Critical Minerals

For Prelims: Critical Minerals, Supply Chain, Renewable Energy, Semiconductors, Lithium, Rare Earth Elements, Geological Survey of India (GSI), Obvious Geological Potential (OGP), Mines and Minerals (Development and Regulation) Amendment Act, 2021, National Mineral Exploration Trust (NMET), Electric Vehicles (EVs), International Energy Agency, Secondary Markets, NITI Aayog, Council on Energy, Environment and Water (CEEW).

For Mains: Role of Critical Minerals for greener and sustainable future of India

What are Critical Minerals?

- **About:**
  - **Critical minerals** are those minerals which are **essential** for **economic development** and **national security** of a country.
  - 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.**

Why Critical Minerals are Important for India?

- **Foundation of Modern Technology:**
  - Critical minerals are the **foundation** on which **modern technology** is built.
  - They are used in a wide range of **essential products,** from mobile phones to solar panels to electric vehicle batteries to medical applications.
- **Energy Transition:**
  - They are vital to **renewable energy technologies** that will be required to meet the **"Net Zero" commitments** of many countries around the world.
  - The world needs critical minerals to build products like **solar panels, semiconductors**, **wind turbines** and **advanced batteries** for storage and transportation.
- **Futuristic Economy:**
  - The **future global economy** will be powered by technologies that depend on minerals such as lithium, graphite, cobalt**, titanium** and **rare earth elements**.
  - Critical minerals are the building blocks for the **green** and **digital economy.**
- **Self Reliance:**
  - Identification of critical minerals will help India 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.

What Factors Impact the Criticality of Minerals?

- For most of the countries the criticality is judged by **two main parameters** i.e., **economic importance** and **supply risk.**
  - In the Indian context also, the same two parameters were taken into consideration.

- **Two Main Parameters:**
    - **Economic Importance**: It examines how raw materials are **distributed** to different industrial uses and **evaluates** the effects on that industry when certain minerals are unavailable in the supply chain.
    - **Supply Risk:** It examines how **global production** of raw materials is **concentrated** in certain countries, the **governance** and **environmental practices** of these supplier countries, reliance on imports and **trade restrictions** in other countries.

What are the Five Pillars of the Critical Minerals Value Chain?

- The entire **value chain** for critical minerals implies building capacity at each stage of the value chain namely geoscience and exploration, mineral extraction, intermediate processing, advanced manufacturing and recycling.
- **Geoscience and Exploration**:
    - **Geological Mapping** by the **Geological Survey of India (GSI)** has led to the identification of **Obvious Geological Potential (OGP)** areas which are the **geologically favorable** areas for various mineral commodities such as Gold, Base Metals, Platinum Group of Elements, Rare Earth Elements, Tin, Tungsten, Nickel, Cobalt etc.
    - The **Mines and Minerals (Development and Regulation) Amendment Act, 2021** has allowed the participation of the private sector as exploration agencies.
        - This has provided the required opening for private explorers to participate in mineral exploration with the support of **National Mineral Exploration Trust (NMET).**
- **Mineral Extraction:**
    - The two main modes of mining are **surface** and **underground mining.**
    - 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.
- **Intermediate Processing:**
    - India’s 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.
- **Advanced Manufacturing:**
    - 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 **Electric Vehicles (EVs)** motors and wind turbines.
    - Sectors that use critical minerals for the manufacture of several vital components are:
        - Large scale electronics manufacturing
        - Telecom & Networking products
        - White goods (ACs & LED)
        - High efficiency solar PV modules
        - Advance Chemistry Cell (ACC) battery
- **Recycling:**
    - The **International Energy Agency** forecasts that recycled mineral volumes 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.

What are the Initiatives Taken for Critical Minerals in India?

- **Planning Commission**:

- A Planning Commission **report** (now **NITI Aayog**) in **2011** highlighted the need for the assured availability of mineral resources for the country's industrial growth.
    - **12 minerals** and **metals** were **identified** as **strategic minerals** which included Tin, Cobalt, Lithium, Germanium, Gallium, Indium, Niobium, Beryllium, Tantalum, Tungsten, Bismuth and Selenium.

- **Ministry of Mines:**
    - The **Ministry of Mines** constituted a steering committee in 2011 to review the status of the availability of **rare-earth elements (REE)** and energy-critical elements.
    - The study titled **"Rare Earths and Energy Critical Minerals: A Roadmap and Strategy for India"** reviewed India's production, consumption and reserves.
- **Council on Energy, Environment and Water (CEEW):**
    - A study conducted by **CEEW** highlighted the paucity of research in India related to ensuring **mineral resource security** for the manufacturing sector.
    - The study identified **13 minerals** that would become most critical by 2030.
        - 13 minerals included Rhenium, Beryllium, Rare Earths (Heavy), Germanium, Graphite, Tantalum, Zirconium, Chromium, Limestone, Niobium, Rare Earths (light), Silicon and Strontium.
- **Geological Survey of India (GSI):**
    - A strategic plan for enhancing REE exploration in India was jointly submitted by the **Geological Survey of India (GSI) and Atomic Mineral Division (AMD).**
    - It emphasized on securing rare earth elements for India.
- **Centre for Socio and Economic Progress (CSEP):**
    - In 2023, CSEP released a working paper titled **"Assessing the Criticality of Minerals in India".**
    - It evaluated the criticality of **43 non-fuel minerals** in India based on two dimensions i.e., economic importance for the Indian economy and supply risks.

What is the Mandate of the New Committee on Critical Minerals?

- The **Ministry of Mines** constituted a **committee** for the identification of **critical and strategic minerals.**
- The committee was **chaired** by **Dr. Veena Kumari Dermal**, Joint Secretary, M/o Mines.
- It concluded that **categorization** of critical minerals depends upon a number of factors such as **availability, monopoly on resources, use for frontier technologies/ clean energy, substitutability, supply risk, recycling** etc.
- **Criteria** used for identifying the critical minerals:
    - 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**.
        - In the **second stage,** an **inter ministerial consultation** was carried out with different ministries to identify minerals critical to their sectors e.g., Ministry of Power, Ministry of New and Renewable Energy, Department of Atomic Energy etc.
        - In the **third stage**, a detailed **statistical exercise** was carried out for precise computation of various factors such as **substitutability index, minerals cross-cutting index, import reliance etc.**
- Based on the three-stage assessments process, a total of **30 minerals** are found to be **most critical** for India out of which two minerals are critical as fertilizer minerals.

What are the Applications and Availability of Critical Minerals in India?

S. No.	Critical Minerals	Major Applications	Availability in India
1.	Antimony	**Flame retardants**, Lead-acid batteries, Lead alloys, Plastics (catalysts and stabilizers), Glass and ceramics	No proved reserves and only inferred reserves are available in Lahul & Spiti districts of Himachal Pradesh.

			It is obtained commonly as a by-product in lead zinc-silver smelting by **Hindustan Zinc Limited.**
2.	Beryllium	Manufacture of computer, electronic and optical products	Not available. Current requirements are made through imports.
3.	Bismuth	Chemicals, Pharmaceuticals, Casting of Iron	Not available. Current requirements are made through imports.
4.	Cadmium	Manufacture of electrical equipment, Chemical products, **Solar cells**, Electroplating, and Silver soldering	**Cadmium** is recovered as a by-product during zinc smelting and refining.
5.	Cobalt	**Electric Vehicles (EVs)**, Batteries, corrosion resistant alloys, Aerospace applications, Pigments and Dyes, Organic and inorganic chemical compounds.	Not available. Current requirements are made through imports.
6.	Copper	Electrical and electronics products, Electrical Wiring, Solar Panel, **Automotive industry.**	Current copper concentrate production meets only 4% of the demand for copper smelters and refineries, requiring substantial imports.
7.	Gallium	**Semiconductors,** Integrated Circuits, LEDs, Specialized thermometers, **Barometric sensors.**	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.
8.	Germanium	**Optical fibers**, **Satellites,** Solar cells, **Infrared night vision systems.**	Not available. Current requirements are made through imports.
9.	Graphite	Batteries, **Lubricants**, Fuel cells for EVs, Electric Vehicle	9 million tonnes reserves exist.
10.	Hafnium	Superalloy, Catalyst precursor, **Semiconductors**, Nuclear reactors.	Normally, all **Zirconium** compounds contain between 1.4% and3% hafnium. **Indian Rare Earths Limited (IREL)** and **Kerala Minerals and Metals Ltd (KMML)** are involved in production of Zircon.
11.	Indium	Electronics (Laptops, LED Monitors/TVs, Smartphones), and **semiconductors.**	Not available. Current requirements are made through imports.
12.	Lithium	Electric Vehicle, **Rechargeable batteries**, Glassware, Ceramics, Fuel manufacturing, Lubricant.	**lithium-inferred resources** of 5.9 million tonnes in the **Salal-Haimana area** of the Reasi district in Jammu and Kashmir (J&K).

13.	Molybdenum	Steel alloys, Lubricants, Medical field, Electrical and Electronics.	Mineable reserves are available in Harur of Tamil Nadu State.
14.	Niobium	Metal alloys (steel), Jet engines, Rockets, Construction beams, Oil rigs and pipelines, Superconducting magnets, MRI scanners, **Nuclear power plants.**	Not available. Current requirements are made through imports.
15.	Nickel	Stainless steel, **Solar panels**, Batteries, Aerospace, Defence applications and **Electric Vehicle.**	**Vedanta** has a nickel and cobalt plant at Goa named **NICOMET.**
16.	Platinum Group Elements (PGE)	Jewelry, Medicine (**pacemakers, chemotherapy**), Electronic equipment used by military, **Optical fibers,** LCDs, Turbine blades	**Nilgiri, Boula Nuasahi** and Sukinda areas in Odisha. **Hanumalpura** area in Shimoga schist belt of Karnataka.
17.	Phosphorous	Mineral fertilizer, Detergents, Food additives, Animal Feed, Rust removers, **Corrosion preventers**	Rajasthan, Jharkhand and Madhya Pradesh.
18.	Potash	Chemical fertilizers, Water softener, **Road de-icing,** pH adjustment, Explosives.	**Nagaur** (Rajasthan), **Panna** (Madhya Pradesh), Sonbhadra **& Chitrakoot** (Uttar Pradesh)
19.	Rare Earth Elements (REE)	Permanent magnets, Catalyst, Polishing, Batteries, Electronics, Defence technologies, Wind energy sector, Aviation and Space	Resource estimate of **Monazite** from beach sand in India is 11.93 Mt having 55%-65% of rare earth oxides.
20.	Rhenium	**Super-alloys**, Aerospace, Catalysts in petroleum industry	Not available. Current requirements are made through imports.
21.	Selenium	Pigments for ceramics, paint and plastics, Useful in photocells, solar cells and photocopiers, Additive to make stainless steel	Not available. Current requirements are made through imports
22.	Silicon	**Semiconductors,** Electronics and transport equipment, Paints, Aluminum alloys	India reported production of 59000 metric tonnes of silicon and ranks 12th in production as per 2022 data
23.	Strontium	Alloys of aluminum, Pigments and Fillers, Glass, Magnets, Pyrotechnic application	Not available. Current requirements are made through imports
24.	Tantalum	**Capacitors**, Superalloys, Carbides, Medical technology	Not available. Current requirements are made through imports
25.	Tellurium	Solar power, Thermoelectric devices, Rubber vulcanising	Not available. Current requirements are made through imports
26.	Tin	**Lead acid batteries,** Metal Packaging, Solders, Home decor	Produced in the form of concentrates and metal in Chhattisgarh
27.	Titanium	Color pigments in paint, Plastics, and paper, Metal alloys (aluminum, steel, molybdenum), Aircraft, Spacecraft, Missiles and rockets, **Non Corrosive pipes**,	Coastal districts of Tamilnadu, Andhra Pradesh, Odisha, Kerala, Gujarat and Maharashtra

		Ship and submarine hulls	
28.	Tungsten	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 requirements are made through imports
29.	Vanadium	Metal alloys (steel), **Military armor plating**, Nuclear reactor components, Manufacturing of superconducting magnets	Total estimated reserves of vanadium ore as on1.4.2015 are placed at 24.63 million tones.
30.	Zircon	Good **nuclear fuel-rod cladding** metal, **Re- entry vehicles** and coatings in jet engines, Used in heat shield in **space shuttles**	Obtained as a by-product during the beneficiation of heavy mineral sands in **Manavalakurichi in Tamil Nadu.**

What are Additional Recommendations of the Committee?

- There is a need for establishing a **National Institute on Critical Minerals** on the lines of **Commonwealth Scientific and Industrial Research Organisation (CSIRO).**
  - CSIRO is an **Australian government** corporate entity and one of the world's multidisciplinary science and research organizations.
- A wing in the Ministry of Mines can be established as a **Centre of Excellence for Critical Minerals (CECM).**
  - It will focus on identifying more **efficient ways** for discovering **next generation critical mineral deposits.**
  - It will **periodically update** the list of **critical minerals** for India, preferably every three years, and notify the **critical mineral strategy** from time to time.

Conclusion:

India's focus on clean energy and reducing emissions has increased the importance of critical minerals, essential for electric vehicles and renewable energy systems. These minerals are vital for India's transition to a greener and more sustainable future. Understanding and utilizing these resources will fuel India's growth, competitiveness, and sustainable development.

UPSC Civil Services Examination Previous Year Question (PYQ)

Prelim:

Q1.Consider the following minerals: (2020)

1. Bentonite
2. Chromite
3. Kyanite
4. Sillimanite

In India, which of the above is/are officially designated as major minerals?

(A) 1 and 2 only

(B) 4 only

(C) 1 and 3 only

(D) 2, 3 and 4 only

Ans: D

Q2.Recently, there has been a concern over the short supply of a group of elements called 'rare earth metals'. Why? (2012)

1. China, which is the largest producer of these elements, has imposed some restrictions on their export.
2. Other than China, Australia, Canada and Chile, these elements are not found in any country.
3. Rare earth metals are essential for the manufacture of various kinds of electronic items and there is a growing demand for these elements.

Which of the statements given above is/are correct?

(A) 1 only

(B) 2 and 3 only

(C) 1 and 3 only

(D) 1, 2 and 3

Ans: C

Mains:

Q. Discuss the multi-dimensional implications of uneven distribution of mineral oil in the world. **(2021)**