Executive Summary

In India, the growth of domestic manufacturing has not been able to match the rapid growth in the demand for consumer goods and technology-enabled products, neither in scale nor in terms of diversity. The Make in India program, which was launched by the current government, is well timed to provide the necessary impetus for domestic manufacturing. However, a thriving industrial base needs a steady supply of raw materials and must anticipate future demand. Existing policies and actions recognise India's dependence on the outside world for a sustained supply of oil and natural gas (and coal also in recent times) and there is a much better understanding of the country's long-term demands, and as a result efforts have been made to diversify the supply basket, acquire assets overseas and incentivise domestic exploration. However, the same level of understanding of the demand for non-fuel minerals is not prevalent. The notion of 'strategic minerals' or 'critical minerals' is relatively new to policy makers in India as compared to other major economies of the world. The current organisation of ministries and departments in India, and the delineation of their roles and responsibilities, limit the scope for cross-cutting analysis and policy-making. Ensuring mineral resource security for the manufacturing sector requires concerted efforts on multiple fronts, and at present no institution (barring the national security establishment, which looks at conventional security issues) exists, that possesses the necessary resources to address this challenge.

From a review of existing studies and literature, it evident that developed countries have made significant inroads in understanding mineral resource security and that it is matter of concern today for all nations aspiring to achieve sustained and environmentally sustainable economic growth. This study helps in identifying the mineral demand of India's manufacturing sector. ***The main aim is to assess the impact of critical minerals on the manufacturing sector directly arising from supply constraints (such as the impact of recycling potential and substitutability).*** The study provides the necessary evidence-based analysis for policy makers as they take steps to ensure a sustainable supply of minerals to meet the increasing consumption needs of the economy. ***The total number of non-fuel minerals considered in this study is 49.*** They were identified mainly on the basis of their economic contribution to the manufacturing sector. This list also includes *'strategic minerals'* as defined by the Planning Commission study (2011).

The framework adopted for this analysis is similar to those that have been used in pioneering studies (to analyse mineral resource criticality) in developed economies. It takes into consideration both ***economic importance*** and ***supply risks*** in evaluating criticality. Economic importance is an indirect measure of the quantum of use of a mineral in a particular (sub) sector, and factors in the contribution of this (sub) sector to the overall manufacturing GDP as well (Figure 1). ***Even if a mineral is used in small quantities, in a high-value-add manufacturing sector it can be more critical as compared to a mineral used in large quantities in a low-value-add manufacturing sector.*** The economic importance of the mineral is the overall ***score*** arising from the distribution of its usage across the manufacturing sectors of varying economic importance (as measured by value addition).

The evaluation of economic importance takes into account two factors: (i) **the overall economic structure (and that of the industrial sector within it)**; and (ii) **the consumption pattern of a mineral in each industrial sub-sector.** The overall supply risk pertaining to each mineral resource is determined on the basis of the following indicators: (i) **domestic endowment of the resource**; (ii) **geopolitical risk associated with trade in that resource**; (iii) **level of substitutability at the end-use application**; and (iv) **potential share of the recycled mineral in the primary manufacturing of products.**

What will be critical in the future?

The figure below illustrates the relative importance of 49 minerals that find use (currently as well as in the future) in the Indian manufacturing sector, for the year 2030. The risk matrix is partitioned into four zones, as shown in the figure below, and can be interpreted as follows:

a. Zone I: high economic importance and high supply risk (most critical)

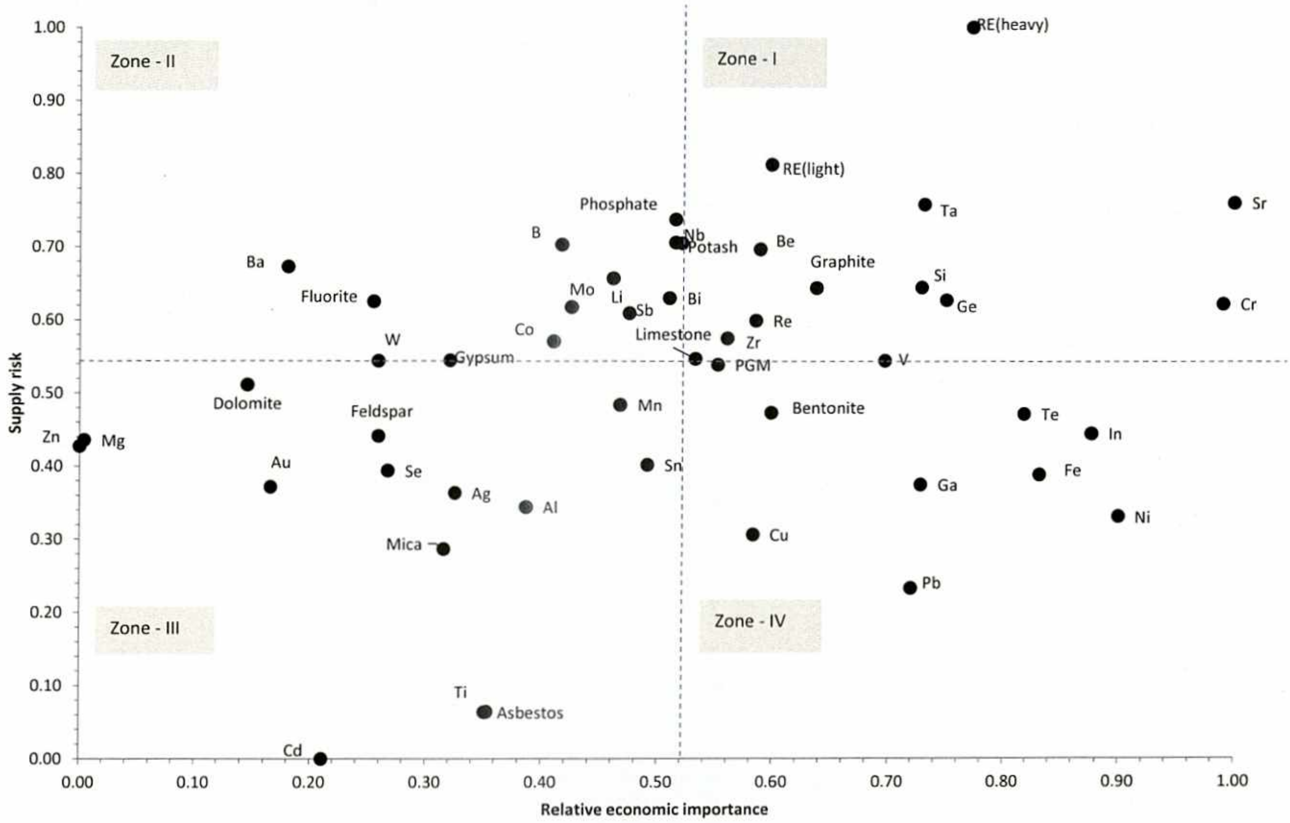
b. Zone II: low economic importance and high supply risk (moderately critical)

c. Zone III: low economic importance and low supply risk (least critical)

d. Zone IV: high economic importance and low supply risk (moderately critical)

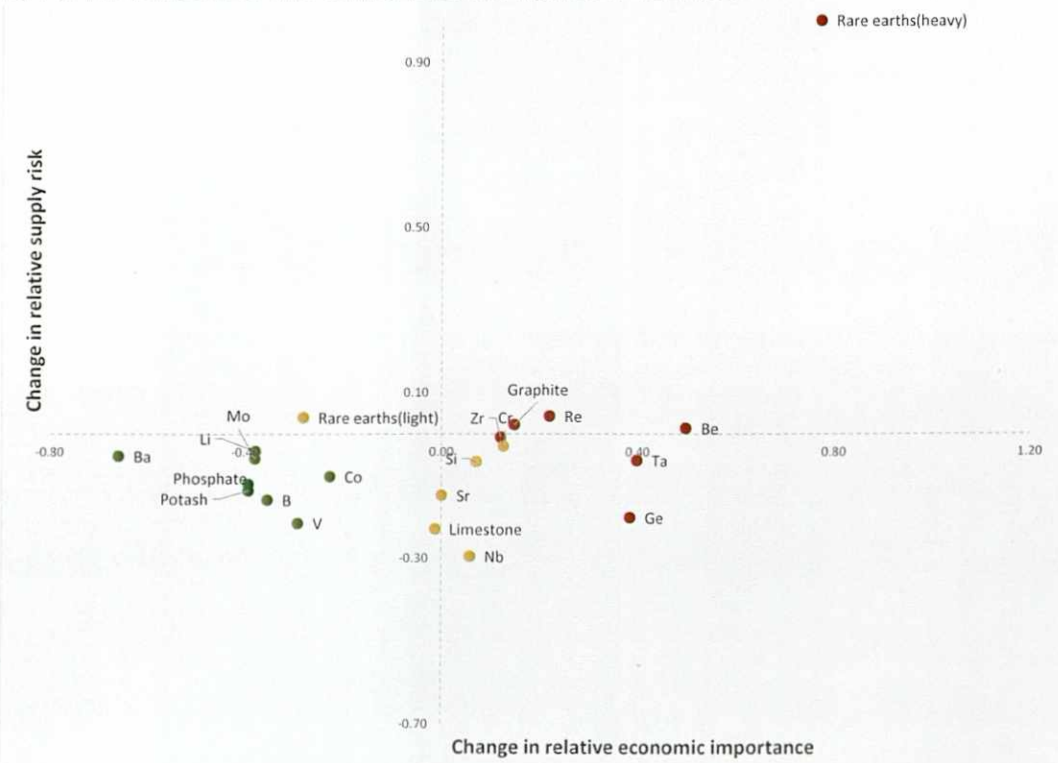
A 20 year time frame is chosen to provide a future perspective on critical mineral resources. The reason being that, any measurable impact of the current policies on the manufacturing and mineral sector (mining and processing) is visible only over such a period. The structure of the manufacturing sector, mining output, geopolitical will be visible only in the medium to short-term while technology has impact only in the medium to long term. This analysis focuses on the medium term – an intersection where the impact of multiple factors can be seen.

SNAPSHOT OF CRITICAL MINERALS FOR THE YEAR 2030



Source: CEEW analysis

TRANSITION OF MINERALS INTO THE CRITICAL ZONE FROM 2011 TILL 2030



Red: Minerals which will become critical in 2030; **yellow:** minerals which are critical both in reference year and future year; **green:** minerals which will are only critical in the reference year

Source: CEEW analysis

It can be seen from the figure above that over a period of 20 years, a change in the overall manufacturing structure has an impact on the level of criticality associated with various minerals. It is the transition in criticality, between the two periods, that is most significant. Nine new minerals have been added to the most critical zone by 2030. This transition can largely be attributed to their increased economic importance (movement along the X-axis), and, to a lesser extent, to the heightened overall supply risk. This is of more interest because risk (associated with supply) mitigation enters hitherto unchartered territory. From the policy maker's perspective, it is important to track the key drivers influencing such developments. The table below highlights the minerals that are likely to be critical to India's manufacturing sector in 2030 and the reasons why they take on more importance.

KEY DETERMINANTS OF THE TRANSITION OF MINERALS TO THE MOST-CRITICAL QUADRANT

S.No	Critical minerals – 2030	Key parameters to impact economic importance	Key parameters to impact Supply risk
1	Rhenium	Super-alloys in aerospace and machinery uses rhenium as a principal alloying element	India is currently 100% import dependent, with no declared resource/reserve so far, as it is mainly obtained as a by-product of copper/molybdenite ores.
2	Beryllium	Current use is exclusively in the paper sector (very low value add), in future finds its use in a diversified group of sectors	Complete import dependency with 99% of global supplies controlled by US and China only. For most of the applications, substitutes are difficult to find.
3	Rare earths (Heavy)	a) All the major green technologies depend on heavy rare earths imparting the special properties to them b) Extensive applications within the defense industry	India is 100% import dependent, with 94% of global supplies controlled by China. India bears mainly deposits for lighter rare-earth elements (in form of monazite).
4	Germanium	Decline in its consumption from steadily growing machine manufacturing, while gaining demand from high value sectors (electronics and metals)	India is likely to continue with 100% import dependency. It is a secondary mineral. recovered mainly as a by-product of Zinc (also from silver, lead and copper). Recyclability is low and alternative substitutes are a difficult find.
5	Graphite	Diversification of its use from electronics alone into other value add sectors as well	Majority of the resources of graphite are unexplored and those identified are of poor grade. Only 5% of declared resource have been translated into viable reserves. India can minimise future risk by carrying out survey and exploration activities to open new mines.
6	Tantalum	Decline in its consumption from steadily growing machine manufacturing, while gaining demand from high value sectors (electronics and metals)	No declared resource available in India, while 95% of global supplies are controlled by a single country Brazil. Substitutes are difficult to find, whereas recycling potential is also low.
7	Zirconium	Rising demand from the high value chemical manufacturing and electronics sector	75% of domestic resource is already identified as a viable reserve. Although R/P is very high (53 years), but lesser options for substitutes and difficulty in recycling makes it susceptible to high risk.

KEY DETERMINANTS OF THE TRANSITION OF MINERALS TO THE MOST-CRITICAL QUADRANT

S.No	Critical minerals – 2030	Key parameters to impact economic importance	Key parameters to impact Supply risk
8	Chromium	All were identified critical in the reference year (2011) as well.	Major application is in manufacturing of stainless steel for which nearly no substitutes are available at prevailing cost and efficiency. Potential environmental hazard, and has low R/P
9	Limestone		a) No substitute is available at present for its use in cement manufacturing. b) Recovery/recycling from cement is less likely, as construction work has a high lock-in period. c) Import dependency would rise from 0% to 20% if no accretion of reserves happens in coming 20 years.
10	Niobium		100% import dependency; No reserve/resource declared by ministry of mines
11	Rare earths (light)		India is 100% import dependent, Its reserves are associated with coastal beach sands of India, but its mining is not open for private sector till date
12	Silicon		Obtained from sand, which is abundantly available. However, processing of specific grade of sand into Silicon is highly energy intensive. Much of the silicon grade resource is yet to get translated into reserve category.
13	Strontium		India has not declared any resource for them and is 100% import dependent. 90% of global supplies are controlled by China and Spain. Hence, there are higher chances of supply side monopoly in global trade.

Source: CEEW compilation

Takeaways and Recommendations

The two-dimensional framework adopted to evaluate criticality, and the methodology used to arrive at measures of economic importance and supply risk, constitute a large portion of the value of this first of a kind exercise that CEEW has undertaken. It has the potential to be a strategic tool in the hands of Indian policy makers, industry leaders, researchers, and investors in the mining and mineral sector for identifying and anticipating the potential supply bottlenecks for minerals crucial to the manufacturing sector. Our recommendations, stemming from our experience in carrying out this study and based on the results emerging from the criticality framework employed, can be categorised under three broad heads as below:

i. Institutional reforms to aid better analysis and anticipation

ii. Domestic interventions: Enhanced exploration and R&D in mining and mineral processing) technologies

iii. International interventions: Strategic acquisition of mines and signing of diplomatic and trade agreements

a. Institutional reforms to aid better analysis and anticipation

Lack of coordination between various stakeholders and insufficient institutional capacity are the key barriers for advanced and integrated planning at the national level. The Geological Survey of India (GSI) and Indian Bureau of Mines (IBM) (both under the Ministry of Mines) can play a much more significant role in mineral planning. National Mineral Exploration Policy (NMEP) has been introduced at an opportune moment and gives specific directives for prioritisation of critical minerals in industry and strategic minerals for national security. However, better coordination between several departments and ministries (as shown in Figure 13 of the report) is necessary to carry out the analytics that will truly result in the optimisation of resource exploration planning. The NMEP also talks about setting up a not-for-profit autonomous body - the National Centre for Mineral Targeting (NCMT), to do this task. The institutional arrangements discussed later in this report and the nature of analysis carried out would be a useful starting point for such a think-tank within the Ministry of Mines.

b. Domestic interventions: Enhanced exploration and R&D in mining and mineral processing technologies

A clear understanding at the national level, of India's mineral resource base, is a prerequisite for any kind of strategic planning for resource security. Currently, less than 10% of India's total landmass has been geo-scientifically surveyed for an assessment of the underlying mineral wealth. This is a big deterrent for private exploration agencies to invest, as they require good baseline data to justify risky investments. Further, the recently amended MMDR Act, 2015 advocates for a transparent regime for the grant of mining leases, but it certain provisions such as the non-exclusive reconnaissance permit act as deterrents to private investment. The expectation of returns when risk capital is employed is also high and provisions of royalty to RP holder (from the subsequent miner) are not seen as lucrative.

As recognised by the NMEP (2016), a prioritisation of exploratory activities is essential to make best use of the limited amount of resources available with the government. The study proposes a useful decision-tree analysis, overlaid with indicators of criticality of specific mineral, which then provides a priority order for exploration efforts. This is not a definitive approach but also identifies interventions at other levels – trade, recycling or finding technical substitutes. The study also highlights minerals with low or no reserves in India, and the ones, which are available only as an associated, or by-product from other mineral processing. These include bismuth, cadmium, gallium, germanium, indium, molybdenum, rhenium, selenium and tin, and all require specific attention at the national level.

The R&D ecosystem in India is still at a nascent stage and framework prioritises a set of minerals for which research – by way of identifying substitutes is crucial in order to mitigate supply risks in the near future. ***However, it is clear that finding substitutes or being able to recycle better does not fully mitigate supply risks and new sources are necessary for all minerals identified as critical.***

c. International interventions: Strategic acquisition of mines and signing of diplomatic and trade agreements

India is dependent on imports for more than half of the minerals covered in this study. The reasons, as stated before, are (a) lack of clarity on resource availability; (b) lack of recovery of secondary/by-product minerals; (c) non-establishment of commercial and technical viability of resources (proven reserves); and (d) rapid depletion of existing (proven) reserves and the fact that they constitute a small share of estimated reserves.

Across the world, countries are developing strategies to secure raw materials required for various economic activities. Diplomatic ties between countries play a crucial role in international trade relations, specifically in the acquisition of overseas mining rights and their development, and can have a telling impact on long-term security of resource supply. Strategic diplomatic efforts help to mitigate risks on the supply side. The table below illustrates a list of go-to countries for mineral specific supply contracts.

DEVELOPMENT OF INTERNATIONAL TRADE AGREEMENTS FOR THE LONG TERM

Mineral	Category	Primary/ Secondary	Source Mineral (S)	Major supplier countries		
				Country -1	Country -2	Country -3
Germanium	No resources	secondary	Zinc, Copper, Lead	China (85%)	Finland (10%)	USA (3%)
Niobium		primary	--	Brazil (95%)	Canada (4%)	Rest of world (1%)
Rhenium		secondary	Copper	Chile (57%)	USA (19%)	Poland (11%)
Strontium		Primary	--	China (79%)	Spain (11%)	Mexico (5%)
Tantalum		primary	--	Brazil (95%)	Canada (4%)	Rest of world (1%)
Rare earths(heavy)		primary	--	China (94%)	Russia (5%)	Malaysia (1%)
Rare earths(light)	Resource: Yes Reserve: No	primary	--	China (94%)	Russia (5%)	Malaysia (1%)
Beryllium	Resource: Yes Reserve/Resource < 50%	Primary	--	USA (88%)	China (11%)	Mozambique (1%)

Source: CEEW compilation using IBM (IBM, 2014a) and World Mineral Statistics (BGS, World Mineral Statistics, 2016)[1]

Similarly, acquisition of overseas mining rights is also a diplomatic strategy adopted by many countries. Given India's nascent mining industry and limited expertise, the government may not be able to pursue this option aggressively. Instead, India can strategically develop joint partnerships with existing global players (private firms or governments) in these countries.

1 BGS: British Geological Survey

RECOMMENDED MINERALS FOR ACQUIRING OVERSEAS ASSETS

Mineral	Category	Name of major reserve/resource bearing Countries
Lithium	No resources	Chile; China, Argentina, Australia
Niobium		Brazil
Strontium		China
Tantalum		Brazil, Australia, Mozambique
Rare earths(heavy)		China, Brazil, Australia
Barium	Domestic reserve more than 50% of resource	China, Kazakhstan, Turkey, Thailand
Feldspar		Portugal, Poland, Czech Republic
Zirconium		China, South Africa, Mozambique

Source: CEEW compilation using (IBM, 2014a)