



Projecting Critical Mineral Needs for India's Clean Energy Transition

How Much of Which Minerals Are Needed for the Transition?

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Critical minerals, in both primary and processed forms, are essential inputs to the production processes of an economy. Their supplies are likely to be affected due to the risks of non-availability or unaffordable price spikes (Chadha, Sivamani, & Bansal, 2023a). Without access to these essential minerals, India's and the rest of the world's clean energy transition plans may face multiple setbacks. Compared with traditional energy generation equipment, renewable energy devices, including solar, wind, and nuclear, require considerably large amounts of critical minerals. The same holds for electric vehicles (EVs) when compared with conventional internal combustion engine vehicles. Battery energy storage systems (BESS) and EV batteries also need considerable quantities of critical minerals (IEA, 2021). Hence, the global demand for critical minerals is set to rise rapidly as the world transitions to clean energy technologies to reduce emissions and meet the net zero emissions target. However, the risks of future availability are elevated due to the significant concentration of extraction and processing of critical minerals across very few countries.

India has undertaken a clean energy transition programme for climate change mitigation, energy security, and environmental preservation. At COP26 held in Glasgow in 2021, India presented its climate action strategy, including a commitment to achieving the target of net zero emissions by 2070 (PIB, 2022a). However, there are several challenges in achieving these targets, including mobilising adequate investments, solving technical and operational challenges, and creating a just transition framework. Another imminent concern is ensuring resilient access to the requisite green technologies and the raw materials needed for their manufacturing, referred to as "critical minerals." A World Bank report highlights the mineral needs for various clean energy technologies and provides global mineral demand projections until 2050 (Hund, La Porta, Fabregas, Laing, & Drexhage, 2020). It states that "a low-carbon future will be very mineral intensive because clean energy technologies need more materials than fossil-fuel-based electricity generation technologies." A 2021 report from the International Energy Agency (IEA) highlights that "the data shows a looming mismatch between the world's strengthened



climate ambitions and the availability of critical minerals that are essential to realising these ambitions” (IEA, 2021). The report adds that “while there is no shortage of resources worldwide, today’s supply and investment plans for many critical minerals fall well short of what is needed to support the accelerated deployment of solar panels, wind turbines, and electric vehicles.”

India has a significant slack in the domestic availability of critical minerals and manufacturing of clean technology equipment. Hence, India must evaluate its critical mineral needs and their availabilities to meet its emissions reduction commitments. While India may consider exploring and mining critical minerals, the process may take years since the extant resources have not been converted into reserves and the known reserves have not been adequately exploited. India must consider all its options, including extracting and processing in the country, joining global supply chains at various processing stages, and owning mines and processing facilities abroad. The mining sector must gear up to meet the growing demand for critical minerals. Alternative technologies requiring fewer or different critical minerals must be found.

The *Make in India* initiative of the Government of India seeks to create domestic integrated manufacturing value chains, which are further being incentivised through various production-linked incentive (PLI) schemes. Most PLIs require domestic value addition throughout the supply chain. Hence, it is important to project the magnitude of the raw materials required for manufacturing the requisite clean energy equipment. Without resilient access to these minerals, India would have to rely on imported mineral-embedded components to feed into its manufacturing sector. Policymakers should design mineral-wise strategies to ensure domestic manufacturing of green technologies equipment has access to its requisite raw material inputs. The issue becomes particularly pertinent for the minerals for which India has no known domestic geological potential, as any strategies would necessarily involve some form of critical minerals cooperation with one or more countries.

This paper projects the mineral requirements to manufacture the clean energy technologies needed for India to meet its climate action commitments. It highlights the cases in which India has access to these materials domestically and the reliance on imported minerals (in either their raw, processed, or component-embedded forms) to meet the needs of the growing domestic clean energy equipment manufacturing sector. Though the mineral requirements for EV manufacturing have not been considered in this paper, a substantial demand is expected from this sector as well. Considering the significant amount of minerals needed to manufacture EVs, especially lithium for batteries, a follow-up study should examine the projected increase in EV sales to estimate the corresponding mineral requirements. Other sectors being electrified in India include cooking and heating, but their mineral requirements are

not computed in this study. This study considers both the existing and more advanced technology options, which may be promising alternatives. These options are available for procurement to determine the mineral requirements for clean energy devices. However, given the current pace of technological progress and the potential for disruptive, more efficient technologies to emerge, it would be prudent to revise and update this analysis every two to three years to account for any new technologies, as well as updated policy prescriptions.

In continuation of an earlier piece on projecting mineral requirements (Sivamani, 2023), this study focuses on renewable electricity capacity and the required BESS to facilitate its operation. We compute the annual addition in power capacity based on various scenarios, accounting for replacing older decommissioned plants. We then examine the various technology options for each source and devise scenarios on technology trends based on available literature. Finally, the mineral intensities for each technology option for each electricity source are used to compute the mineral requirements. We also show how recycling reduces the need for virgin ores and metals, which may decrease the impending supply gap and reduce greenhouse gas emissions. Various scenarios have been considered to project India’s critical mineral needs for the clean electricity transition, such as for electricity capacity, lifespans of power stations, recycling rates, and future technology changes.

The annual mineral requirements to manufacture the three technologies (solar, wind, and battery storage) have been computed for each of the scenarios highlighted above. While mineral intensities data are available for all the minerals required to manufacture each device, this study focuses on the needs of non-bulk critical minerals. India is well-endowed with supplies of bulk minerals like iron ore, limestone (for cement), and bauxite (for aluminium). Hence, the requirements of bulk materials are not discussed in these results but are available in the Excel addendum. The study presents results for fiscal years (FY) 2025, 2026, 2027, and then every fifth year after that until 2047, which is the last year for which the IESS (India Energy Security Scenarios) projects electricity capacities. Results for 2030 are also provided as it is a milestone year for India’s climate targets and also the year in which the electricity capacity scenarios switch from the Central Electricity Authority (CEA) of India to IESS projections.

Policymakers can use the results of the projections exercise to devise strategies for secure supply chains of the minerals required for the clean technology transition. These strategies may be devised by considering the current status of mineral development in the country and the projected growth in their demand. For cases where India produces the mineral, strategies should focus on bolstering the domestic mining and processing regimes. India may also wish to share its expertise and invest in countries seeking to expand their domestic capabilities. In cases where India has reserves of a

mineral, but a relatively high share of demand is being met through imports (i.e., low self-sufficiency), efforts may be made to allocate more mining blocks to boost production levels.

While this study projects the critical mineral requirements of clean energy technologies, other green technologies key to the net zero transition also need attention. A subsequent study must consider various scenarios on the rise in demand

for EVs, amongst other green technologies, and the technology options available to compute the critical mineral needs to manufacture EVs. These projection studies should also be updated regularly to account for changes in available technologies, including both reducing mineral intensities and technological disruptions. They should also be updated to account for any new policies which redirect efforts towards different green devices.

About the authors



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