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India's Critical Mineral Resources: A Trade and Economic Analysis

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Among its major completed projects, CEEW has: published the 584-page National Water Resources Framework Study for India's 12th Five Year Plan; written India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; undertaken the first independent assessment of India's 22 gigawatt solar mission; analysed India's green industrial policy; written on the resource nexus and on strategic industries and technologies for India's National Security Advisory Board; facilitated the $125 million India-U.S. Joint Clean Energy R&D Center; published a business case for phasing down HFCs in Indian industry; worked on geoengineering governance (with UK's Royal Society and the IPCC); published reports on decentralised energy in India; evaluated energy storage technologies; created the Maharashtra-Guangdong partnership on sustainability; published research on energy-trade-climate linkages for the Rio+20 Summit; produced comprehensive reports and briefed negotiators on climate finance; designed financial instruments for energy access for the World Bank; designed irrigation reform for Bihar; and a multi-stakeholder initiative to target challenges of urban water management.

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CEEW's **work covers all levels of governance**: at the national level, resource efficiency and security, water resources, and renewable energy; at the global/regional level, sustainability finance, energy-trade-climate linkages, technology horizons, and bilateral collaborations, with Bhutan, China, Iceland, Israel, Pakistan, Singapore, and the US; and at the state/local level, CEEW develops integrated energy, environment and water plans, and facilitates industry action to reduce emissions or increase R&D investments in clean technologies.

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BACKGROUND

India's emergence as an economic power house has largely been a result of the prolific growth witnessed by the service sector in the last decade. Post the economic liberalization of the early 90's, the sector has grown nearly 50%, as compared to the near stagnation shown in the industrial sector (which is largely manufacturing driven).[1] India is endowed with large natural resource base and yet, has had a stagnant manufacturing sector contributing approximately 14% - 17% of GDP, as compared to China where industry consistently contributes more than 30% over the last three decades.[2] The manufacturing sector requires a much needed boost to meet employment needs and address social and developmental challenges in the years ahead. In order to achieve this, technology adoption and resource availability are one of the crucial elements.

Minerals are indispensable in modern industrial activities; infrastructure and manufacturing sectors, as indeed all sectors of economy. However, non-fuel materials (minerals and metals) have so far not received the same attention as have oil and natural gas. Non-fuel minerals even while directly contributing to less than 2% of GDP (in the form of mined ores), are the backbone that supports 15% of GDP, through the manufacturing sector. This illustrates clearly that even with only 4% of India's import bill, non-fuel minerals can have an equally large impact on the economy, as that of fuel minerals which contribute to nearly 16% of the country's imports.[3]

Malthusian or resource optimist; inescapable is the notion that most of the resources we rely on in modern society are worryingly finite. The global demand for minerals[4] has increased steadily over the last 50 years and it is likely that demand will continue its upward trend in response to the pullulating global population, burgeoning prosperity and consumerism of BRIC economies as well as the exploding demand for modern rare-mineral intensive technologies. Mineral consumption has diversified over time in conjunction with technological advances; as the unique physical and chemical properties of a growing number of elements of the periodic table have been exploited innovatively. Most people are not aware that modern cars, flat screen televisions, smartphones and a variety of day to day utility products rely on range of materials such as cobalt, lithium, antimony, molybdenum, copper, gallium etc., that have gained prominence in recent years. Securing the supply of these, to satisfy the exponentially growing demand for consumer products, civil engineering, transport

[1] RBI (2013) *Handbook of statistics on Indian economy 2012-13,* New Delhi: Reserve Bank of India.

[2] World bank (2013) "World Development Indicators" available at http://data.worldbank.org/indicator/NV.IND.MANF.ZS; accessed 30 January 2014.

[3] Ministry of Statistics and Programme Implementation (2014) "Statistical Year Book, India 2014 – Chapter 15" available at http://mospi.nic.in/Mospi_New/upload/SYB2014/index1.html; accessed 24Feb2014.

[4] The use of the word minerals in this document refers to non-fuel minerals only, unless and otherwise clearly indicated. It does not cover petroleum, coal and other fuel minerals.

and energy infrastructure among others in a sustainable fashion, has become a major challenge to many resource dependent countries.

Resource security is a matter of concern today for the global economy. In recent years several countries have begun to recognise and undertake critical minerals assessment studies for them; the US in particular has been very active in this field. In 2008 it developed an on-going critical minerals programme which has resulted into "National Strategic and Critical Minerals Policy Act of 2013" getting passed in the house of representatives and at present under consideration of senate. This novel legislation aims to promote an adequate and stable supply of minerals to maintain the economic well-being, security, and manufacturing, industrial, energy, agricultural, technological capabilities of the United States (US).

The National Mineral Policy (1993) for non-fuel and "non-coal" minerals (amended in 2008) has its primary objective, the achievement of zero waste mining and ensuring technology upgradation for development of domestic resources.[5] This singular focus of the policy merely skims the issue of importance of minerals in foreign trade and the need to add value domestically. Recognising India's resource security needs, the Planning Commission has formed a dedicated working group to recommend strategies for raw material security along with other key aspects under its XII Five Year Plan.[6] One other important dimension that is recognised by the national security establishment is the efficiency in the use of mineral resources and is often not the focus of planners.

An initiative was taken by ministry of mines (Centre for Techno Economic Mineral Policy Options – CTEMPO) in sponsoring a study titled "Rare Earths and Energy Critical Elements: A Roadmap and Strategy for India". Nevertheless, despite all the efforts by Indian policymakers towards addressing non-fuel mineral resource security of the country, the attempts either remain restricted to a specific sector or a group of minerals, or are too qualitative in highlighting the supply risks associated with a broader set of minerals. In India, no publicly available exercise has been conducted to objectively determine the criticality of specific minerals based on the underlying economic importance.

A strategic understanding of mineral resource security and critical minerals would require an informed analysis that juxtaposes the advancements in technology and changing consumption patterns with India's resource endowments, geo-political challenges of sustaining imports, environmental goals and the rapidly evolving global economic conditions.

[5] Ministry of Mines (2008) "National Mineral Policy," available at http://mines.nic.in/NMP2008.pdf; accessed 24 February 2014.

[6] Ministry of Mines (2011) *Metals and Minerals – Strategy based upon the demand and supply for the mineral sector*, report by sub-group II, New Delhi.

RESOURCE SECURITY IN THE INDIAN CONTEXT

Import Dependency

India is endowed with some finite reserves (and in some cases large reserves) of approximately 85 mineral resources[7] (11 metallic, 52 non-metallic, and 22 minor[8]). As is indicated in Table 1 (below) the supply of many minerals is constrained not merely due to the geological availability within India, but more due to the lack of suitable technology adoption and inefficient policy mechanisms to drive mining and mineral exploration (Table 1).

Table 1: Status Quo of Availability of Some Key Minerals

	No domestic reserve	Poor reserves	Not explored well for potential reserves	Technical/economic issues in primary recovery
Minerals	Cobalt	Boron, Copper, lead, titanium	Molybdenum, Chromium, Graphite, Boron, Rare earths, Platinum Group Materials, Gypsum, tungsten, Gold, perlite, antimony	Chromium, Graphite, Boron, Rare earths, Platinum Group Material, Gypsum, tungsten, perlite
	Technical/economic issues in secondary recovery	Environmental/Social	Policy issues/Corruption	Significant Proven Reserve & Commercially extractable
Minerals	Molybdenum, Vanadium, Nickel, Cobalt, Gallium	Chromium, Iron ore, Silica	Rare earths, Iron ore	Manganese, Magnesite, Bauxite, Zinc, Tin, Bentonite, Iron Ore, fireclays, Zircon, Limestone, feldspar, asbestos, Talc, Barytes

Source: Adapted from Indian Bureau of Mines, 2011

Domestic supply constraints could be a manifestation of any of the following: (a) low/poor domestic reserve base, (b) technical ability in exploiting reserves economically, (c) adverse environmental and social impacts due to resource extraction, and (d) poor policies and governance that hamper the exploitation of these reserves.

The efforts in India to map the mineral reserves of country have been far from satisfactory. India's annual spend on mapping its reserves over the last three decades has been a paltry USD 50 million each year, whereas a mineral resource giant like Australia spends nearly 30 times more than India in mineral exploration activities.[9] Technology adoption in exploration

[7] IBM 2011

[8] Minor minerals refer to building stones, gravel, ordinary clay, ordinary sand and any other mineral which the central government may declare officially as minor

[9] Mining Weekly (2013) "Geological survey of India looks to industry for funding," available at

has also lagged behind the global benchmarks and capacity exists to explore only upto the depth of few hundred metres, while other counterparts are already exploring depths extending in kilometers from the surface of the earth.[10]

Domestic production is augmented by imports of raw minerals and processed ores/ metals that impose a non-significant import bill that amounts to 3% - 4% of GDP. For those minerals for which India is reliant solely (or to a large degree) on imports, the additional issues of concern are (a) concentration of reserves/ monopoly of production in few regions of the world and (b) geopolitical stand-offs / poor trade relationships with countries that hold these reserves. Imports are increasingly a matter of more concern with the emerging trend of resource nationalism that has been kindled the likes like China and Indonesia, which imposed moratoriums on export of rare earths and metals like nickel and tin, respectively. Many other countries such as the Democratic Republic of Congo, Argentina and Mozambique have increased taxes on exports to deter mining activity. In addition, nationalisation of mineral assets in countries such as Bolivia and Papua New Guinea adds a whole new risk dimension as supply is left to the political whims of those at the helm.[11]

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http://www.miningweekly.com/article/geological-survey-of-india-looks-to-industry-for-funding-2013-11-20; accessed 02 February 2014.

[10] Business Standard (2013) "GSI in talks with ONGC to fund Rs 4,500 cr mineral exploration plan," available at http://www.business-standard.com/article/companies/gsi-in-talks-with-ongc-to-fund-rs-4-500-cr-mineral-exploration-plan-113110100409_1.html; accessed 03 February 2014.

[11] Ernst & Young (2013) "Resource Nationalism Update" available at http://www.ey.com/Publication/vwLUAssets/EY-M-and-M-Resource-nationalism-update-October-2013/$FILE/EY-M-and-M-Resource-nationalism-update-October-2013.pdf: accessed 10 February 2014

CRITICAL MINERAL RESOURCES – A PRELIMINARY EVALUATION

Criticality

One of the cited definitions suggests that a mineral is labelled as critical when the risk of supply shortage and associated impact on the economy is (relatively) higher than the other raw materials.[12] Risk of supply shortage (simply referred to as supply risk), itself is a multi-dimensional metric, would ideally capture import dependence, recycling potential and substitutability of the mineral in question. In addition, elements such technical difficulties in mineral extraction and the concomitant social and environmental impacts could amplify the supply risk in a manner which would be difficult to quantify. This definition of a critical mineral was adapted in the US analyses (mentioned earlier) and the subsequent legislation that resulted from the analysis. The European Union (EU) also carried out a similar exercise and categorised critical minerals along these two dimensions. An initial examination carried out by the CEEW research team characterised the supply risk purely from the perspective of import dependence. Economic importance is determined by the direct value added by the various minerals through the purification process – from ore to pure metal forms. The assumption is that the market price of the metals captures the true opportunity cost of the mineral and its importance for users downstream

In our analysis, the two dimensional representation of criticality pits economic importance (y-axis) against supply risks. Both the values are normalised on to a scale (1-10) and plotted to determine the distribution of minerals along the spectrum on both criteria. The representative set chosen for the study comprises 33 minerals which contribute significantly to the manufacturing sector and account for 75% of India's overall non-fuel mineral (raw, processed, and finished goods) import bill.[13] The choice of the minerals for the analysis, while restrictive, also underlines the importance accorded to those minerals that India relies on the outside world for their supply. Those minerals that are available domestically in large quantities pose less of an immediate risk (supply) and hence have an insignificant impact on the import bill itself.

The overall criticality status for the 33 minerals is shown in Figure 1, and the location of minerals can be in one of four zones:
a) Zone I - High economic importance with high import dependency (5 minerals)
b) Zone II - High economic importance with low import dependency (9 minerals)
c) Zone III - Low economic importance with low import dependency (6 minerals)
d) Zone IV - Low economic importance with high import dependency (13 minerals)

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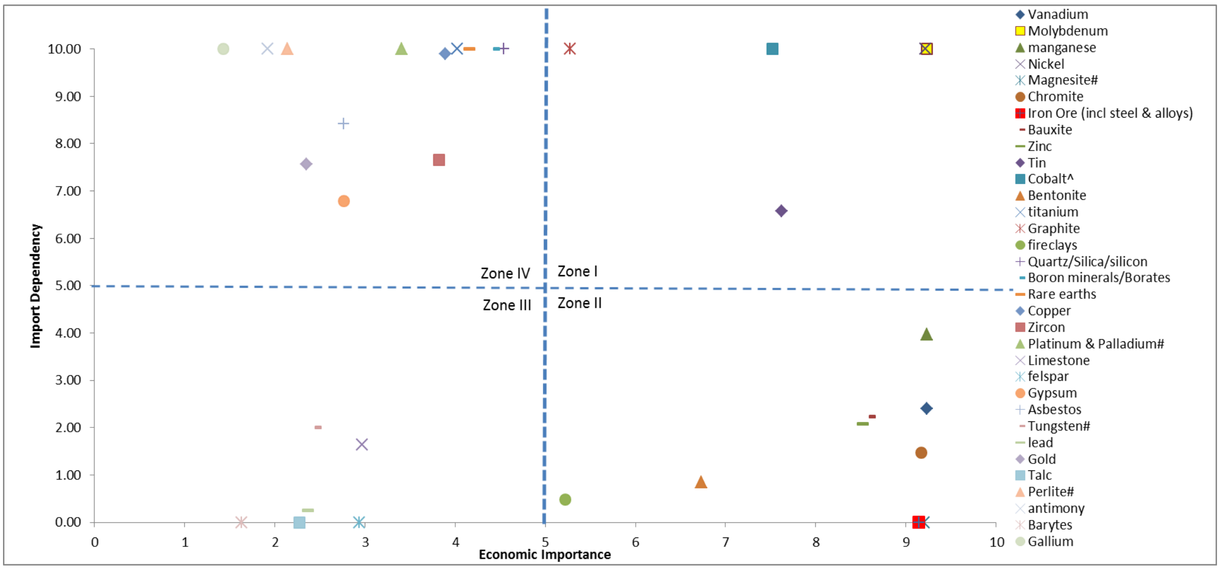
[12] European Commission (2010) "Critical raw materials for the EU," available at http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf; accessed 03 February 2014

[13] CEEW analysis

Figure 1: Economic Importance versus Import Dependency of Minerals



Source: CEEW analysis

Figure 1 indicates that few minerals (five in number) today fall in the category that would be labelled as critical (Zone I). However, the status quo is likely to change significantly (both adversely and positively) with the realisation of any or all of the following scenarios:

a) Expansion of manufacturing in India and cutting edge technology assimilation would increase the economic importance associated with the critical minerals;
b) Pursuit of low carbon technologies, which are intensive in the use of minerals and thereby fuel global demand;
c) The rate of depletion of reserves in countries that currently supply India with its mineral basket;
d) Better technologies for recycling materials from the waste and scrap of industries; and
e) Disruptive technology innovations finding suitable alternatives or substitutes of these minerals.

Minerals falling in Zone II could shift towards Zone I if the second or third scenarios detailed above materialise – increased demand leading to increasing import dependence. Similarly, it is also possible for minerals in Zone I to move to Zone II or Zone III, if technologies to recycle minerals are made available or if substitutes are discovered which would reduce their economic importance in current applications. All said import dependency is still the most critical factor in the determination of supply risk. Understanding the nature of import dependency would also help in evaluating the areas where suitable interventions would be necessary to avoid a shift to a largely imports dependent scenario.

Internal Opportunities Lost

While the discussion so far has stressed on those minerals where we lack reserves or those that are poorly explored, other minerals (of which India has significant reserves) also present significant opportunities. In such cases, India is losing out on the opportunity to add value domestically, for want of suitable infrastructure to beneficiate mined ores further. This, in turn, increases the reliance on reimports of processed ores and other finished metal products.

Table 2 compares mineral specific imports and exports by India on the basis of price per unit (USD/ Ton). Each mineral is broadly aggregated into two categories for purposes of the analysis: (Category-A) Raw and concentrated ores and (category-B) Processed minerals/metal/products. Cells coloured in 'red' indicate higher value per unit for imports than exports, while area marked 'green' are indicative of higher export prices. The 'yellow' coloured portion presents data inconsistency/ unavailability, while 'blank' area shows no imports occurring under that category.

Table 2: Comparative assessment of exports versus imports based on average prices (colour coded) and trade surplus (in USD million)

Mineral resource	**A**	**B**	**Mineral resource**	**A**	**B**
Molybdenum	-137	-38	Boron minerals/Borates	-12	-33
Manganese	-134	521	Rare earths	-5	-10
Vanadium	-3	-16	Copper	-4526	1237
Nickel	-22	-657	Zircon	-44	1
Magnesite	-4	-95	Platinum & Palladium	Not applicable	77
Titanium	34	8	Limestone	-90	134
Chromite	151	577	Felspar	23	1
Iron Ore (incl steel & alloys)	4826	-2037	Asbestos	-1	-140
Bauxite	92	-413	Gypsum	-36	0
Zinc	112	222	Tungsten	0	-21
Tin	-5	-103	Lead	69	-421
Cobalt	-38	-19	Gold	19	-26368
Bentonite	4	27	Talc	14	8
Graphite	-7	-12	Perlite	0	-3
Fireclays	0	5	Antimony	-13	-1
Quartz/Silica/silicon	-29	-241	Barytes	57	-5
			Gallium		

Note – colour of the boxes represents average trade price difference between exports and imports, whereas values indicated in box denotes difference in traded value (exports minus imports)

Source: CEEW analysis

A quick look at three minerals, which India is significantly endowed with, namely Iron Ore, Bauxite (Aluminium) and Zinc illustrates the need for a rethink of the export strategy. It is clear that India exports low value ores (or ores which are valued at a low level) and these overall exports are at nearly USD 40 billion. However, we are reliant on imports to a large degree both in the case of finished products of aluminium and iron (specialised steels, alloyed steels). An interesting case in point is the high reliance on imports for specialised steel that incorporate vanadium. India has a poor vanadium reserve base and as a result must either import the mineral or finished products thereof (like ferro-vanadium). The industry seems to have opted for the latter option and resulted in significant imports of the finished products. In contrast, ferro-manganese is exported in large quantities, on the back of imports of manganese ores, which are imported to supplement the poor quality of domestic ores. This is then used to manufacture ferro-manganese domestically. This is a good example of domestic value add would have spill over effects for manufacturing sector as a whole. One would argue that for want of better value addition domestically, some of the minerals are artificially being projected as being critical (on account of high reimport of finished products).

As a counterfactual analysis, if we assumed that the overall exports by India for the raw non-fuel mineral ores and concentrates (excluding gold and platinum) were on par with import prices, the incremental revenue generated would be equivalent to ~ 0.57% of India's GDP.

The Benefits of Recognising Critical Minerals

A wider acknowledgement of critical minerals and the resulting prioritisation accorded to mineral resource security would have numerous monetary and long term (strategic) advantages as listed below:

a) Assist Indian policymakers to strategically focus on areas where India needs to enact coherent policies and make smart investments (either for domestic mineral value addition and development, or stake in acquisitions abroad) to ensure uninterrupted mineral supply to the required industry.

b) Dedicated business friendly policies would encourage mining and mineral companies to increase their investments in India and bring in international best practices to a sector, which is almost entirely inwardly focused today. The increased mining activity could directly benefit the manufacturing sector.

c) Encourage research community to

   i. Explore the options to substitute critical minerals in current and upcoming applications, and

   ii. Conceptualise economically viable and environmentally friendly mineral beneficiation technologies, and technologies for extraction of secondary minerals from the by-products, which are currently discarded.

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