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India's Mineral Requirements in a World of Economic and Geopolitical Transition

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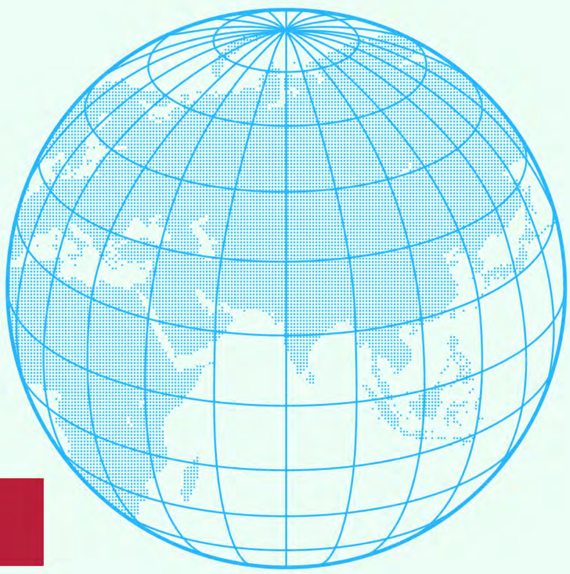

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Designed by Umesh Kumar

India's Mineral Requirements in a World of Economic and Geopolitical Transition*

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*This paper was written in January 2024, and updated in February 2025.

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Abbreviations

BALCO	Bharat Aluminium Company Limited
COP	Conference of the Parties
CEEW	Council on Energy, Environment, and Water
CSR	Corporate Social Responsibility
CSTEP	Centre for Study of Science, Technology and Policy
CTEMPO	Centre for Techno-Economic Mineral Policy Options
DMF	District Mineral Foundation
DoD	Department of Defense (US)
DoE	Department of Energy (US)
E&P	Exploration and Production
EU	European Union
EV	Electric Vehicle
G7	Group of Seven
GDP	Gross Domestic Product
GSI	Geological Survey of India
HZL	Hindustan Zinc Limited
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
KABIL	Khanij Bidesh India Ltd
MoM	Ministry of Mines
MSP	Mineral Security Partnership
NATO	North Atlantic Treaty Organization
NITI	National Institution for Transforming India (NITI) Aayog
NZE	Net Zero Emissions
OECD	Organisation for Economic Cooperation and Development
ONGC	Oil and Natural Gas Corporation (ONGC Videsh)
OPEC	Organisation of the Petroleum Exporting Countries
OPEC+	Organisation of the Petroleum Exporting Countries Plus (a larger group of oil-exporting nations, including Russia)
PIB	Press Information Bureau
PSU	Public Sector Undertaking
PV	Photovoltaic
REE	Rare Earth Element
USGS	United States Geological Survey
WTO	World Trade Organization

Executive Summary

Minerals, until recently a mundane subject, have gained widespread public attention. In 2022–2023, several developments drew global attention to minerals now deemed "critical" for their essential role in renewable energy, electronics, high-tech equipment, and defence industries. The simplest explanation for this surge in activity is that our high-tech, digital world, transitioning to low-carbon energy, has been made conscious of its mineral roots. It is increasingly recognised that the transition away from fossil fuels, which provide 80% of the world's primary energy, will create a mineral-dependent global economy. Policymakers planning for Net Zero Emissions (NZE) by mid-century now acknowledge the criticality of minerals in supply chains for decarbonising energy and industry. India is experiencing faster economic growth, with a greater role for manufacturing, while taking up the challenge of a rapid energy transition. The mineral economy is thus one of increasing significance.

Historically, major economic powers recognised the vital role of key minerals for their prosperity. China, as it embarked on rapid industrialisation in the 1980s, was always cognisant of raw material requirements, particularly essential minerals. In 1999, China embarked on a "Go Global" strategy, buying mineral reserves abroad.

The growing sense of the importance of minerals has become specific because of their role in decarbonisation and the transition to a world of non-fossil energy systems. The 2015 Paris Accords brought minerals into popular discourse. In the years after the Paris Accords, global goalposts shifted to targets for achieving NZE by mid-century. A 2019 World Bank report, "The Mineral Intensity of the Clean Energy Transition," found that the production of minerals such as graphite, lithium, and cobalt could increase by nearly 500% to meet the growing demand for clean energy technologies.

As minerals are now recognised as the foundation for future energy systems, securing the supply of minerals deemed critical has become a key feature of the national security calculus of the world's major powers. There has also been a transformation of international relations, marked by growing geopolitical competition between the US and China. The US and its allies have rapidly become aware of China's predominance in the mining and processing of key minerals. As US-China relations have become not just competitive but adversarial, existing economic and technological frameworks have begun to splinter, leading to moves now underway to restructure global supply chains. In June 2022, 11 countries set up the Mineral Security Partnership (MSP) to "catalyse investment in responsible critical mineral chains globally"; India joined in June 2023.

The path to NZE will call for a massive transition in global economies. Solar and wind energy for electricity, Electric Vehicles (EVs), and hydrogen all require critical minerals.

India has a great historical legacy in mining and metallurgy. In the post-independence era, there was considerable investment in mining. However, India's mineral sector was bogged down by slow-moving bureaucratic procedures and overregulation. A new National Mineral Policy in 1993 opened the sector to private and foreign investment, but did not materially change the scenario.

Despite the efforts of successive governments, mining in India remains a story of potential locked underground. Mining generates only about 2% of Gross Domestic Product (GDP), as against 7.5–12% in other mining jurisdictions like Australia and South Africa, with whom we share geological characteristics. Presently, only 30% of India's obvious geological potential has been properly explored. Imports of minerals and metals cost India US$157 billion in 2022. For four minerals critical for renewable energy—copper, nickel, lithium, and cobalt—India is 93–100% dependent on imports.

At the Conference of the Parties in Glasgow in 2021 (COP 26), India joined the NZE bandwagon with a target date of 2070. The more immediate targets are for 2030, including renewable energy generation to be stepped up to 500 GW. This increase will lead to a massive increase in mineral requirements. In June 2023, the Ministry of Mines (MoM) released a report identifying 30 critical minerals for India. Securing these minerals will require policy measures enhancing private sector participation and incentives for exploration. The time has come for policymakers to plan a critical mineral stockpile.

Despite India's excellent geological potential, there are many identified minerals for which we will continue to rely on imports. There is a need to build external supply chain partnerships. For India, exchanging dependence on the Organisation of the Petroleum Exporting Countries (OPEC) for oil with China for critical minerals is a recipe for disaster. India's membership in the MSP is a step forward, not only because it can enable it to become part of supply chains for mineral security: the MSP declares that the group will help countries get the full economic benefits of their geological endowments.

It is crucial to keep in mind the need for India to develop its resources. The time has come for a new perspective on mining in India. In the future, the capacity for mining and metallurgy will become a part of the calculus of national power and strategic capabilities. Sourcing more minerals within the country can save over US$100 billion in imports every year. Mining's contribution to GDP can be at least doubled from the 2% presently and become a source of large-scale employment. At the social level, mining needs a paradigm shift in popular perception to a more balanced understanding of its essentiality. Local communities have to be stakeholders in sustainable mining. The growing consensus on the unavoidable need for increased mineral use for the energy transition provides an opportune occasion to alter the popular discourse regarding the mineral economy of India.

This paper analyses the global and domestic challenges facing India's mineral economy. With a strategic shift, India can not only secure its own critical mineral needs but also become a key player in global mineral supply chains. To achieve this, the paper proposes a comprehensive policy framework with the following key recommendations:

- Strengthening Domestic Mining:
  - Incentivise high-risk exploration by adopting an Exploration and Production (E&P) licensing model and consider offering incentives like those used in other mining jurisdictions.
  - Secure the social license to operate by ensuring local communities become direct beneficiaries. District Mineral Foundation (DMF) funds should be efficiently and transparently utilised to this end.
  - Establish a National Critical Mineral Stockpile to buffer against supply shocks and geopolitical volatility.
- Securing External Supplies of Minerals:
  - Empower Khanij Bidesh India Ltd (KABIL) to proactively acquire and develop strategic mineral assets abroad, taking inspiration from the model of Oil and Natural Gas Corporation (ONGC Videsh).
- Enhancing Global Mineral Cooperation:
  - Actively leverage the MSP, and other international partnerships, to co-invest in responsible mining projects and learn from the best practices of advanced mining jurisdictions.

1. Introduction

A global and historical overview of the importance of minerals in the modern economy is appropriate before we turn our focus to India's circumstances.

Minerals, until recently a mundane subject for geologists, traders, and specialists in the metallurgical industry, have begun to receive widespread public attention around the world in recent years.

In 2022–2023, several developments drew world attention to minerals deemed "critical" as they are essential in currently used technologies for renewable energy, electronic and other high-tech equipment, and defence industries. In June 2022, a group of 11 Western/industrialised countries formed the MSP; India joined a year later (Press Information Bureau [PIB], 2023). In July 2023, China announced export controls on gallium and germanium, which excited much political commentary, though these minerals would have been obscure subjects earlier (Lv, 2024). The US, in fact, said it would invoke national security regulations—the Defense Production Act—to ensure that supplies of the two minerals were available, indicating just how critical these minerals are deemed. China followed up with controls over technologies for processing rare earths, with potentially serious consequences, as China controls over 80% of the world's supply of processed rare earth materials. Earlier in the year, Indonesia announced export bans on bauxite and nickel—and it was criticised by the International Monetary Fund (IMF) and hauled before the World Trade Organization (WTO) by the European Union (EU), all amid higher-than-usual media interest for a commercial dispute (Indonesia Business Post, 2023).

There are many explanations for this surge in activity and heightened public interest. The simplest is that our high-tech, digital world, in transition to low-carbon energy, has been made conscious of its mineral roots. It is increasingly recognised that the transition away from fossil fuels (which provide 80% of the world's primary energy) will create a mineral-dependent global economy. This is happening amid global geopolitical and geo-economic changes, which have underlined the importance of access to the required minerals. Policymakers planning for NZE by mid-century now acknowledge the criticality of minerals in supply chains for the decarbonisation of energy and industry. India is in the process of faster economic growth, with a greater role for manufacturing, while taking up the challenge of rapid energy transition. The mineral economy is thus one of increasing significance, opening up both risks and opportunities for the country.

Therefore, this paper sets out to achieve three broad objectives. Firstly, it analyses the geopolitical and economic shifts that have increased the importance of critical minerals for the modern world. Secondly, it evaluates India's historical and current policy frameworks for the mineral sector and identifies some of the key impediments that have led to its underperformance. Finally, it proposes specific policy recommendations for India to enhance its mineral security, enhance domestic mineral production, and navigate the increasingly complex global landscape.

To achieve these objectives, this paper is structured as follows. Section 2 begins by providing a historical overview of mineral security, followed by Sections 3 and 4 describing how the net-zero transition and geopolitical competition have shaped the sector. Section 5 considers the Indian context, examining the country's historical legacy and the policy issues that have left its mineral potential locked. Based on this analysis, Section 6 provides policy recommendations to address these challenges under the pillars of domestic production, external sourcing, and global cooperation. The paper concludes by summarising the main arguments and reinforcing the urgency of a new strategic approach for India to ensure mineral security.

2. Historical Background

The Industrial Revolution in Europe was powered by coal and built on iron ore for steel. As industries grew in size and sophistication, major economic powers recognised the vital role of key minerals for their prosperity. They used tools of economic and foreign policy to ensure access to and availability of those resources. Minerals have even been the cause of wars and imperial adventures. The Spanish plunder of South America in the pre-industrial era was essentially for metals like gold and silver; however, the 19th-century European imperial contests over Asia, Africa, and Latin America involved the quest for not just precious metals and gemstones but industrial raw materials like copper, tin, nickel, manganese, etc., in addition to iron ore and coal. Even after European empires were formally ended in the mid-20th century, Western powers sought to keep control over vital mineral resources, particularly in Africa.

Nevertheless, in the post-World War II era, the abundance of mineral supplies in the US and the Soviet Union, or controlled by them, the global reach of international mining companies and the liberalisation of global trade, resulted in the world having reasonably unhindered access to the supply of minerals for industry. Oil became the strategic issue, and control over oil resources was the source of much geopolitical competition. But the Second World War experience of huge mineral demand for manufacturing military equipment led both superpowers to maintain reserves of critical minerals for defence and other strategic industries—particularly those minerals for which there was a high degree of dependence on imports.

The US strategic mineral stockpile, set up by an Act of Congress in 1939, was used during World War II and substantially built up during the Cold War after the Soviet Union embargoed the export of its chromium and manganese in 1949. The US National Defence Stockpile was later—and still is—managed by the Defence Logistics Agency of the Pentagon.

The US kept track of mineral supply security more broadly to sustain its industrial base. In 1973, the US Geological Survey published a report with three leading questions (Brobst & Pratt, 1973): How important are minerals to our present industrial civilisation and standard of living? How much do we have, and how much is technologically and economically available? How and where to find more if needed?

It is noteworthy that President Nixon believed (in the context of the Cold War tussle) that Soviet President Brezhnev had said to an African leader, "Our aim is to gain control of the two great treasure houses on which the West depends—the energy treasure house of the Persian Gulf, and the mineral treasure house of central and southern Africa" (Nixon, 1980).

By the end of the 20th century, with rapid industrialisation spreading across the globe and ever-increasing demand for natural resources, the importance of key mineral inputs became more recognised worldwide. Major industrial powers relied on their industries working on a mix of domestic and foreign investments for maintaining supplies, with only low-key political direction, as most economies had access to commodity traders who kept global mineral trade flowing. Some of these trading companies are giant corporations based in the Swiss Alps and offshore tax havens. Though little is known outside the trade, they continue to be major players in international commerce in commodities, including minerals. Much of the international trade passed through Western trading centres like the London Metal Exchange, which also had a major influence over the pricing of commodities.

The oil shocks of the 1970s, accompanied by the manifestation of OPEC's price-setting and supply-limiting power, demonstrated to the industrialised countries their vulnerability to dependence on imports of oil. They began establishing strategic petroleum reserves and sharing mechanisms through the International Energy Agency (IEA). The IEA requires member countries to hold reserves equal to 90 days of imports. At the same time, concerns grew over efforts by other commodity producers to replicate the success of OPEC by setting up similar producer cartels, such as the International Bauxite Association in 1974. Major industrial powers, like Japan, France, and Sweden, began reviewing their dependence on external supplies of minerals and other industrial raw materials and set up strategic mineral stockpiles. However, some like Germany and the UK, baulked at the financing of stockpiles and continued to rely on the availability of mineral resources in global trade (or from foreign mining assets controlled by their nationals, in the case of the UK). Japan started keeping stocks in the 1970s and formally established a strategic stockpile in 1983, while Korea expanded the scope of its stocks, which were first maintained from the late 1960s. The aim was to ensure raw material availability for their world-leading industries in case of a supply squeeze similar to what they faced in the oil crisis. Korea relied on mandatory stock maintenance requirements by its private sector.

China, as it embarked on rapid industrialisation in the 1980s, was always cognisant of raw material requirements, particularly essential minerals. In 1986, Chinese scientists came up with the 863 Plan for Strategic High Technology Development, which fed into the Four Modernisation programmes of central planners during the leadership of Deng Xiaoping (Bryant, 2015). These programmes identified special materials, including rare earths, as essential for China's modernisation thrust.

Rare earths were specially identified as providing China with opportunities to take the lead over the world. The 863 Plan was followed up by the 973 Program in 1997, which "placed special emphasis on rare earth elements' research, and development of rare earth related end products," as analysed by Gregory Bryant in 2015 (Bryant, 2015).

Deng Xiaoping is credited with having said as early as 1992 that "The Middle East has oil, China has rare earths." Through the 863 Plan and 973 Program, according to Bryant, "China is attempting to become a world leader in downstream fields that depend on rare earths such as biotechnology, space technology, information technology, laser technology, automation, energy, and new materials."

The rare earths story is a special one, cited to highlight the strategic significance of minerals identified early on by Chinese leaders. More broadly, China recognised the need for the security of supply of various critical minerals as the country's industrial growth, which maintained an extraordinarily high speed for decades, made it the world's major consumer of minerals. In 1999, China embarked on a "Go Global" strategy, buying mineral reserves abroad and investing in the equity of mining companies in foreign countries. This strategy took off around 2002–2003, by which time the import and export of minerals accounted for 20% of China's total trade. In 2006, China announced a five-year plan to build up strategic reserve stockpiles for critical minerals.

This historical overview shows the divergence in strategic thinking. At the time when other industrial nations, particularly China, proactively identified the importance of minerals for economic and national security, India's approach has been comparatively passive. The long-term and state-directed strategies employed by China gave them the first-mover advantage and now a dominant position in nearly all critical minerals supply chains. This has left India, along with several other countries, in a disadvantageous position, needing to rely on just one country for its mineral and component needs. Such reliance on one country is the key challenge this paper focuses on, with subsequent sections highlighting how the global shift to net-zero emissions has amplified the importance and supply risks of critical minerals.

3. The Mineral Foundations of the Net Zero Transition

The growing importance of minerals has become specific and entered the domains of public consciousness and general knowledge because of their role in decarbonisation and the transition to a world of non-fossil energy systems. Minerals—as the basis for energy—attract attention, just like oil, which remains a subject of household interest in the fossil fuel era.

Specialists in geology and industry and researchers in think tanks have, for some decades, analysed the increased reliance of renewable energy on mineral resources, without gaining much public prominence. One of the first published governmental reports which linked the criticality of minerals to their use in clean energy and drew some public attention was that of the US Department of Energy (DoE) in 2010, titled "Critical Minerals Strategy" (US DoE, 2010). In a foreword, Energy Secretary Steven Chu wrote that "Many new and emerging clean technologies, such as components of wind turbines and electric vehicles, depend on materials with unique properties." The report noted inter alia that "wind turbines, electric vehicles, photovoltaic cells, and fluorescent lighting use materials at risk of supply disruptions in the short term… clean energy technologies currently use 20% of global consumption of critical materials… and this is likely to grow as clean energy technologies are deployed more widely." The report identified five rare earth elements as most critical.

In 2011, the European Commission identified 14 critical minerals in a report on "Tackling challenges in commodity markets and on raw materials" (European Commission, 2011), which the EU adopted as part of its study "Europe 2020 Strategy to ensure smart, sustainable, and inclusive growth." In 2014, a new list of 20 critical minerals was identified, and in 2017, the list was expanded to 27 minerals (European Commission, 2017).

The 2015 Paris Accords brought minerals into popular discourse. Think-tanks and individual government reports on minerals are increasingly mentioned in mainstream news channels. In 2017, the World Bank report "The Growing Role of Minerals and Metals for a Low Carbon Future" made the need for critical minerals a talking point for the public as well as policymakers (World Bank Group, 2017).

In the years after the Paris Accords, global goalposts were shifted from national contributions to reducing global greenhouse gas emissions (to keep temperatures below 2°C above pre-industrial levels), to targets for achieving NZE by mid-century (the Intergovernmental Panel on Climate Change (IPCC) in its 2018 report introduced the term NZE [IPCC, 2018]). This accentuated concern for critical minerals. A new World Bank report in 2019, "The Mineral Intensity of the Clean Energy Transition," found that production of minerals such as graphite, lithium, and cobalt could increase by nearly 500% to meet the growing demand for clean energy technologies (World Bank Group, 2020). Similar reports were published by the International Renewable Energy Agency and the IEA in 2021 (IEA, 2021). The Group of Seven (G7) Summit in Germany in 2022 took note of an Organisation for Economic Cooperation and Development (OECD) report on the Security of Supply for Critical Raw Materials, which cited IEA data showing that green transition could increase demand for lithium by 42 times, graphite 25 times, cobalt 27 times, and the platinum group of metals 151 times by 2040 (OECD, 2022).

The underlying reason for this dramatic increase in demand is that the core technologies of the energy transition are highly mineral-intensive. The path to NZE will call for a massive transition in global economies involving the gamut of energy, industry, agriculture, and services. This would include changes in lifestyle as well. Yet the transition path chosen by the international community, focusing on decarbonisation, starts with energy. Solar and wind energy for electricity, supported by battery storage, new transmission lines, and advanced grid management. EVs are envisaged for mobility, hydrogen, and biofuels as alternate liquid fuels/gas sources for industry. All of these technologies require minerals.

The sun and wind generate energy but do not produce usable electricity. Minerals are used in devices for the conversion of solar energy to electric power because of their specific electronic, optical, and magnetic properties. They enhance electrical conductivity, light absorption, generational efficiencies, and durability of solar power equipment. Magnets using specialised mineral elements enhance the efficiency of wind turbines. Minerals are in the catalysts used in electrolysers for chemical reactions for hydrogen. EVs are currently charged by batteries which use cobalt, manganese, nickel, and graphite.

The electrical grids consume huge amounts of minerals like copper, aluminium, and steel. Looking at global industry more generally, in the NZE era, electronics and digital industries have become more important than the smokestacks of traditional industry. Therefore, it is relevant to recall that our ubiquitous smart mobile phones and other electronic gadgets use rare earths in addition to lithium, cobalt, and aluminium. Over 60 minerals are used in high-speed integrated circuits and electronics for our digital infrastructure.

4. The Geopolitically Strategic Importance of Minerals

As minerals are now recognised as the foundation for future energy systems, securing the supply of minerals deemed critical has become a key feature of the national security calculus of the world's major powers. As already noted, the process of identifying critical minerals and their sources has been underway for over a decade. The World Bank report estimated that "over three billion tonnes of minerals and metals will be needed to deploy wind, solar and geothermal power, as well as energy storage for achieving a below 2 degrees C future" (World Bank Group, 2019). The IEA and OECD reports drew focus on the fact that for many key minerals (nickel, bismuth, cobalt, lithium, and rare earth elements were cited), most production is concentrated in just three countries—i.e., far greater than the geo-economic concentration of oil in OPEC+ countries.

During this period of policy change over the last decade, there has also been a transformation of international relations, marked by growing geopolitical competition between the US and China. In the process, the US and its allies in the industrialised world have rapidly become aware of, and increasingly concerned by, the fact of China's predominance in the mining and processing of key minerals, as well as in the manufacture of the mineral-based products which are essential for a wide range of new energy systems. And that their defence industries use vast amounts of minerals imported from China.

This predominance is a product of the era of globalisation, with China emerging as the lowest-cost producer, given its scale of production, which was built on minimal regulation, relatively cheap coal-based energy, massive infrastructure expenditure by local authorities, and foreign investment, which profited from China's low labour, infrastructure, and shipping costs. Globalisation made China a pivotal player in industrial and commercial supply chains on which the West, and indeed much of the world, has come to depend. However, as US-China relations have become not just competitive but adversarial, existing economic and technological frameworks have begun to splinter, leading to moves now underway to restructure global supply chains.

China's long march to predominance in new energy requirements started more than two decades ago. It began with China's starting on solar Photovoltaic (PV) technology imported from the West in the mid-1990s, going on to using its regulations, requiring the transfer of technology for permitting access to its burgeoning domestic market, to build world-beating production scales. In 2000, Chinese solar PV manufacturing was still only 1% of the world's total; by 2022, it was close to 80% of all stages of the production process—producing and refining polysilicon to ingots, wafers, modules, and solar PV panels (IEA, 2022).

The secret of China's success lay in its vertical integration—starting with the "dirty" business of mining and refining silicon for the industry, which was a messy business the environmentally conscious West was happy to outsource to China. A similar trajectory is evident for rare earths, used in a wide range of renewable energy systems. China mines 50% of the world's rare earth elements but refines and produces almost 90% of processed rare earth elements and industrial products, utilising extremely polluting and energy-intensive processes. For cobalt and lithium, used in EV batteries and other low-carbon products, the dependence on China for refined products is equally noteworthy; China imports cobalt and lithium from the major raw mineral producers—the Democratic Republic of Congo and Australia, respectively—but dominates world markets for processed metals from both.

China has used its market dominance for political goals, as seen when it cut off supplies to Japan in 2010 during tensions over disputed islands. According to the US Department of Defense (DoD), China also "strategically flooded the global market," selling rare earths at cheaper prices to drive out and deter current and future competitors (US DoD, 2018). In the face of such security challenges, building new national and regional supply chains has been part of the US strategy. In fact, with globalisation splintering, all countries face the challenge of ending reliance on cheaper but politically risky imported supply arrangements. In December 2017, President Trump revived the US strategic mineral stockpile (which had declined after the Cold War ended) through an Executive Order and defence authorities began supporting the development of rare earth processing facilities in the US (Federal Register, 2017). Japan had begun earlier, reaching out to India, Australia, and other countries to develop alternative supply chains for rare earths.

Under the Biden administration, the US brought the weight of the Western alliance, which it leads, to bear on measures to face up to China's potential weaponisation of mineral monopoly. Through the G7 and North Atlantic Treaty Organization (NATO)—and with Asian allies (Japan and South Korea)—the alliance members signalled to their industry the need for an effective response. In June 2022, 11 countries set up the MSP (which was dubbed a "metallic NATO" by one analyst (Home, 2022) to "catalyse investment in responsible critical mineral chains globally." The MSP, which focuses on minerals and metal supply chains most relevant for clean energy technologies, has been expanded to 14 members, including India (which joined in June 2023), and began outreach dialogues with mineral-rich countries in Africa, Latin America, and Asia.

5. India's Mineral Economy

5.1 A Great Historical Legacy

It is against this global background that it is appropriate to look at the experience of India, the place of minerals in the Indian economy, and risks and opportunities going forward.

India has a great historical legacy in mining and metallurgy. In the ancient period of our history, mining and metalworking were among the foundations of the advanced material civilisation which developed on our soil, and which sustained the efflorescence of our great and sophisticated cultures. Archaeologists have unearthed bronze and copper tools from Harappan sites (2500–1700 BCE). Historians assess that as far back as 800 BCE, metals known and used in India included iron, gold, silver, lead, and tin, in addition to copper. In the early years of the first millennium AD, zinc was first smelted in the Zawar region of Rajasthan, and by 300 AD, steel was forged in India. Kautilya's Arthashastra (2nd or 3rd century BCE) gives indications of the great importance attached to metals in the economy, with senior government functionaries appointed to hold charge of mines and metalworks. D. D. Kosambi, one of the first historians focusing on the material basis of our historical eras, noted that the Arthashastra suggests that the rulers' "treasury was based upon mining" (Kosambi, 1964).

Mining and metallurgy continued to be important in the medieval period, but after the advent of British colonial rule, these sectors gradually stagnated. Though the Geological Survey of India (GSI) was one of the first to be established in the world in 1851, India missed out on the Industrial Revolution, as it remained yoked to British controls over mining and manufacturing, and imports from Britain. Some efforts to revive mining (particularly coal) and steel production in the late 19th and early 20th centuries did not materially change the picture of the Indian economy. At independence in 1947, India had a small mining industry, with a value of production of only ₹58 crore; it relied on imports for most industrial inputs like copper, zinc, and lead (Indian Bureau of Mines, 2012).

5.2 Mineral Development in India's Post-Independence Period

In the post-independence era, there was considerable investment in mining to support industrial development in the first and second Five-Year Plans and the Industrial Policy Resolution of 1956. The Mines and Minerals (Development and Regulation) Act of 1957 (covering mines and mineral development under the control of the Central government—the States control the rest) was enacted. The GSI was strengthened for the exploration of minerals, and the Indian Bureau of Mines was set up. Mining of major minerals was reserved for the public sector, and the National Mineral Development Corporation was set up in 1958 to promote the exploration and production of industrially required minerals, such as iron ore, copper, limestone, dolomite, and graphite. Subsequently, Public Sector Undertakings (PSUs) for the production of minerals and refineries were set up, such as Bharat Aluminium Company Limited (BALCO) in 1965, Hindustan Zinc Limited (HZL) in 1966, and Hindustan Copper in 1967—apart from giant corporations for coal and steel production.

Special mention is necessary of the significance attached by Indian policymakers to rare earths like ilmenite and monazite (found in beach sands on India's southern coasts) for their potential use in atomic energy. Rare earth elements were put under the jurisdiction of the Atomic Energy Commission and a PSU, the Indian Rare Earths Limited, which was set up as early as 1950 for their extraction.

Despite regulatory bottlenecks and public sector resource constraints, considerable progress was made. Discoveries of bauxite put India on the world map for this resource, and reserves and production of iron ore, manganese, copper, lead, zinc, chromite, and limestone all increased substantially. By 1999, the value of mineral production had gone up to ₹45,000 crore (then equal to over US$10 billion), with mineral extraction spread over 21 States with more than 9,000 mining leases.

Nevertheless, set against the growing needs of the Indian economy and the much more rapid growth of mining in other countries, the achievements were seriously inadequate. India's mineral sector—largely reserved for the public sector—was bogged down by slow-moving bureaucratic procedures and over-regulation, which marked policies set in place in the 1970s. It was, therefore, in dire need of overhaul by 1993, when a new National Mineral Policy opened up the sector to private and foreign investment for non-fuel and non-atomic minerals (Indian Bureau of Mines, 2015). Foreign and Indian private companies demonstrated interest. However, this did not materially change the scenario of difficulties in getting adequate investment into mining, with failure to work out an appropriate exploration policy with incentives for exploration companies, regulatory and licensing bottlenecks afflicting the mining companies, and a lack of support infrastructure. Hence, there was continued reliance on imports of many key minerals, adding to chronic trade deficits. Efforts to bring in reforms have continued since then, right to the present, without really achieving the goal of "unlocking the potential of the Indian Mining sector," as a strategy paper for the MoM put it in 2011.

In 2005, a high-level committee was set up in the (erstwhile) Planning Commission, which, after consulting State Governments and relevant stakeholders, submitted a report which formed the basis of a new National Mineral Policy in 2008 (Planning Commission, Government of India, 2006). In 2011, the Ministry's report led to a long process of trying to repeal the 1957 regulation, which had been repeatedly amended, and enacting a Mines and Minerals (Development and Regulation) Bill. The overhaul of the laws saw fruition only in 2015 under a new government, which passed the Mines and Minerals (Development and Regulation) Amendment and followed up with a New Mineral Policy in 2016. This policy was again revised in 2019 and amended in 2022, with a vision for 2050.

During this prolonged saga of reform efforts, many official reports did draw attention to the significant role of mining for the economy, but without much change in actual policy implementation or in public opinion about the need to review dependence on foreign supplies.

5.3 India's Current Mineral Scenario

Despite all the efforts of successive governments, mining in India remains a story of potential locked underground. Apart from regulatory and bureaucratic impediments at both the Central and State levels, the mining sector got mired in accusations of corruption and lack of transparency, leading to judicial intervention. The 2012 judicial ruling, interpreted to mean that public resources could only be allocated for commercial use through auctions, introduced complications and distortions deterring investment (Mahapatra, 2012). In addition, the growing environmental movement and concerns over the alienation of tribal habitats and deforestation for industrial activity have led to public hostility against mining and a challenge to companies' social license to operate.

The results of this track record of inadequacies are evident from even a cursory glance at the details. Mining generates only about 2% of GDP, as against 7.5–12% in other mining jurisdictions like Australia and South Africa, with whom we share geological characteristics. The US Geological Survey's (USGS) World Mineral Handbook estimated that in 2018, mining contributed 2.7% of China's GDP (USGS, 2023); however, during the earlier phases of its rapid industrialisation, the contribution was larger; in 2006, mining's contribution was 4.8% of GDP (Ali, 2011). In the 2011 strategy paper for India's MoM (Planning Commission of India, 2011), it was estimated that mining could add US$250 billion, equal to 7% of the GDP by 2025, generating employment for 13–15 million people. Much of this employment would be generated in relatively underdeveloped parts of the country and could mitigate regional imbalances.

Presently, only 30% of India's obvious geological potential has been properly explored (Rajya Sabha, 2023). Exploration companies are unwilling to risk capital without being able to exploit discoveries commercially, as is the practice in most successful mining jurisdictions. India's policy of only auctioning mining leases has been reformed, but it does not adequately attract explorers (Chadha, Sivamani, & Bansal, 2023b). High taxes—including royalties and other taxes to governments—act as disincentives. Permitting delays, land acquisition problems, and duplication of environmental clearances (along with anti-mining activism by well-organised groups) have all added to the reluctance of mining giants to work in India.

Meanwhile, imports have soared, which generates profits and employment for these companies abroad. Imports of minerals and metals (including gold and precious stones) cost India US$157 billion in 2022—nearly 25% of imports by value, adding to our worrisome trade deficit (Duggal, 2022). For four minerals critical for renewable energy—copper, nickel, lithium, and cobalt—India is 93–100% dependent on imports costing US$4 billion, according to data provided in Parliament (Lok Sabha, 2023).

This high import dependency on various minerals can also be seen as a strategic opportunity for India. Just as oil refining has enabled India to become a major exporter of refined products, including gasoline and diesel—despite having to import over 85% of its crude oil requirements—smelting and refining of critical minerals (with appropriate environmental safeguards) at competitive costs will provide India with the opportunity to become a key player in global supply chains. Further, mining's contribution to GDP can be at least doubled from the 2% presently and become a source of large-scale employment.

Increased mineral production would also support a wide range of national policies, while failure to step up self-reliance on key minerals could have national security and economic repercussions. As our defence manufacturing is expanding rapidly with self-reliance as the goal, so will our requirements of sophisticated steel alloys with special materials, copper, bismuth, titanium, and aluminium. Missiles use rare earths like samarium, and lasers need neodymium. Both gallium and germanium are used in advanced defence technologies.

Producing more gold, which can be added to official reserves, can be a source of strength for our currency at a time of global financial uncertainties.[1] In addition to the geological prospects for gold in Karnataka, Rajasthan, Jharkhand, and Andhra Pradesh, the tailings from the old Kolar Gold Fields in Karnataka are estimated to have substantial amounts of extractable

[1] Note that the Reserve Bank of India (RBI) is buying gold in international markets just like many other central banks.

gold. India is a world leader in the diamond cutting and polishing industry. Still, it depends on imports for the rough diamonds used by the industry and is now under pressure to curb imports from Russia. In this context it is unfortunate that a potentially significant kimberlite source of diamonds at Bunder in Madhya Pradesh, identified by Rio Tinto, could not be brought into production despite a decade of effort (Bloomberg, 2017).

Many of these mineral requirements and shortfalls have been studied and published in official reports in the past. In 2011, the Planning Commission Group on Mineral Exploration and Development reported that the "metals and minerals sector, including primary metals, downstream products, special alloys and specific application materials have a direct bearing on the growth, development, depth and sustainability of the infrastructure and manufacturing sectors—as indeed almost all other sectors of the economy" (Planning Commission of India, 2011). In July 2012, the Centre for Techno-Economic Mineral Policy Options (CTEMPO) drew up a study on "Rare Earths and Energy Critical Elements Roadmap and Strategy for India" (C-TEMPO & Centre for Study of Science, Technology and Policy (CSTEP), 2012). The Council on Energy, Environment, and Water (CEEW) in 2014 lamented that non-fuel minerals had not received as much attention as oil and gas; however, they directly contribute to 2% of India's GDP and are the backbone that supports 15% of GDP through the manufacturing sector (Gupta & Ganesan, 2014). In an updated report in 2016, the CEEW, in a vision for 2030, identified rare earths as being essential for all green technologies, which were of increasing national relevance given India's commitments made in 2015 when it signed up to the Paris Accords (Gupta, Biswas, & Ganesan, 2016). It also reported that India's manufacturing sector was unable to keep pace with the growing demand for consumer goods and technologically enabled products. In this context, a steady supply of raw materials was deemed essential.

5.4 India's Commitment to NZE by 2070

At the COP 26, India joined the NZE bandwagon with a target date of 2070 (Ministry of Environment, Forest, and Climate Change, 2022). This was not very distant when it was announced—just 48 years, which is within the lifespan of most of the present population. The more immediate targets Prime Minister Modi announced at Glasgow—as pathways to 2070—are of greater relevance: these targets are for 2030. The vision is for renewable energy generation to be stepped up to 500 GW (from 170 GW in 2022). In the transport sector, the target for EVs is to go to fleet strengths of 30% for cars, 40% for buses, and 70% for two-wheelers, which is extremely ambitious as the actual EV penetration of the overall transport fleet in India in 2022–2023 stood at 2%. In tandem, India's private sector giants have announced world-scale plans for producing hydrogen, the best known being the Reliance group's ambition of spending US$75 billion on the entire value chain for green hydrogen, bringing the cost down to US$1 per kg, or more than 60% lower than current costs.

All this will mean a massive increase in mineral requirements for India, which aspires to be *Atmanirbhar* (self-reliant). Therefore, in 2023, access to minerals, their availability, and affordability finally became subjects of widespread national attention.

5.5 Identification of Critical Minerals

In June 2023, the MoM released a report identifying 30 critical minerals after detailed inter-ministerial consultations, which drew on the needs of various stakeholders (MoM, 2023). This report drew upon the quantitative study by the Centre for Social and Economic Progress (CSEP) to define the criticality of a mineral (Chadha, Sivamani, & Bansal, 2023a). The MoM report has explained why they are deemed "critical":

A) In terms of their economic importance and high supply risk, MoM indicated that more work is required to assess substitutability with alternate minerals, future import reliance, potential for disruption in supplies, and recycling possibilities.

B) In terms of their uses for energy transition, high-tech industry, and for food security, i.e., as inputs for agriculture and fertilisers. India's list is probably unique in including food security. It means that in addition to the usual suspects found in most national lists, like lithium, silicon, cobalt, the 14 rare earth elements, etc., potash and phosphorous have been included.

In addition, India also needs to take a long-term view of minerals required for some of its key industries (like chemicals and pharmaceuticals) if their feedstock base has to shift out of dependence on petroleum when the transition away from oil and gas moves ahead. A separate study on the mineral requirements of defence industries is also necessary.

6. A Policy Framework for Securing Critical Minerals

India requires a comprehensive and coherent policy framework to secure critical minerals that addresses some structural issues in the sector. To address the multifaceted challenges, policy recommendations are provided under three pillars: strengthening the domestic sector, accessing minerals from abroad, and strengthening our international partnerships.

These three pillars can be viewed as components of a strategic framework that policymakers should consider for any given critical mineral to determine whether to prioritise the development of domestic resources or to secure the mineral from external sources. This choice will dictate which set of policy levers is most appropriate for the given mineral, based on an assessment of India's geological potential, the technical feasibility of extraction, the economic viability of domestic production, as well as the time it would take to develop the asset to the mining stage.

This decision creates two distinct, yet interconnected, pathways of policies. The first pathway focuses on domestic resources as the preferred route for minerals, where India possesses known or potential reserves. This path requires increasing incentives for exploration, streamlining the regulatory environment, and creating a social license from communities to operate mines. For minerals where India lacks the geological potential, an alternative pathway, looking outside the country, is needed. This second path involves a further set of choices ranging from diplomatic engagement through partnerships like the MSP, to more direct commercial strategies such as promoting India's companies to acquire strategic assets abroad, or securing long-term supply through offtake agreements. The policy recommendations in this section are organised along these strategy options.

6.1 Domestic Mineral Potential

The MoM report itself includes the useful comments of NITI Aayog (which replaced the Planning Commission in 2015), which point policymakers in the right direction, when it said that for 10 of the identified minerals, India could produce or scale up to meet domestic requirements within the country. The report says that "technical and administrative issues" hampering production need to be taken up with the companies concerned. As already stated, the issues are not administrative or technical, but the laws, regulations, and tax policies which constrain production, all of which lie in the domain of the Central and State governments.

The MoM report includes the Ministry's response to NITI Aayog's comment, and this echoed this author's analysis, by saying that scaling up production is being taken up through "policy measures" allowing private sector participation in exploration, incentives for exploration of deep-seated and critical minerals, etc.

These steps by themselves are not adequate. Explorers have to be incentivised, as they are abroad—otherwise, best-in-class explorers will not invest their time, technology, and analytical expertise in India. For instance, Canada's "flow-through shares" mechanism allows exploration companies, primarily junior explorers, to pass on tax deductions for exploration expenses directly to investors. Similarly, Australia has a Junior Minerals Exploration Incentive, allowing exploration companies to give up a portion of their losses in exploration projects for refundable tax offsets. E&P should be allowed so that a company successful in exploration can be licensed seamlessly to take up production itself or can sell the asset to other investors. Contiguous mining beyond the lease boundaries should be efficiently licensed to make deep underground assets efficiently extractable. Mechanisms are needed to bring Central or State governments—together with the industry—on a common platform to speed up clearances for critical mineral exploration, followed seamlessly by the production and processing of the minerals. Where appropriate for India's participation in international supply chains, the export of minerals or processed metals should be licensed without regulatory bottlenecks.

Many critical minerals used in high-technology products, misleadingly called "minor minerals," are usually extracted during the refining/smelting or processing of bulk minerals. These include metals used in renewable energy applications, such as cadmium, selenium, tellurium, germanium, and indium. Production of such "minor minerals" from waste streams or as separate by-products needs to be encouraged through specific tax incentives. Many of these minor minerals, vital for renewable energy, are not viable for standalone mining even when they can be geologically located. Three years ago, this author identified gallium and germanium—which are now becoming an international problem—as key minerals requiring incentives for the companies refining bauxite and zinc, respectively, to be economically extracted from further processing of waste tailings (Mathai, 2020). However, India's royalty and tax regimes still make life even harder for mineral industries wanting to extract wealth from waste.

As future mining resources will be increasingly for deep-seated minerals, there is an opportunity to decrease the adverse impact of strip and open-pit mining above the ground. It is also an opportunity to introduce in all mining areas, the best-in-class mining practices with emphasis on safety, high skills training, and automation where necessary. Such changes have the collateral benefit of distinguishing mining from the destructive sand-bed "mining" and stone quarrying, which has given mining itself a pejorative connotation.

As new mining projects emerge, it will also be essential to secure the social licence to operate from local communities, making them direct beneficiaries of activities. To this end, the Central government introduced the DMF scheme in 2015 to benefit mining-affected communities. The large amounts paid into these funds by mining companies (in August 2021, the Minister of Mines told Parliament that ₹50,000 crore had been collected since 2015, of which half was unspent [Koshy, 2025]) must be used effectively, in tandem with the Corporate Social Responsibility (CSR) initiatives of mining companies, to make local communities stakeholders. Modernisation and focus on sustainability can help maintain the social license for mining. The growing consensus on the unavoidable need for increased mineral use for energy transition provides an opportune occasion to alter the popular discourse regarding the mineral economy of India.

Additionally, as India's defence industry is now growing, the time has come for policymakers to plan a critical mineral stockpile on the lines of the Strategic Petroleum Reserve to ensure raw material supplies. Some work has been undertaken in respect of rare earths, but the plan needs to be broadened and, if required, be based on a partnership with private industries.

India needs to accelerate geological mapping, focusing on minerals like lithium, cobalt, nickel, and rare earth elements. Regulatory procedures need to be streamlined with single-window fast-track clearance processes put in place, minimising bureaucratic delays. There is an urgent need to reform the auctions and allocation procedures. Further, an impetus must be provided to develop domestic processing capabilities through establishing mineral processing parks and promoting recycling.

6.2 External Supplies of Minerals

Despite India's excellent geological potential, there are many identified minerals for which we will continue to rely on imports. We need to build external supply chain partnerships.

A public sector enterprise, KABIL, was set up in 2019, but it is not adequate for the task of building robust global partnerships (MoM, 2019). The model of ONGC Videsh Limited, which acquires stakes in oil and gas assets abroad or operates such holdings, could be adapted to make this organisation an effective player in world mining. The focus on external supplies is essential because we live in a world of competition for resources, many of which are scarce or geologically proven in only a few countries.

Critical minerals are even more concentrated than oil, and a mineral cartel will make OPEC look weak in its ability to control prices and volumes brought to the global marketplace. Understanding this requires looking at mineral supply chains at three levels: geology and mineral extraction, beneficiation and refining, and the processing and manufacture of end-use products like permanent magnets. As has been cited in the IEA/OECD reports and many other well-regarded research analyses, at some point in these three processes—the production of lithium, cobalt, Rare Earth Elements (REEs), nickel, and bismuth—to name just the best-known minerals—just three countries dominate production. China looms large in a variety of cases, like cobalt, lithium, and REEs. In 2022, the US DoE estimated that a Chinese ban on rare earth exports lasting a year would cause production outside China of magnets—used in energy, defence, medical, and electronic industries—to fall by 40%. For India, which faces unrelenting hostility from its northern neighbour, exchanging dependence on OPEC for oil with China for critical minerals is a recipe for disaster.

6.3 Global Mineral Cooperation

During Prime Minister Modi's visit to the US in June 2023, it was announced that India would become the 14^{th} member of the MSP. This author was one of the first to draw attention to the MSP when it was set up, and our membership is a step forward, but not only because it can enable us to become part of supply chains for mineral security (Mathai, 2022). The MSP declares that the group will help countries get the full economic benefits of their geological endowments. India can benefit from the experience of advanced mining jurisdictions on the policies and regulations designed to ensure the best use of our geological potential for responsible, sustainable mining, processing, and refining of minerals. For example, we should also participate in the research on alternatives to scarce and high-cost minerals necessary for the energy transition, like the platinum group of metals. Whether palladium or iridium, these are expensive and are not economically viable for a mass-scale increase in catalyst production required for electrolysers. As mentioned earlier, the 2022 OECD report mentioned that production would have to be scaled up 150 times by 2050 to meet the requirements of NZE. Whether so much of the platinum group minerals can be found and economically extracted from the earth's crust remains open to question. Scientific research on alternatives to these minerals for electrolysers has advanced. India should be part of this collaborative research.

Such collaboration is being pursued and can be taken forward with individual countries which have advanced mining industries, such as Australia and the US. Russia, too, should be among our future partners. In addition, we can build partnerships with countries in Africa, Asia, and Latin America, not just for sourcing minerals but sharing expertise and investments in value addition through beneficiation, refining, processing, and industries such as battery manufacture.

7. Conclusion: The Criticality of Mining in India

While keeping alert to possibilities in the world outside, it is crucial to keep in mind the need for India to develop its resources. The time has come for a new perspective on mining in India. In the world outside, both climate deniers and climate alarmists exaggerate their case on the impact—whether environmental, social, or economic—of the massive increase in mining, which will be required to achieve NZE, based on current technology. After all, the three billion tonnes of minerals and metals required to be deployed globally in the next few decades, according to the World Bank's 2019 estimate, will have major environmental and economic implications for the world. That debate will go on, but we need to recognise that the capacity for mining and metallurgy will become part of the calculus of national power and strategic capabilities, as well as managing essential energy needs in the future, just as oil production and refining are now.

As India's economy grows, we must use the opportunity to rely on and make the best use of our resources. Policymakers have to ask why India, which inherited a great legacy of mining and metallurgy, has fallen behind other countries. The value that can be generated by catching up with advanced mining jurisdictions should be broadly appreciated within government structures, including at the state level.

Sourcing more gold, silver, diamonds, and other minerals within the country can save us over US$100 billion in imports every year, easing the balance of payments. Enhanced mining and metallurgy will give impetus to the faster growth of the manufacturing sector of the economy. There is considerable scope for foreign direct investment, as well as domestic investment in India's mining sector, given the obvious but untapped geological potential. Further, mining's contribution to GDP can be at least doubled from the 2% presently and become a source of large-scale employment.

At the social level, mining needs a paradigm shift in popular perception to a more balanced understanding of its essentiality. Mining companies have thus far come to be regarded with hostility as despoilers of tribal habitats and forest cover, sources of pollution and environmental damage, and entities engaged in the capture of resources through dubious means. Responsibility lies both with industry and opinion makers, and governments, but primarily with industry. Mining operations should proceed after the end of the mine plan to restore the environment in the areas exploited after the economic life of the mine. Management and treatment of mining waste to minimise hazards has to commence simultaneously with mining operations. Local communities have to be stakeholders in sustainable mining. India's economic growth can then be enhanced from the ground up.

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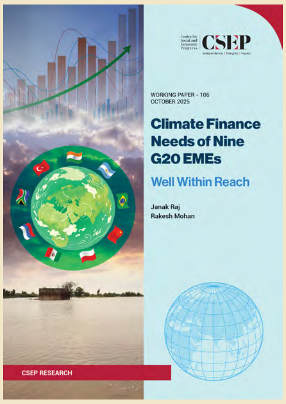
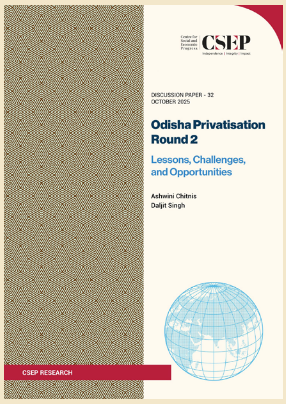
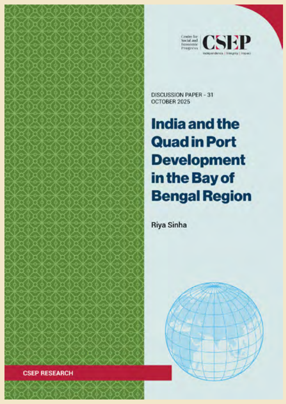
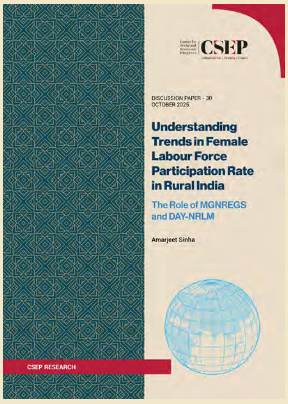
Mathai has been speaking about and writing on the importance of mining to India's national security and economy for the past several years. He has particularly highlighted the need to ensure resilient supply chains of critical minerals and metals, which are the essential raw material inputs required for India's manufacturing ambitions and climate change mitigation goals.

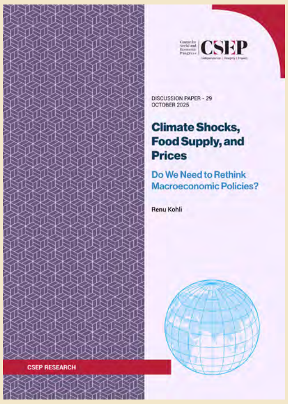
Other publications

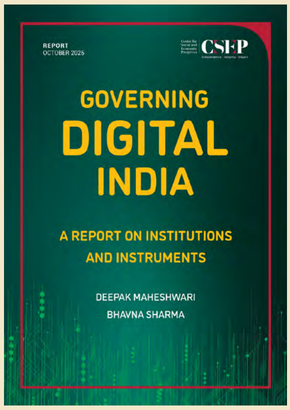


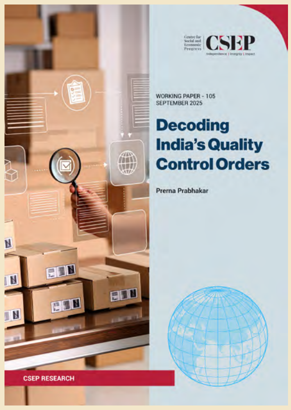


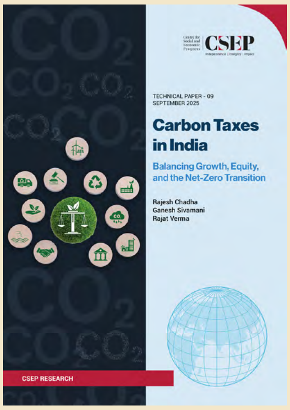


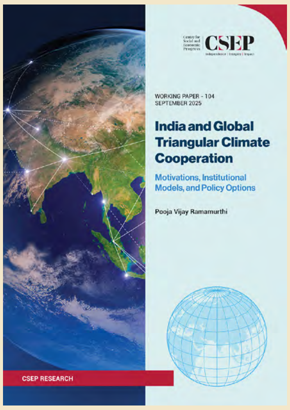


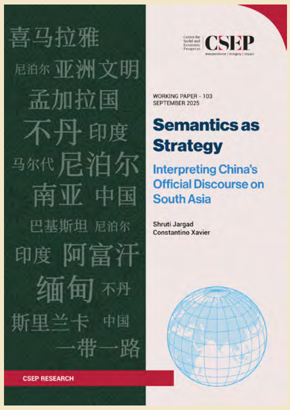


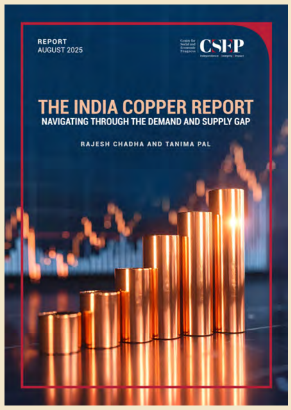


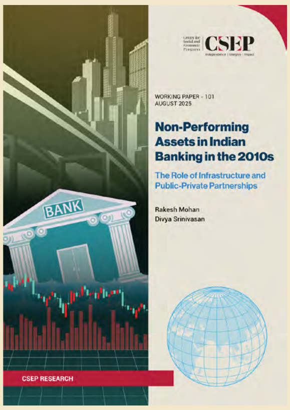


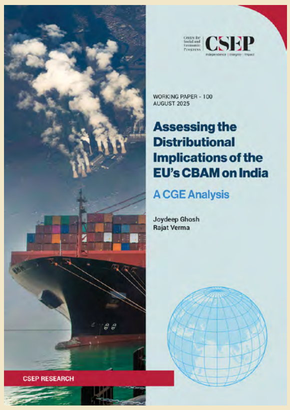


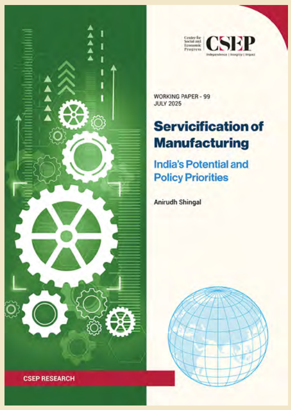












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