Critical Minerals for India: Assessing their Criticality and Projecting their Needs for Green Technologies

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Climate Change Mitigation in India

- During COP26, India pledged to:
  - Increase the share of non-fossil fuel energy capacity
  - Reduce the carbon intensity of the economy
  - Achieve net-zero emissions by 2070
- Manufacture of green technologies for climate change mitigation requires specific minerals and metals, such as lithium, cobalt, and silicon
- Transition from thermal to renewable electricity generation will have large implications on jobs in coal mining – *Just Transition*

Critical Minerals for Green Technologies

- These minerals have highly complex global supply chains – from mining, processing, to manufacturing
- Some critical minerals are highly concentrated:
  - China produces 58% of rare earth elements
  - DR Congo produces 70% of cobalt
  - Australia produces 55% of lithium
- COVID-19 and geopolitical issues with critical minerals supply chains
- CSEP evaluated the criticality of select minerals based on their supply-side risks and economic importance

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Critical Minerals Assessment Methodology

Objective: to quantify which minerals are most important for the Indian economy and the risks in their supply – focus on green technologies

- Economic Importance
  - Mineral impact on manufacturing GVA
  - Substitutability
  - GVA multiplier coefficient
- Supply Risk
  - Mineral Concentration by Country
  - World Governance Indicators
  - Import Reliance and Self-sufficiency
  - Recycling Rates
  - Substitutability

Minerals Investigated

Iron ore	Chromium	Manganese	Molybdenum	Nickel
Niobium	Vanadium	Zinc	Bauxite	Strontium
Cobalt	Copper	Graphite	Indium	Lead
Lithium	Silicon	Silver	Limestone	Neodymium
	Heavy rare earths	Light rare earths	Titanium	

Key Uses

- Solar
- Wind
- EVs / Batteries
- Cross-Cutting
- Others

Economic Importance

Quantifies the impact on the national economy if the mineral is not available through the supply chain

$$EI = \left(\sum_{s} A_s Q_s \right) \times \sigma_{EI} \times \mu$$

A_s: share of the mineral consumption in sector s

Q_s: share of GVA of sector at NIC 5-digit level in manufacturing GVA

σ_{EI}: substitutability index

μ: mineral GVA multiplier coefficient

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Sectoral Mineral Usage

$$\sum_{s} A_s Q_s$$

- Annual Survey of Industries 2017-18 used (latest)
- Mineral use computed at the NIC 2008 5-digit level
- NPCs of mineral ores, chemicals, and ferro alloys (e.g., iron ore, basic chromium sulphate, ferro cobalt, etc.)

Substitutability

σ_{EI} quantifies the degree of substitutability, which dampens economic importance

$$\sigma_{EI} = \sum_{s} A_s \sigma_s$$

A_s: share of mineral consumption in sector s to total consumption

σ_s: cost-performance score for sector s

- Cost performance scores evaluated for each mineral and its end-use (between 2- and 5-digit NIC levels) through literature search
- Score varies from 0.6 (high substitutability) to 1.0 (not substitutable)

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Substitutability – Cost Performance Score

Efficiency of substitute / Cost of substitute	Better	Similar	Reduced	No substitute
Much higher	0.8	0.9	1.0	1.0
Slightly higher	0.7	0.8	0.9	1.0
Similar or lower	0.6	0.7	0.8	1.0

- A chromium substitute in stainless steel production is molybdenum, which has a slightly higher cost and similar performance (0.8)
- Aluminium can theoretically substitute tantalum for capacitors, but would be highly inefficient

Mineral GVA Multiplier Coefficient

μ quantifies the direct and indirect effects of a mineral on factor incomes

$$\mu = \sum_{s} A_s \mu_s Q_s$$

A_s: share of mineral consumption in sector s to total consumption

μ_s: GVA multiplier for sector s

Q_s: GVA share of sector s to total manufacturing GVA

Supply Risk

SR_G quantifies the vulnerability in global mineral supply chains due to mineral concentration by country with adjustments

$$SR_G = \left[(HHI_{WGI})_{GS} \times \frac{IR}{2} + (HHI_{WGI})_{IS} \times \left(1 - \frac{IR}{2}\right)\right] \times (1-\rho) \times \sigma_{SR} \times \epsilon$$

HHI_{WGI}: Herfindahl–Hirschman Index of mineral concentration

WGI: world governance indicators

GS: global supply, *IS*: Indian sourcing

IR: import reliance

ρ: end-of-life recycling rate

σ_{SR}: substitutability in supply risk

ϵ: self-sufficiency adjustment factor

Herfindahl-Hirschman Index – Concentration

HHI measures the concentration of a) global extraction, and b) Indian sourcing of mineral imports

$$HHI_{WGI} = \sum_{c} S_c^2 WGI_c$$

S_c: share of mineral extraction in country c

WGI_c: World Governance Indicators score for country *c* to dampen SR

- World Mining Data, British Geological Survey, and US Geological Survey data used for country-wise production
- IBM Yearbooks and WITS Database used for Indian imports sourcing

Worldwide Governance Indicators & Environmental Performance Index

- World Bank dataset measures the quality of governance in each country through 6 indicators measured from -2.5 to 2.5:
- WGI normalized between 0 (best) and 100 (worst) to adjust the HHI scores
- EPI: Yale study measures the state of sustainability by country
- 0.78 correlation with WGI, and supply risk results had a 0.98 correlation
- For this study, EPI has been excluded

Import Reliance

$$IR = \frac{import - export}{domestic\ production + import - export}$$

- Indian Bureau of Mines Yearbook provides data on self-sufficiency of minerals
- For minerals with no domestic mining, IR = 100%
- If exports > imports, IR = 0%

Recycling of Minerals

- Literature review used to find end-of-life recycling rates of minerals
- Scored on level of recycling
- In India, only copper and steel has some recycling, rest close to no recycling

Level of recycling	Score
Almost no recycling	0.00
Some recycling	0.33
Mostly recycled	0.67
Almost all recycled	1.00

Substitutability in Supply Risk

σ_{SR} quantifies the level of substitutability in the mining of minerals

$$\sigma_{SR} = \sqrt{(\sum_{s} A_s \sigma_P)(\sum_{s} A_s \sigma_{BC})}$$

A_s: share of mineral consumption in sector s to total consumption

σ_P: production substitutability (0.9 / 1.0)

σ_{BC}: co-/by-production score (0.8 / 0.9 / 1.0)

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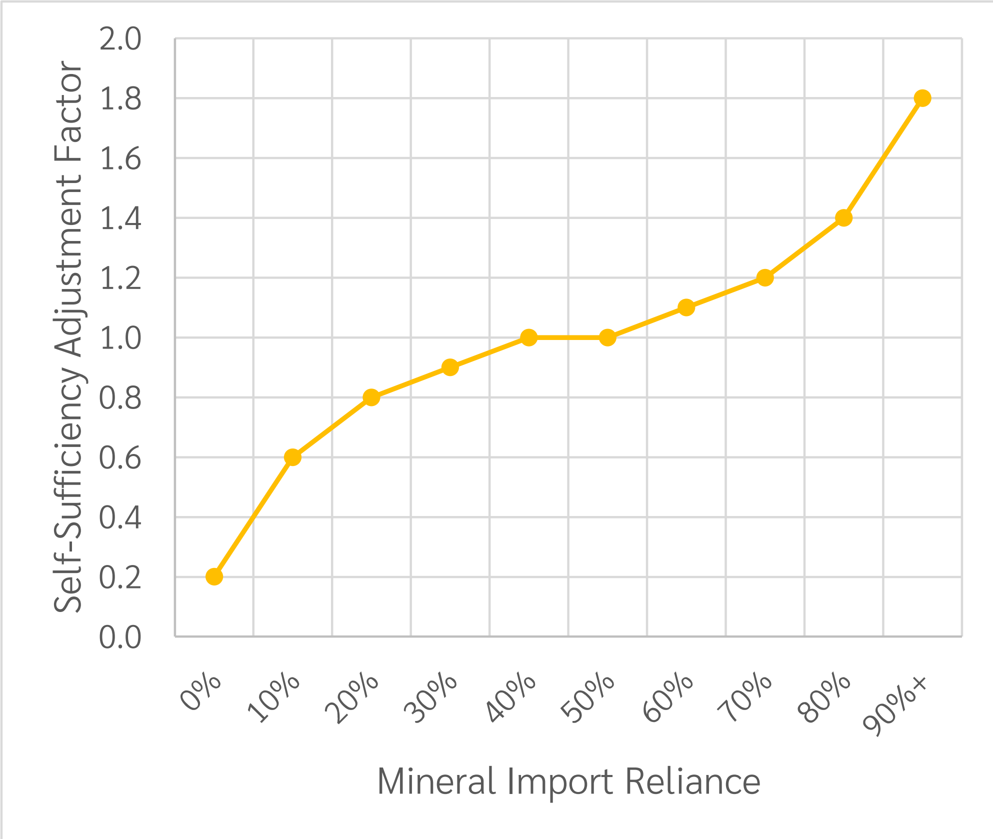
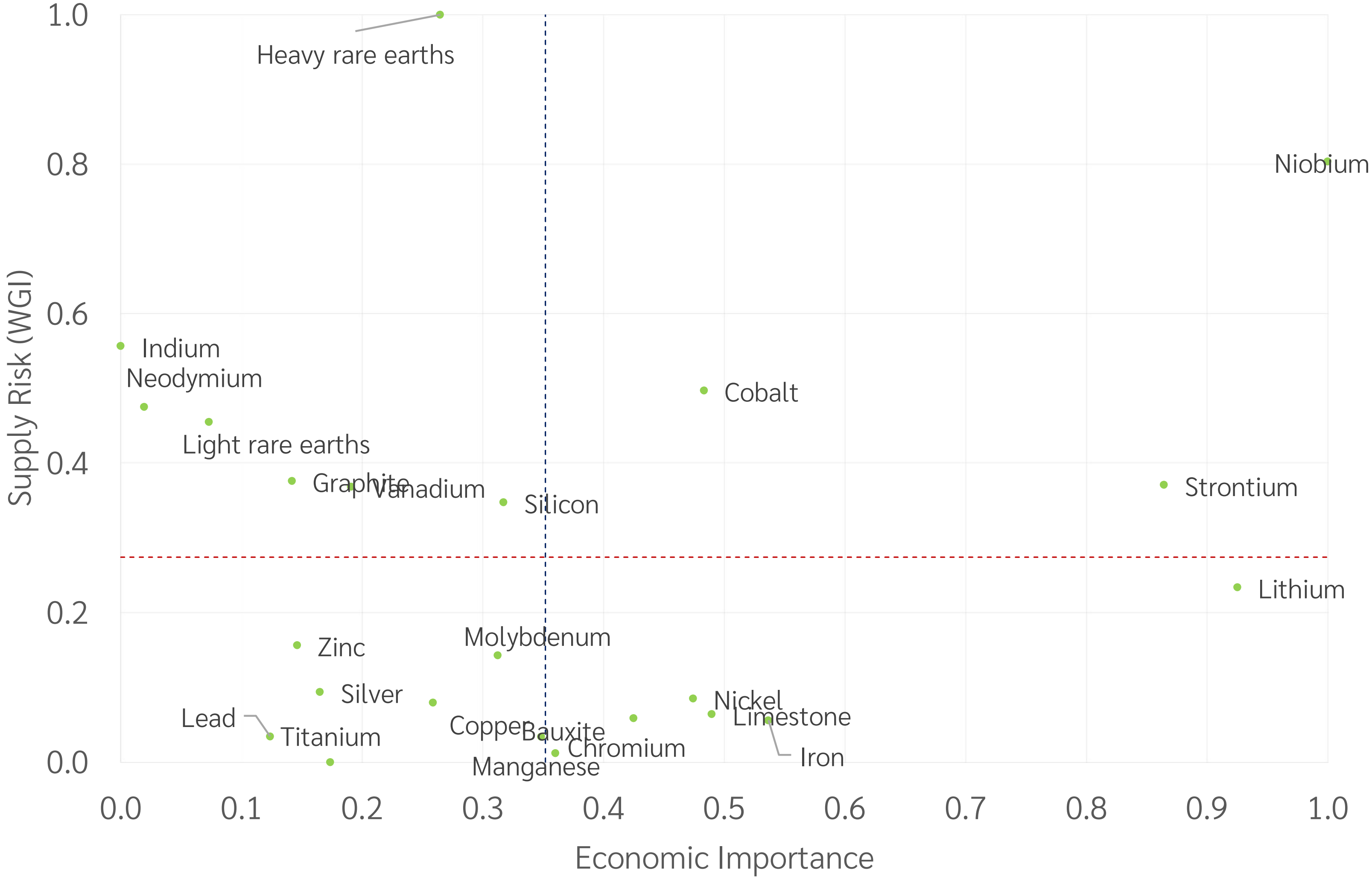
Mineral Self-Sufficiency Adjustment Factor

- Adjusts the supply risk of the mineral by a factor proportional to the import reliance of the mineral
- Minerals with low import reliance will have lower supply risks





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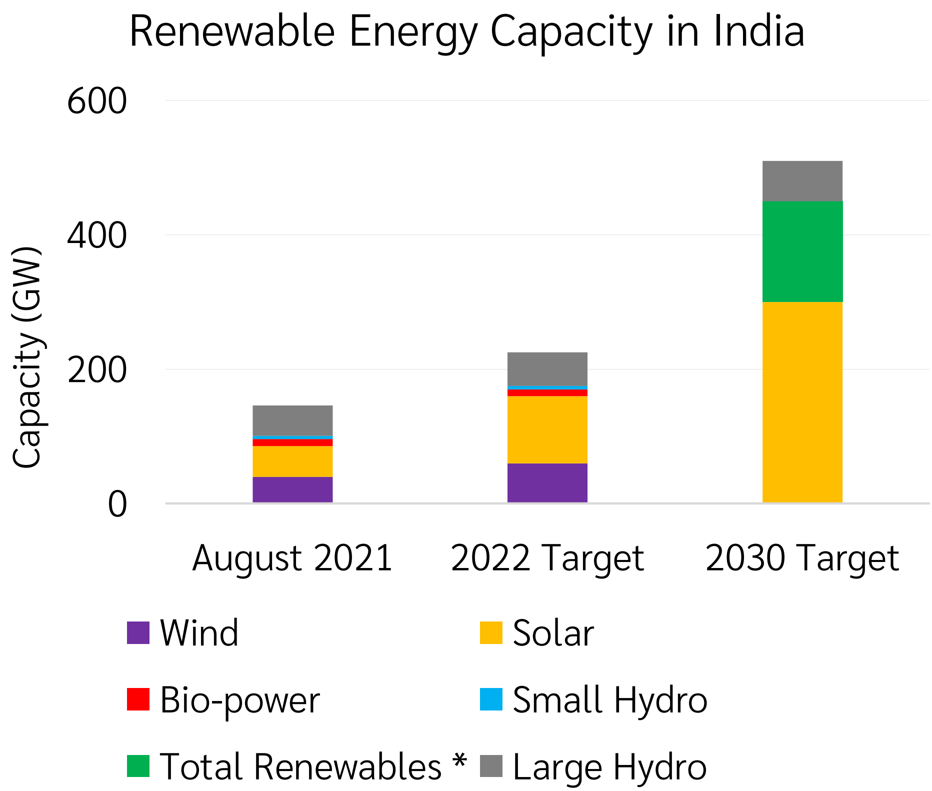
Projecting the Needs of Critical Minerals for Green Technologies

- Early attempt in projecting the requirements of critical minerals for India’s green technology transition
- Based on various assumptions of climate change targets and technologies to be used
- More work to be done to refine these results

Renewable Energy Targets

- India targeting 450 GW renewable energy capacity by 2030 including 300 GW solar
- Critical minerals needed for manufacturing wind turbines include: chromium, manganese, molybdenum*, nickel*, and rare earths*

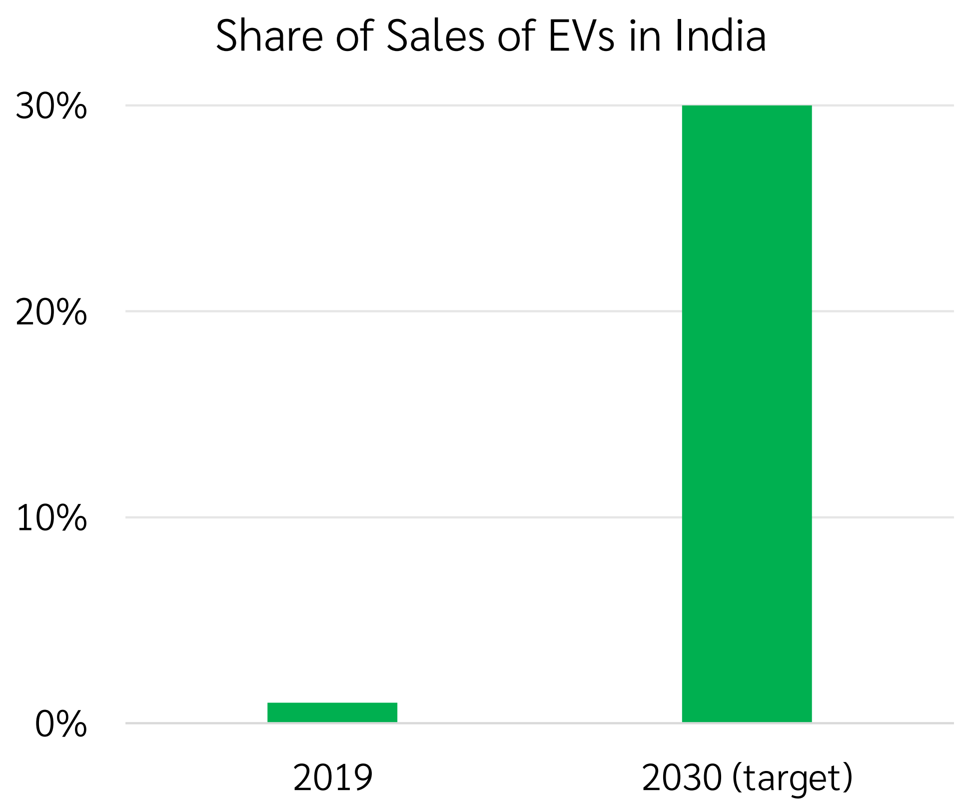
* Not produced in India



* Total renewables includes wind, bio-power, and small hydro

Electric Vehicle Targets

- FAME and National Mission on Transformative Mobility and Battery Storage
- Critical minerals needed in the manufacture of EVs include: lithium*, cobalt*, and rare earths*



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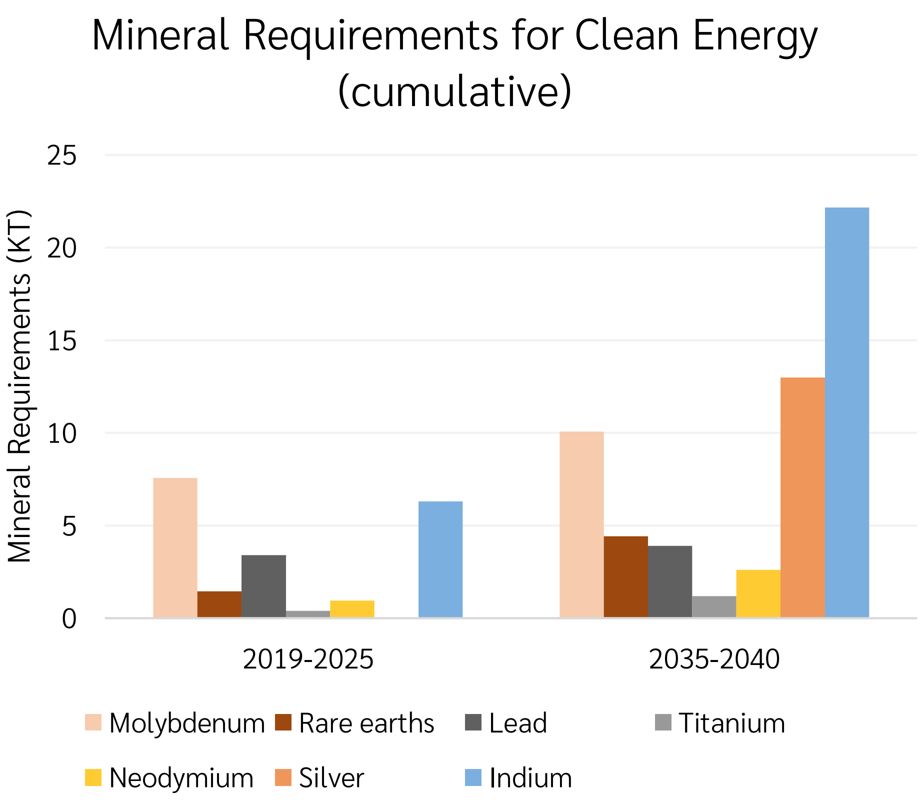
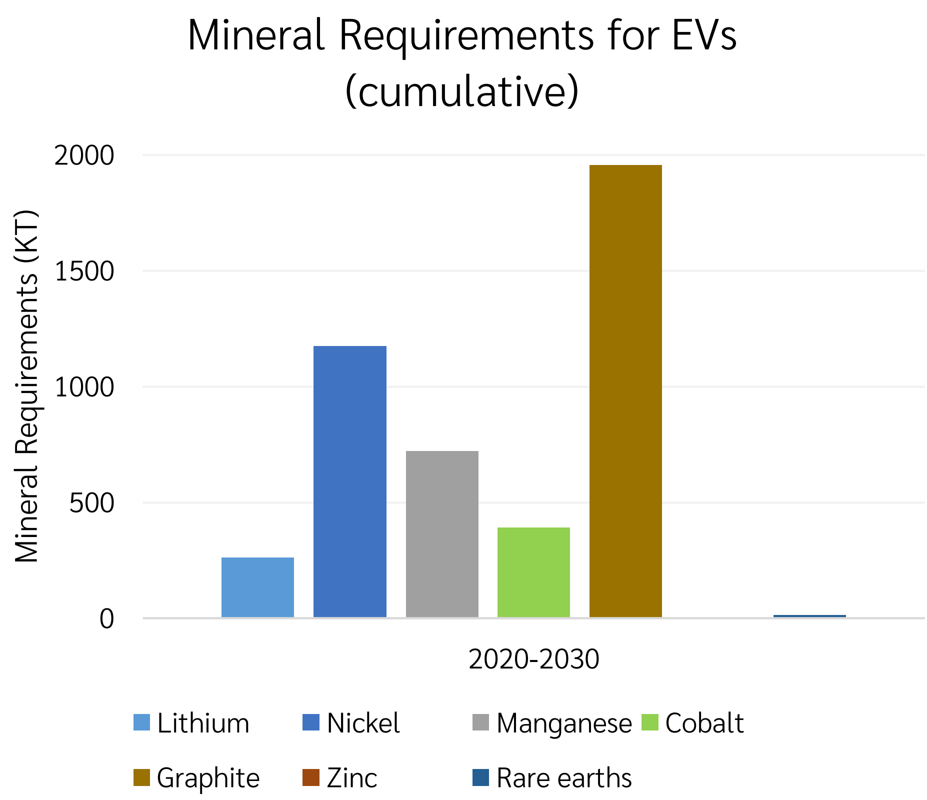
Select Mineral Requirements



Source: IEA & others



Source: CEEW, IEA & others

Indian Mineral Inventory

Mineral	Reserves (KT)	Total Resources (KT)	Mineral Needs (KT)
Copper	2,735	12,158	4,813
Cobalt*	0	44,910	399
Graphite*	7,961	1,94,887	1,955
Chromium*	1,02,210	3,44,016	354

* KT of ore – actual content of mineral will be much lower

Source: Indian Bureau of Mines

Wage Incomes in Green Technologies Transition

- Wage income multipliers (WIMs) computed using 34-sector CSEP Hybrid Energy Input Output Table
- Agriculture and allied sectors have highest WIMs (0.52–0.54)
- Coal mining has one of the lowest WIMs (0.33)
- Renewable electricity generation has highest WIM of all electricity generating sectors (0.41); coal electricity generation has second highest WIM (0.39); other thermal electricity has lowest (0.35)
- Machinery and equipment manufacturing has a relatively low WIM (0.36)

Policy Implications

- Enhancing domestic mineral exploration and extraction
- Differentiated allocation process for deep-seated minerals
- Developing resilient supply chains
- Signing trade agreements with producing countries
- Acquiring mining assets abroad – G2G engagement (KABIL*) to be supplemented with acquisition of private mines
- Developing and setting up recycling facilities

* Khanij Bidesh India Ltd. (MECL, NALCO, HCL)

Thank you

Current Issues with Critical Minerals

- Battery mineral prices have been rising since mid-2020
  - Cobalt, nickel and lithium
- COVID-19-related lockdowns in China have led to shutdowns at several electric vehicle producers
- Uncertainties over Russia-Ukraine conflict
- Disrupted auto parts manufacturing and slowed flows of material to downstream users
- Various risks to passenger EV production and sales, supply chain flows, and battery metal prices
- This may derail the e-mobility transition entirely

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