

Renewable Energy Applications

The renewable energy sector is increasingly vulnerable to supply, pricing, and processing challenges concerning key transition minerals—copper, platinum group metals (PGMs), and tellurium. These are essential for wind turbines, solar photovoltaic cells, hydrogen electrolyzers, and grid-scale electrification systems.

Copper supply is under strain due to falling ore grades, high energy costs in top producers like Chile and Peru, and delays in new project permits. PGMs, especially platinum and iridium, are geopolitically risky due to their concentration in South Africa and Russia, directly impacting hydrogen fuel cell scale-up. Tellurium, a low-extraction byproduct of copper refining used in CdTe solar panels, is hampered by limited refining capacity and remains a bottleneck. Without strategic intervention, these constraints may derail India’s clean energy targets and slow solar and hydrogen tech deployment.

Mineral	Global Production 2023 (Tonnes)	Global Reserves 2023 (Tonnes)
Copper	49,000	1,000,000
Rare Earth Elements	350,000	110,000,000
Platinum Group Metals (Palladium + Platinum)	390,000	71,000,000
Tellurium (Refinery)	640	36,000

Data Source- [USGS Commodity Summaries](#) (2024)

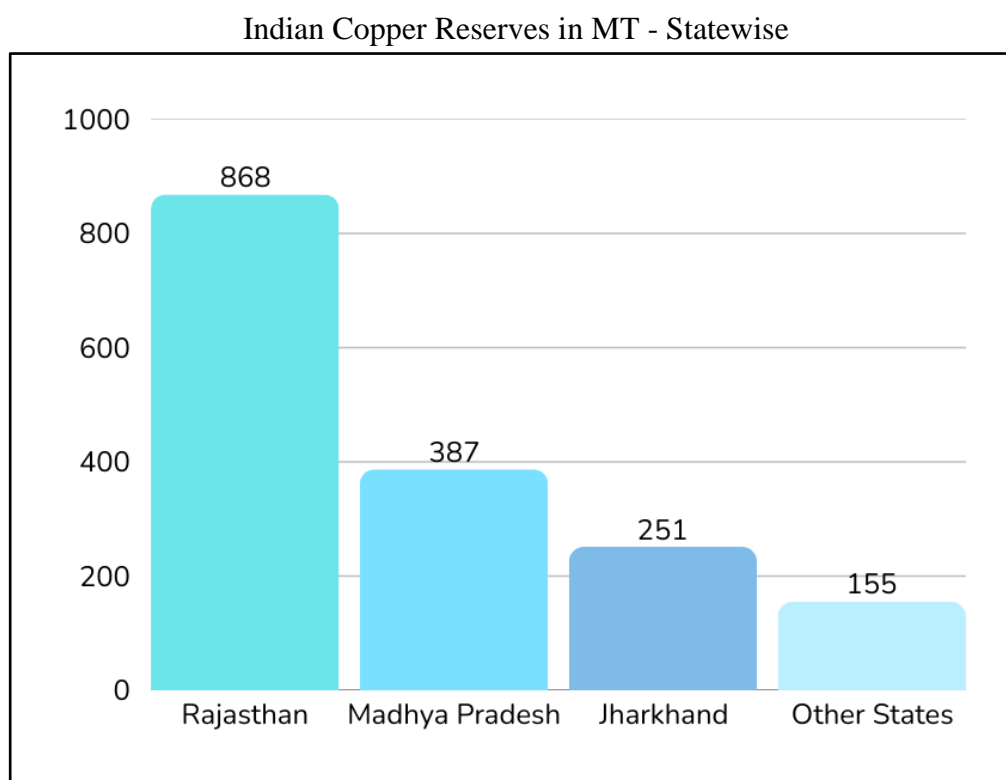
Domestic Availability and India’s Current Value Chain

Copper

India is not self-sufficient in copper ore production despite having significant smelting capacity. As per IEA data, global copper demand is expected to double by 2040. Hindustan Copper Limited (HCL) remains the sole integrated public-sector company engaged in copper mining, smelting, and refining (IBM Yearbook, 2024d). Private players like Hindalco and Vedanta operate international mines and rely heavily on imported copper concentrates.

According to the Indian Bureau of Mines (IBM), India’s total copper ore reserves/resources as of Q1 2020 stood at 1.66 billion tonnes. Of this, only 163.89 million tonnes (9.87%) fall under the ‘Reserves’ category, while the remaining 1.5 billion tonnes (90.13%) are listed as ‘Remaining Resources’. Critically, India lacks any reserves above 1.85% copper grade; the 163.89 million tonnes of ore fall within the 1%–1.85% grade range (IBM Yearbook, 2024d, Chapter 5, p. 2).

Rajasthan holds the largest share of these reserves at 868 million tonnes, followed by Madhya Pradesh (387 million tonnes) and Jharkhand (251 million tonnes). The remaining 9.33% is spread across Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Meghalaya, Nagaland, Odisha, Sikkim, Tamil Nadu, Telangana, Uttarakhand, and West Bengal. In FY 2021–22, Madhya Pradesh led copper concentrate production (57%), followed by Rajasthan (43%).



Data Source - Indian Bureau of Mines

HCL's operations span five units: the Indian Copper Complex (ICC) at Ghatsila in Jharkhand; the Khetri Copper Complex (KCC) in Rajasthan; Malanjkhand Copper Project (MCP) in Madhya Pradesh; Taloja Copper Project (TCP) in Maharashtra; and Gujarat Copper Project (GCP). The company operates four underground mines and one opencast mine, with an annual production capacity of 3.5 million tonnes (IBM Yearbook, 2024d, Chapter 5, p. 8).

In terms of end-use, the electrical and telecommunication industries consume the bulk of India's refined copper, followed by transport, consumer durables, construction, and general engineering goods. Notably, FY 2021–22 saw higher imports of refined copper than exports, increasing domestic availability from 430,288 tonnes to 514,545 tonnes.

Imports of copper are received in ten forms: ore and concentrates, refined copper, copper alloys, brass and bronze, scrap, cement copper, mattes, blister, worked forms (bars, rods, plates), and copper powders/flakes. In 2021–22, copper ore and concentrate imports surged by 145% to

1,018,934 tonnes, up from 415,136 tonnes in 2020–21 (IBM Yearbook, 2024, Chapter 5, p. 15). Chile was the top supplier (37%), followed by Indonesia (20%), Peru (12%), Australia (11%), Panama Republic (9%), Saudi Arabia (4%), Canada (3%), and Brazil (3%).

In contrast, refined copper imports declined by 11% to 138,531 tonnes in 2021–22, down from 155,038 tonnes in the previous year. Japan accounted for 86% of these imports, followed by Tanzania (7%) and the UAE (3%). Among other import forms, copper alloys contributed 553,443 tonnes, and copper scrap 116,755 tonnes.

Volza's import data reports 166,428 copper shipments into India between March 2023 and February 2024. India's key suppliers are China, the United States, and Vietnam, with Vietnam ranking among the top three exporters of copper to India (Volza, 2024c).

Platinum Group Metals

India's PGM reserves are limited, with Odisha accounting for 67% of the total, followed by Uttar Pradesh (13%) and Tamil Nadu (8%) (IBM Yearbook, 2024, Chapter 13, p.2). Boula-Naushi, 170 km northeast of Bhubaneswar, is the only proven deposit. Potential PGM mineralisation has also been reported in the Shakar-Ganga load in Odisha and in the mafic-ultramafic complex of the Shivamogga schist belt, Karnataka (IBM Yearbook, 2024, Chapter 13, p.2). These reserves are not commercially viable for large-scale extraction and face technological and economic barriers.

Volza data reports that India imported 11,953 rhodium shipments between March 2023 and February 2024 from 289 foreign exporters—marking a 281% increase over the previous year. This represents a 733% year-on-year increase from February 2023 and a 550% month-on-month rise from January 2024. India leads global rhodium imports, followed by Peru and the US (Volza, 2024a).

India also imported 525 shipments of iridium in the same period, reflecting a 21% annual increase. Despite a -24% year-on-year decline from February 2023, India remains among the top importers, along with the US, the Netherlands, and Germany (Volza, 2024a). Iridium, osmium, and ruthenium imports in semi-manufactured forms stood at USD 3,638.25K and 282 kg, primarily sourced from the UK (USD 3,238.72K, 238 kg), South Africa (USD 355.48K, 37 kg), Japan (USD 25.97K, 2 kg), the US (USD 6.61K, 1 kg), and China (USD 6.39K, 1 kg) (World Integrated Trade Solutions, 2023a).

Tellurium

Tellurium is recovered as a byproduct at the Ghatsila Copper Smelter of HCL in Jharkhand, with a licensed capacity of 10,000 kg (IBM Yearbook, 2024, Chapter 14, p.1). No production has been reported since 2004–2005. Anode slime from copper refining, which contains 50–60%

tellurium, is a key source. Hindalco's Dahej smelter has developed a process to extract copper telluride powder from slime leachate (IBM Yearbook, 2024, Chapter 14, p.1).

Volza data shows India imported 330 shipments of tellurium between March 2023 and February 2024, supplied by 80 exporters. This marks a 5% increase from the prior year, despite a -13% year-on-year dip in February 2023 and a -33% sequential drop from January 2024. Key exporters include Germany, the US, and the UK (Volza, 2024b).

India's boron and tellurium imports totalled USD 655.39K and 6,609 kg, sourced from China (USD 348.57K, 3,240 kg), Japan (USD 170.29K, 2,350 kg), the US (USD 70.30K, 159 kg), Belgium (USD 64.97K, 850 kg), and Canada (USD 0.52K, 1 kg) (World Integrated Trade Solutions, 2023b).

Mineral Specific Challenges

Copper

Copper's primary challenges lie in cost, environmental concerns, and geopolitical supply risks. Smelting is a low-margin business, and high labour and energy costs make it difficult for India to compete with China (IEA, 2024, p. 108). Moreover, a high concentration of reserves in Chile, Peru, and the DRC creates vulnerabilities. Labour unrest in Chile and security issues in the DRC threaten consistent supply. Latin America is also experiencing rising resource nationalism, with governments demanding a greater share of copper revenues.

The US–China rivalry adds complexity to copper supply chains. Tariffs and restrictions can alter trade patterns rapidly, pushing prices higher. The US is attempting to build secure supply chains by investing in domestic production and allied trade networks. However, in 2023, US copper output declined by 11% compared to 2022 (USGS, 2024, p. 64). With reduced refining capacity, the US increasingly depends on Chilean imports—though China remains Chile's largest copper buyer (S&P, 2023, p. 78). The EU and US also face challenges in obtaining mining permits. Harmonising their approaches is key to avoiding discord, particularly in light of the US Inflation Reduction Act's unilateralism (Hendrix, 2023).

Logistically, sourcing from Latin America and Africa presents challenges, including landlocked deposits, weak transport networks, and limited port infrastructure. New mines typically take a decade to become operational, with delays stemming from permitting, environmental reviews, and local opposition. Additionally, copper is highly sensitive to global economic shifts, creating price volatility that deters long-term investment. High upfront capital requirements and long gestation periods further raise financial risks, making it challenging to compete with China.

Platinum Group Metals (PGMs)

PGMs are vulnerable to supply shocks. Persistent electricity issues in South Africa and geopolitical uncertainties surrounding Russian palladium, particularly from Norilsk, pose significant threats (IEA, 2024, p. 201). The industry faces technical and geographical rigidity: PGM catalyst production is concentrated in specific regions, making capacity transfer challenging and slow to adjust (Li Pengyuan et al., 2023, p. 15).

Fluctuating demand, particularly from the automotive sector, adds to uncertainty. As the world shifts to electric vehicles (EVs), demand for PGMs in catalytic converters is expected to decline. Environmental regulations and sustainability concerns raise the bar for new projects, which require high capital investment. PGM recycling infrastructure is still nascent in many countries, including India. South Africa, the largest PGM producer, suffers from frequent load shedding and unreliable energy supply, along with recurring labour disputes that hinder production schedules and volumes.

Tellurium

India's tellurium supply is constrained due to limited natural reserves and high dependence on imports. Supply chain disruptions, especially from China, could seriously impact India's solar manufacturing ambitions. Political instability, trade restrictions, and technological challenges further complicate tellurium access. Rising demand from the solar and electronics sectors risks creating a supply-demand imbalance, inflating prices.

Tellurium's extraction is economically viable only when copper prices are high, as it is typically recovered as a byproduct. If copper prices fall, tellurium production becomes less attractive, compounding supply risks.

Recommendations

Copper

Alternate Chemistries

Aluminium is a well-established substitute for copper in power cables, automotive radiators, electrical equipment, and plumbing systems. Optical fibre has replaced copper in telecommunications, and plastics serve as substitutes in water pipes and other structural applications (IBM Yearbook, 2024, Chapter 5, p.12).

The US and Chile are pioneering bioleaching methods to extract copper from low-grade ores. India should consider bilateral technology transfer agreements with firms like Freeport-McMoRan to test bioleaching in Indian geological contexts. Funding should be allocated to institutions such as NML and the IITs to accelerate research on aluminium-for-copper substitution, especially for EVs and smart grid applications. Bureau of Indian Standards (BIS)

can help standardise aluminium-based power cable manufacturing to support broader market adoption.

Focus on Recycling

India, a leader in copper recycling, must upgrade its technology and expand capacity to meet future demand. Collaboration with Japan on R&D for next-generation recycling technologies would be valuable.

According to IBM data, there is a paucity of reliable data due to the unorganised nature of India's scrap collection system. As of May 2010, the Central Pollution Control Board (CPCB) had licensed 35 units with a combined annual capacity of 2.42 lakh tonnes, while another 132 units recovered copper alongside other metals, with a capacity of 5.17 lakh tonnes (IBM Yearbook, 2024, Chapter 5, p.11). Scaling these operations is crucial.

Engagement with Multilateral Alliances

India should integrate copper supply chain discussions into BRICS and G20 agendas. Collaborative frameworks could include joint exploration and shared technology for refining. Additionally, India can establish a “regional critical mineral hub” with Bhutan and Nepal for copper logistics, improving resilience.

Platinum Group Metals

Alternate Chemistries

While the cash price of platinum is higher than that of gold, palladium is nearly half the price of gold. However, it is easier to substitute metals of the platinum group, especially the alloys, ‘than to use alternative materials, which is evident from the total dominance of ruthenium-based resistors over the palladium silver resistors for high-powered applications’ (IBM Yearbook, 2024, Chapter 13, p.12).

Substitutes in electrical use include ‘tungsten, nickel, silver, gold, and silicon carbide with alternative catalysts such as nickel, molybdenum, tungsten, chromium, cobalt, vanadium, silver and rare earth’ (IBM Yearbook, 2024, Chapter 13, p. 3). Rhenium has been the most reliable substitute for platinum as a catalyst in the petroleum refining sector. The automotive sector has witnessed a shift from platinum to palladium in catalytic converters, with new technology now allowing up to ‘25% substitution of platinum in diesel catalytic converters with palladium’ (IBM Yearbook, 2024, Chapter 13, p. 4). Hydrogen fuel cells, which have been a significant application of PGMs, are moving towards innovations aimed at reducing or replacing PGMs.

Japan's Toyota and South Korea's Hyundai are developing fuel cells that minimise platinum use. Toyota has introduced novel catalysts, and Hyundai's 'NEXO' cuts platinum content by 20%. In the US, the Department of Energy's "H2@Scale" programme funds non-PGM fuel cell research. The EU's Clean Hydrogen Partnership is also exploring platinum-free electrolyzers, including through Germany's REFHYNE project.

India's CSIR, BHEL, and IITs should lead domestic R&D on PGM substitutes like rhenium- or nickel-molybdenum-based catalysts. A national-level "PGM Alternatives Innovation Program," modeled after ARPA-E in the US, could provide dedicated funding and help commercialise new technologies.

Diversification of Supply

Global efforts to set up mining projects for PGM resources are underway in politically stable regions such as Canada, Australia, and Finland. India can capitalise on such projects through joint ventures and/or partnerships in the form of memoranda of understanding (MoUs) and multilateral agreements such as the MSP. Investment in exploration and the development of new PGM deposits is crucial for long-term supply stability. Companies, particularly in the automotive and energy sectors, are collaborating with mining and recycling firms to secure long-term PGM supplies, a space Indian companies could explore to secure its PGM supply chains.

Tellurium

Alternative Chemistries

To reduce dependence on tellurium, the US has invested in First Solar's thin-film technology. China's Tongwei Solar is shifting towards copper indium gallium selenide (CIGS) technologies. The EU supports perovskite solar research through Horizon Europe's PHOTOTRACK, and Australia's CSIRO is exploring organic photovoltaics (OPVs). Tellurium substitutes include amorphous silicon and copper-indium-gallium selenide (CIGS) for CdTe in thin-film PV solar cells, bismuth selenide and organic polymers for thermal devices, and sulphur/selenium-based vulcanisation agents (IBM Yearbook, 2024, Chapter 14, p.2).

Domestically, the MNRE (Ministry of New and Renewable Energy) and SERIUS (Solar Energy Research Institute for India and the U.S.) can lead initiatives to pilot alternative solar chemistries, while Indian firms like Adani Solar and Tata Power Solar can be incentivized to diversify technology portfolios beyond cadmium telluride. Moreover, leveraging Make in India and PLI schemes for solar manufacturing, India can foster domestic innovation in non-tellurium thin-film technologies.

Upgrading Recycling Capabilities

Developing specialised facilities for recycling tellurium from end-of-life CdTe solar panels and anode slime is essential. Public–private partnerships and the Critical Minerals Mission (2025) should fund this effort to reduce dependence on primary extraction and enhance domestic resilience.

India’s clean energy ambitions hinge not just on technology deployment, but on securing resilient, diversified, and future-ready mineral supply chains. Copper, PGMs, and tellurium present distinct vulnerabilities—from import dependence and refining bottlenecks to geopolitical risks and limited domestic production. Strategic investment in recycling, alternative chemistries, and international partnerships—particularly through initiatives like the Critical Minerals Mission and PLI schemes—will be essential to mitigate risks, build self-reliance, and ensure that mineral scarcity does not become a bottleneck to India’s energy transition.

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