global Supply Chains, 2022; Electronics for you Business, Indosol aims for world's first whole solar module manufacturing, launches plant in Andhra Pradesh, 2024

Domestic refining | Raw-material self-reliance for polysilicon could be achieved post 2030 but is contingent on success of private players in establishing cost competitive domestic metallurgical grade refining

Roadmap for developing a skilled workforce for indigenising cleantech manufacturing



Domestic polysilicon refining (2025-2030)

- Target **75-90 GW** total capacity (including 45 GW announced capacity) to achieve 50% indigenisation
- **Import Metallurgical Grade Silicon** as current estimated domestic cost is 2-3X import cost
- **INR 7,500-12,500 Cr Government support** required for cost competitive polysilicon production across input-side capex subsidies and interest subvention

Metallurgical grade silicon refining readiness (2027-2030)

- **50 GW upstream (raw materials)** capacity has already been announced
- Identify pathways to **reduce projected domestic Metallurgical grade silicon cost**; e.g., explore **G2G partnerships** with Australia and Africa to source **Bituminous coking coal** at favorable costs
- Identify **domestic suppliers for Electric Arc Furnaces** as per required temperature ratings

Domestic Metallurgical grade silicon refining (Beyond 2030)

- Target Metallurgical grade silicon refining capacity expansion to **75-90 GW** if announced capacity is **successfully installed**, and **achieves cost competitiveness** with global Metallurgical grade silicon prices

Source: Electronics for you Business, Indosol aims for world's first whole solar module manufacturing, launches plant in Andhra Pradesh, 2024; Industry announcements, Expert consultations and Dalberg Analysis

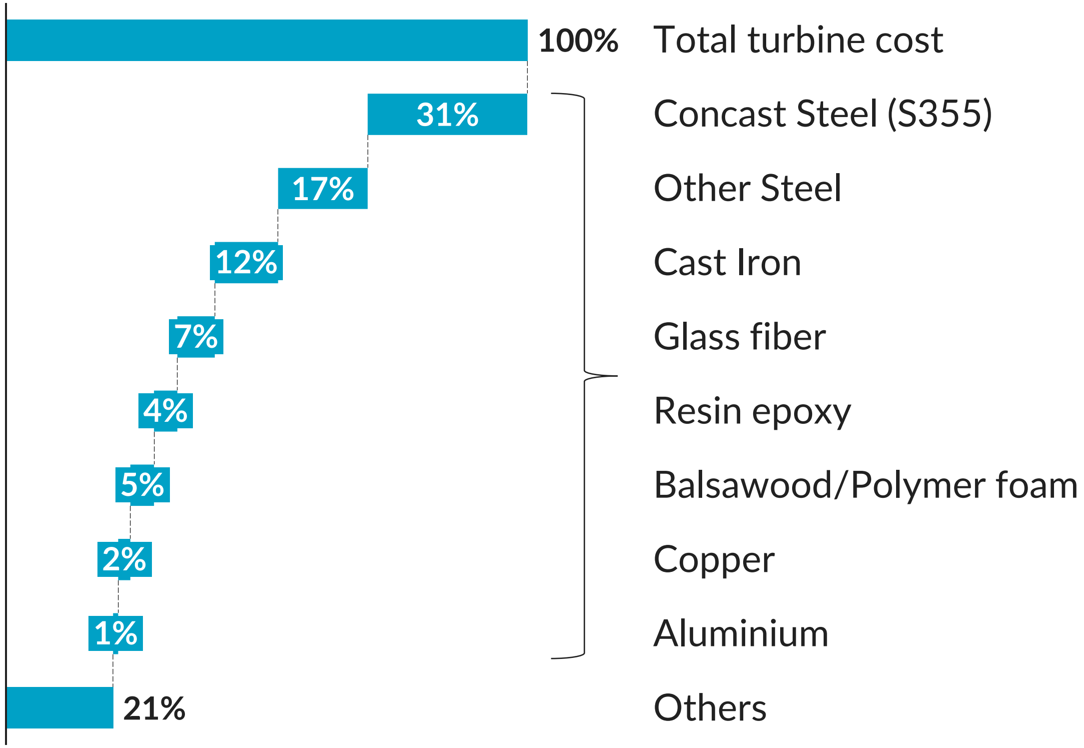
SECTION TWO, SUB-SECTION B

WIND INDIGENISATION PATHWAYS

India imports a large quantity and value of raw materials used in the manufacturing of a WTG, despite having domestic capability to produce some of these, like steel

A wind turbine has following raw materials along with the given value contribution

Raw materials account for ~60–70% of the total cost of a wind turbine in India



Key raw materials like continuous casted steel S355, glass fiber and balsawood are imported in India

Component name	Quantity required till 2030 ('000 t)	Current procurement	Domestic availability	% of total reserves
Continuous casted steel (S355)	5,456	Import	Yes	0.02%
Glass Fiber	727	Import	Yes	NA
Balsawood	273	Import	No	NA
Aluminium	909	Domestic	Yes	0.02%
Copper	136	Domestic	Yes	0.01%

- **India imports large quantities of raw materials like concast steel S355**, despite having domestic reserves, due to their high local cost as limited domestic demand and capabilities with few companies
- India also imports glass fiber due to fluctuating domestic prices and balsawood for blades due to their **unavailability in the domestic market**

India should reduce raw material import dependence by improving S355 steel manufacturing capability through ~INR 2500 Cr production linked incentives (PLI) to bridge capex GAP

Of the three potential pathways to reduce import dependence for S355 steel, two-thirds of the domestic demand could be met by increased domestic manufacturing capacities by 2030

Pathways for reducing India's raw material import dependance in the wind value chain

Sources of minerals and metals

	2030 Potential	Investment / Enabler
Improving S355 steel manufacturing capability	Total concast S355 steel required by 2030: 8 lakh tonne/year[1]	Incremental investment for improving existing and developing additional manufacturing facilities: ~INR 10,000 to 15,000 Cr[3] Total PLI required: ~INR 5,000 Cr[2]
Scaling circularity	R&D in early stages, currently low potential for reuse in wind in India	*To be estimated*
Diversifying import partners	Additional imports required to meet balsawood, glassfiber demand and unmet capacity	Leverage bi-lateral, multilateral G2G partnerships with other Steel producers, Glassfiber producers - **Japan**, **South Korea**

Key insights

- India possesses the capability to produce S355 concast steel plates, but low demand and limited scale make domestic supply expensive compared to imported alternatives
- R&D in early-stage on **recycling and reusing turbine components like tower, shafts, bearings etc.** to enable closed-loop circular use and reduce imports
- The domestic demand would still require some imports for glassfiber, balsawood and some S355 steel till the time its localised

Note: (1) Concast steel is ~30% of total turbine weight i.e. 100 tonne/MW (2) PLI is considered as ~25% of CAPEX requirement in order to get breakeven in ~8 years (3) Cost for setting up 1 plant of 1 lakh tonne annual capacity in India taken as ~1,250 Cr; total 8 lakh tonne/year capacity required

Source: MNRE; Ministry of Power; NREF; EU Commission research; Niti Aayog; IJRET; Material Assessment; Mdpi; KTH institute, Sweden; MEC+ analysis

The government should support S355 steel manufacturing for domestic use & exports through PLI, secure key raw materials via domestic sourcing & strategic imports & invest in steel production infrastructure

Roadmap for self-reliance on concast steel S355

PLI scheme for domestic S355 steel manufacturing (2025-2028)

- Ministry of Steel and MNRE should introduce a targeted **PLI scheme** to support Indian steelmakers in scaling up high-grade S355 steel production and **compete with low-cost imports**
- This initiative aims to **drive investments by steelmakers in S355 concast steel production** which is currently low due to low-cost competitiveness of domestic supply

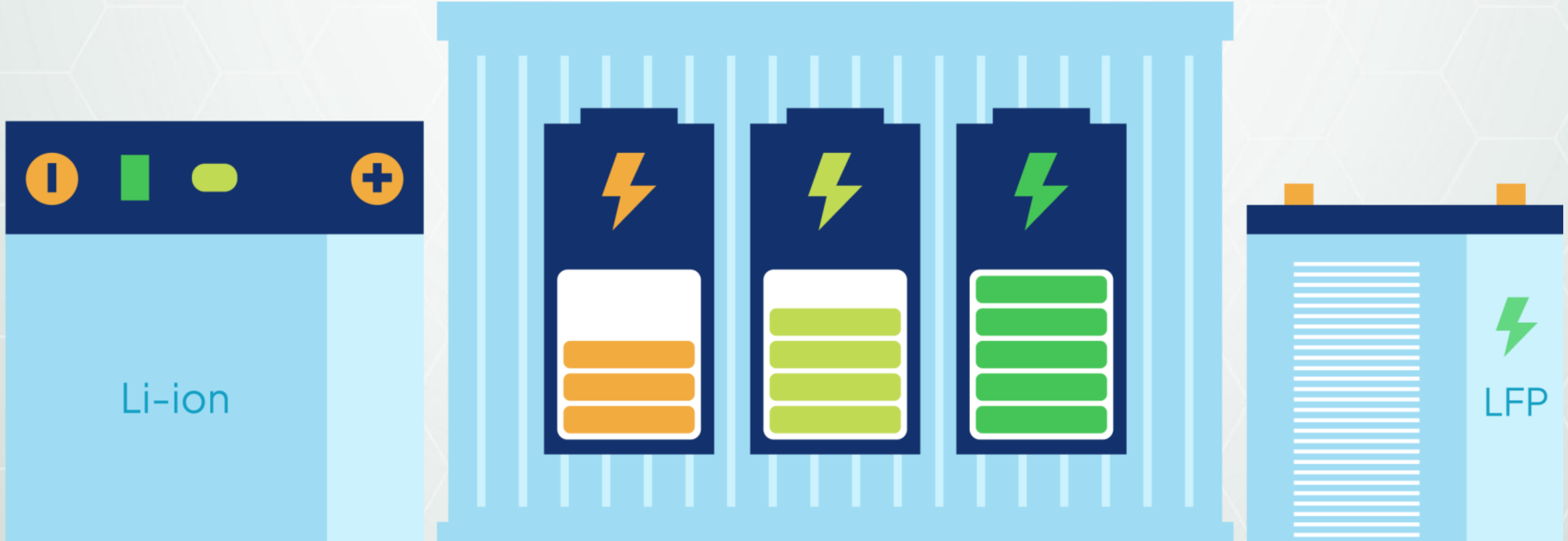
Infrastructure investment for specialized steel production (2028-beyond 2030)

- India currently has limited facilities for S355 production
- **To improve localisation and aim to become steel hub**, India should invest in clean steel technology, rolling capacity and quality testing

Source: MNRE; Ministry of Steel; Niti Aayog; IJRET; MEC+ analysis

SECTION TWO, SUB-SECTION C

BATTERY INDIGENISATION PATHWAYS



India's demand for critical minerals could increase by 10x in 2030 and 35x by 2040 vs. today which could lead to higher over-dependence on China which controls ~75% critical minerals global refining capacity

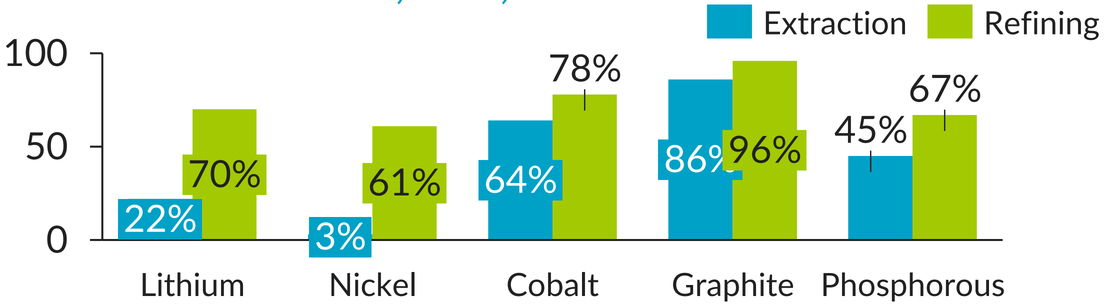
India has already started exploring potential mining agreements to leverage global reserves for Indian consumption; focusing on building domestic refining capacities would be crucial to reduce this over-dependence on China

Longer lead times for extraction and refining commercialization warrant **planning for 2040** requirements or beyond

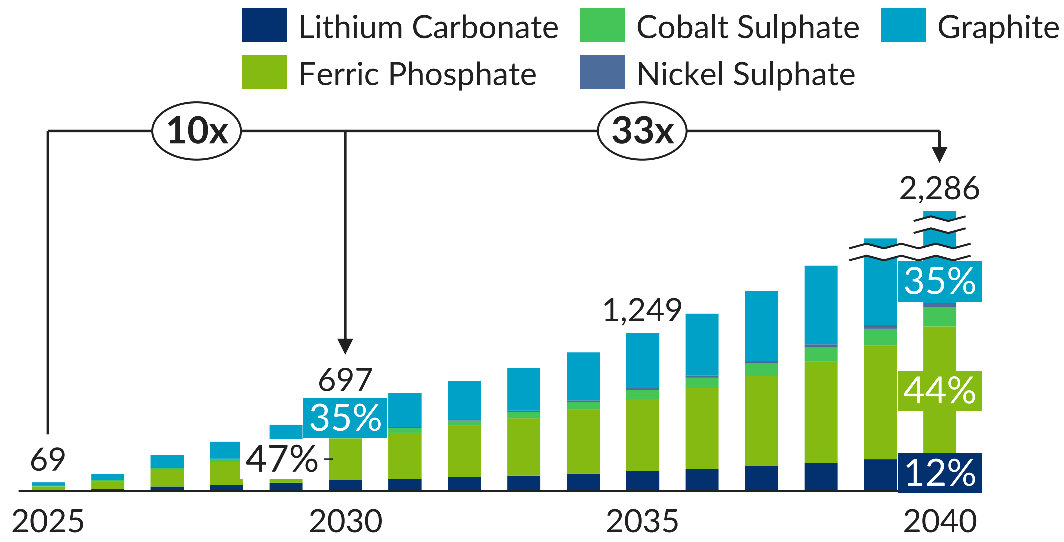
- **China's ~75% control** of critical minerals supply could lead to potential **pricing** and **supply stability challenges**
- **On-shoring trends** observed globally to address this dependence. (e.g., USA, EU, Japan)
- **India's recent efforts**:
  - **Extraction:** Exploring **mining agreements** with resource rich countries: E.g., **COAL India** working on a **JV with YPF (Argentina PSU); KABIL** acquired mining rights in **Argentina** for **Lithium exploration and extraction**
  - **Refining:** Targeting **partnerships** with prominent **players in mineral refining** (e.g., **Australia**) to:
    - Secure access to **overseas refining capacities**
    - **Facilitate technology transfer** with overseas refineries **(e.g., Australia's Tianqi Lithium Energy's refinery)** to foster establishment of domestic refining capacities

Significant acceleration and scaling-up of these efforts would be required to ensure self-reliance and sufficiency for critical minerals

China's share of global extraction and refining capacities for critical minerals, 2024, % kTPA



India's critical minerals demand, 2025-2040, kTPA



Sources: IEA, Global Critical Minerals Outlook, 2025; Reuters, EU picks 13 critical material projects, including in Greenland, 2025; Reuters, US open to minerals partnerships with DRC, 2025; Council on Foreign Relations, China in Africa: March 2025, 2025; USGS, Mineral Commodity Summaries, 2025; Dalberg Analysis

Stockpiling in short term and strategic investments in increasing domestic refining capacity and accelerating circularity in long term could meet ~80% of India's critical mineral demand by 2040 and reduce China dependence

Circularity and domestic refining capacity advancements could meet 85-90% of critical minerals demand for India by 2040 supported by key interventions taking place in 2025

Pathways for reducing India's critical minerals import dependance in battery value chain

SOURCES OF MINERALS

Pathway details	Details	2030 Potential *kTPA (% of demand)*	2040 Potential *kTPA (% of demand)*	Investment Required *INR Cr by 2030*	KEY ENABLERS
1 *Domestic mineral refining*	Global and domestic reserves extraction with domestic refining	Graphite: 752 (80%) Lithium: 267 (80%) Cobalt: 143 (80%) Nickel: 32 (80%)		**~INR 75,000 Cr** (upfront capex for Graphite refining only)	• G2G tech transfer partnerships with **Japan, South Korea and Australia** • Cumulative **~INR 16,300 Cr** electricity and capex subsidies, interest subvention, import duty waiver till **2030**
2 *Scaling circularity*	Closed loop recycling for metal recovery from battery waste	Lithium: 2 (2%) Nickel: 0.7 (6%) Cobalt: 3 (6%)	Lithium: 36 (13%) Nickel: 2 (7%) Cobalt: 10 (7%)	**INR 68,400-72,000 Cr** (cumulative upfront capex for circularity[1])	• Establishment of **160-180 collection centres, INR 1,200-1,500 Cr capex** • Refurbishment to address 2nd-life battery market worth **INR 1,500-1,600 Cr** by **2030** • **Ministry authorization** for recycling infrastructure development
3 *Import diversification & stockpiling*	Stockpiling up to 25% of annual demand for critical minerals	Graphite: 60 Cobalt: 8 Lithium: 22	Graphite: 200 Cobalt: 38 Lithium: 71	**~ INR 7,100 Cr** (including INR 50-60 Cr capex investment)	• Stockpiling targets for **25% of annual demand by 2030 for precursor forms** (e.g., Battery-grade graphite)

(1) Capex investment for circularity includes cumulative upfront capital investment across collection (INR 1,200-1,500 Cr), refurbishment (INR 17,000-18,500 Cr) and recycling (INR 39,000-44,500 Cr)

1 Domestic Refining | Developing domestic mineral refining capacity could unlock long-term self reliance in sourcing battery grade raw materials for domestic consumption and potential exports

China controls 60-96% of global critical mineral refining capacity, however as countries look to diversify their raw material supply, there is an opportunity for India to emerge as a global refining hub for battery grade minerals

Concentration of global supply of refined minerals:

Up to **96%** of global **Battery-grade Graphite refining** capacity is **under China's ownership**

Potential pathway for India:

2025-2030

- **Refining tech-transfer and industry set-up:** Leverage experience in refining industry set up (e.g., **oil and gas, aluminium, iron**) to set up refining capacities for critical minerals.
- Targeted subsidies 2026 onwards to incentivize investment and ensure active refining capacity established by 2030
- **Extraction:** Leverage **existing Graphite extraction** for domestic battery grade graphite refining; Expedite commercialization of overseas mining blocks (e.g., **KABIL**, **COAL** India MOUs / deals)

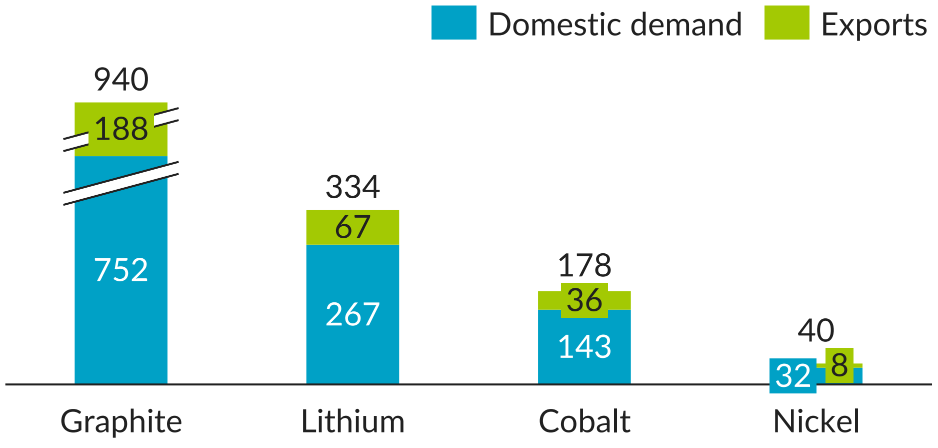
2030-2035

- **Refining:** Infrastructure setup and scale-up of capacities through subsidy support until 2030
- **Domestic exploration** and initiating **extraction**

Beyond 2035

- **Global refining hub for critical minerals** with potential to export refined critical minerals such as battery-grade Graphite worth **USD 980 Mn – 1.27 Bn** annually by leveraging G2G partnerships
- Eg., With US exploring "Country of Origin Clause"; with EU diversifying supply base through China plus one strategy

Domestic refining capacity targets, by 2040, kTPA[1]



Potential feedstock sources for refining, 2040, %

	Graphite	Lithium	Cobalt	Nickel
Overseas mining	77%	92%	48%	56%
Domestic extraction	23%	8%	52%	44%

(1) Assuming 85% capacity utilization based on secondary sources and expert inputs;

Source: The Hindu, Initial findings positive for lithium blocks in Argentina, 2025; Reuters, Indian state firm's seek stake in SQM's Lithium projects in Australia, 2025

1 Domestic Refining | ~INR 16,300 Cr cumulative subsidies on electricity, capex and interest subvention till 2030 could support cost-competitive development of 85 kTPA domestic refining capacity for Graphite by 2030

High-electricity consumption and front-loaded capex investment in refining could lead to high domestic refining costs which would require government support for improved output costs

Key insights

High expected cost of domestically refined graphite driven by:

- High electricity costs (45% of total refining costs)
- High interest and capex costs for front-loaded investment (25% of total refining costs)

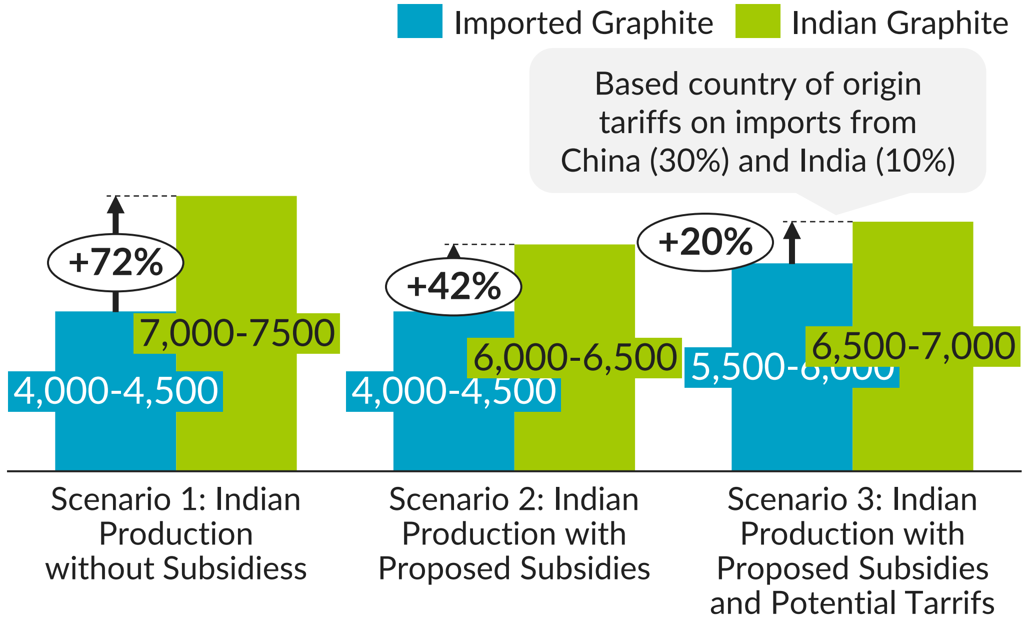
Proposed government support and interventions could reduce costs by 13-17%:

Intervention type	Cumulative Impact (INR Cr)
Upfront capex subsidy of **20%** from 2026 to 2030	~14,900
Interest subvention of **20%** from 2026 to 2030	~680
Electricity price subsidy of **30%** in 2030	~670
Import duty waiver on raw material inputs in 2030	~20

Potential pathways

Mineral prioritization	Initially develop **capacities for Graphite** (96% global capacity under China) and scale to Lithium, Nickel and Cobalt
Phased-capacity scaling	Support development of **initial capacity across minerals,** gradually scale to meet 2040 targets

Comparison of landed cost of imported and Indian battery grade Graphite cost, USD/MT, ex-GST



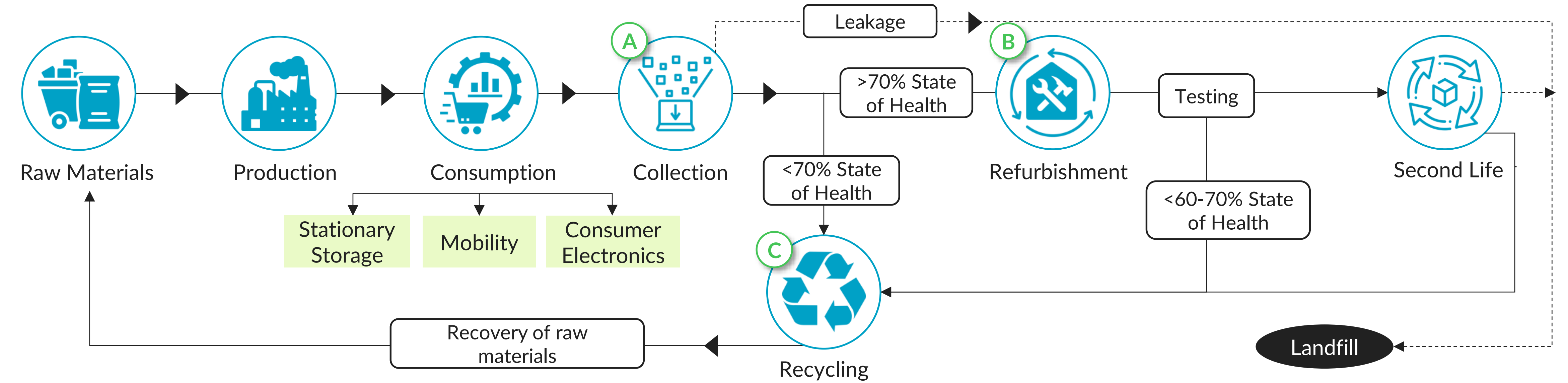
Required cumulative capex investment to begin development of **423 kTPA Graphite refining capacity** by 2030[1]: **INR 75,000 Cr**

Cumulative targeted subsidies on electricity, capex, interest subvention and import waiver till 2030: **INR 16,300 Cr**

(1) Expected to come online by 2034-2035; Source: Dalberg analysis, expert consultations

Circularity | Beyond EPR mandated battery collection targets, scaling circularity potential requires policy interventions across collection, refurbishment (second life applications) and recycling

90-95% Battery waste collection targets by 2040 and interventions across collection, refurbishment and recycling could unlock battery circularity potential – 96 GWh refurbished batteries and 970 kTPA recycled waste by 2040



Potential for waste collection, refurbishment and recycling, kTPA

	Waste collection	Waste refurbishment[1]	Waste recycling
2030	68	13	55
2035	533	221	313
2040	1,738	768	970

Proposed EPR targets on collection, by producer type, %

	BESS suppliers / RE developers (Stationary storage)	Automotive OEMs (Mobility)	Others (Consumer electronics and other e-waste producers)
2030	60-65%	90-95%	25-30%
2035	80-85%	90-95%	40-45%
2040	90-95%	95%	60%

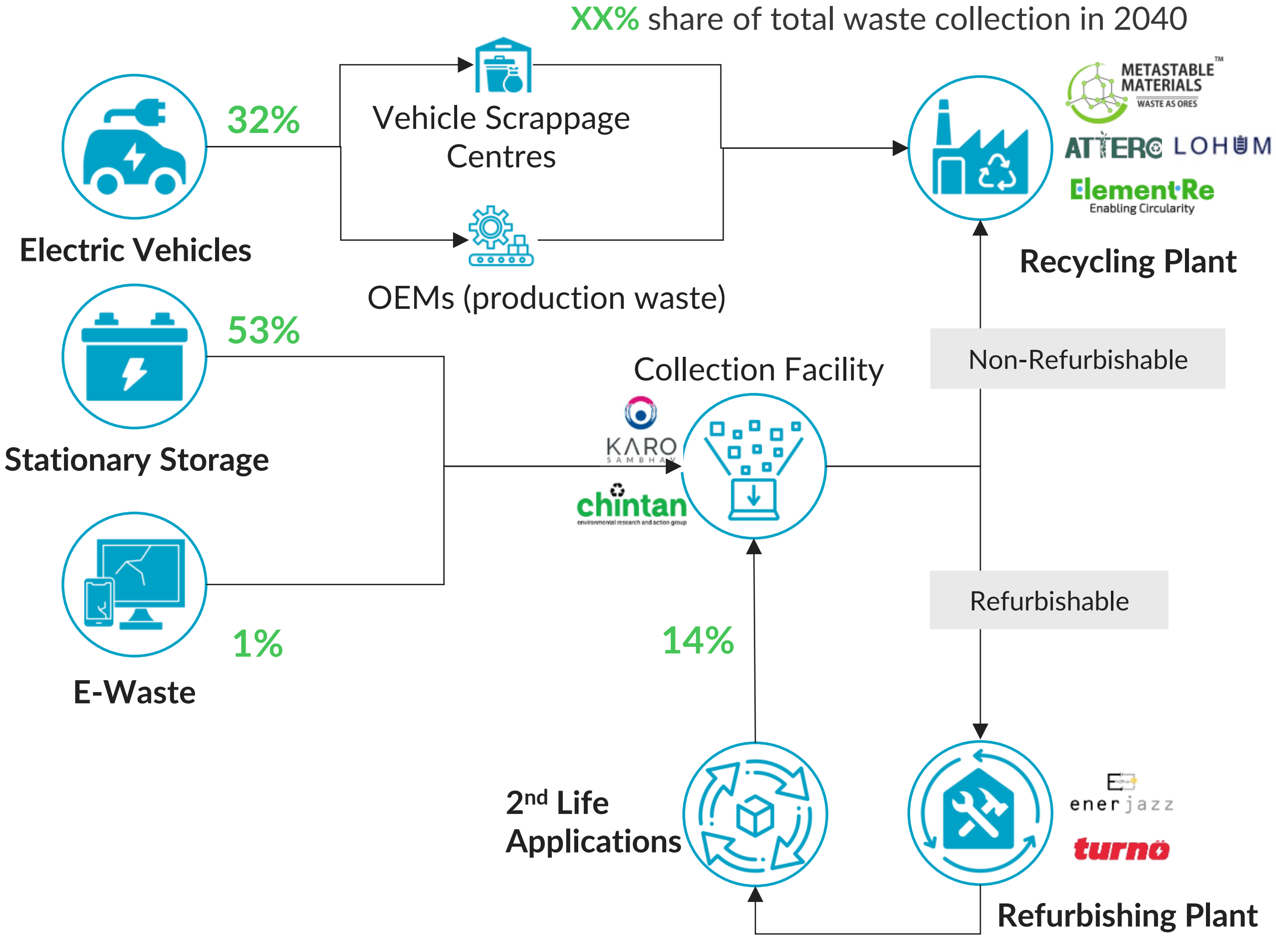
Refurbishment and recycling: *100% of the battery waste collected in each year*

(1) Assuming refurbishment rates of 50% for 4W EV batteries, 15% for 2/3W EV batteries and 70% for stationary storage batteries out of annual waste collection
Source: Dalberg Analysis, expert consultations

2A Collection | Total capital investment of INR 1,200-1,500 Cr in development of 160-180 collection centres could support streamlined collection of battery waste

Achieving high collection rates for end-of-life batteries, especially for stationary storage and e-waste (laptops, cellphones) batteries would require dedicated collection facilities to streamline waste collection

Collection Streams Value Chain



Required investment in collection infrastructure:

	Number of waste collection centres	Cumulative capex investment (INR Cr)
Tier 1 and Metro Cities	30-40	200-400
Tier 2 cities	130-140	1,000-1,100
Total	**160-180**	**1,200-1,500**

Enablers for development of collection infrastructure:

- **Integrate battery waste collection** with **existing and upcoming Material Recovery Facilities** (for e-waste only or multiple waste streams) by equipping them with requisite battery testing, storage and safety equipment
- **Extend Central Share budgetary assistance** under waste management programs such as **Swachh Bharat Mission – Urban 2.0**, to battery waste collection facilities
- Provide **land parcel identification support** and offer land at concessional rates for battery waste collection facilities

(1) Considering 2-4 collection centres for every Tier 1 and Metro city, and 1-2 centres for every Tier 2 city

Sources: Press Information Bureau, Management of Waste, Garbage and Sewage, 2025; Dalberg analysis, Expert consultations

2B

Refurbishment | Second-life battery applications could be scaled by leveraging modified "Battery Passport" regime along with incremental supportive regulations to ensure quality

Annual potential of 96 GWh by 2040 to utilize >70% state of health batteries from mobility and stationary applications for low-cost urban mobility and small buffer storage applications by scaling up refurbishment systems in India

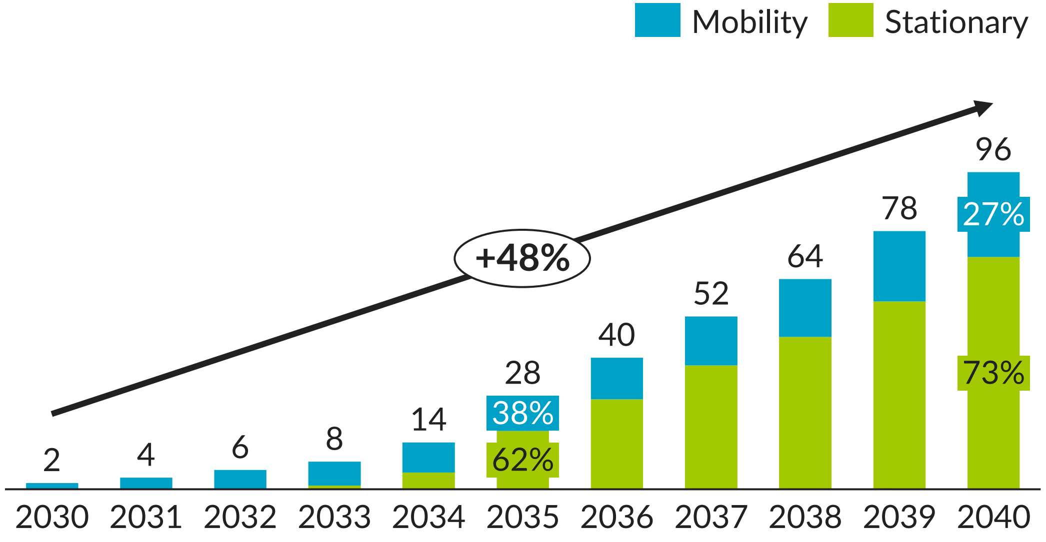
Key benefits of refurbishment for second-life applications:

- Maximum value extraction from materials with extended usage life
- Potential to cater to lower-cost battery demand as second life batteries cost **50-60% less than virgin batteries:**
  - **Mobility:** Last mile urban mobility with e-rickshaws (e3W L3), smaller electric 2-wheelers
  - **Stationary:** Solar street-lamps, storage for rooftop solar applications, buffer storage for EV charging stations

Interventions required:

- **Regulatory: Certification regulations** for second-life batteries developed under **ICAT** and **ARAI**
- **Infrastructure: Upfront capex subsidy** - **INR 2,900 – 3,100 Cr** on cumulative investment required by 2040 to meet annual potential of 96 GWh, disbursed at 20% of capex investment

Projected potential for second-life application of batteries, 2030-2040, GWh



	Annual market potential (INR Cr)[1]	Cumulative investment required (INR Cr)
2030	1,500-1,600	450-560
2040	77,000-81,000	16,200-17,400

(1) Market potential calculated basis current battery pack prices

Sources: Times of India, Centre plans battery passport to boost EV safety, quality and exports, 2025; Dalberg analysis, Expert consultations

2C Recycling | Exception regulatory approvals and financial support at recycling infrastructure setting up stage could catalyse development of 1,200-1,250 kTPA recycling capacity by 2040

Large scale recycling capacity development would require policy interventions (exception approvals and financial subsidies) at the setting-up stage and continued financial support at the scaling-up stage

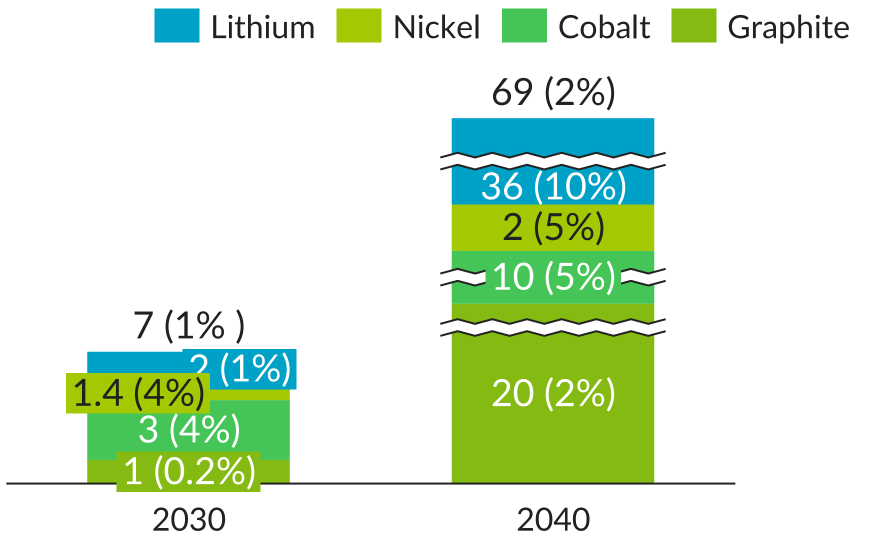
Key challenges in setting up recycling facilities impede a scaled battery recycling ecosystem:

Setting up recycling facilities:

Challenges	Potential Enablers
Long lead times in getting regulatory approvals – CTO, CTE, EC	Authorization by relevant ministry to grant **1-year exception CTO, CTE approvals** for up to 50 recycling startups[1]
High working capital requirements to ensure consistent feedstock supply	•Subsidized working capital loans to support 15 days feedstock inventory •2-year deferral on GST
Securing land as a Red Category Industries	Support on land parcel identification, prioritization in e-waste recycling parks
High upfront capex investment	Upfront subsidies - **INR 9,000-9,500 Cr[2]** for 2040 target capacity; Deferred GST on capital equipment till production

Scaling up recycling facilities: Continued policy support through working capital loans till 2030, gradually phased out by 2035

Projected mineral recovery potential, 2030 and 2040, kTPA (% of critical mineral demand)



	Target capacity (kTPA)[2]	Cumulative Investment required (INR Cr)
2030	90-100	3,900-4,500
2040	1,200-1,250	50,100-53,200

(1) Exception approvals granted by relevant ministry for 1 year, post which due processes on audits and diligence can be carried out to grant permanent certificates; (2) Assuming a capacity utilization factor of 60% by 2030 and 80% by 2040 , to recycle 55 kTPA waste by 2030 and 970 kTPA waste by 2040; (2) Capex subsidies on cumulative capex investment required by 2040, disbursed at 20% of capex investment; Sources: Dalberg analysis, Expert consultations

Stockpiling up to 25% of annual demand for select critical minerals (cathode and anode precursor materials) could ensure supply consistency and protection from price fluctuations for India (1/2)

Presently, India lacks domestic cathode and anode manufacturing capacities but as they develop, mineral stockpiling could safeguard supply of feedstock precursor materials[1] such as Graphite, Cobalt Sulphate and Lithium Carbonate

Key Benefits:

- **Continued access to minerals** during global supply constraints
- **Protection of domestic battery manufacturing ecosystem** against global mineral price fluctuations

Focus materials for stockpiling[2]:

- **Battery-grade Graphite**, owing to China's stronghold on global refining (96%), **Cobalt Sulphate** and **Lithium Carbonate** due to lack of both domestic extraction and refining capacity

Secure 25% of annual demand:

- Establish stockpiling targets of **25% of 2030's annual raw material demand (90 kTPA)**

Leverage either of 2 existing models for stockpiling:

Public-sector led	**ISPRL (India)** - PSU-led acquisition of oil resources, government funded storage infrastructure that can be leased to private sector
Public-private	**JOGMEC (Japan)** - Government mineral stockpile mandate for private sector, supported by interest subvention for private sector

Potential stockpiling partnerships/sources for India

China | US | Chile | Rest of the world | Japan | Argentina | Finland

Key materials	Target stockpile, 2030, kTPA	Value of stockpile (INR Cr)[3]	Global refining capacity, %
Battery-grade Graphite	60	~3600	96%, 2%, 2% — 100%
Cobalt Sulphate	8	~890	78%, 12%, 8% — 100%
Lithium Carbonate	22	~2600	70%, 20%, %, 5% — 100%
TOTAL	**90**	**~7,100**	

Upfront capex investment required
INR 50-60 Cr[3]
for developing **90-100 kTPA** storage capacity

(1) Precursor materials can be stored for long durations without suffering material degradation; (2) Stockpiling refers to the accumulation of raw materials beyond regular demand to ensure uninterrupted access during future supply disruptions or shortages. (3) Storage infrastructure costs for the ISPRL Padur reserve have been considered as a reference to compute mineral storage infrastructure costs; (2) Value computed as per current international metal prices ; Sources: ISPRL, Detailed project report for phase II of strategic storage program for crude oil, 2013

3 Stockpiling up to 25% of annual demand for select critical minerals (cathode and anode precursor materials) could ensure supply consistency and protection from price fluctuations for India (2/2)

Globally, there are 2 stockpiling models that India could draw inspiration from to undertake stockpiling of critical minerals

	Public sector led stockpile	Public-Private Stockpile
Objective	• Strategic (to supply minerals during supply emergencies) and / or economic (to manipulate global mineral prices)	• Strategic (to ensure continued mineral availability during supply challenges)
Key responsible entity	• Appointed government entity	• Individual private sector entities, undertake stockpiling under government mandates and incentives
Source of funds	• Budgetary allocation and excess funds from sale of additional stockpiled resources	• Private sector funds, leverage government incentives (e.g., interest subvention on finance for resource acquisition and storage)
Investment required	• Capital investment in developing resource storage & maintenance infrastructure	• Financial incentives (e.g., interest subvention, capex subsidies for storage infrastructure)
Examples	Indian Strategic Petroleum Reserve (ISPRL), *special purpose vehicle – based stockpile, PSUs fund acquisition of oil resources, government funds storage infrastructure*	JOGMEC Rare Metals Stockpile, *government mandated stockpile maintained by private sector which leverages government incentives on finance required*

Sources: Defense Logistics Agency, About Strategic Minerals; ASPI, China shows how Western governments should stockpile minerals, 2024; IEA, International resource strategy – National Stockpiling System, 2025

SECTION TWO, SUB-SECTION E

E-MOBILITY INDIGENISATION PATHWAYS

Securing supply of and building domestic supply chains for Rare Earth Elements is critical to safeguarding national progress across key strategic sectors such as Cleantech, Space and Defence

Rare Earth Elements (REEs) are critical raw materials[1] for multiple sectors:

- REEs form key raw materials in **EV motors**, **Wind Turbine generators**, **Consumer electronics, space** and **defence sector,** spanning various applications – magnets, catalysts, phosphors, lasers, etc.

REEs are commonly traded as Rare Earth Oxides (REOs):

- REEs occur collectively in ores, but commonly traded as separated oxides (e.g., **Neodymium Oxide**, **Dysprosium Oxide**)
- Further processed into **metals or alloys** for use in **permanent magnets** (e.g., Neodymium-Iron-Boron magnets) **– key components in EV motors, Wind turbine generators**
- **Heavy REOs** are key materials in strategic sectors such (**space** and **defence**), occur less commonly than Light REOs

REO production is processing heavy:

- REO production requires **cost and resource intensive hydrometallurgical processes** (leaching and solvent extraction) to convert feedstock (**Rare Earth Concentrate**) into separated Oxides

Rare Earth Oxide Value Chain

Exploration and Mining
Conventionally use open-pit mining near surface levels to break REE bearing rocks and deposits

REE Concentrate Formation
Beneficiation of ores done through froth-floatation to reduce impurities and form REE Concentrates

Rare Earth Oxide Production
Concentrate separated into Oxides by Leaching and Solvent Extraction with various solvents depending on Concentrate's composition

Processed into metals, alloys, etc., for end use applications

EV Motors | *Wind Turbines* | *Consumer Electronics*

(1) Other critical raw materials for E-mobility include Silicon for semiconductors, which has been covered in the analysis on the Solar sector
Sources: MRS Bulletin, Processing the ores of rare-earth elements, 2022; JOM, Material and energy requirement for Rare Earth production, 2013

Today, global rare earth supply is concentrated in China, which controls 67% of Rare earth extraction and 90% of Oxide capacity globally

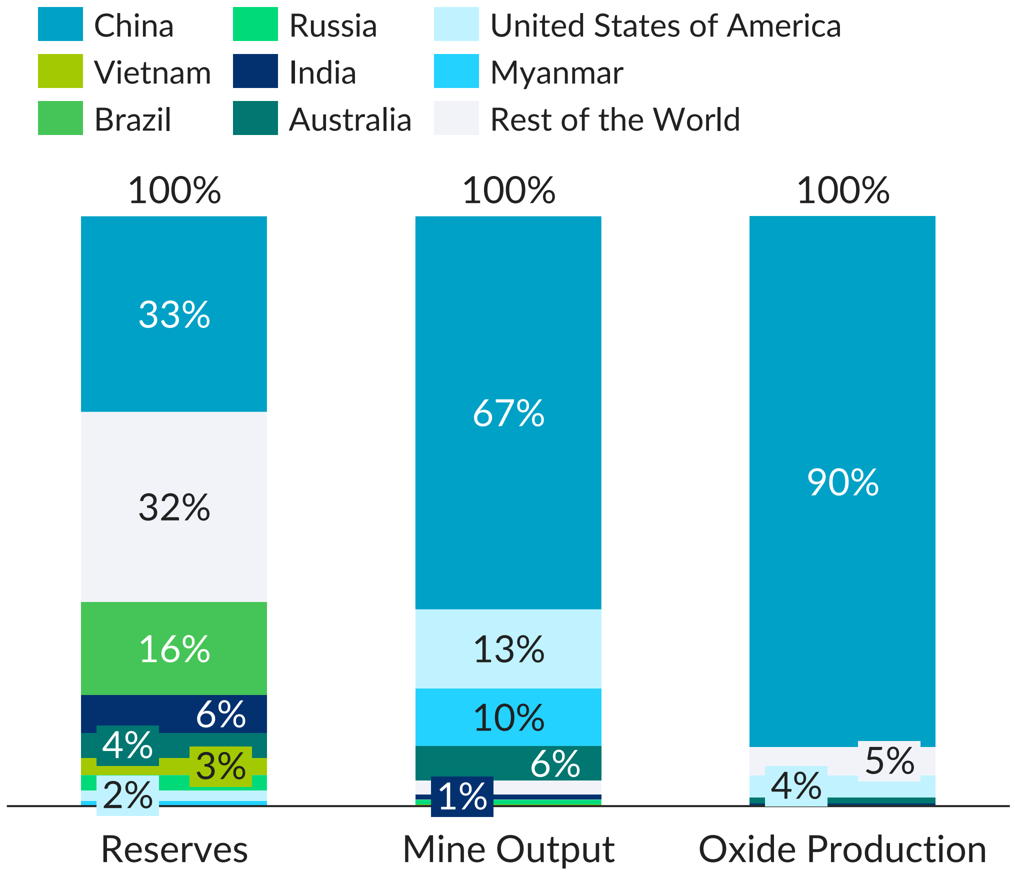
Global Rare Earth Supply is heavily concentrated in China with countries onshoring REO capacities to reduce dependency:

- China has **~33% of global Rare Earth reserves** but accounts for **90% of Oxide production**; dominance to continue as it safeguards supply and invests in new Heavy REO deposits in conflict regions such as **North and East Myanmar**
- **US**, **Canada**, **Malaysia** are **emerging alternative Rare Earth Oxide suppliers** investing in building and scaling oxide production capacity

Despite having significant domestic resources, India has shown limited success in mining them:

- **India** has the 3rd largest REE reserves (**6% of global reserves**) but contributes **less than 1%** to global production
- In FY 25, India imported **~2 kTPA REE Compounds** including Oxides, and **~53 kTPA finished goods (magnets)** – with respectively **60-70%** and **85-90%** of these imports coming from China

Distribution of global rare earths reserves and extraction capacity, % TPA REO equivalent



Sources: Mining.com, China flexes rare earth dominance with million-tonne discovery, 2025; ORF, India's REE Strategy: Turning resources into capacity, 2025; USGS, Mineral Commodity Survey – Rare Earths, 2025; Discovery Alert, Myanmar's Critical Role in China's Rare Earth Dominance, 2025; Investing News Network, Rare Earth Reserves, 2025; Reuters, China backed militia secures control of new rare earth mines in Myanmar, 2025

Currently India has heavy import reliance across finished goods as well as standalone Rare Earth Oxides for use in applications such as EV motors, Wind turbine generators, consumer electronics, etc.

Rare Earth Oxide Demand 2025
4-4.3 kTPA

85% → **Finished Goods: Rare Earth Magnets**

Majority of total REO demand is met entirely through imports of finished Rare Earth Magnets

Magnet manufacturing requires Rare Earth Oxides, thus domestic magnet capacities could unlock demand for REOs

~100%
Import dependence

China · *Belgium* · *Canada*

85-90%** of Rare Earth Magnet Imports come from **China

15% → **Standalone Rare Earth Oxides**

Remaining REO demand is met by a mix of imports and domestic production

50%
Import dependence

China · *Japan* · *South Korea*

50%
Domestic production by IREL

>90%
import reliance faced by India
in sourcing **Rare Earth Oxides**, since significant chunk of India's Oxide demand is **tied up in imports of finished goods such as permanent magnets**

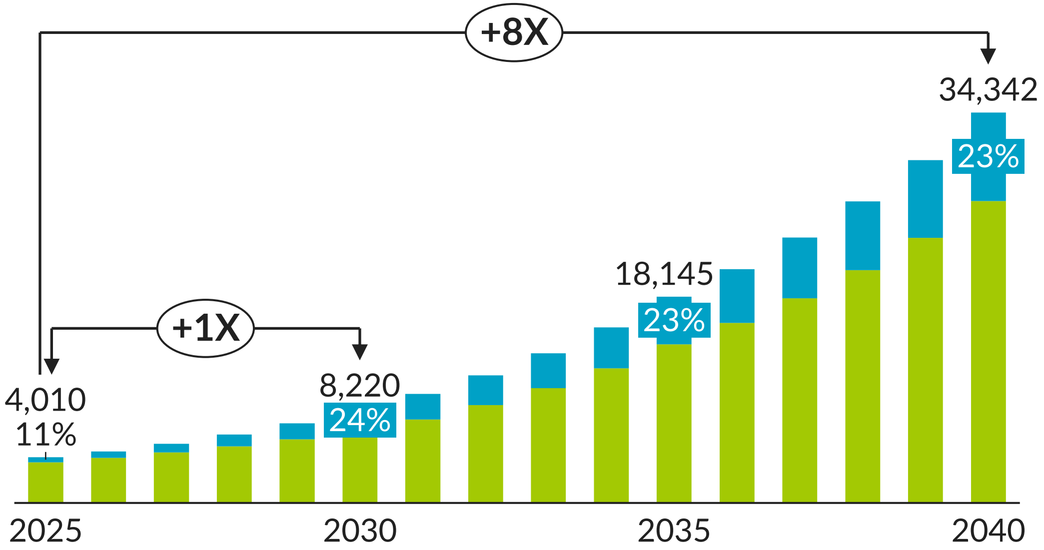
If existing import reliance is not checked, India's rising Rare Earth Oxide demand could risk further increasing import reliance for REOs

Annual Rare Earth demand expected to grow by 1-2X till 2030, 8-18X till 2040, compared to 2025, driven by rising EV penetration and policy tailwinds across other sectors such as offshore wind energy, consumer electronics and defense

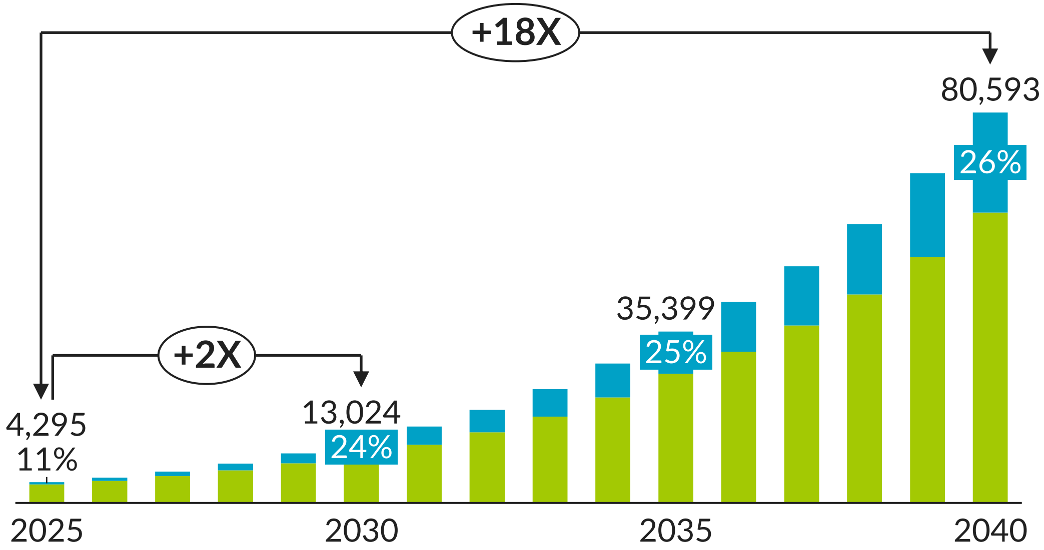
India's aggregate[1] rare earth oxides demand, 2025-2040, TPA

EVs | Other sectors

Conservative Scenario



Optimistic Scenario



Continued ***import dependence*** *for Rare Earth Oxides could result in* ***import bills*** *worth* ***USD 100-160 Mn*** *by* ***2030****, (assuming 90% import reliance)*

Across scenarios, ***95%*** *of EVs are assumed to have* ***Rare Earth Oxide magnets*** *and* ***REO weight*** *is considered to be* ***30%*** *of permanent magnet weight*

(1) Refers to total REO demand including demand represented by finished REO products (rare earth magnets) and REO itself. It is assumed that 15% of total annual EV demand will continue to be met by imports – REO demand for the same has been excluded from this assessment

Conservative Scenario: (1) In 2025, **EVs** assumed to account for **11%** of **total REO demand;** (2) By 2030, rising EV penetration expected to **more than double EVs' share** to **24%;** (3) Beyond 2030, EV share anticipated to grow at a **deaccelerated pace** due to expected **growth in demand from other sectors** (e.g., Offshore Wind)

Optimistic Scenario: (1) **EV penetration** expected to **rise more aggressively** in the optimistic scenario, thus **increasing absolute REO demand** from EVs; (2) REO demand **from other sectors** expected to rise **proportionately to EVs** in the optimistic scenario due to **policy tailwinds** (e.g., VGF scheme for offshore Wind, National Manufacturing Mission to boost consumer electronics production, rising funding for defence sector); (3) Thus **EVs' share** in total REO demand in optimistic scenario **differs minimally** from conservative

India is already focusing on reducing import reliance by facilitating access to overseas Rare Earth mineral resources and incentivizing downstream demand but still faces challenges in catalysing domestic capacities

India is already doubling down on developing Rare Earth extraction and downstream magnet manufacturing...

KABIL exploring **G2G partnerships** with **Australia, Brazil** and **Dominican Republic** for overseas mining

IREL engaging **South Korea** and **Japan** to support technology transfer for and development of **domestic magnet capacity**

Ministry of Heavy Industries working on an **INR 7,350 Cr** PLI scheme to support development of domestic magnet manufacturing capacities

..but continues to face challenges in scaling domestic REO production and recovery capacity

Exploration and extraction projects have **long lead times** (7-10 years), resulting in delayed access to output and limited uptake by private players due to **extended ROI timeline**

While existing domestic capacity and reserves cover Light REO, India lacks **technical capacity** and **access to deposits** for **Heavy REO production** (critical for **defence** and **space** sectors)

Amidst a growing mineral recycling ecosystem, India lacks **technical capacity** for **REO recovery** from end of life **Rare Earth magnet applications**

Sources: Business Standard, Govt to launch INR 7,350 Cr plan to boost production of rare-earth magnets, 2025

Reducing import reliance on REOs from 85-90% to 50% requires simultaneous efforts across domestic extraction and REO capacity development, and scaling magnet circularity to unlock and domestically meet aggregate demand

Investments in scaling domestic extraction and expanding refining and circularity capacity could support meeting up to 50% of India's total REO demand domestically, supported by key interventions taking place between 2025 and 2030

Pathways for reducing India's Rare Earth Elements import dependance

SOURCES OF MINERALS

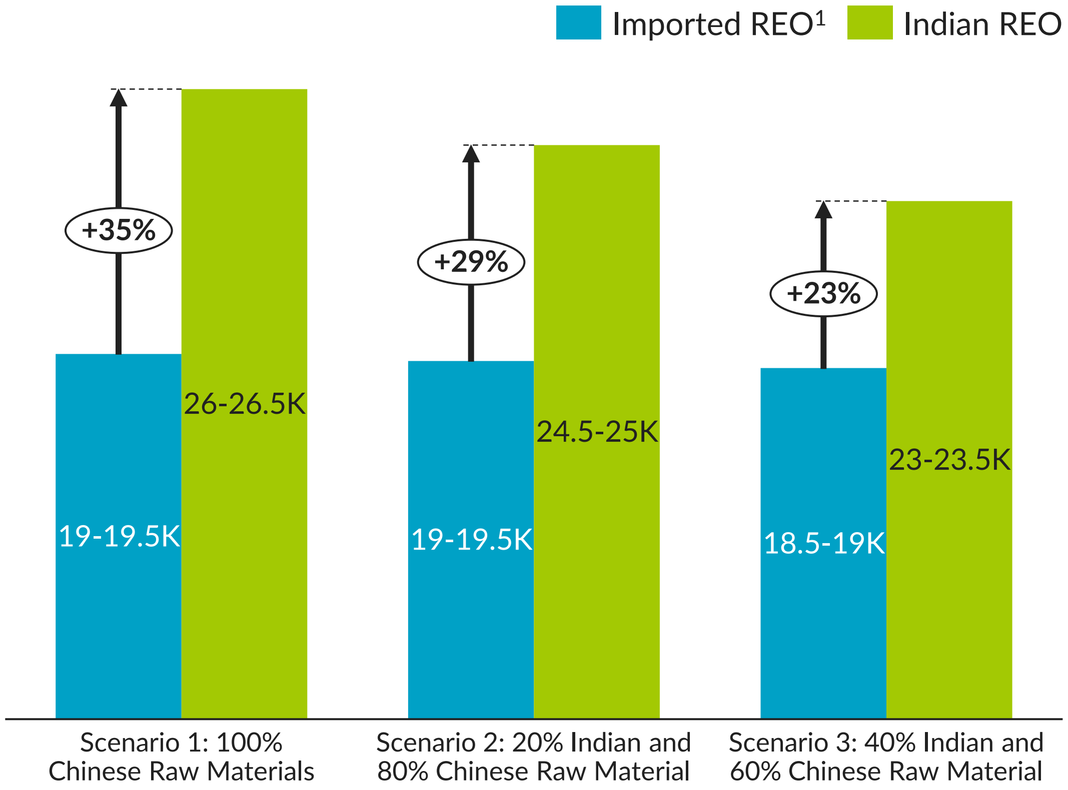
Pathways	Details	2030 Potential	2040 Potential	Investment Required	KEY ENABLERS
		kTPA (% of aggregate demand)	*kTPA (% of aggregate demand)*	*INR Cr by 2030*	
1 *Domestic mineral refining*	Global and domestic reserves extraction with domestic oxide production	**Heavy REO:** 0.47-0.7[1], (50%), **Light REO :** 7.8-8.3 (61-65%) in conservative and 10.1-10.5 (50-52%) in optimistic demand scenario[1,2]		**Heavy:** INR 150-210 Cr **Light:** INR 570-640 Cr, INR 1,230-1,320 Cr *(cumulative capex for incremental capacity[3])*	• G2G partnerships with **Australia, Myanmar, Brazil for Light and Heavy REE Concentrate[4]** • **20%** upfront capex subsidies for incremental capacity - **INR 130-140 Cr, INR 260-270 Cr[5]** • Supporting development of **downstream magnet capacity**
2 *Scaling circularity*	Closed loop permanent magnet recycling for REO recovery	**REO recovery:** 0.076, (~1%)	**REO recovery:** ~2, (2-6%)	**INR 4,400-4,700 Cr** (cumulative upfront capex for **6.5-7 kTPA** magnet recycling capacity)	• Tech transfer partnerships with prominent recyclers, e.g., Germany's Rocklink • **INR 780-840 Cr** upfront capex subsidies for **magnet recycling facilities** for **2040** • Collection infrastructure capacity expansion • Policy support in setting up recycling infra.
3 *Import diversification & stockpiling*	Stockpiling up to 25% of annual demand for REO	**REO:** 2-3.3, (25%)	**REO:** 8.6-20.2, (25%)	**INR 5-10 Cr** capex for developing storage facility	• Stockpiling targets for **25% of annual demand by 2030 for Rare Earth Oxide forms of REEs**

(1) Capacity requirement considers assumed utilisation factors – 60% in both scenarios; (2) Considers total Light REO capacity including total 5.7-6.4 kTPA announced capacity; (3) Refers to total investment required for additional REO capacity targeted beyond announced capacity; (4) Import and overseas mining partnerships under Domestic refining pathway focus on sourcing intermediate raw materials for safeguarding domestic production; (5) Range of capex subsidies across conservative and optimistic demand scenarios

Domestic Refining | Currently India's existing domestic REO capacity is not cost competitive with imported REOs and will require investments in improving feedstock availability to reduce the cost differential

Cost competitiveness of domestically produced REO with imported REO can be boosted by increasing local feedstock (Rare Earth Concentrate) availability, but would require additional interventions to equate it to cost of imported REO

Comparison of landed cost of imported REO and cost of REO domestically produced, USD/MT, ex-GST



Domestic REO production is not cost competitive with imported REOs and is limited by feedstock availability:

- **35% expected difference** in cost of domestically produced REOs and imported REOs[2], due to dependence on **imported raw material**
- Up to **40% integration** of domestic raw material can reduce the differential by **12%**, but is **limited by low feedstock** (Rare Earth Concentrate) availability

Increasing feedstock availability will not be sufficient to address the cost differential and will require additional support:

- While incremental feedstock (Rare Earth Concentrate) capacity can **bring down the cost differential** between imported and domestically produced REOs, imported REOs will **continue to be cheaper**
- Targeted **input side interventions** such as **electricity and capex subsidies**, **interest subvention** and **protective import duties** are required to make domestic REO cost competitive

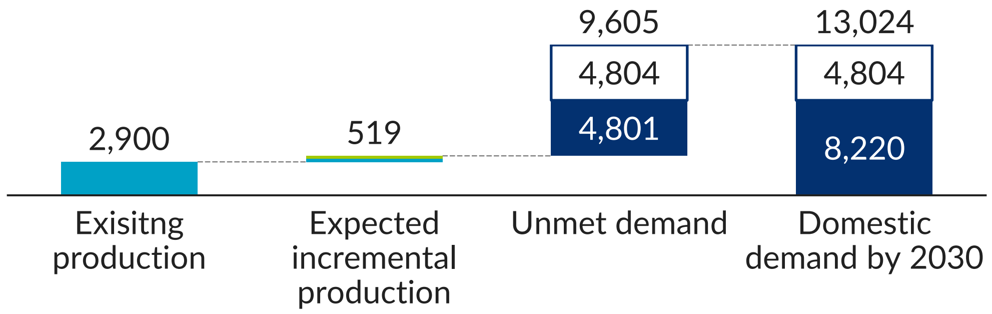
(1) The cost of Imported REO has been adjusted basis the composition of Rare Earth Oxide achieved by mixing Indian and imported Rare earth concentrates in different proportions; (2) Assuming domestic REO production is entirely import dependent for sourcing raw material – Rare Earth Concentrate; Source: Dalberg Analysis; JOM, Material and energy requirement for Rare Earth production, 2013

Domestic Refining | While IREL and GMDC have announced capacity expansion for REE mining and Light REO production, they're expected to meet 26-47% of REO demand[1], requiring incremental capacity additions

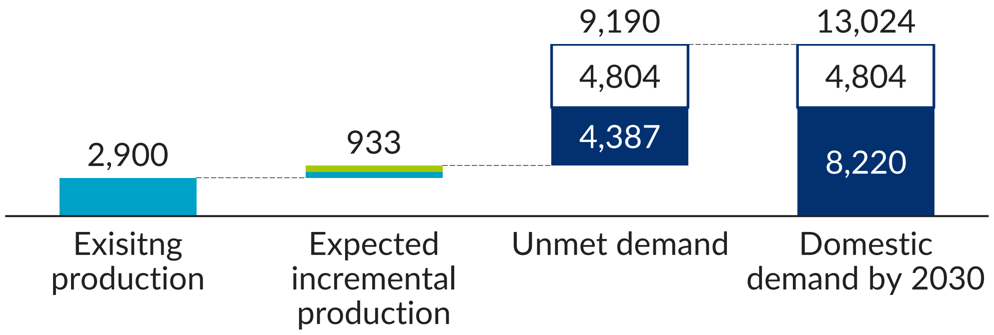
Expected domestic annual oxide production and total demand for Rare Earth Oxides by 2030, TPA

IREL | GMDC | Conservative Demand | Additional Optimistic Demand

Conservative Capacity Scenario



Optimistic Capacity Scenario



IREL and GMDC announced capacity expansion for Light REO by 2030[2]:

- **IREL** announced **mining capacity expansion** by **4x by 2032**, targeting total 13 kTPA REO capacity by 2032 (**~7.2 kTPA by 2030**)
- **Gujarat Mineral Development Corporation** (GMDC), a mining PSU, announced development of **12 kTPA REO** production capacity by 2028

Incremental capacity additions required to meet 50% aggregate demand domestically and build Heavy REO capacity:

- IREL and GMDC's capacity expansion primarily **targeted at Light REOs** and may be delayed – limited evidence of GMDC's progress on capacity development plans which were targeted for 2028

Scenario descriptions:

Conservative Capacity: Annual production to meet **26-42%** demand in 2030

- IREL slated to meet only **13% of targeted incremental capacity** at current pace of growth[3]; it is assumed GMDC could follow similar success (13% of targets)
- **REO Capacity utilisation by 2030** expected to be same as IREL's current Oxide capacity utilisation, **~60%**, due to limited **mining output scale up**

Optimistic Capacity: Annual production to meet **29-47%** demand in 2030

- Assuming IREL and GMDC double the rate of capacity addition than the conservative scenario (meet **26% of capacity targets**)
- **REO Capacity utilisation by 2030** assumed to remain constant at **60%**

(1) Based on aggregate demand which excludes REO demand for 15% of annual EV registrations assuming they may continue to correspond to imported REO components/imported finished vehicles; (2) Vedanta has displayed interest in REO production with Hindustan Zinc winning composite exploration and mining rights to an REE block in 2025, but no capacity announced; (3) IREL needs 30% YoY growth in mine output (FY24-30), against current 5% YoY growth (FY21-24) to achieve their targeted mining capacity expansion; Sources: IREL Annual Reports; Economic Times, Rare earths miner IREL eyes 40% capacity expansion for clean energy, 2023,GMDC, Business Update, 2024

1 Domestic Refining | Incremental REO capacity additions to further reduce import reliance are limited by key challenges across exploration and extraction, private sector participation and reliable downstream demand

1 Limited domestic Rare Earth exploration and extraction

- Geological Survey of India augments **~480 Mn MT Rare Earth Ores** (varying in quality)
  - These resources are **pending exploration** and are limited to **Light Rare Earth Oxides**
- Success of IREL and GMDC's capacity expansion and development plans is also contingent on successful **acquisition**, **exploration** and **commercialization** of **domestic Rare Earth Deposits**
- Further, limited feedstock availability results in underutilisation of existing Oxide capacity – **~60% capacity utilisation** of IREL's current REO plant

2 Regulatory challenges in gaining private sector support

- Limited private sector participation in domestic exploration :
  - Less attractive **revenue share norms** for exploration license (EL) holders, involving **long payment timelines** – Mining License holder to pay share of auction premium to EL holder, once Mining License auction concludes
  - **Limited access** to **financial support** offered by NMEDT – schemes typically available to Notified Private Exploration Agencies
- Regulatory challenges (e.g., obtaining **environmental and forest clearances**) add to compliance burden, disincentivizing mining agencies from investments in commercializing deposits

3 Low downstream demand from magnet manufacturing

- **Magnets** represent a large chunk of total REO demand but currently face **~100% import dependence**
- India's limited magnet manufacturing landscape does not provide **long term offtake security** for REO production plants – **limiting investments** in capacity development for **REO production**

Source: PIB Department of Atomic Energy, Parliament Question: Rare Earth Minerals, 2025; The Hindu, Initial findings positive for lithium blocks in Argentina, 2025; Reuters, Indian state firm's seek stake in SQM's Lithium projects in Australia, 2025

1

Domestic Refining | Strategic interventions across mineral exploration and extraction, and oxide production could catalyse requisite incremental REO capacity to achieve 50-65% self sufficiency in REOs

Interventions targeted at scaling mineral extraction, incremental oxide production, reducing costs of domestic Rare Earth Oxides and securing downstream Oxide demand could unlock aggregate REO demand and reduce India's import reliance

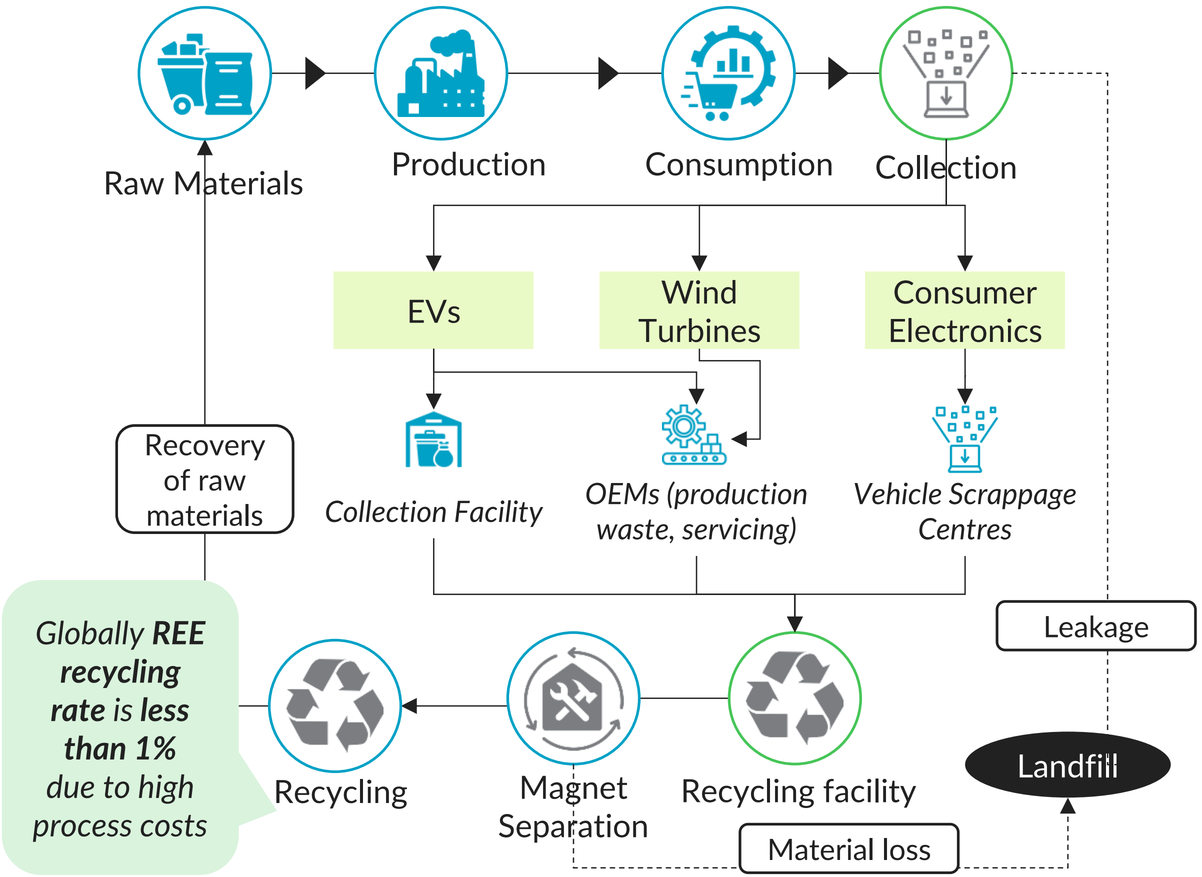
	Expanding exploration and extraction	*Scaling mineral to Oxide capacity*	*Securing downstream demand*
Current progress	• NMEDT funded reimbursement scheme to refund 50% exploration expenses[1] • Fast-tracked approvals for critical mineral projects by Environment Ministry	• GMDC announced capacity development for 12kTPA Light REO capacity by 2028 • IREL targets scaling existing 5kTPA REO capacity to 13 kTPA by 2032	• PLI scheme worth INR 7,350 Cr for domestic magnet manufacturing - expected to target 6,000 MT magnet capacity
Proposed interventions	• Expedite exploration and composite license auctions for domestic REE blocks • Secure access to Heavy Rare Earth Ores by exploring G2G partnerships with such as Myanmar, Australia	• Secure low-cost Rare Earth Concentrate to improve cost competitiveness in short term (Light REO: Australia, US, Brazil; Heavy REO: Australia, Myanmar) • Facilitate tech transfers with key global refiners (e.g., Lynas) to support Heavy REO capacity development • Support initial capacity development for Heavy and incremental for Light REOs through capex subsidies to build a strong REE processing portfolio for India	• Support REO off-take agreements with key magnet manufacturers • Identify low-cost raw materials sources to support cost competitiveness of oxides and promote domestic offtake • Offer idle PSU land sites to magnet manufacturers at subsidized rates
Potential	By 2030, 9-14 kTPA of REE concentrate annual production required to meet raw material demand for targeted domestic REO capacity	470-700 TPA Heavy REO capacity to meet 50% of 2030 annual Oxide demand, and 1,900-2,100 TPA incremental Light REO capacity in conservative and 4,100-4,400 TPA in optimistic demand scenario[2]	1,800 TPA expected REO demand by 2030 from magnet capacity targeted under PLI
Cumulative investment required till 2030		**Conservative Scenario:** INR 570-640 Cr for Light and INR 150 Cr for Heavy REO **Optimistic Scenario:** INR 1,230-1,320 Cr for Light and INR 210 Cr for Heavy REO capacity	

(1) NMEDT funded scheme – allows for 50% reimbursement on expenses incurred in exploration, repayable upon mine commercialization; (2) Additional nameplate REO production capacity, beyond announced capacity. Targeted to meet at least 50% of 2030 demand domestically in both scenarios at 60% capacity utilisation.; Sources: Business Standard, Govt offers 50% refund to license holders for critical mineral exploration, 2024; Business Standard, Govt to launch INR 7,350 cr plan to boost rare earth magnet production, 2025

2 Circularity | Circularity for permanent magnet applications of Rare Earth Elements aligns with national focus on boosting REE recycling and has the potential to further reduce dependence on imported Rare Earth Oxides

Rare Earth Elements have a variety of applications and circularity for permanent magnet applications displays strong potential, driven by existing policy focus and growing EV industry (serves as feedstock for magnet recycling)

Permanent magnet circularity value chain:



Permanent magnets display strong potential for Circularity:

- Permanent magnets are most common **(25-30% of REE demand)** amongst Rare Earth applications (magnets, catalysts, phosphors)
- Catalyst and phosphor recycling technologies have not yet been commercialized, thus have low potential for circularity

Permanent magnet recycling has an active research and policy landscape:

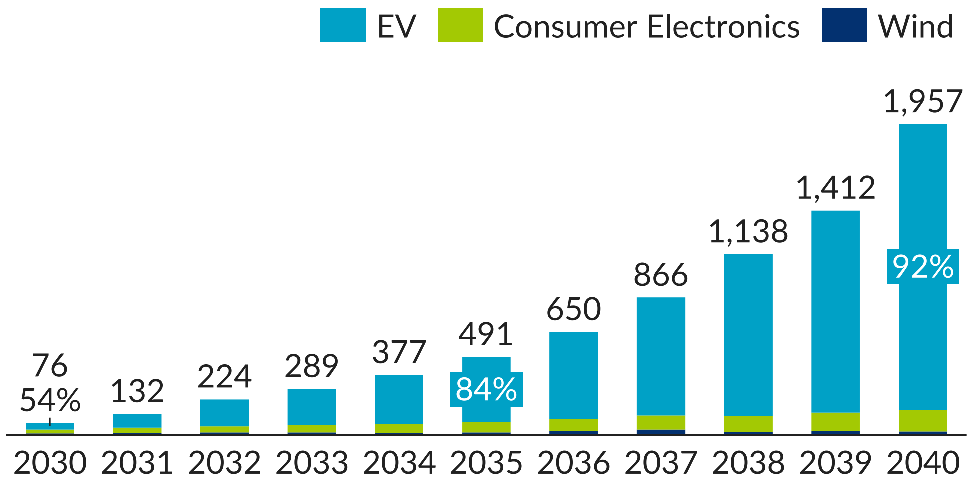
- Permanent magnet recycling currently dominated by **hydrometallurgical recycling – well documented** recycling process also used for Battery Black Mass recycling
- **Emerging short loop magnet[1] recycling technologies** such as **Hydrogen Decrepitation**, though still **under development**, can recover Rare Earth powders for direct use in magnet production
- Rising domestic focus on Recycling **– INR 1,500 Cr incentive scheme** for critical mineral recycling, including **rare earths[2]**
- Increasing **EV penetration** expected to foster a **growing and reliable feedstock supply** for permanent magnet recyclers

(1) Refers to magnet to magnet recycling, which doesn't require separation of recycled material into oxides; (2) The scheme considers e-waste, Lithium Ion Battery scrap and other end of life scrap materials in vehicles such as catalytic converters; Source: TIME, Trump wants Rare Earths but challenging China's dominance will take more than tariffs, 2025; PIB, Cabinet approves INR 1,500 Cr scheme to promote critical mineral recycling, 2025

Circularity | Magnet circularity is a strategic long-term bet; targeted interventions across Magnet Collection and Recycling could meet 2-6% of aggregate rare earth demand by 2040, though the short term potential is low

Recovered Rare Earth Oxides from end-of-life permanent magnets could meet 2-6% total REO demand by 2040

Projected Rare Earth recovery potential, 2030-2040, TPA:

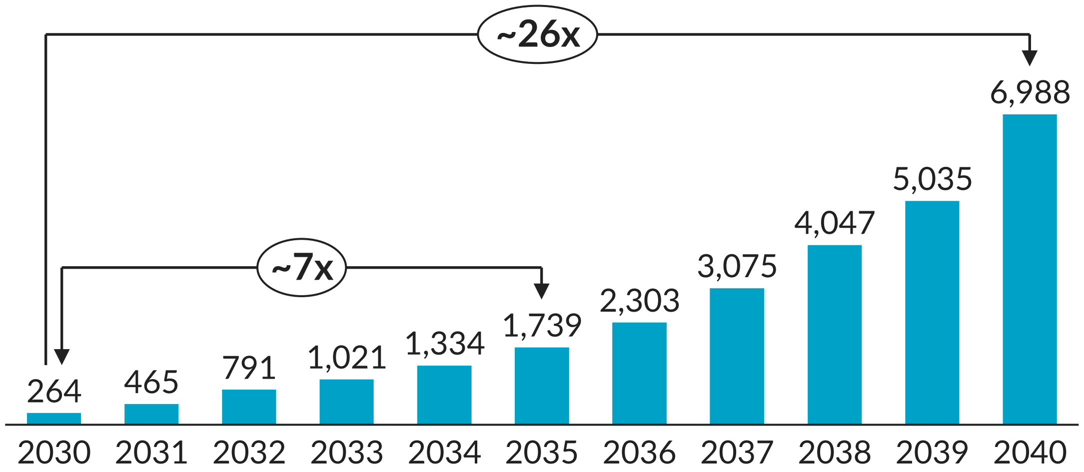


Recently approved INR 1,500 Cr incentive scheme for recycling is stepping stone to building domestic ecosystem:

- Incentives include **Capex subsidies of 20%** on plant and machinery associated with setting up recycling and mineral recovery capacities; **INR 5-10 Cr Opex subsidies**, on achievement of threshold sales

Tapping this potential needs strategic investments in developing 6.5-7 kTPA domestic magnet recycling capacity

Projected Magnet recycling capacity requirement, 2030-2040, TPA:



Opportunity to tap into active momentum in magnet recycling landscape:

- Magnet recycling is **underexplored** in India, with existing rare earth recycling capacity largely focused on **consumer electronics** (e.g., Attero, Recyclekaro)
- Domestic recyclers are beginning to engage in **tech transfers** for **magnet recycling capacity** – BatX engaged with German recycler Rocklink

(1) Refers to target feedstock capacity

Source: PIB, Cabinet approves INR 1,500 Cr scheme to promote critical mineral recycling, 2025; EV Story, BatX-Rocklink Rare Earth pilot to go live in 12 months, commercial production by FY 27, 2025

2 Circularity | Tech transfer partnerships, cumulative INR 4,400-4,700 Cr capex investment in recycling facilities and other policy levers could catalyse circularity potential of ~2 kTPA recovered Rare Earth Oxides by 2040

India's magnet circularity potential is impeded by structural and regulatory challenges, requiring investments targeted at scaling collection infrastructure and supporting economic sustainability and ease of operations for recycling facilities

	COLLECTION	RECYCLING		
Challenges	**Insufficient Infrastructure**	**Low Economic Feasibility**	**Limited Capacity**	**Red Category Industry**
	• Limited E-waste collection centers and Vehicle Scrappage Facilities • 174 registered vehicle scrappage units present against estimated need of 550-750 centers by 2025 and 700-950 by 2030	• Recycled REO not competitive with virgin REO production • Fluctuating mineral prices add uncertainty to economic feasibility • Higher working capital needed to manage inconsistency in feedstock expected in the near term[1]	• Limited domestic focus on magnet recycling as a source of REO recovery	• Recycling is a Red Category Industry in India and faces long approval timelines for establishment and operation of facilities (CTE and CTO) • Challenges in siting land to setup operations
Interventions				
	• Support development of 160-180 E-waste collection facilities[2] and additional ~350-600 Vehicle Scrappage Centers via 20% capex subsidies	• Explore Price Guarantee Measures to boost economic sustainability for recyclers • Explore 2-year GST deferrals on feedstock (permanent magnet scrap/end-of-life motors) • Facilitate access to magnet scrap from EU/US – regions with higher EV scrap availability	• Support development of 6.5-7 kTPA magnet recycling facilities via 20% capex subsidies • Leverage platforms such as EU-India Trade and Tech Council to access existing and new recycling tech	• Offer additional policy support (by relevant ministries) to grant 1-year exception CTO, CTE approvals for up to 50 recycling startups that meet certain threshold requirements[3]
Cumulative Investment till 2030	**INR 14,200-16,500 Cr** capex investment[4] across e-waste and vehicle scrappage facilities		**INR 4,400-4,700 Cr** capex investment for magnet recycling facilities	

(1) This is since key magnet-based industries (EVs, Wind turbines) are nascent sectors in India, resulting in low volumes of waste reaching end of life by 2030; (2) As detailed in the Battery indigenisation pathways; (3) Exception approvals granted by relevant ministry for 1 year, post which due processes on audits and diligence can be carried out to grant permanent certificates; (4) Includes INR 1,200-1,500 Cr capex investment proposed under the Batteries Indigenisation Pathways presentation

3 Import diversification and Stockpiling | Leveraging existing MoUs with resource rich nations and stockpiling 25% of 2030 notional REO demand could safeguard India's downstream sectors from global REE supply shocks

As India looks to reduce import dependence, it's imperative to parallelly diversify supply for remaining Rare Earth imports and additionally invest in stockpiling of REOs to safeguard growth of downstream sectors – e.g., Permanent Magnets, EVs

Strategic imports of Rare Earth Concentrates and Oxides could support development of domestic Oxide and Magnet Capacity:

- Low-cost Rare Earth Concentrate imports critical to support cost-competitiveness and initial sustainability for oxide capacity
- Domestic Heavy REO production is dependent on imports of Heavy REE rich concentrates due to lack of domestic availability

India could leverage existing bilateral ties and multilateral ties and partner with key resource rich countries to secure these resources:

- **Brazil, Australia, US, Myanmar, Vietnam – key REE rich nations**
  - Brazil and Australia represent 20% of global REE reserves
  - Myanmar's heavy REE rich reserves form ~90% of China's heavy REE imports
  - US, Myanmar and Australia hold 29% of global mine output
  - Vietnam – emerging RE source targeting 60 kTPA REO capacity by 2030
- **Existing bilateral and multilateral relations:**
  - Opportunity to leverage the Critical Minerals Investment Partnership with Australia, and Quad Critical Minerals Initiative
  - India already exploring REE partnerships with Brazil, Dominican Republic

In tandem, Stockpiling could supplement import diversification to safeguard domestic manufacturers from global supply risks

- Stockpiling could ensure continued access to minerals and protect domestic manufacturers against global price fluctuations
- Focus stockpiling efforts on Rare Earth Oxides – more stable forms of elements, serve as raw materials for multiple applications, and have a longer shelf life increasing the timeline for inventory refreshment
- Establish stockpiling targets - 25% of 2030 demand (2-3.3 kTPA)
- INR 5-10 Cr capex investment required for development of Rare Earth storage facilities[1]

Leverage either of 2 existing models for stockpiling:

Public-sector led	ISPRL (India) - PSU-led acquisition of oil resources, government funded storage infrastructure that can be leased to private sector
Public-private	JOGMEC (Japan) **-** Government mineral stockpile mandate for private sector, supported by interest subvention for private sector

(1) Calculated assuming rare earth storage facility costs could reach around 1-2% of the budget allocated for stockpiling under NCMM, given the low volume of Rare Earth Stockpile requirement; Sources: The Hindu, Initial findings positive for lithium blocks in Argentina, 2025; Reuters, Indian state firm's seek stake in SQM's Lithium projects in Australia, 2025; Rare Earth Exchanges, Vietnam's Rare Earth Awakening, 2025

SECTION TWO, SUB-SECTION E

GREEN HYDROGEN INDIGENISATION PATHWAYS

Some raw material indigenisation is feasible for PEM electrolyser minerals through circularity, while Alkaline electrolyser minerals remain largely import dependent

Potential for indigenisation pathway: Low | Medium | High | Long term potential beyond 2030 may exist

Electrolyser Type	Mineral Requirements	Import Dependency	Pathway to Indigenisation: Extraction	Pathway to Indigenisation: Refining	Pathway to Indigenisation: Circularity
Alkaline *~75% of the electrolyser capacity[1]*	**Nickel**	Indonesia, Russia, Canada	Laterite reserves exist but no commercial output; ~45,000 t/yr[2] **demand met by imports**	Only small-scale operations (Vedanta)-**bulk refining absent.** Potential to make nickel foam/sheet/coatings exists	Most recycled nickel goes into new alloys and stainless steel, **not the specialised form** needed for electrolysers
	Zirconia	Australia, South Africa	Imported due to **limited reserves** in India	Refined for nuclear/industrial use with high grade refined zirconia produced by **global specialist producers**	Recycling of Zr from electrolysers is an area of pilot R&D and **not commercially developed**
	Molybdenum	China, Thailand, Chile	No domestic mines with all mineral concentrate **being imported**	Low grade molybdenum processed, however, **absence of dedicated refining operations**	Molybdenum loadings in electrodes are thin catalytic layers, making **mineral recovery challenging** with current recycling methods
	Zirfon (Specialty Chemical)	Proprietary material imported from companies like Agfa	*Not Applicable*		
PEM *~25% of the electrolyser capacity[1]*	**Platinum**	South Africa, UAE, UK	Platinum group deposits exist in Odisha but **no operating mine** ; 100% import dependent	Lack of large-scale platinum refining. All primary platinum is **imported**	**Established recovery methods** from auto catalysts and fuel-cell stacks exist[5]
	Iridium	South Africa, USA, UAE	No Indian production today and **no known commercial deposits**	Refined by **specialist firms** which are concentrated abroad	**Recoverable** from end-of-life CCM
	Titanium	China, Netherlands, South Korea	India has 11%[3] of world's ilmenite reserves but **mining is limited** due to regulations	India has only 1 Ti sponge plant with **low capacity. Potential** to compact & sinter Ti exists	**Established recovery methods** from scrap and biplor plates
	Gold	Switzerland, UAE	Domestic gold mining is negligible	**Organized refinery sector** for gold has rapidly grown in India	~11% of India's supply comes from **"old gold" scrap[4]** with collection networks expanding
	Nafion (Specialty Chemical)	Proprietary material imported from companies like Du Pont	*Not Applicable*		

Notes: 1. Computed based on the global electrolyser capacity by 2030 (Global Hydrogen Review 2023) and the awarded electrolyser capacity under the SIGHT electrolyser manufacturing scheme. 2. Indian Minerals Yearbook 2017, 3. Fortune India, 4 World Gold Council, 5. Heraeus

India refines some REEs to oxides but lacks high-purity grades for SOE electrolyser use while circularity for most of the minerals remains research-stage and not commercialized

Potential for indigenisation pathway: Low | Medium | High | Long term potential beyond 2030 may exist

Electrolyser Type	Mineral Requirements	Import Dependency	Pathway to Indigenisation		
			Extraction	Refining	Circularity
SOE *Still in the nascent stages and hence would not contribute to the 2030 electrolyser capacity*	**Nickel**	Indonesia, Russia, Canada	Laterite reserves exist but no commercial output; ~45,000[2] t/yr **demand met by imports**	Only small-scale operations (Vedanta) with **bulk refining absent**	Most recycled nickel goes into new alloys and stainless steel, **not the specialised form** needed for electrolysers
	Zirconia	Australia, South Africa	Imported due to **limited reserves** in India	Refined for nuclear/industrial use with high grade refined zirconia produced by **global specialist producers**	Recycling of Zr from electrolysers is an area of pilot R&D and **not commercially developed**
	Lanthanum[1]	China	Lanthanum is available domestically, but **advanced grades** required for electrolysers are imported.	Basic refining capacity exists in facilities such as IREL[3], but **advanced processing remains nascent**	**Emerging research efforts** to extract La from end-of-life SOE stacks exist but no commercial recycling stream exists
	Cerium[1]	China	Cerium reserves present in monazite sands, however most cerium for **specialised applications is imported**	Advanced downstream processing and alloying for SOE components is **generally limited**	Studies exist to extract cerium for end-of-life electrodes, but **no such recycling is in the commercial phase**
	Gadolinium[1]	China	Vast majority of gadolinium required for SOE and other **advanced technological applications is imported**	High-purity, application-specific forms are still largely **processed overseas** with India have refining capabilities for basic industrial uses	Research to produce Gd from materials such as hospital effluents exist but **recycling is nonexistent**
	Scandium[1]	China	Scandium reserves exist however **scandium production has remained minimal** at 45 tonnes in 2022[4]	Advanced processing is **predominantly conducted abroad**	**No commercial application** indicating the production of scandium through circular recycling method
	Strontium	Mexico, Germany	All SOE-grade strontium is **produced internationally** due to purity constraints	Most **specialist processing is performed in exporting countries** before import into India	Research has shown recycling of Sr from industrial wastes but **no evidence** of commercial scale recycling

Notes: 1. These minerals are rare-earth elements (REEs) , 2 Indian Minerals Yearbook 2017, 3 Compendium on Rare Earths and Heavy Minerals 4. imarcgroup

While raw material import dependency will continue, processing and manufacturing of most Alkaline and PEM components can be done in-house in the near term

Currently most components of the electrolyser stack are directly imported. However, India can produce these in-house, while importing only the minerals required

Component	Alkaline	PEM	SOE
Membrane	Membranes can be **developed locally** using imported zirconium, but domestic capacity and know-how must be built; efforts to produce substitutes would rely on **sustained R&D**	Can develop indigenous cheaper substitutes of Nafion, but requires **significant R&D** and licensing/tech partnerships to reach electrolyser grade quality	Raw Material (SSZ[1] powder) would need to be imported. India can develop **tape-casting and ball mining capabilities** to mix SSZ with organic solvents to make the electrolyte membrane
Cathode	Ni and Mo would be imported , Ni sheet processing (catalyst coating) can be made in-house through the **plasma coating process**[4]	Cathode material (Pt, Ir, ionomer, Ru) would be imported with the potential of doing cathode **ink preparation & coating** in house[3]	Imported nickel oxide and gadolinia-doped ceria (GDC) can be used to **prepare and screen print** cathode slurry in-house
Anode	Ni (powder & porous sheet) would be imported with potential to make catalyst coated Ni sheet in-house through the **plasma coating process**[4]	Anode material (Pt) would be imported with potential to do the anode **ink preparation and coating** on the membrane in house[3]	Imported lanthanum strontium cobalt ferrite (LSCF) powder can be used to **prepare and screen print** anode slurry in-house
PTL[2]	Imported Ni can be used to do the **processing of polyurethane foam** (electrodeposition of nickel and sintering) in house	**Compacting, sintering and gold coating** of imported Ti powder can be done in house, **Carbon cloth** can also be produced in house	GDC powder would need to be imported while the further processing (**screen printing and sintering**) can be done in house to prepare the GDL[2]
Bipolar Plates[2]	**Nickel coating of stainless steel** can be done domestically by importing nickel	The production of gold coated stainless steel bipolar plates is **already indigenised**	**Manufacturing of interconnect** can happen in house with essential raw material for coating (manganese cobalt oxide) and ferritic steel being imported
End Plate	The production of end-plate using stainless steel is **already indigenised**	The production of end-plate using stainless steel is **already indigenised**	There is **potential to indigenise** production of end-plate using stainless/cast steel

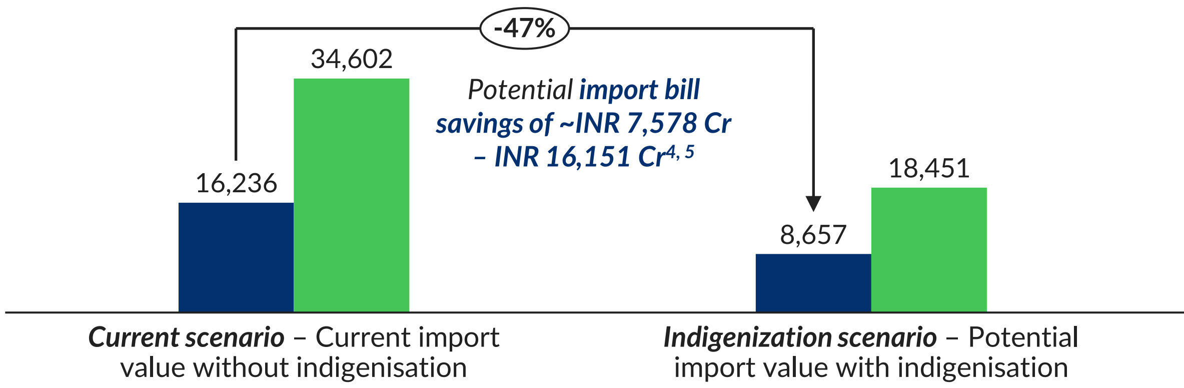
Component's production already indigenised | Short term potential to make component in house while importing raw materials | Long term potential beyond 2030 to make component in house while importing raw materials

Source: CEEW Report Notes: 1 SSZ - Scandia-stabilised zirconia powder 2. In SOE electrolysers ,the functional equivalent of a PTL is the gas diffusion layer (GDL) and that of a bipolar plate is the interconnect. 3. Active R&D efforts are underway to reduce Pt/Ir loadings through atom efficient catalyst designs. 4. Active R&D efforts are underway to replace pure Nickel loadings with nickel & cobalt/iron alloys (i.e. high entropy alloys) to reduce dependence on imported Nickel

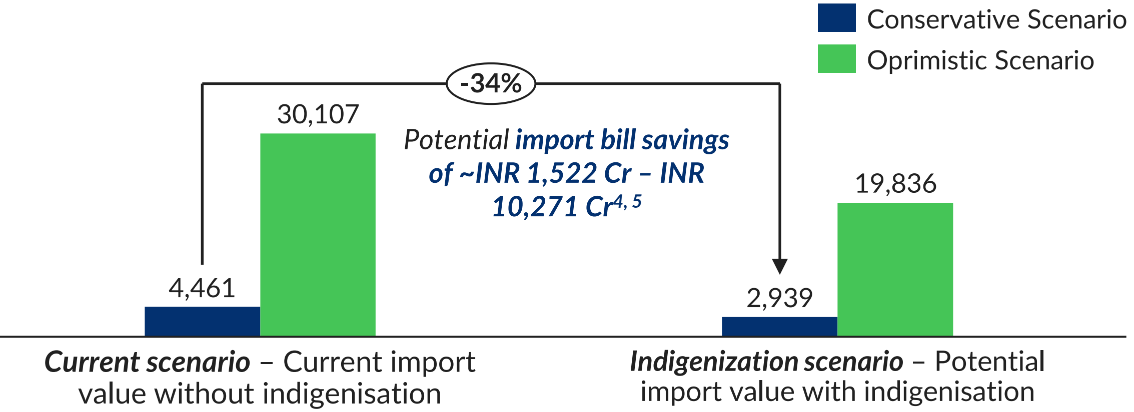
In-house component processing & manufacturing will lead to import bill savings worth ~INR 9,000 Cr - INR 27,000 Cr to meet domestic electrolyser manufacturing capacity by 2030

A component level analysis of the potential import bill savings accrued by indigenising electrolyser component manufacturing *(in INR Cr)*

Alkaline Electrolysers[1]



PEM Electrolysers[2]



- Indigenisation scenario considers **in-house manufacturing of Zirfon membrane, electrodes, PTL, bipolar plates, and BoP components** *(power electronics, sensors)* while still importing the upstream raw materials
- Graph above considers total estimated domestic alkaline electrolyser capacity of **~8 – 17 GW,** with
  - Import cost of finished components without indigenisation at **INR 20,202/kW**
  - Import cost with indigenisation at **INR 10,772/kW** (The analysis assumes that imports will be restricted to raw materials, with most of the finished components manufactured domestically)
- Thus, **import bill savings of ~INR 7,578 Cr – INR 16,151 Cr** are accrued due to indigenising component manufacturing (Indigenising component manufacturing allows these savings to circulate within the domestic economy)

- Indigenisation scenario considers **in-house manufacturing of Catalyst Coated Membranes (CCMs), PTL, and BoP components** *(power electronics, sensors)* while still importing the upstream raw materials
  - Bipolar plates (stainless steel with gold coating) are already indigenised and hence do not feature in above scenario
- Graph above considers total estimated domestic PEM electrolyser capacity of **1 – 10 GW,** with
  - Import cost of finished components without indigenisation at **31,095/kW**
  - Import cost with indigenisation at **INR 20,487/kW** (The analysis assumes that imports will be restricted to raw materials, with most of the finished components manufactured domestically)
- Thus, **savings of ~INR 1,522 Cr – INR 10,271 Cr** are accrued due to indigenising component manufacturing (Indigenising component manufacturing allows these savings to circulate within the domestic economy)

Sources: 1. Alkaline electrolyser analysis based on: CEEW's Study, 2 PEM electrolyser analysis based on: NREL's Study 4. Internal Dalberg and CEEW analysis estimates total import and indigenisation costs based on 2030 electrolyser targets, assuming **80% Alkaline** and **15% PEM** capacity (see annex for details) 5.The lower limit of the range corresponds to the conservative scenario and the upper limit to the optimistic scenario

Moreover, raw material import dependency can be reduced through refining and circularity pathways for Alkaline and PEM electrolysers in the near-term

Electrolyser Type	Pathway to Indigenisation
Alkaline	**Near-term pathway – *a) Refining***: Scope to scale domestic refining capacity for electrolyser-grade nickel (foam/sheet) **Long-term pathway -** *a)* ***Circularity***: Emerging recycling routes for Ni and Zr can reduce net import dependence, however the potential is long term and requires substantive R&D *b)* ***Extraction***: India has laterite reserves for Nickel but no active mines, potential exists to commercialize extraction in long term
PEM	**Near-term pathway –** *a)* ***Refining***: Specialised refining is concentrated abroad; Scope exists to indigenise Ti refining; Gold refining is already well developed *b)* ***Circularity***: Established recovery routes for all metals (from end-of-life electrolyser components, automobile parts etc.) exist. **~20% -50%[1] of platinum, iridium and titanium** required for electrolyser production can be recovered through commercial circularity by 2030 **Long-term pathway – *a) Extraction***: Long-term potential exists for Pt (Odisha PGM deposit) and Ti (large ilmenite reserves)
SOE	**Long term pathway –** *a)* ***Extraction***: Some potential to commercialize Nickel extraction in the long term, however all other critical inputs (REEs Zr, Sc) are highly import-dependent *b)* ***Refining***: Some early-stage capabilities exist with potential to build advanced facilities (advanced downstream refining is still nascent) *c)* ***Circularity:*** Recycling R&D is emerging for REEs and Sr, but no commercial-scale recovery streams are in place yet

Sources: State of the Sector, Critical Energy Transition Minerals For India; Enabling fuel cell circularity with platinum; Recycling of Critical Raw Materials for a Circular Hydrogen Economy; Compendium on Rare Earths and Heavy Minerals Book Notes: 1. Internal Dalberg estimates

For the raw materials that would continue to be imported, there is a need for de-risking supply through long-term contracts, diversification of partners, and recycling

	Alkaline Electrolysers	PEM Electrolysers	SOE Electrolysers
Key Dependency Risks	• **Nickel and zirconium are strategic chokepoints**, with India lacking both upstream reserves and refining scale, leaving supply exposed to a few countries • **Molybdenum and Zirfon are niche imports**, where even small market shifts can inflate costs due to thin global supply chain	• Mineral supply is **tightly** concentrated (for instance South Africa is a dominant Pt and Ir supplier) creating **exposure to price shocks** • PFSA Membranes (Nafion) are dominated by **proprietary suppliers** limiting supplier diversification and creating a **supply choke point**	• Rare earth elements (REEs) are almost **entirely processed in China**, making India highly dependent • High-purity zirconia and dopants (scandia, ceria) are **niche products with thin supply chains**, where small disruptions can cause major cost spikes
Recommendations	• Pre-emptively secure medium to long-term **offtake contracts** via a central aggregator, sourcing from **multiple suppliers/geographies** to diversify origin risk[3] • Pursue **equity investments** (with sovereign partners and experienced local firms) to **acquire mining and processing stakes** overseas[3] *(for instance KABIL seeking a 20% stake in SQM's Lithium projects in Australia[4])* • De-risk processing/refining concentration by evaluating domestic processing capacity and **pursuing diversified processing access[3]** (through joint ventures or partnerships with processors across multiple geographies)	• Use **incentive schemes[2]** provided under the **National Critical Mineral Mission (NCMM)** to prioritize **PGM recycling in India** (from spent catalysts and electronics), which has proven recovery rates of 90–95%[1] globally, to reduce fresh imports • Secure **dual supply lines for membranes** by signing long-term contracts with membrane suppliers, while evaluating a joint venture for small-scale domestic PFSA production	• Pursue **strategic partnerships & joint ventures[6]** to diversify REE supply, ensuring technology transfer and mutual value creation by **expanding partnerships with countries such as Australia[5]** reducing over-reliance on Chinese supply • Leverage NCMM's recycling fund of INR 1500 cr[2] to **pilot REE recovery from e-waste and industrial residues** to build a partial local loop • **Form joint R&D–supply partnerships with established SOE material suppliers** to co-develop alternative materials for electrolytes to reduce dependence on imported REEs

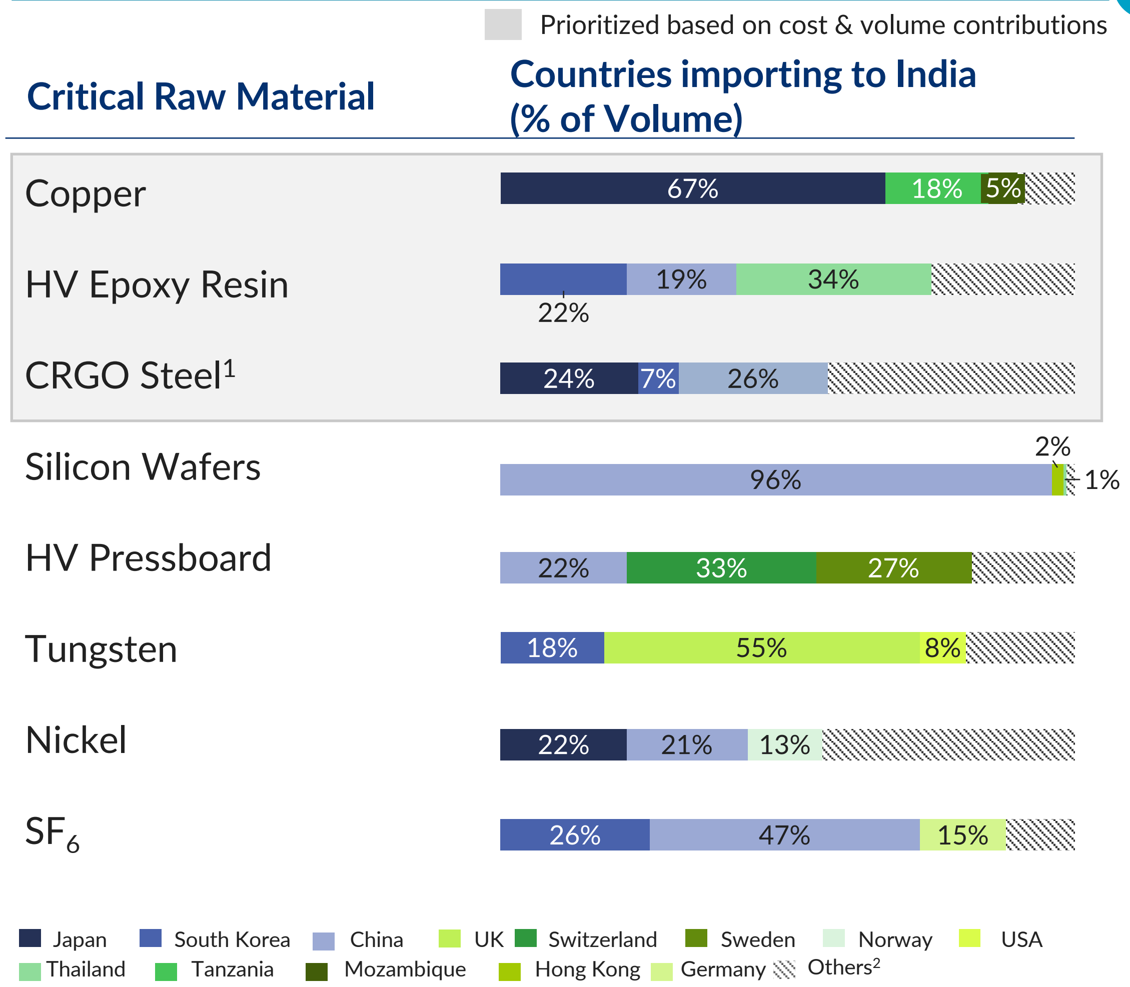
Source: 1 Science Direct, 2 PIB, 3 CEEW (Building Resilient Mineral Supply Chains for Energy Security), 4 Money Control, 5 Discovery Alert 6 ODI Europe

SECTION TWO, SUB-SECTION E

TRANSMISSION INDIGENISATION PATHWAYS

Raw Materials | Targeted incentives and investments can help reduce India's import dependence on Copper and HV graded epoxy resins that are critical for HV transmission equipment

India has significant import dependency on raw material required to manufacture HV transmission equipment



With focused investments and incentives, capacity for Copper and HV Epoxy Resin material can be increased

Current Status	Recommendation
Copper	
• More than 50% of India's copper needs are currently met through imports • HV transmission requires high purity (99.99%) copper which has even lower recycling rates	• Provide capex subsidies for recycling copper to meet 40-50% of the transmission demand locally[3] • Formalize and upgrade scattered and unorganized sector engaged with collection and recycling.
HV Epoxy Resin	
• Limited domestic manufacturing know-how and dependent on import for raw material ie. BPA and ECH and high purity curing agents	• Build capacity for high-voltage epoxy resin with export potential • Accelerate domestic manufacturing of BPA and ECH
CRGO	
• > 90% of CRGO is currently imported • Capacity expanding (JSW-JFE JV) to cover domestic demand by 2028	• De-risk cost inflation short term through time bound strategic buffer stocks for projects needed in the next 3-4 years until domestic capacity ramps up

(1) Cold Rolled Grain Oriented Steel – assumed import mix is the same for both cold rolled and hot rolled grain oriented electrical steel; Import data from 2024-25 where Chinese manufacturers with existing contracts could still export to India (2) Others' category may include countries already shown in the legend; (3) Assuming current import dependence is at least 50%

Source: Ministry of Commerce and Industry: Trade Stats , Ministry of Mines: Press Release; Copper India Report ;PIB Dalberg Analysis

Current import dependency among transformers and transmission lines could be addressed through targeted scaling of recycling and process capacities of critical materials (1/2)

Execution Potential: High | Medium | Low

Raw Material	Current bottlenecks	Indigenisation pathways: Production expansion	Indigenisation pathways: Recycling	Indigenisation pathways: Import diversification
CRGO steel	• Complex technology and limited patents • Domestic producers shifted their production to CRNO which is used in EV • No long-term demand assurance to manufacturing firm by govt.	Manufacturing capacity under development that can cover domestic demand by 2028 (JSW-JFE partnership) (Low)	Recycling not suitable for high-voltage converter transformers as scrap CRGO has higher core losses. (Low)	High-grade CRGO steel produced only by a few global suppliers due to tech constraints (Low)
Copper	• Domestic smelting/refining capacity is less than demand; higher reliance on imported cathode/rod. • For recycling there's a fragmented collection units and underdeveloped recycling infrastructure • 67% percent of copper comes from Japan	Listed as a critical mineral under Critical Minerals Mission. Demand may still outgrow supply (Low)	Copper can be fully recycled and reused - needs capex to build out plants (High)	Potential to diversify to other countries such as Chile and Congo (High)
Silicon Wafers	• Getting specialized tools (power-wafer process IP) and process for fabrication is challenging • Long lead times to set up fabrication units	Leverage existing domestic capability to localise press-pack assembly while **continuing to import dies;** potential for localisation through tech transfer (High)	Recycled silicon wafers are unsuitable for HVDC systems; only limited value from recovering silver/nickel (Ag/Ni) from wafer metallization. (Low)	Potential to diversify our imports from Japan, Taiwan, South Korea and EU Stockpile for at least 6 month for any supply shock (Medium)

Source: Dalberg analysis; PIB India; U.S. Department of Energy (DOE) :Electric Grid Supply Chain Review(2022); Economic Times; CEA: imported Equipment list

Current import dependency among transformers and transmission lines could be addressed through targeted scaling of recycling and process capacities of critical materials (2/2)

Execution Potential: High Medium Low

Raw Material	Current bottlenecks	Indigenisation pathways: Production expansion	Recycling	Import diversification
Insulation Material (pressboard Insulation)	• Kraft pulp required for pressboard still needs to be imported from cold weather countries • Very few mills have the technology to produce IS-compliant electrical pressboard used in HV	Upgrade select board mills to HVDC electrical grades—India has capacity for Lower Voltage applications	Not recyclable for HVDC-grade insulation	Limited countries to provide pulp required
Insulation Material (Epoxy Resin in bushings)	• Limited domestic know-how for electrical-grade high voltage epoxy formulations and curating agents • Raw material precursors for resins Bisphenol-A (BPA), Epichlorohydrin (ECH), specialty hardeners etc. also must be imported	Accelerate domestic manufacturing of epoxy resins and hardeners using LV epoxy manufacturing capabilities	HV complex resins can't be recycled	Limited countries manufacturing HV grade epoxy resins
SF6	• No local manufacturing capacity exists • Global pressure to not use SF6 in future hence no demand visibility to invest	Limited demand as industry moves to SF6-free alternatives	Need to import tech required to recycle SF6	Import concentrated in China and Norway; potential to diversify across Russia, USA, Europe
Nickel	• No existing Ni mining in India for extraction	Not applicable	Nickel is 60-70% recyclable and can be used in HVDC systems	Nickel imports are diversified—key suppliers include Norway, Russia, Cannada & Japan.
Tungsten	• India's tungsten reserves are very limited • India imports ~43% of its tungsten from China	Domestic mining/refining at scale takes time and and high-capex	Tungsten can be recycled and used in HVDC	Potential to diversify toward South Korea, the USA, Austria, and Germany

Source: Dalberg analysis; PIB India; U.S. Department of Energy (DOE) :Electric Grid Supply Chain Review(2022); Economic Times; CEA: imported Equipment list

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