खान मंत्रालय
MINISTRY OF MINES

CRITICAL MINERALS FOR INDIA

Report of the Committee on Identification of Critical Minerals

Ministry of Mines
June 2023

प्रल्हाद जोशी
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सत्यमेव जयते

संसदीय कार्य, कोयला एवं खान मंत्री
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MINISTER OF PARLIAMENTARY AFFAIRS,
COAL AND MINES
GOVERNMENT OF INDIA
NEW DELHI

75 आज़ादी का अमृत महोत्सव

Foreword

I am delighted to introduce the report on the list of critical minerals for India, which not only highlights the strategic importance of these minerals but also emphasizes the crucial role they play in achieving sustainable development and realizing the vision of Atma Nirbhar Bharat. I am proud to inform that this is first time our country has identified the comprehensive list of critical minerals taking into account the needs of sectors like defence, agriculture, energy, pharmaceutical, telecom etc.

In addition to addressing vulnerability in the supply chain, India's focus on clean energy and lower emissions has further amplified the significance of critical minerals. From electric vehicles to renewable energy systems, these minerals play a pivotal role in accelerating the transition towards a greener and more sustainable future.

As an emerging global economic powerhouse, it is essential to understand and harness the potential of critical minerals to fuel the country's growth, competitiveness, and sustainable development. By developing a comprehensive understanding of India's critical mineral resources, this work empowers policymakers, researchers, and industry stakeholders to make informed decisions and drive the clean energy revolution.

I commend the members of the committee for their meticulous efforts in compiling this publication timely. I am confident that this report will contribute significantly to our collective understanding of critical minerals and propel India's journey towards self-reliance and sustainable development.

As we navigate the complexities and opportunities in the domain of critical minerals, it is imperative that we embrace a holistic approach that encompasses economic, social, and environmental dimensions. Together, let us strive towards a future where India's critical minerals needs are met in a sustainable, responsible, and equitable manner.

(Pralhad Joshi)

रावसाहेब पाटिल दानवे

Raosaheb Patil Danve

सत्यमेव जयते

Azadi Ka Amrit Mahotsav

राज्य मंत्री
रेल, कोयला एवं खान मंत्रालय
भारत सरकार

Minister of State of Railways,
Coal & Mines
Government of India

Foreword

In an era marked by rapid technological advancements and an ever-increasing global demand for high-tech products, the role of critical minerals has become paramount. India, with its vision of Atma Nirbhar Bharat, recognizes the importance of securing a sustainable and resilient supply chain for listed critical minerals.

In recent years, the world has witnessed exponential growth in technological advancements and growing demand for clean energy solutions. This paradigm shift towards a sustainable and low-carbon future has brought to the forefront the critical importance of securing a reliable supply of minerals.

One of the key challenges in the critical mineral supply chain lies in the global market dynamics, which can result in price volatility and supply disruptions. To overcome these challenges, the Government of India has been working tirelessly to identify and develop domestic sources of critical minerals. In the absence of a list of minerals critical for the country, it is difficult to formulate policy measures to secure the country from supply chain vulnerability of these minerals. This proactive approach not only ensures the availability of these minerals for our industries but also strengthens our national security and contributes to our vision of Atma Nirbhar Bharat.

This report on the list of critical minerals for India serves as a testament to the nation's commitment to building a robust and self-sufficient mineral ecosystem.

I extend my heartfelt appreciation to the Hon'ble Minister of Mines for his vision and unwavering commitment to securing India's critical mineral supply chain. I also applaud the efforts of the authors, researchers, and contributors who have worked diligently to compile this comprehensive list. May this serve as a guiding light, empowering us to unlock the immense potential of critical minerals for the betterment of our nation and the world.

(Raosaheb Patil Danve)

विवेक भारद्वाज, भा.प्र.से.
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Dated: 14th June, 2023

Foreword

It gives me immense satisfaction to bring forth this report on identifying critical minerals for India. The significance of critical minerals in the modern world cannot be overstated. These are the building blocks of the new economy. India's rapid industrialization has escalated the nation's reliance on these minerals. As the demand for these minerals continues to rise, understanding their availability, extraction, and utilization becomes crucial for countries seeking to secure their economic, technological, and environmental future.

Most of the countries in the world have identified critical minerals as per their national priorities and future requirements. In India also, some efforts have been made in the past to identify the minerals which are critical for the country. However, international commitments towards reducing carbon emissions requires the country to urgently relook at its mineral requirements for energy transition and net-zero commitments. This Ministry has therefore identified the thirty critical minerals needed for meeting the growing demands of the country. We will be revisiting the list periodically.

The committee constituted by the ministry has analysed the list of critical minerals of various countries, taken inputs from stakeholders and ministries to identify the requirement of minerals for their sectors, analysed the reserve position of these minerals in the country and import dependency of such minerals before finalizing the list. I wish to place on record my sincere appreciation for the excellent work done by Mrs. Veena Kumari Dermal, Joint Secretary, Ministry of Mines and other Members of the Committee, who have, through an objective process, identified Critical Minerals for India.

It is my sincere hope that this report serves as a valuable resource for policymakers, industry leaders, researchers, and all stakeholders involved in shaping India's critical minerals strategy. By offering a comprehensive understanding of the current scenario and future prospects, this report seeks to foster informed decision-making, sustainable resource management practices, and collaborative partnerships both within India and across international borders.

It is time to seize the potential of critical minerals to fuel India's economic growth and technological advancement. Together, we can forge a path towards a resilient and secure, critical mineral supply chain for India.

(Vivek Bharadwaj)

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Executive Summary

Critical minerals are those minerals that are essential for economic development and national security. The lack of availability of these minerals or concentration of extraction or processing in a few geographical locations may lead to supply chain vulnerabilities and even disruption of supplies. The future global economy will be underpinned by technologies that depend on minerals such as lithium, graphite, cobalt, titanium, and rare earth elements. These are essential for the advancement of many sectors, including high-tech electronics, telecommunications, transport, and defence. They are also vital to power the global transition to a low carbon emissions economy, and the renewable energy technologies that will be required to meet the 'Net Zero' commitments of an increasing number of countries around the world. Hence, it has become imperative to identify and develop value chains for the minerals which are critical to our country.

The Ministry of Mines accordingly constituted a seven-member Committee under the chairmanship of Joint Secretary (Policy), Ministry of Mines vide order No. 11/1/2022-IC dated 01.11.2022 to identify the list of minerals critical to our country. The Committee had a series of deliberations amongst the members and decided to have a three-stage assessment to arrive at a list of critical minerals.

The first stage of assessment was to study the critical minerals strategies of various countries to determine the parameters for assessing criticality and come up with a set of minerals for identification as critical minerals. Accordingly, a total of 69 elements / minerals that were considered critical by major global economies such as Australia, USA, Canada, UK, Japan and South Korea were considered for study. Due importance was given to domestic initiatives also. The key studies carried out in this aspect are by Centre for Social and Economic Progress (CSEP)- a not-for-profit, public policy think tank and Council on Energy, Environment and Water (CEEW)- an independent, non-partisan, not-for-profit policy research institution.

In the second stage of assessment, an inter-ministerial consultation was carried out to identify minerals critical to the sectors concerned. A meeting was held with representatives from the Ministry of Power (Central Electricity Authority), Department of Atomic Energy (DAE), Ministry of New and Renewable Energy (MNRE), Ministry of Chemicals & Fertilizers (Department of Fertilizers), Ministry of Electronics & Information Technology (MEiTY) and IREL (India) Limited. Comments and suggestions were received from the Ministry of Power, Department of Atomic Energy, Ministry of New and Renewable Energy, Department of Fertilizers, Department of Science and Technology, Department of Pharmaceuticals, and NITI Aayog for sharing the list of minerals which are critical to their respective sectors. Thus, a list of minerals critical for different sectors, based on inter-ministerial consultation was arrived at.

The third stage assessment was to derive an empirical formula for identifying the list of critical minerals. In order to derive the criticality index, a meeting was held with International Energy Agency (IEA). The Ministry of Mines also had a series of deliberations with CSEP, who have adopted the EU methodology to arrive at a list of critical minerals. The EU methodology, considers two major factors - economic importance and supply risk. The formula covered crucial parameters such as disruption potential, substitutability, cross cutting usages across different sectors, import reliance, recycling rates etc. However, it was observed that minerals like limestone, iron ore and bauxite also came out as critical as per the factors considered in the formula used by CSEP. The Committee is of the view that a detailed statistical exercise needs to be carried out for precise computation of various factors such as substitutability index, minerals cross-cutting index, import reliance etc. Hence if felt necessary, a separate sub-committee may be constituted by Ministry of Mines to exclusively work out the formula to develop the criticality index. In the present exercise, the Committee has compared the list of critical minerals derived by CSEP (based on EU methodology) with its own set of minerals derived after going through the two-stage assessment process mentioned above. Accordingly, the elements/ minerals with high Economic Importance, high Supply Risk, and both parameters high were selected as critical by the Committee.

Based on the three-stage assessment process mentioned above and also considering important parameters such as resource/ reserve position in the country, production, import dependency, use for future technology/ clean energy, requirement of fertilizer minerals in an agrarian economy, the Committee has identified a set of 30 critical minerals. These are **Antimony, Beryllium, Bismuth, Cobalt, Copper, Gallium, Germanium, Graphite, Hafnium, Indium, Lithium, Molybdenum, Niobium, Nickel, PGE, Phosphorous, Potash, REE, Rhenium, Silicon, Strontium, Tantalum, Tellurium, Tin, Titanium, Tungsten, Vanadium, Zirconium, Selenium** and **Cadmium.**

The Committee also recommends creation of a Centre of Excellence for Critical Minerals (CECM) in the Ministry of Mines. The Centre of Excellence will periodically update the list of critical minerals for India and notify the critical mineral strategy from time to time and will execute a range of functions for the development of an effective value chain of critical minerals in the country.

1. Introduction

Critical minerals are the foundation on which modern technology is built. From solar panels to semiconductors, wind turbines to advanced batteries for storage and transportation, the world needs critical minerals to build these products. Simply put, there is no energy transition without critical minerals, which is why their supply chain resilience has become an increasing priority for major economies. India's future economic prosperity will depend on how well we can use our vast energy and mineral resources to play to our strengths, and how well we can adapt to follow the global market shift towards zero emissions.

The Indian economy has undergone a transformative process of New Age reforms in the last decade. These diverse policies converge toward improving the economy's overall efficiency and realizing its growth potential. The use of technology, in particular digital technology, underpins the reforms. The future global economy will be powered by technologies that depend on minerals such as lithium, graphite, cobalt, titanium and rare earth elements. These are essential for the advancement of many sectors, including high-tech electronics, telecommunications, transport, and defence. They are also vital to power the global transition to a low-emission economy, and the renewable energy technologies that will be required to meet the 'Net Zero' commitments of an increasing number of countries around the world.

The evolving geo-political situation presents an opportunity for India to benefit from the diversification of global supply chains. The last few years have exposed multinational firms and countries to unprecedented risks due to global trade tensions, pandemic-induced supply chain disruptions, and the conflict in Europe. Firms were exposed to the risk of concentrating their production in a single country. Therefore, given the global policy uncertainty, multinational firms are gradually exploring strategies to diversify their production bases and supply chains. The United Nations Conference on Trade and Development (UNCTAD), in one of its reports, mentions that 'reshoring, diversification, and regionalization will drive the restructuring of global value chains in the coming years'. With enabling policy frameworks, India presents itself as a credible destination for capital diversifying out of other countries.

To build competitive value chains in India, the discovery of mineral wealth and identifying areas of its potential by use of advanced technologies is essential. Identification of critical minerals will help the country to plan for the acquisition and preservation of such mineral assets taking into account the long-term need of the country. This will also in turn reduce the import dependency as India is 100% import dependent for certain elements (Table.1).

Sl. No.	Critical Mineral	Percentage (2020)	Major Import Sources (2020)
1.	Lithium	100%	Chile, Russia, China, Ireland, Belgium
2.	Cobalt	100%	China, Belgium, Netherlands, US, Japan
3.	Nickel	100%	Sweden, China, Indonesia, Japan, Philippines
4.	Vanadium	100%	Kuwait, Germany, South Africa, Brazil, Thailand
5.	Niobium	100%	Brazil, Australia, Canada, South Africa, Indonesia
6.	Germanium	100%	China, South Africa, Australia, France, US
7.	Rhenium	100%	Russia, UK, Netherlands, South Africa, China
8.	Beryllium	100%	Russia, UK, Netherlands, South Africa, China
9.	Tantalum	100%	Australia, Indonesia, South Africa, Malaysia, US
10.	Strontium	100%	China, US, Russia, Estonia, Slovenia
11.	Zirconium(zircon)	80%	Australia, Indonesia, South Africa, Malaysia, US
12.	Graphite(natural)	60%	China, Madagascar, Mozambique, Vietnam, Tanzania
13.	Manganese	50%	South Africa, Gabon, Australia, Brazil, China
14.	Chromium	2.5%	South Africa, Mozambique, Oman, Switzerland, Turkey
15.	Silicon	<1%	China, Malaysia, Norway, Bhutan, Netherlands

Table.1 The net import reliance for critical minerals of India (2020) (Source: A report on 'Unlocking Australia-India Critical Minerals Partnership Potential' by Australian Trade and Investment Commission, July 2021)

2. Constitution of the Committee

2.1 The Ministry of Mines vide order No. 11/1/2022-IC dated 01.11.2022 constituted a Committee for the identification of critical and strategic minerals (Annexure I). The composition of this Committee is as follows:

Dr. Veena Kumari Dermal Chairperson Joint Secretary, M/o Mines	**Shri Pradeep Singh** Member Director (Technical), M/o Mines	**Shri Pankaj Kulshrestha** Member CCOM, IBM
Shri Hemraj Suryavanshi Member Adviser, KABIL	**Shri D. V. Ganvir** Member DDG, GSI	**Shri Kundan Kumar**[2] Member Adviser, NITI Aayog
Shri Dheeraj Kumar[1] Member-Secretary Deputy Secretary, M/o Mines	Subsequently, [1]Shri Alok Kumar, Deputy Secretary was nominated as Member Secretary of the above Committee. [2]Shri R. Saravanabhavan, Deputy Adviser (Minerals) was nominated as a Member of the Committee by NITI Aayog.	

Ministry of Mines vide email dated 20.11.2022 requested three institutes namely IIT Bombay, IIT Kanpur and Indian Institute of Science to nominate an officer to provide academic inputs on the matter. In reply, IIT Bombay vide email dated 21.11.2022 nominated Prof. Santanu Banerjee from Department of Earth Sciences, IIT Bombay.

The Committee had a series of deliberations under the chairmanship of Dr. Veena Kumari Dermal, Joint Secretary, M/o Mines. The first meeting being held on 18.11.2022. In the meeting, the country-wise methodology to assess and determine the criticality of minerals was discussed. It came up during the discussion that many of the minerals are common in the list of critical minerals for major global economies like USA, Australia, Japan, UK etc. It was decided to study the critical minerals strategies of various countries to determine the parameters for assessing the criticality and come up with a methodology for identifying critical minerals. It was also suggested to identify and explore the possibility to include minerals from other sectors like fertilizer minerals in the list.

The second meeting of the Committee was held on 12.12.2022. Prof. Santanu Banerjee from IIT (B) was included in this meeting for academic inputs. A presentation was made by Centre for Social and Economic Progress (CSEP) on their study conducted for 49 non-fuel minerals including rare-earth for computing the criticality in India. It emerged that categorization of critical mineral depends upon a number of factors such as availability, monopoly on resources, use for frontier technologies/ clean energy, substitutability, supply risk, recycling etc. The members were of the view that the studies carried out worldwide on the subject provide a good basis for the Committee to work upon. However, the local techno-economic factors of the Indian mineral sector have to be taken into consideration while assessing the criticality of the minerals for India. It was decided that in the first instance, the list of minerals critical to major mineral economies of the world and other countries like Japan and South Korea which are processing/ manufacturing hubs and the critical minerals identified by Indian organizations like DST-CEEW and CSEP in their recent studies will be examined based on which, a list of the minerals critical for India will be prepared. Accordingly, the Committee has gone through the critical minerals list of various countries and made a comparative study.

An inter-ministerial consultation was held with different Ministries in the third meeting held on

27.12.2022. For this meeting, different ministries viz. Ministry of Power, Department of Atomic Energy (DAE), Ministry of New and Renewable Energy (MNRE), Ministry of Chemical & Fertilizers (Department of Fertilizers), Department of Science and Technology (DST), Ministry of Heavy Industries, Ministry of Defence, Department for Promotion of Industry & Internal Trade (DPIIT) and Ministry of Electronics & Information Technology (MEiTY) were invited. The meeting was attended by representatives from Ministry of Power (Central Electricity Authority), Department of Atomic Energy (DAE), IREL (India) Limited, Ministry of New and Renewable Energy (MNRE), Ministry of Chemicals & Fertilizers (Department of Fertilizers) and Ministry of Electronics & Information Technology (MEiTY). Based on the deliberations of the meeting, comments and suggestions were provided by Ministry of Power, Department of Atomic Energy, Ministry of New and Renewable Energy, Department of Fertilizers, Department of Science and Technology, Department of Pharmaceuticals and NITI Aayog sharing the list of minerals which are critical to their respective sectors. An exercise has been carried out to compile the list of critical minerals for different sectors, based on inter-ministerial consultation. This is discussed separately in para 8.II of this report.

Meetings were also held with International Energy Agency (IEA) and Centre for Social and Economic Progress (CSEP) to work out an empirical formula. CSEP has adopted the empirical formula based on EU methodology and arrived at a certain set of critical minerals. It was observed by the Committee that the formula adopted by CSEP has led to the inclusion of certain set of minerals such as Limestone, Bauxite, Iron Ore etc. as critical minerals. The Committee was of the opinion that the CSEP list of critical minerals may be compared with the list prepared by the Committee to arrive at the final set of minerals taking into consideration important parameters such as resource/ reserve position in the country, production, import dependency etc.

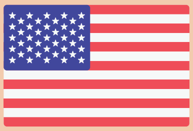
Therefore, based on different assessments, the Committee has identified a set of 30 critical minerals which are detailed in the later part of this report.

3. Definitions

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. The risk of supply shortage would ideally capture import dependence, recycling potential, and substitutability of the mineral in question. In addition, technical difficulties in mineral extraction and the concomitant social and environmental impacts could amplify the supply risk in a manner that would be difficult to quantify. This definition of a critical mineral was adopted in the US and the subsequent legislation that resulted from the analysis. The European Union (EU) also carried out a similar exercise and categorized critical minerals along two dimensions viz. supply risk and economic importance. Australia refers to critical minerals as: "metals, non-metals and minerals that are considered vital for the economic well-being of the world's major and emerging economies, yet whose supply may be at risk due to geological scarcity, geopolitical issues, trade policy or other factors". Hence, an ideal definition of Critical Minerals may be stated as follows: -

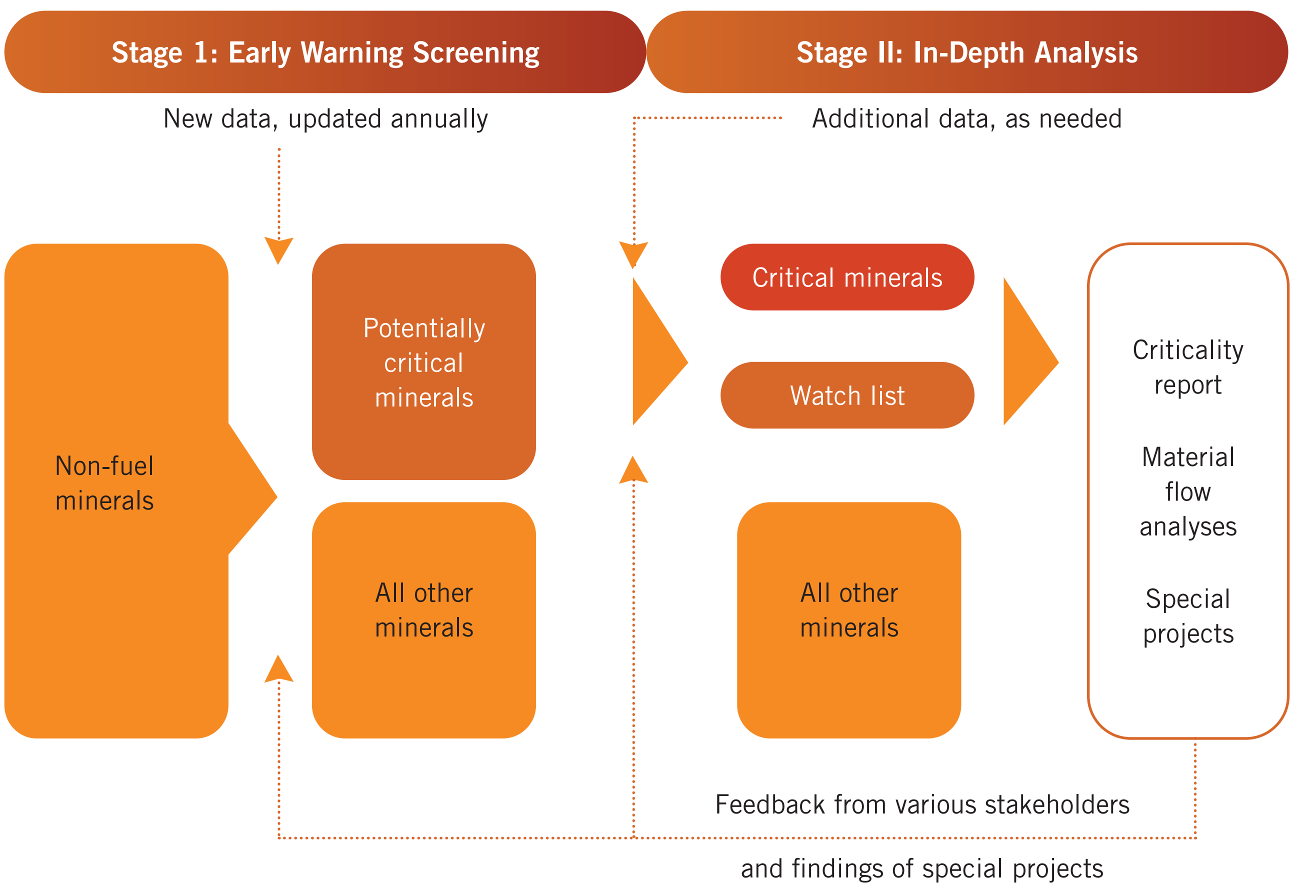
> *Critical minerals are those minerals which are essential for economic development and national security, the lack of availability of these minerals or even concentration of existence, extraction or processing of these minerals in few geographical locations may lead to supply chain vulnerability and disruption*

4. Global Overview



United States of America (USA)

The United States of America (USA) adopted a two-stage screening methodology to arrive at the list of critical minerals. The early warning screening tool (Stage I) assesses a mineral's potential criticality using three fundamental indicators: Supply Risk, Production Growth, and Market Dynamics. The indicators use data published annually by USGS, as well as other sources. This is followed by an in-Depth Supply Chain Analyses (Stage II) and Productive Inter-Agency collaboration wherein detailed analysis of the underlying factors have been carried out that resulted in the subset of minerals identified as potentially critical by Stage I of the screening tool.



The United States Geological Survey has released a list of 50 mineral commodities critical to the U.S. economy in the year 2022.

United Kingdom (UK)

The criticality to the UK economy were determined in terms of their global supply risk (S) and the economic vulnerability (V) to such a disruption. Three indicators were used to estimate S for each CM: production concentration, companion metal fraction and recycling rate. V was calculated from six indicators: production evolution, price volatility, substitutability, global trade concentration, UK import reliance and UK gross value-added contribution. A total of 18 minerals were identified as critical to the UK Economy.

European Union (EU)

The European Commission has been issuing a list of critical raw minerals since 2011 which is updated every three years. The most recent list of critical minerals was published in 2023. The main parameters used to determine the criticality of the mineral for the EU are Economic importance - in terms of end-use applications and the value added (VA) of corresponding EU manufacturing sectors. Supply risk is the other parameter and is determined based on the EU import reliance (IR), the global suppliers and the countries from which the EU is sourcing the raw materials. Substitution and recycling were also considered as risk-reducing measures. A total of 34 raw materials are identified as Critical Raw Materials for 2023.

Japan

Japan's first list of critical minerals was prepared by the Advisory Committee on Mining Industry in 1984, under the direction of the Ministry of International Trade and Industry (the predecessor of the current METI). The list appears to have stayed constant in the subsequent decades. In March 2020, Japan released its latest perspective on how to secure its supply chains for critical minerals and materials as part of the New International Resource Strategy. The strategy underscored the growing importance of critical minerals for EVs and renewable power generation equipment in the context of the carbon emissions mitigation effort. In formulating the strategy, policymakers took into account critical minerals identified by global economies like United States and Europe. Japan has identified a set of 31 minerals as critical for their economy.

Australia

In 2019, the Australian Government released its inaugural Critical Minerals List and associated national strategy. A list of 24 critical minerals was first identified in 2019. Two more elements were added in the latest critical mineral strategy released by Australia in 2022, thereby defining a set of 26 minerals as critical for Australia. Comparative studies were also made with critical minerals list of USA, EU, Japan and India.

5. Background

An early initiative in this direction came from the Planning Commission of India report (now NITI Aayog) in 2011 which highlighted the need for the assured availability of mineral resources for the country's industrial growth, with a clear focus on the well-planned exploration and management of already discovered resources. The report analyzed 11 groups of minerals under categories such as metallic, non-metallic, precious stones and metals, and strategic minerals. A separate group outlining 12 minerals and metals as strategic minerals included tin, cobalt, lithium, germanium, gallium, indium, niobium, beryllium, tantalum, tungsten, bismuth, and selenium. The recommendations indicate the need for expedited exploration, overseas mineral acquisition, resource efficiency, recycling of minerals, and finding substitutes through suitable R&D. It also noted the great need for an understanding of the economics associated with a mineral, in terms of its end-use consumption and the quantification of supply risks associated with individual minerals.

Further, Ministry of Mines constituted a steering Committee in 2011 to review the status of the availability of REEs and energy-critical elements, and to investigate the development or adoption of exploration, extraction, and mineral processing technology for a predetermined list of critical (deemed-to-be-critical) minerals. Their study titled "Rare Earths and Energy Critical Minerals: A Roadmap and Strategy for India" (CSTEP & C-Tempo, 2012) reviewed India's production, consumption, and reserves and suggested policy initiatives. The supply chain for minerals broadly consists of exploration, mining, processing, and manufacturing. The study also suggested that initiatives be taken in refining, metal / alloy production, and manufacturing components for end-use.

A study conducted by the Council on Energy, Environment and Water (CEEW)-an independent, non-partisan, not-for-profit policy research institution (Gupta, Biswas, & Ganesan, 2016), with support

from the Department of Science and Technology (DST) highlighted the paucity of research in India related to ensuring mineral resource security for the manufacturing sector. A pioneering attempt at computing a criticality index for 49 non-fuel minerals, including rare earth minerals was taken up. The study identified 13 minerals that would become most critical by 2030, of which six were critical even in the reference year 2011: Rhenium, Beryllium, Rare Earths (Heavy), Germanium, Graphite, Tantalum, Zirconium, Chromium, Limestone, Niobium, Rare Earths (light), Silicon and Strontium.

From 2017-2020, major thrust was given on the study of exploration and development of Rare Earth Elements in the country. The Geological Survey of India (GSI) and Atomic Mineral Division (AMD) jointly submitted a report on Potential Rare Earth Element Deposits of India (May 2017) to NITI Aayog, New Delhi. A strategic plan for enhancing REE Exploration in India was jointly submitted by GSI and AMD in November 2020. Similarly, the working Paper No: 97 by India Exim Bank, September 2020 emphasized on securing Rare Earth Elements for India.

The Centre for Socio and Economic Progress (CSEP)- a not for profit, public policy think tank that works on economic growth & development, energy, resources & sustainability and foreign policy & security, has worked extensively in identifying the list of critical minerals for India. The CSEP adopted EU methodology to arrive at the set of critical minerals. The discussion note-6 on “Assessing the Criticality of Non-fuel Minerals in India” (September 2021) assesses the criticality of 11 minerals viz. lithium, niobium, strontium, light rare-earths (cerium), copper, heavy rare-earths (yttrium and scandium), silicon, chromium, cobalt, iron ore and limestone. This was followed by CSEP Working Paper on – Critical Minerals for India: Assessing their Criticality and Projecting their Needs for Green Technologies: Policy Brief in October 2022 which assessed the criticality level of 23 select minerals for India’s manufacturing sector and projects their needs for green technologies needed for climate change mitigation.

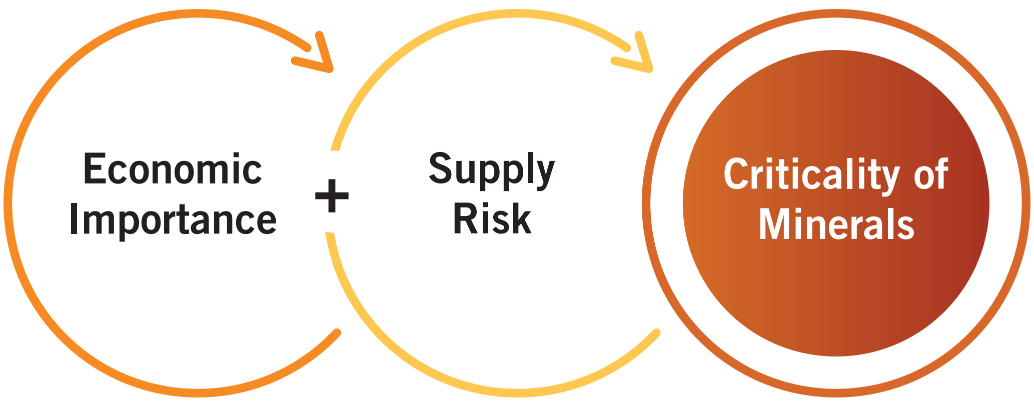
Recently, CSEP has released a working paper-49 on “Assessing the Criticality of Minerals in India” (2023) evaluating the criticality of 43 non-fuel minerals in India based on two dimensions: economic importance for the Indian economy and supply risks. The study uses the EU methodology (European Commission, 2017) with some modifications.

This report has considered the set of critical minerals derived after using the EU methodology of CSEP. These minerals have been further analysed as per the resource and reserve position in the country to arrive at a final set of critical minerals.

6. Factors impacting criticality

As stated earlier, each country has its own classification of raw materials or critical minerals depending on levels of economic development, industry requirements, national interests and security concerns, technology, market changes and natural resource endowment. While the methodology in particular for criticality assessment varies across studies, the underlying rationale remains similar. For most of the countries the criticality is judged by two main parameters, economic importance and supply risk. In Indian context also, the same two parameters were taken into consideration.

Economic Importance (EI) looks in detail at the allocation of raw materials to end-uses based on industrial applications, and measures the impact on that sector when minerals become unavailable in the supply chain. Supply Risk (SR) looks at the country-level concentration of global production of primary raw materials and sourcing, the governance of supplier countries, including environmental aspects, the contribution of recycling (i.e., secondary raw materials), substitution, import reliance and trade restrictions in third countries.



Economic Importance	Supply Risk
Disruption Potential	Governance-Weighted Mineral Concentration
Substitutability Index (EI)	End-of-life Recycling Rates (EOL-RR)
GVA Multiplier Score	Import Reliance (IR) and Self-Sufficiency (SS)
Cross-Cutting Index (CCI)	Substitutability Index (SR)

The Indian Critical Minerals Identification process tries to address five core objectives:

1. Supporting economic growth, competitiveness, and job creation
2. Driving research, innovation, and exploration
3. Enhancing global security and partnerships with allies
4. Raw material security for state-of-the-art defence
5. Promoting climate action and environmental protection

However, in order to achieve the desired objective, the complete value chain from exploration to manufacturing to recycling needs to be addressed, which may be considered as the main pillars of the critical minerals value chain.

7. Five Pillars of the critical minerals value chain

For the critical mineral strategy to be successful, India needs to develop the entire value chain from exploration to recycling. The development of the entire value chain for critical minerals, in essence, implies building capacity at each stage of the value chain namely geoscience and exploration; mineral extraction; intermediate processing; advanced manufacturing and, recycling.

Upstream Exploration

India has a landmass of 3.2 lakh sq. km with a multitude of geological – tectonic domains. This entire landmass has been covered by Geological Mapping by the Geological Survey of India (GSI). With the basic understanding that acquisition, processing and interpretation of pre-competitive baseline geoscience information plays a pivotal role in any successful exploration process, the mapping of the host rock geology of the entire country has been carried out by GSI with a significant thrust to locate the occurrence of mineral deposits. This has led to the identification of Obvious Geological Potential (OGP) areas which are the geologically favourable areas for various mineral commodities such as Gold, Base Metals, Platinum Group of Elements, Rare Earth Elements, Tin, Tungsten, Nickel, Cobalt etc. The detailed mineral exploration is carried out in the country by Mineral Exploration & Consultancy Limited (MECL) - a PSU under the Ministry of Mines and Department of Mines and Geology of State Governments. However, till now, most of the exploration has been focussed on bulk commodities like limestone, coal and iron ore. With the advancement in technologies and growing demand for technology-driven minerals, it is the right time to shift the focus from the exploration of bulk commodities to the exploration of deep-seated and critical minerals. A number of major reforms have been initiated by the Central Government to accelerate mineral exploration activities in India. As a result, search and exploration for other commodities like lithium, graphite, nickel, REE etc, has been intensified in the country in recent years. The MMDR Amendment Act 2021 has allowed the participation of private sector through the accreditation and notification of private entities as exploration agencies. This has provided the required opening for private explorers to participate in mineral investigation with the support of National Mineral Exploration Trust (NMET).

Upstream Mining and Extraction

Mining is the process of extracting minerals and/or other useful materials from the earth. The two main modes of mining are surface and underground mining. The mode of mining depends on the size, shape, and ore grade or mineral richness of the deposit. While specific operations may differ, they generally involve the use of heavy machinery for drilling, blasting, excavating, loading, and hauling the minerals away for processing.

Midstream — Processing, Refining and Metallurgy (e.g., semi-finished inputs and materials)

Though a greater amount of thrust through these legislative reforms in recent years has been given to boost the mineral exploration, mining and advanced manufacturing, the most vital - intermediate processing, has not got due attention. As India moves forward towards the goal of becoming a 5 trillion-dollar economy, its industrial expertise needs to be leveraged in environmental, social and governance (ESG) frameworks so as to develop technology for refining critical minerals with minimal environmental footprint. Metal refining technologies like vapor metallurgy are the future. It has to be ensured that the lack of metal refining infrastructure does not become a stumbling block in building up the critical minerals ecosystem in India. The major mineral economies of the world give a lot of attention for innovation funding in processing and refining technologies needed to effectively and efficiently transform minerals from primary and secondary sources into intermediate materials. Though India has a robust network of research and development labs, the research is mostly confined to laboratory-scale studies. There is a need to scale-up support through funding mechanisms to de-risk innovations through research, piloting, and deployment to advance sustainable technologies and processes towards commercialization in identified priority value chains. An innovation funding mechanism should be initiated to focus on processing and refining technologies needed to effectively and efficiently transform minerals from primary and secondary sources into intermediate materials, including post-consumer waste (e.g., used batteries) and mining waste (e.g., tailings). This can be done through setting up of incubation centres in identified labs of DST as well as in IBM.

Downstream — Component Manufacturing and Clean, Digital, and Advanced Technology Production (e.g., ZEV manufacturing, aircraft, and semiconductors)

Once processed, the metals make their way into numerous products. Separated rare earth oxides that were converted into metals can be combined to create permanent magnets that are important components of EV motors and wind turbines. Significant initiatives have been introduced under Aatmanirbhar Bharat and Make in India programmes to enhance India's manufacturing capabilities and exports across industries. The Production-Linked Incentives (PLI) scheme is the latest addition to the list of reforms introduced under the aegis of the 'Aatmanirbhar Bharat Abhiyan' (Self-sufficient India) initiative. The scheme aims to make domestic manufacturing globally competitive and to create global champions in manufacturing. Out of the 13 sectors in which the PLI scheme has been introduced, the following seven sectors use critical minerals for the manufacture of several vital components-

- Large Scale Electronics Manufacturing: Ministry of Electronics and Information Technology
- Electronic/Technology Products: Ministry of Electronics and Information Technology
- Telecom & Networking Products: Department of Telecommunications
- White Goods (ACs & LED): Department for Promotion of Industry and Internal Trade
- High-Efficiency Solar PV Modules: Ministry of New and Renewable Energy
- Automobiles & Auto Components: Department of Heavy Industry
- Advance Chemistry Cell (ACC) Battery: Department of Heavy Industry

Material Recovery and Recycling

Recycling is a keystone of the new economy and the ife blood of India's LiFE initiative. It can relieve some pressure on primary supply and can be a more cost-effective, environmentally friendly alternative to opening new mines. For example, the recycling of end-of-life lithium-ion batteries to recover valuable minerals can also reduce primary supply requirements for these minerals. Currently, recycled mineral volumes are relatively minimal overall (except for steel, lead, copper, and aluminium which have higher volumes), but the International Energy Agency forecasts they will become much more significant by 2040.

The global transition to a greener future is expected to increase the volume of end-of-life clean and digital technologies. Therefore, a robust recycling policy is the need of the hour to increase access to the minerals and metals contained in post-consumer goods through robust recycling infrastructure and secondary markets and encourage their recovery from mining and industrial waste streams.

8. Methodology

A three-stage assessment has been carried out to arrive at the list of minerals critical to India.

8.I Comparative Study of the Global Critical Minerals:

The "Criticality" combines a comparatively high economic importance with a comparatively high risk of supply disruption. The most common framework widely adopted for evaluating material criticality is based on a metal's supply risk and the impact of a supply restriction. One of the most common and widely adopted methods for arriving at the list of critical minerals is to carry out a comparative study of the global critical minerals. This has been used by countries like Australia, USA, Japan etc. This method has also been featured in the critical mineral study carried out by agencies like Centre for Social and Economic Progress (CSEP) in India. An assessment has been made of the 69 elements that were considered critical by major global economies such as Australia, USA, Canada, UK, Japan and South Korea. In the Indian context, the key studies carried out in this aspect by CSEP and Council on Energy, Environment and Water (CEEW) have also been considered. In addition, the remaining resource and reserve positions for each element, the import dependency, and elements of strategic interest have also been taken into consideration to arrive at a set of critical minerals. A table on the comparative study made is provided below in Table 2. It has been observed that while considering the Rare Earth Elements (REE), different countries have considered different sets of elements depending upon the need as well as beneficiation and refining technologies available with them. As the value chain for Rare Earth Elements and the Platinum Group of Elements is yet to be fully developed in India, it has been decided to include the complete set of REEs and PGEs in the Critical Minerals list.

An Inter-Ministerial Committee on Strategic Minerals, under the Ministry of Mines, submitted a 'Report on Strategic Non-Fuel Minerals for India' in July 2015. In the report, the Committee had defined strategic minerals as "'strategic mineral is one that is required for Defence preparedness and industrial sufficiency but has to be obtained largely or entirely from foreign sources because the supplies available within the country would not be adequate". The Committee had listed a total of 12 minerals which are considered as 'Strategic'-Boron; Cobalt; Lithium; Molybdenum-Rhenium; Nickel; Niobium-Tantalum; Platinum Group of Elements; Rare Earth Elements; Titanium; Tungsten; Vanadium and Zirconium-Hafnium. These 12 elements were also taken into consideration while deciding on the critical minerals list. The following assumptions were made to narrow down the most critical minerals:

Sl. No.	Description	Colour Code	Degree of Criticality
1.	Element Critical in >5 countries		Most Critical
2.	Element Critical in 3-5 countries		Moderately Critical
3.	Element Critical in <3 countries		Least Critical

In India, agriculture accounts for about 22 percent of gross domestic product. Fertilizer is one of the vital inputs required for enhancing agricultural production. India ranks second in the world and first among the South Asian Association of Regional Cooperation (SAARC) countries in terms of total fertilizer consumption. Considering India as one of the largest agrarian economies, fertilizer minerals like Potash and Rock Phosphate (Phosporite) have also been included in the list.

Table 2: A comparative study to arrive at a set of critical minerals based on global critical mineral strategies and Indian resource / reserve position

Sl. No.	Minerals	Australia 2022	US 2022	Canada 2022	UK 2021	Japan 2018	South Korea 2020	INDIA		Remaining Resource as on 01.04.2020	Reserve as on 01.04.2020
								CSEP 2022	CEEW 2016		
1	Antimony	✓	✓	✓	✓	✓	✓		✓	Ore-11,180 Tonne, Metal- 179.92 Tonne	Ore-7,503 Tonne, Metal- 75 Tonne
2	Beryllium	✓	✓			✓	✓		✓	*	*
3	Bismuth	✓	✓	✓	✓		✓		✓	*	*
4	Cobalt	✓	✓	✓	✓	✓	✓	✓	✓	Ore-45 million Tonne	0
5	Gallium	✓	✓	✓	✓	✓	✓		✓	By-product of alumina	
6	Germanium	✓	✓	✓		✓	✓		✓	*	*
7	Graphite	✓	✓	✓	✓			✓	✓	203,060,176 Tonne	8,563,411 Tonne
8	Indium	✓	✓	✓	✓	✓	✓	✓	✓	*	
9	Lithium	✓	✓	✓	✓	✓	✓	✓	✓	*	*
10	Molybdenum			✓		✓	✓	✓	✓	Ore-27,203,398 Tonne	0
11	Niobium	✓	✓	✓	✓	✓	✓	✓	✓	*	*
12	Nickel		✓	✓		✓	✓	✓	✓	Ore- 189 million Tonne	
13	PGE	✓	✓	✓	✓	✓	✓		✓	20.92 Tonnes of Metal Contained	0
14	REE	✓		✓	✓	✓	✓	✓	✓	459,727 Tonne	0
15	Silicon	✓			✓		✓	✓	✓	*	*
16	Tantalum	✓		✓	✓	✓	✓		✓	*	*
17	Tellurium		✓	✓	✓		✓		✓	*	*
18	Tin		✓	✓	✓	✓	✓		✓	Ore- 83,720,794 Tonne, Metal- 102,782.91 Tonne	Ore- 2,101 Tonne, Metal- 973.99 Tonne
19	Titanium	✓	✓	✓		✓	✓	✓	✓	411,108,526 Tonne	15,998,625 Tonne
20	Tungsten	✓	✓	✓	✓	✓	✓		✓	Ore- 89,432,464 Tonne, Metal- 144,650.07 Tonne	0
21	Vanadium	✓	✓	✓	✓	✓	✓	✓	✓	Ore- 24,633,855 Tonne	0
22	Chromium	✓	✓	✓		✓	✓	✓	✓	253,150 kilotonne	78,535 kilotonne
23	Magnesium	✓	✓	✓	✓	✓	✓			393, 047 kilotonne	6,6070 kilotonne
24	Manganese	✓	✓	✓	✓	✓	✓	✓	✓	Ore- 428,583 kilotonne	Ore- 75,041 kilotonne
25	Barite		✓				✓		✓	*	*
26	Cesium		✓	✓			✓			*	*
27	Copper			✓		✓		✓	✓	Ore- 1,496,979 kilotonne, Metal- 10,035.52 kilotonne	Ore-163,891 kilotonne, Metal- 2,161.57 kilotonne

Sl. No.	Minerals	Australia 2022	US 2022	Canada 2022	UK 2021	Japan 2018	South Korea 2020	INDIA		Remaining Resource as on 01.04.2020	Reserve as on 01.04.2020
								CSEP 2022	CEEW 2016		
28	Hafnium	✓	✓				✓			*	*
29	Lead					✓		✓	✓	Metal- 10,969.8 kilotonne	Metal- 1,900.19 kilotonne
30	Rhenium	✓				✓	✓		✓	*	*
31	Scandium	✓	✓	✓						*	*
32	Strontium					✓	✓	✓	✓	*	*
33	Zinc		✓	✓		✓		✓		Metal- 25,732.32 kilotonne	Metal- 7,438.05 kilotonne
34	Zirconium	✓				✓	✓		✓	1,674,435 Tonne	669,466 Tonne
35	Phosphorous					✓	✓		✓	280,377,392 Tonne	30,876,093 Tonne
36	Potash			✓					✓	23,091 million Tonne	0
37	High purity Alumina	✓								*	*
38	Aluminium		✓	✓						*	*
39	Arsenic		✓				✓			*	*
40	Bauxite							✓		3,240 million tonnes	656 million tonnes
41	Boron						✓		✓	74,204 Tonne	0
42	Cadmium						✓		✓	By-product of Zinc: Production (Rajasthan 2017-18)- 5685 Tonne	
43	Cerium		✓							*	*
44	Diamond					✓				Carats- 30,876,432	Carats- 847,559
45	Dysprosium		✓							*	*
46	Erbium		✓							*	*
47	Europium		✓							*	*
48	Fluorite					✓			✓	20,588,239 Tonne	404,241 Tonne
49	Fluorspar		✓	✓					✓	*	*
50	Gadolinium		✓							*	*
51	Gold					✓				494,506,270 Tonne	23,728,100 Tonne
52	Gypsum								✓	*	*
53	Helium	✓		✓						*	*
54	Holmium		✓							*	*
55	Iron							✓		Haematite- 17,848,870 kilotonne, Magnetite- 11,024,791 kilotonne	Haematite- 6,209,034 kilotonne, Magnetite- 202,823 kilotonne
56	Limestone							✓	✓	208,560,789 kilotonne	19,028,470 kilotonne
57	Lanthanum		✓							*	*
58	Lutetium		✓							*	*
59	Neodymium		✓					✓		*	*
60	Praseodymium		✓							*	*

Sl. No.	Minerals	Australia 2022	US 2022	Canada 2022	UK 2021	Japan 2018	South Korea 2020	INDIA		Remaining Resource as on 01.04.2020	Reserve as on 01.04.2020
								CSEP 2022	CEEW 2016		
61	Rubidium		✓							*	*
62	Samarium		✓							*	*
63	Silver					✓		✓		Ore-398,197,732 Tonne, Metal-22,560.84 Tonne	Ore-170,446,020 Tonne, Metal-7,707.07 Tonne
64	Selenium						✓		✓	*	*
65	Terbium		✓							*	*
66	Thulium		✓				✓			*	*
67	Uranium			✓						*	*
68	Ytterbium		✓							*	*
69	Yttrium		✓							*	*

*information not available

Green: 5 & above

Yellow: 3 to 4

Orange: less than 3

Blue: Fertilizer Minerals

Strategic Minerals

100% import dependant

More than 50% import dependant

Source:

1. Australia's Critical Mineral Strategy- 2022
2. IEA- US Geological Survey 50 critical minerals- 2022
3. Canadian Critical Mineral Strategy- 2022
4. British Geological Survey, UK criticality assessment of technology critical minerals and metals- 2021
5. Su, Y., & Hu, D. (2022). Global Dynamics and Reflections on Critical Minerals. E3S Web of Conferences. doi:https://doi.org/10.1051/e3sconf/202235203045
6. India- Centre for Social and Economic Progress (CSEP)- October 2022
7. India- Council on Energy, Environment & Water (CEEW)- July 2016

8.II Inter-ministerial Consultation

In order to identify the minerals critical and strategic in different sectors, a meeting with representatives of different Ministries / Departments was held on 27.12.2022 at Ministry of Mines, New Delhi. The meeting was attended by representatives from various Ministries / Departments such as Ministry of Power, Ministry of Electronics, Information and Technology, Ministry of Chemicals and Fertilizers and Department of Atomic Energy. After the meeting, a tentative list of critical minerals, based on the exercise made above was shared with different ministries. Comments and suggestions were obtained from Ministry of Power, Department of Atomic Energy, Ministry of New and Renewable Energy, Department of Fertilizers, Department of Science and Technology, Department of Pharmaceuticals and NITI Aayog. A compiled and brief statement on the comments of the Ministries along with response of the expert Committee is tabulated below:

Table 3: Response of the Expert Committee against the comments from different Ministries / Departments

S. No	Comments Received from Ministry / Departments	Response

1.	**Department of Atomic Energy (IREL)**
	The following minerals are identified as critical based on their role in nuclear and defence applications:
	1. Titanium minerals
	2. Zircon
	3. Monazite (source of Rare Earths)
	4. Rare Earths which include:
	  1. Neodymium
	  2. Praseodymium
	  3. Dysprosium
	  4. Europium
	  5. Yttrium
	  6. Terbium
		1. As the Ministry of Mines has included all REEs in the list of critical minerals, it will cover all types of ores of REE including Monazite.
		2. In Global Economies like USA, Australia and Canada, the value chain for processing and beneficiation of REE is much better developed. As a result, such countries segregate and select fewer REE elements from the total 17 REE elements as per their present criticality. In India, the value chain of REE is yet to be fully developed. Hence, in the first instance, all the REEs are considered to be critical.

2.	**Ministry of Power (Central Electricity Authority)** List of Critical Materials / Minerals in Power Sector: 1. Lithium 2. Nickel 3. Silicon	1. Lithium, Nickel, Silicon, Cobalt, Phosphate, Natural Graphite, Copper, PGE, REE have been included in the initial list prepared by Ministry of Mines 2. India has sufficient resources of Zinc, Manganese, Bauxite and Limestone. 3. The Committee agreed to include Cadmium in the list.

S. No	Comments Received from Ministry / Departments	Response
2.	4. Cobalt 5. Manganese 6. Phosphate 7. Natural Graphite 8. Copper 9. Bauxite 10. Zinc 11. Cadmium 12. Platinum Group of Elements (PGE) 13. Rare Earth Elements (REE) 14. Limestone	
3.	**Ministry of Chemicals & Fertilizers (Department of Fertilizers)** Two fertilizer minerals have been identified as critical minerals: 1. Rock Phosphate 2. Potash	Agreed Rock Phosphate and Potash are included in the initial list prepared by Ministry of Mines.
4.	**Department of Science & Technology (DST)** The identified minerals are very critical and strategic and essentially required for the defence, mobility, energy, space program and other sectors. The specific comments are: 1. The list of critical minerals should be revised every three years as technology is changing fast and what is not critical mineral today may be critical tomorrow. 2. There must be a clear supply chain strategy as they are mostly imported and prone to supply chain disruption. 3. Neodymium and Gadolinium are not included in most critical minerals, first is essential for magnets and required for renewable energy and electronic equipments, second is required for MRI, X-Ray and other medical techniques.	1. The list of critical minerals will be revised periodically, as per global practices. 2. Supply chain strategy will be elaborated in the Critical Minerals Policy which is being formulated by Ministry of Mines. 3. Neodymium and Gadolinium are part of Rare Earth Elements, which are included in the list of Critical Minerals identified by Ministry of Mines.

S. No	Comments Received from Ministry / Departments	Response
4.	4. Availability of primary resources for critical minerals are being looked after the Ministry of Mines and other bodies. However, varieties of secondary materials are available which are potential resource, e.g. urban ores (e-waste, batteries), fly ash, red mud, tailings, etc. There is urgent need to map all the secondary resources as source of critical minerals. 5. Lot of R&D work has been done at various CSIR and other research institutes and many proof of concept and process has been developed for extraction of strategic and critical metals. All these can be compiled. A threefold approach may be adopted (a) technology which has been developed at pilot scale, efforts should be made to transfer it to industry, (b) process which has developed at lab scale, but has potential of upscaling, should be up-scaled in partnership with industry, and (c) processes which are not available but needed by the country, should be developed. 6. The following minerals may also be incorporated if not already done. 1. Graphene 2. Fullerene 3. Scheelite 4. Rare Earth Elements • from different sources like Carbonatites, Tuffs, Cherts etc. • from beach sands. 5. Platinum group of elements like Platinum and Palladium etc.	4 & 5. These suggestions will be part of Critical Mineral Policy. 6. (1 & 2) Graphene and Fullerene are allotropes of Carbon. Graphene occurs as sheets of carbon while fullerene occurs as spheres of carbon. Both can be obtained from Natural Graphite which is included in the list of minerals identified as critical by Ministry of Mines. (3) Scheelite is an ore of Tungsten(W). Tungsten is included in the list of minerals identified as critical by the Ministry of Mines. (4 & 5) REE and PGE are already included in the initial list by Ministry of Mines
5.	**Ministry of New and Renewable Energy (MNRE)** Ministry of Mines to consider including: 1. Quartz 2. Platinum 3. Palladium 4. Iridium 5. Manganese 6. Lead 7. Zinc 8. Aluminium	1. Silicon is included in the list of critical minerals. 2, 3 & 4. PGE is included in the list of critical minerals. 5, 6, 7, 8. India has sufficient resources of Manganese, Lead, Zinc, Bauxite.

S. No	Comments Received from Ministry / Departments	Response
5.	9. Cadmium 10. Lanthanum 11. Silver 12. Yttrium	9. Cadmium is included in the list of critical minerals 10, 12. REE is included in the list of critical minerals 11. Not critical presently.
6.	**Department of Pharmaceuticals** The list of minerals critical to Pharma sector is as follows: **Pharmaceuticals** Metallic Minerals: 1. Copper 2. Sodium 3. Calcium 4. Potassium 5. Chromium 6. Magnesium 7. Molybdenum 8. Cobalt Other Minerals: 1. Oxides (rutiles, zincite, periclase, hematite, maghetite, magnetite) 2. Phosphates 3. Hydroxides (goelithe) 4. Carbonates (calcite, magnesite) 5. Sulfates (gypsum, anhydrite) 6. Chlorides (halite, sylvite) 7. Phyllosilicates (clay minerals like talc and kaolinite etc.) Medical Devices 1. Zinc Oxide IP Grade – 99.90% (Lead Free) 5 to 10 Tons/ Year 2. Titanium Dioxide- USP Grade 3-5 Tons/ Year 3. Aluminium Foil as Pouches etc. 20-30 Tons/ Year 4. Special Alloy Steel for Dyes- Like HCHCr.- 1 Ton/ Year	Elements like Copper, Potassium, Molybdenum, Cobalt, Phosphorous, Titanium were already included in the list. Rest of the elements/ minerals, as suggested by the Department of Pharmaceuticals do not possess any risk of supply chain disruption. The other elements/ minerals may be considered once the list is updated after three years, if the need arises.

S. No	Comments Received from Ministry / Departments	Response
7.	**NITI Aayog**	
	(i) The report on the whole has discussed for 69 minerals and finally arrived that 29 minerals are critical for India. (Page Nos'.62 to 66) The current position of the 29 critical and strategic minerals provided in Table No.2 (vide Page Nos'.62 to 66 read with Page No.76) has been listed out in a generalized manner without taking into account the availability of these minerals within the country and manner in which the mineral resources can be developed and established. The detailed analysis of the same has been carried out and enclosed as Annexure.	(i) Analysis done by NITI Aayog has been included as a part of the report.
	(ii) Data from Ministry of Commerce and Industries needs to be collected and correlated to know the exact import of all the 29 minerals discussed above, based on which the actual imports coming into the country along with grade can be ascertained.	(ii) The inter-ministerial consultation was done for finalizing the list of critical minerals. However, the import data for these minerals will also be collected and correlated to know the exact import of these mineral commodities in the country.
	(iii) Based on the data obtained the critical minerals which needs to be perceived through the import route can be easily identified along with the geography from which it has to be imported. (iv) The demand in the downstream industries of all the 29 minerals discussed above needs to be further accessed, based on which serious thoughts for importing can be discussed.	(iii) & (iv) The demand for critical minerals in the downstream industries, details of import routes, and geographies from which critical minerals have to be imported shall be elaborated in the "Critical Mineral Strategy / Policy for India" which is being formulated by the Ministry of Mines.
	(v) Lithium which is crucial for the EV sector has to be acquired from Argentina, Bolivia, Chile and Australia due to their widespread occurrences in these countries. However, the private companies including the PSUs have already entered into a business agreement with international lithium producing companies for their unhindered supply. In this condition, the exact requirement of lithium for the EV sector needs to be established for better understanding.	(v) Noted.
	(vi) Out of the 29 minerals discussed, Indian has the potential and the technology to produce or to scale up the production of at least 10 critical minerals. The technical and administrative issues hampering the production of these critical minerals needs to be taken up with the concerned private and public sector companies.	(vi) The scaling up production of the critical minerals is being taken up through various policy measures like allowing private sector participation in mineral exploration, introduction of incentive schemes for exploration of deep seated and critical mineral commodities etc.

S. No	Comments Received from Ministry / Departments	Response
7.	(vii) Hindustan Copper Limited (HCL) which is a part and parcel of the KABIL Joint Venture has four major copper production units along with significant amount of reserves / resources. Majority of the 23 critical minerals occur with copper as an associated mineral or in the processing of the copper concentrate by the copper producing companies. A detailed plan has to be kick started with Hindustan Copper Limited (HCL), Vedanta and Hindalco for utilizing these critical minerals which may be of greater importance.	(vii) Will be taken up with HCL.
	(viii) Indian Rare Earths Limited (IREL), Gujarat Mineral Development Corporation (GMDC), Chhattisgarh Mineral Development Corporation (CMDC) and Kerala Minerals and Metals Limited (KMML) along with Atomic Minerals Directorate (AMD) has to be involved in the discussion process of the critical minerals which may be of immense value in evaluating the critical minerals.	(viii) The inter-ministerial and stake holders consultation is being carried out for finalising the Critical Minerals Policy.
	(ix) Further in order to meet the technical financial implications in exploring the critical minerals, it is suggested to rope in NMDC for taking up exploration of certain critical minerals as it is an extremely cash rich PSU.	(ix) The Notified Exploration agencies including National Mineral Development Corporation (NMDC) can take up exploration of mineral commodities including critical minerals through NMET funding.
	(x) Since the occurrences and utilizations of the listed 29 minerals are varied, it is suggested not to have the approach of "One size fits all" and to revisit the minerals according to their occurrences, resources availability, possibility of in-house production, requirements within the country, economies of scale involved in production vs. Indian demand, etc. before arriving at a conclusion.	(x) All these aspects will be part of the Critical Mineral Policy.
	(xi) Finally, it is to submit that the demand for these 29 minerals should be based on an estimation of future demand for the next 25 years in order to have a futuristic perspective.	(xi) This Committee proposes to revisit the list of critical minerals at an interval of 3 years as per the current international practice.

Subsequent to the exercise carried out in para 8.I of this report, a total of 38 minerals came out as most to moderately critical for almost all the major economies of the world as well as in India. These 38 elements were compared with the suggestions received from different ministries and is provided in Table 4 below. It has been observed that elements like PGE, REE, Graphite, Phosphorous, Potash, Silicon, Cadmium etc. were found to be most critical for the country. The major critical minerals which came out of this exercise are highlighted in color in Table 4.

Table 4: A comparison of the minerals identified by M/o Mines vis-à-vis minerals suggested by other Ministries / Departments

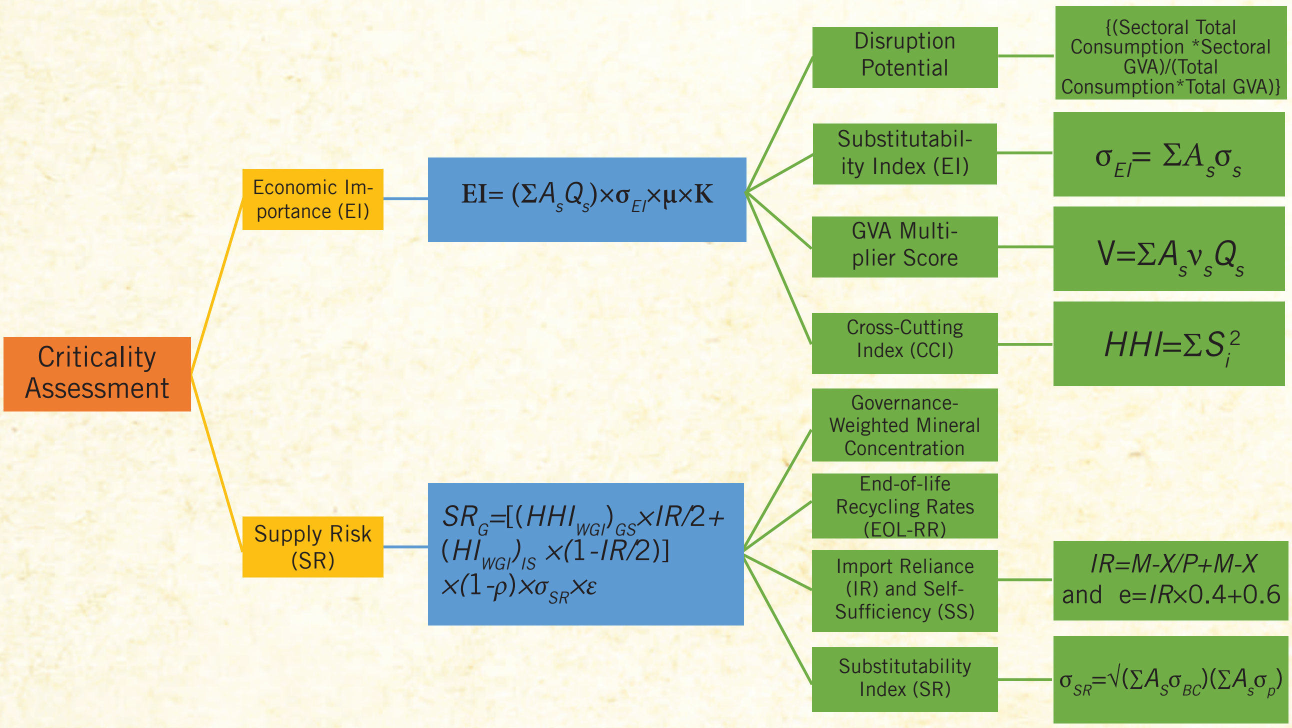
Sl. No.	List prepared by Ministry of Mines	Comments received from Ministries					
		Ministry of Chemicals & Fertilizers (Department of Fertilizers)	Department of Science & Technology	Department of Atomic Energy (IREL)	Ministry of Power (Central Electricity Authority)	Ministry of New and Renewable Energy (MNRE)	Dept. of Pharmaceuticals
1	Copper				Copper		Copper
2	Cobalt				Cobalt		Cobalt
3	Nickel				Nickel		
4	Rare Earth Elements (REE)		Rare Earth Elements (REE)- (i) from different sources like Carbonatites, Tuffs, Cherts etc. (ii) from beach sands	1. Rare Earth Elements (REE)- i. Neodymium ii. Praseodymium iii. Dysprosium iv. Europium v. Yttrium vi. Terbium 2. Monazite	Rare Earth Elements (REE)	Lanthanum Yttrium	
5	Platinum Group of Elements (PGE)		Platinum Group of Elements (PGE)		Platinum Group of Elements (PGE)	Platinum Palladium Iridium	
6	Graphite		1. Graphene 2. Fullerene		Natural Graphite		
7	Lithium				Lithium		
8	Titanium			Titanium Minerals			Titanium
9	Phosphorus	Rock Phosphate			Phosphate		Phosphates
10	Potash	Potash					Potash
11	Zirconium			Zircon			
12	Silicon				Silicon	Quartz	
13	Cadmium				Cadmium	Cadmium	
14	Manganese				Manganese	Manganese	
15	Tungsten		Scheelite				
16	Tellurium					Tellurium	

Sl. No.	List prepared by Ministry of Mines	Comments received from Ministries					
		Ministry of Chemicals & Fertilizers (Department of Fertilizers)	Department of Science & Technology	Department of Atomic Energy (IREL)	Ministry of Power (Central Electricity Authority)	Ministry of New and Renewable Energy (MNRE)	Dept. of Pharmaceuticals
17	Tin					Tin	
18	Molybdenum					Molybdenum	Molybdenum
19	Bismuth						
20	Beryllium						
21	Indium						
22	Vanadium						
23	Gallium						
24	Antimony						
25	Hafnium						
26	Rhenium						
27	Strontium						
28	Niobium						
29	Germanium						
30	Tantalum						
31	Chromium						Chromium
32	Magnesium						Magnesium
33	Barite						
34	Cesium						
35	Zinc				Zinc	Zinc	
36	Boron						
37	Lead					Lead	
38	Selenium						
					Limestone	Aluminium	Sodium
					Bauxite	Silver	Calcium

From the above table, out of 38 elements, chromium, lead, zinc, barite and cesium were dropped by the Committee. During the inter-ministerial consultation elements such as lead, zinc and chromium were flagged as critical by ministries such as MNRE (for lead & zinc), Ministry of Power (zinc) and Department of Pharmaceuticals (for chromium). However, India has sufficient resources of these minerals. None of the Ministries identified barite & cesium as critical to their sector. Finally, after excluding these 5 elements, a total of 33 elements were considered for further assessment by the Committee.

8.III Critical Minerals based on Empirical Formula

In order to derive the criticality index, Ministry of Mines had a series of deliberations on the EU methodology to arrive at the list of critical minerals. The EU methodology is mainly dependant on two major factors- Economic Importance and Supply risk.



A_s= is the share of the mineral's consumption in sectors to its total consumption;
Q_s= is the GVA share of sector s to total manufacturing GVA;
σ_{EI}= is the substitutability index of the mineral;
μ= is the mineral's GVA multiplier coefficient;
κ= is the mineral's cross-cutting index;
σ_s= is the cost-performance score for sectors;
v_s= is the GVA multiplier for sectors;
HHI= is the level of industry-wise concentration of mineral consumption;
S_i= is the share of mineral extraction in industry *i*.
SR_G = is the supply risk accounting for governance indicators;

HHI_{war}= is the Herfindahl-Hirschman Index of mineral concentration, accounting for governance indicators;
GS= is the global supply of extracted or processed minerals;
IS = is the Indian sourcing of extracted or processed minerals;
ρ= is the end-of-life recycling rate of the mineral;
IR= is the import reliance of the minerals;
σ_{SR}= is substitutability in the supply risk axis;
ε= is the self-sufficiency adjustment factor;
M= is the value of imports;
X= is the value of exports;
P= is the value of domestic production;
σ_{BC}= is the co-/by-production score;
σp= is the production substitutability.

However, it has been observed that minerals like limestone, iron ore and bauxite also came out as critical as per the factors considered in the formula. The Committee is of the view that a detailed statistical exercise has to be carried out for precise computation of various factors such as substitutability index, minerals cross-cutting index, import reliance etc. Hence, if felt necessary, a separate sub-committee may be constituted by Ministry of Mines to exclusively work out the formula to develop a criticality index.

However, the Committee had compared the list of critical minerals derived by EU methodology with it's own set of minerals. The comparative study is provided below:

Elements identified by Committee	High EI	High SR	Both High	Elements identified by Committee	High EI	High SR	Both High
1. Copper				18. Gallium			
2. Cobalt				19. Niobium			
3. Graphite				20.Tungsten			
4. Lithium				21.Magnesium			
5. Nickel				22. Hafnium			
6. PGE				23. Strontium			
7. REE				24. Boron			
8. Silicon				25. Manganese			
9. Tellurium				26. Bismuth			
10. Tin				27. Germanium			
11. Titanium				28. Indium			
12.Phosphorous				29. Tantalum			
13. Potash				30. Vanadium			
14. Zirconium				31. Rhenium			
15.Molybdenum				32. Selenium			
16. Antimony				33. Cadmium			
17. Beryllium							

High Economic Importance

High Supply Risk

High Economic Importance as well as High Supply Risk

From the above table, it emerged that out of the 33 elements, a total of 17 elements i.e. Cobalt, Graphite, Lithium, PGE, Nickel, Tin, Phosphorous, Gallium, Niobium, Magnesium, Tungsten, Hafnium, Strontium, Boron, Manganese, Antimony and Beryllium have both high supply risks as well as high economic importance for the country. A total of 7 elements has high supply risks which are- REE, Bismuth, Germanium, Indium, Tantalum, Vanadium and Rhenium. Similarly, a total of 9 elements do have high economic importance which are Copper, Silicon, Titanium, Potash, Molybdenum, Tellurium, Zirconium, Selenium and Cadmium.

However, out of the 33 elements, 3 elements namely Manganese, Magnesium and Boron are not considered as critical for the country in terms of present supply risk vulnerability as well as economic consideration, as the country has adequate resources of Manganese and Magnesium. Further, Boron is mainly used as borax and boric acid in Glass & porcelain industries, for which other substitutes are easily available.

9. Conclusions and Recommendations

The Committee carried out a three-stage assessment for identifying the minerals critical to India. In the first stage, the critical mineral strategies of various countries such as Australia, USA, Canada, UK, Japan and South Korea were studied. Accordingly, a total of 69 elements/ minerals that were considered critical by major global economies were identified for further examination. Due importance was given to domestic initiatives also. The key studies carried out in this aspect by Centre for Social and Economic Progress (CSEP) and Council on Energy, Environment and Water (CEEW) were also considered.

In the second stage of assessment, an inter-ministerial consultation was carried out with different ministries to identify minerals critical to their sectors. Comments and suggestions were received from the Ministry of Power, Department of Atomic Energy, Ministry of New and Renewable Energy, Department of Fertilizers, Department of Science and Technology, Department of Pharmaceuticals and NITI Aayog etc.

The third stage assessment was to derive an empirical formula for evaluating mineral criticality. The EU methodology, considers two major factors - economic importance and supply risk. The Committee is of the view that a detailed statistical exercise needs to be carried out for precise computation of various factors such as substitutability index, minerals cross-cutting index, import reliance etc. for which a separate sub-committee may be constituted to exclusively work out the formula to develop the criticality index.

Based on the three-stage assessments process mentioned above, a total of 30 minerals are found to be most critical for India out of which two minerals are critical as fertilizer minerals. Depending upon the three-stage assessment, the net import reliance and the resource / reserve position of the country, the final set of minerals critical to India are as follows:

1. Antimony	15. Nickel	iv. Neodymium	20. Rhenium
2. Beryllium	16. PGE	v. Promethium	21. Selenium
3. Bismuth	i. Platinum	vi. Samarium	22. Silicon
4. Cadmium	ii. Palladium	vii. Europium	23. Strontium
5. Cobalt	iii. Rhodium	viii. Gadolinium	24. Tantalum
6. Copper	iv. Ruthenium	ix. Terbium	25. Tellurium
7. Gallium	v. Iridium	x. Dysprosium	26. Tin
8. Germanium	vi. Osmium	xi. Holmium	27. Titanium
9. Graphite	17. Phosphorous	xii. Erbium	28. Tungsten
10. Hafnium	18. Potash	xiii. Thulium	29. Vanadium
11. Indium	19. REE	xiv. Ytterbium	30. Zirconium
12. Lithium	i. Lanthanum	xv. Lutetium	
13. Molybdenum	ii. Cerium	xvi. Scandium	
14. Niobium	iii. Praseodymium	xvii. Yttrium	

Usage of these minerals identified above with Indian availability are provided in Annexure II.

10. Additional Recommendations

There is a need for establishing a National Institute or Centre of Excellence on critical minerals on the lines of CSIRO which is an Australian Government corporate entity and one of the world's largest mission-driven multidisciplinary science and research organizations. Though CSIRO has a wider canvass as it is working with the Government, Universities, Industry and the Community on challenges like Food Security and Quality, Health and well-being, Resilient and Valuable Environments etc., it is also the largest minerals research and development organisation in Australia and one of the largest in the world.

A wing in the Ministry of Mines can be established as a Centre of Excellence for Critical Minerals (CECM). The Centre of Excellence for Critical Minerals will focus on identifying more efficient ways for discovering next generation critical mineral deposits through geological knowledge, data analytics and modelling, and machine learning capability. The Center will support building up of new research and analytical infrastructure required to support India's critical mineral demand. The Centre will also provide the necessary support and coordinate with other Ministries/ Departments in framing policies and incentive schemes, required for creating a complete value chain of critical minerals in the country. The Centre may collaborate with international agencies/ KABIL for the strategic acquisition of foreign assets on Critical Minerals. The Centre of Excellence will periodically update the list of critical minerals for India, preferably every three years, and notify the critical mineral strategy from time to time. The Centre will also monitor export management with Ministry of Commerce and Industries and Ministry of External Affairs. The Centre of Excellence will also monitor and prepare the exploration strategy under Ministry of Mines. Financial and administrative support to accelerate the development of critical mineral mining, processing, manufacturing, and recycling may be provided by the Central Government. The development of this Centre will lead to reduced dependency on foreign critical mineral inputs across a range of priority industrial sectors or technologies.

11/5/2023
Shri Pradeep Singh
(Member)

Shri R. Saravanabhavan
(Member)

11/5/2023
Shri Hemraj Suryavanshi
(Member)

11/05/2023
Shri Dinesh Ganvir
(Member)

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Shri Pankaj Kulshrestha
(Member)

11/5/2023
Shri Alok Kumar
(Member Secretary)

12/5/2023
Dr. Veena Kumari. D

Annexure I

1642934/2022/IC Cell

File No. I.C.-11/1/2022-IC Cell (Computer No. 3065835)

1639202/2022/IC Cell
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F. No. 11/1/2022-IC
Government of India
Ministry of Mines
International Cooperation Section

Shastri Bhawan, New Delhi
Dated: the 1st Novermber, 2022

Subject: Constitution of a Committee for identification of critical and strategic minerals

With the advancement in renewable energy technology and need for efficient battery storage, certain elements like lithium and cobalt have been identified as critical for progress of the renewable energy sector. Similarly, certain other elements are critical for progress in electronics, defence and agriculture sector.

2. In order to facilitate and formulate a policy, it is necessary to list these critical minerals for the country. A committee with the following members is constituted for the purpose:

i. Dr. Veena Kumari D. Joint Secretary, Ministry of Mines- Chairperson
ii. Shri Pradeep Singh, Director/Technical, Ministry of Mines-
iii. Shri Pankaj Kulshrestha, I/c CCOM/IBM- Member
iv. Shri Hemraj Suryavanshi- Advisor/KABIL - Member
v. Shir D.V.Ganvir- DDG/GSI Member
vi. Shri Kundan Kumar, Advisor/Niti Aayog
vii. Sh Dheeraj Kumar - Deputy Secretary , Ministry of Mines - Member Secretary

3. The Committee shall take into account the efforts made in this direction by the Niti Aayog, NSCS, KABIL and other organisations.

4. The committee will submit its report within one month.

(Ajay Kadian)
Under Secretary to the Govt. of India

To

1. Dr. Veena Kumari D. Joint Secretary, Ministry of Mines- Chairperson
2. Shri Pradeep Singh, Director/Technical, Ministry of Mines
3. Shri Pankaj Kulshrestha, I/c CCOM/IBM- Member
4. Shri Hemraj Suryavanshi- Advisor/KABIL - Member
5. Shir D.V.Ganvir- DDG/GSI Member
6. Shri Kundan Kumar, Advisor/Niti Aayog
7. Sh Dheeraj Kumar - Deputy Secretary, Ministry of Mines

Copy to:

1. PSO to Secretary (Mines)
2. PPS to Addl. Secretary (Mines)

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Annexure II

Usage and availability of Identified Critical Minerals

S. No.	Critical Minerals	Value Chain	Major Applications	Examples of Specific Products	Indian Availability	Remarks
1	**Antimony**	Advanced manufacturing	Flame retardants, Lead-acid batteries, Lead alloys, Plastics (catalysts and stabilisers), Glass and ceramics	Manufacture of chemicals and chemical products, electrical equipment, fabricated metal products, except machinery and equipment	No proved reserves and only inferred reserves are available in Lahul & Spiti districts of Himachal Pradesh	1. The metal is obtained commonly as a by-product in lead-zinc-silver smelting by Hindustan Zinc Limited 2. The bulk of secondary antimony has been recovered at secondary lead smelters as antimonial lead, most of which was generated and then consumed by the Lead- acid Battery Industry 3. Possibilities exists to recover antimony from lamp phosphor waste (which is considered as a source of rare-earth elements)
2	**Beryllium**	Advanced manufacturing inputs and materials	Automotive components: Transport and Defence-Manufacturin g of Machinery., Electronic and telecommunic ations equipment's	Manufacture of computer, electronic and optical products	Not available	Current requirement is made through imports
3	**Bismuth**	Advanced manufacturing	Chemicals, Pharmaceutic als, Casting of Iron	Manufacture of chemicals and chemical products	Not available	Current requirement is made through imports
4	**Cadmium**	Advanced manufacturing	Batteries, Pigments, Coatings	Manufacture of electrical equipment & chemicals and chemical products, solar cells, electroplating, and silver soldering	Cadmium is recovered as a by-product during zinc smelting and refining. The total annual installed capacity for recovering cadmium was 913 tpy of which HZL accounted for 833 tpy capacity	

S. No.	Critical Minerals	Value Chain	Major Applications	Examples of Specific Products	Indian Availability	Remarks
5	**Cobalt**	Clean technologies	Electric Vehicle, Batteries, corrosion resistant alloys, aerospace applications, Pigments and Dyes	Battery electrodes; metal alloys; turbine engine components, automobile airbags; catalysts in the petroleum and chemical industries; drying agents for paints, varnishes, and inks; magnets, organic and inorganic chemical compounds, textiles, paper, leather and like industries, high speed specialized cutting tools, glass, and ceramics industry	Not available	Current requirement is made through imports
6	**Copper**	Clean technologies and advanced manufacturing	Electrical and electronics products, Electrical Wiring, Solar Panel, Automotive industry	Power transmission lines, electrical building wiring, vehicle wiring, telecommunication wiring, electronic components, fabricated metal products	The current production of the Copper concentrate is able to meet only 4 % of the requirement of Copper Smelter/refineries necessitating a huge number of imports. To fill the gap in demand and supply of Copper, the existing mines have to scale up the production as per the mining plan/ EC limits as well as new mines have to be developed	
7	**Gallium**	Information and communications	Semiconduct ors, Integrated Circuits, LEDs	Electronic circuit boards, LED devices, semiconductors, specialized thermometers, barometric sensors, solar panels, blue-ray technology, pharmaceuticals	Gallium is recovered as a by-product while producing alumina. Two plants, namely, HINDALCO at Renukoot, Uttar Pradesh and NALCO Damanjodi alumina refinery, Odisha, had recovered gallium in the past. Needs to be revisited	
8	**Germanium**	Information and communications, clean technologies, and advanced manufacturing	Optical fibres, satellites, solar cells	Fibre-optic communication networks, camera and microscope lenses, infrared night vision systems, polymerization catalysts	Not available	Current requirement is made through imports
9	**Graphite**	Clean technologies	Batteries, Lubricants, fuel cells for EVs, Electric Vehicle	Metal foundry lubricants, vehicle brake linings, metal casting wear, crucibles, rechargeable battery anodes, EV fuel cells, electrical motor components, frictionless materials, pencils	9 million tonnes reserves exist	Production reported from 12 mines
10	**Hafnium**	Advanced manufacturing	Superalloy, Catalyst precursor, Semiconductors, Oxide for Optical, Nuclear reactors	Manufacture of basic metals, computer, electronic and optical products, neutron absorption in control rods in nuclear power plants, used in iron, titanium, niobium, tantalum, and other metal alloy, liquid rocket thruster nozzle	Normally, all zirconium compounds contain between 1.4% and3% hafnium. IREL & KMML are involved in production of zircon	

S. No.	Critical Minerals	Value Chain	Major Applications	Examples of Specific Products	Indian Availability	Remarks
11	**Indium**	Advanced manufacturing	Electronics (Laptops, LED Monitors/TVs, Smartphones), and semi conductors	Electronics, electrical equipment	Not available	Current requirement is made through imports
12	**Lithium**	Clean technologies and defence & security technologies	Electric Vehicle, Batteries, glassware, ceramics, fuel manufacturin g, Lubricant	Rechargeable batteries (phones, computers, cameras, and EVs); hydrogen fuel storage; metal alloys (military ballistic armour; aircraft, bicycle, and train components); specialized glass and ceramics; drying and air conditioning systems, steam or other vapour generating boilers, pharmaceuticals, medicinal chemical and botanical products, refined petroleum products	Not available	Current requirement is made through imports
13	**Molybdenum**	Advanced manufacturing	Steel alloys, Pigment and Dyes, Catalyst, Electrical and Electronic	Engineering steels, Foundries, Nickel alloys, Lubricants, Field of Medical	Mineable reserves are available in Harur of Tamil Nadu State	Mining Blocks needs to be auctioned to avoid import route
14	**Niobium**	Clean technologies and advanced manufacturing	Construction, transportation	Metal alloys (steel), jet engines, rockets, construction beams, building girders, oil rigs and pipelines, superconducting magnets, MRI scanners, NMR equipment, eyeglasses, titanium niobium oxide anode materials, nuclear power plants, production of electronic components	Not available	Current requirement is made through imports
15	**Nickel**	Clean technologies and advanced manufacturing, defence & security technologies	Stainless steel, solar panels, batteries, aerospace, defence applications and Electric Vehicle	Metal alloys (steel, superalloys, non-ferrous alloys), jet and combustion engine components, rechargeable batteries (phones, computers, EVs), industrial manufacturing machines, construction beams, anti-corrosive pipes, cookware, medical implants, power plant components	Vedanta has a nickel and cobalt plant at Goa named NICOMET. Nickel sulphate and Cobalt sulphate production is 7500TPA	

S. No.	Critical Minerals	Value Chain	Major Applications	Examples of Specific Products	Indian Availability	Remarks
16	**PGE**	Advanced manufacturing	Auto catalyst, Jewellery, medicine, electronic equipment used by military	Used in making optical fibers, LCDs, turbine blades, spark plugs, fabrication of silicon in aerospace, guided missile systems, catalytic converters in reducing toxic emissions, hybrid integrated circuits, medicine (pacemakers, chemotherapy) and jewellery	About14.2 tonnes of metal content of PGM are located in Niligiri, Boula-Nuasahi and Sukinda areas in Odisha and remaining 1.5 tonnes of metal content of PGM in Hanumalpura area in Shivamogga schist belt of Karnataka	
17	**Phosphorous**	Advanced manufacturing	Mineral fertilizer	Utility as a nutrient provider, Detergents, chemicals, food additives, Animal Feed, rust removers, corrosion preventers	Huge reserves/resources are available in Rajasthan, Jharkhand and Madhya Pradesh. There are around 7 reporting mines	
18	**Potash**	Advanced manufacturing	Chemical Fertilizers, Water softener	Industrial chemicals, animal feed, soap making, food production, water softening, road de-icing, pH adjustment, explosives, pharmaceuticals, and glassmaking	Major part of resources are located in Nagaur district of Rajasthan, followed by Panna district, Madhya Pradesh and the balance in Sonbhadra & Chitrakoot districts, Uttar Pradesh	
19	**REE**	Zero-emission vehicles, defence & security technologies	Permanent magnets for electricity generators and motors, catalyst, polishing, Batteries, Electronics, Defence technologies, wind energy sector, aviation, and Space	Laptops, LED Monitors/ TVs, Smartphones, EV drive trains, wind turbines, aircraft components, vehicle components, speakers, steel manufacturing, battery anodes, chemical catalysts, glass manufacturing, specialized glass lenses, hybrid and tactical wheeled vehicles, armoured vehicles, night vision goggles, communication, and navigation systems	Resource estimate of monazite from beach sand in India is 11.93 Mt having 55%-65% of rare earth oxides	Met through domestic production by IREL and through imports
20	**Rhenium**	Advanced manufacturing	Super-alloys, aerospace and machinery uses, Catalysts in petroleum industry	Manufacture of coke and refined petroleum products	Not available	Current requirement is made through imports

S. No.	Critical Minerals	Value Chain	Major Applications	Examples of Specific Products	Indian Availability	Remarks
21	**Selenium**	Advanced manufacturing inputs and materials	Electrolytic, Manganese, Glass, pigments	Pigments for ceramics, paint and plastics, useful in photocells, solar cells and photocopiers, used in anti-dandruff shampoos, used as an additive to make stainless steel	No production.	
22	**Silicon**	Information and communications, advanced manufacturing	Semiconductors, electronics, and transport equipment, Paints, Aluminum alloys	Electronics, computer processors and photovoltaics, steel manufacturing, glass, and glass products	India is reporting production of 59000 metric tonnes of silicon and ranks 12th in production as per 2022 data	
23	**Strontium**	Advanced Manufacturing	Alloys of aluminium, Pigments and Fillers, Glass, Magnets, Pyrotechnic application	Casting of non-ferrous metals, parts and accessories of three wheelers and motorcycles	Not available	Current requirement is made through imports
24	**Tantalum**	Clean technologies and advanced manufacturing	Capacitors, Superalloys, Carbides, Medical technology	Manufacture of machinery and equipment, used in Nickel-based super alloys for aircrafts, gas turbine components, missiles and radio communication systems, preparation of advanced airframes in Defence sector, digital camera, mobile phones, high temperature furnace parts, alloys for air and land-based turbines	Not available	Current requirement is made through imports
25	**Tellurium**	Clean technologies	Solar power, thermoelectric devices, Rubber vulcanising	Metal alloys (copper and steel), solar cells, semiconductors, CDs/ DVDs, vulcanized rubber, chemical catalysts in oil refining	No production	
26	**Tin**	Advanced manufacturing	Aerospace, construction, home decor, electronics, jewellery and telecommunic ations	Lead acid batteries, Tinplate, Metal Packaging, decorative elements for homes, countertops, Solders, chemicals	Produced in the form of concentrates and metal in Chhattisgarh by CMDC & Precision Minerals & Smelting in Dantewada	From domestic production and through partial imports

S. No.	Critical Minerals	Value Chain	Major Applications	Examples of Specific Products	Indian Availability	Remarks
27	**Titanium**	Clean technologies and advanced manufacturing, defence & security technologies	Aerospace and defence applications, chemicals and petro- chemicals, Pigments, Polymers	Colour pigments in paint, plastics, and paper; metal alloys (aluminium, steel, molybdenum); aircraft; spacecraft; missiles and rockets; non-corrosive pipes; ship and submarine hulls; medical implants; sunscreen; specialty Li- ion battery anode materials	Titanium Sponge Plant of India is located at Kerala Minerals and Metals Ltd (KMML), Chavara, Kollam district of Kerala	Major resources / reserves are available in the coastal districts of Tamilnadu, Andhra Pradesh, Odisha, Kerala, Gujarat & Maharashtra
28	**Tungsten**	Advanced manufacturing	Mill and cutting tools, Mining and construction tools, Catalysts and pigments, Aeronautics and energy uses, tungsten carbide	Consumed for production of hard materials like high penetration alloy for weaponry, rockets, missiles, cutting tools (tungsten carbide), filament wires, electrodes and super alloys, oil and gas drilling	Not available	Current requirement is made through imports
29	**Vanadium**	Clean technologies and advanced manufacturing	Alloys, batteries	Metal alloys (steel), military armour plating, vehicle axles, piston rods and crankshafts, vanadium redox flow batteries, nuclear reactor components, manufacturing of superconducting magnets, pigments for ceramics and glass	Total estimated reserves / resources of vanadium ore as on1.4.2015 are placed at 24.63 million tones with an estimated V2O5 content of 64,594 tonnes	R&D on opportunity for production from mine tailings of bauxite has to be strengthened in addition to opening up of new mines
30	**Zircon**	Clean technologies and advanced manufacturing	High value chemical manufacturin g and electronics sector,	Good nuclear fuel-rod cladding metal, useful in nose cones, re- entry vehicles and coatings in jet engines, used in heat shield in space shuttles, as catalytic fuel converters as well as refractories	IREL & KMML are involved in production	Obtained as a by-product during the beneficiation of heavy mineral sands in Manavalakurichi in Tamil Nadu, Chavara

The following value chains have the highest potential:

- Clean technologies, which include zero-emission vehicles (ZEV), wind turbines, solar panels, advanced batteries, hydrogen fuel cells, small modular reactors.
- Information and communication technologies, including semiconductors.
- Advanced manufacturing inputs and materials, such as defence applications, permanent magnets, ceramics, high value-added metals, electronic materials, composites, polymers, and biomaterials.

सत्यमेव जयते

खान मंत्रालय

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