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Options for diversifying India’s critical mineral supply chains

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Policy report

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Summary

India's transition to a low-carbon economy and its ambition to achieve net zero by 2070 will significantly increase demand for critical minerals such as cobalt, copper, lithium, nickel and rare earth elements. These minerals are essential for electric vehicles (EVs), solar photovoltaics (PV), wind turbines and other low-carbon technologies. However, India is heavily dependent on imports of these minerals and faces vulnerabilities due to the geographical concentration of its supply chains, long mine development lead times (averaging 18 years) and limited domestic processing capacity.

This report identifies some of the policy challenges that India faces in securing critical mineral supplies from both domestic and international sources. It provides projections of future critical mineral demand for the deployment of specific low-carbon technologies and by combining information on the profitability of mining projects and country-level risk assessments, reveals investment and partnership opportunities. In response to this analysis, we make recommendations for how India can overcome its policy and supply bottlenecks and meet its future demand for critical minerals by diversifying its critical mineral supply chains.

India's National Critical Mineral Mission (NCMM) faces structural policy challenges linked to the configuration of the current permit and auction-based licensing systems. The auction framework introduced in 2015 has failed to create proper incentives for long-term investment in exploration and mining activities. Risk is not adequately rewarded in either of these two phases. *Composite licences* which provide both exploration and mining rights are limited to brownfield sites, requiring high upfront capital, while *exploration licences* do not grant mining rights, creating a disconnect between exploration risk and reward.

The misalignment of risks and rewards discourages private investment and has led to low participation or irrational bidding in auctions, with some mining blocks later abandoned due to their poor financial viability. These shortcomings, combined with limited domestic processing capacity, underscore the need for reforms that align incentives, reduce permit bottlenecks and support risk-sharing mechanisms to attract sustained investment in India's critical minerals sector.

The structure of India's critical mineral imports reveals stark contrasts in diversification across commodities. Copper and lithium carbonate imports are sufficiently well-diversified across a large number of country partners. By contrast, graphite, nickel and cobalt imports are highly concentrated, exposing India to supply chain risks. In addition, the latter two minerals are imported at low volumes which, in turn, mirrors the lack of domestic processing capacity. This combination of low import levels and high supply concentration underscores the urgency of diversification for these minerals, particularly as India scales up low-carbon technologies.

India's demand for critical minerals is projected to rise by several orders of magnitude as the country pursues its 2070 net zero target. This surge in demand will primarily be driven by the deployment of EVs, which are highly mineral-intensive due to battery technologies that require cobalt, lithium, nickel and copper, as well as rare earth elements for electric motors. While other low-carbon technologies such as solar PV and wind turbines will also contribute to growing demand — solar increasing copper requirements and wind boosting rare earth consumption — EV adoption remains the dominant driver of India's future mineral needs. Estimates under different International Energy Agency (IEA) scenarios confirm that India's energy transition will significantly increase mineral intensity, underscoring the urgency of securing reliable supply chains to support this transformation.

By assessing country risk scores, project profitability and existing trade relationships, the analysis identifies Australia, Canada and Finland as the most attractive partners for diversifying India's critical mineral supply chains. These countries combine low geopolitical risk, competitive cost structures and multi-metal mining portfolios, making them ideal for long-term strategic engagement. Among developing economies, Brazil, the Philippines and Chile emerge as complementary options due to the presence of significant project pipelines for cobalt, nickel and copper in these countries, despite higher risk profiles that require robust mitigation tools and strategies. Diversifying its imports between a mix of stable and emerging market jurisdictions would provide India with a balanced roadmap to strengthen supply chain resilience while supporting its industrial and energy transition goals.

Recommendations

To support the diversification of India's critical mineral supply chains, the Indian Government should adopt policies that:

1. Diversify and invest in foreign and domestic critical minerals capacity urgently, particularly as the mineral intensity of the Indian economy is expected to grow significantly in the coming years as it transitions towards a low-carbon economy.

2. Grant companies that are willing to invest in geological surveys the associated mining rights, or provide better compensation schemes when those rights are auctioned to other companies.

3. Facilitate long-term agreements between local producers of low-carbon technologies and foreign parties with abundant mineral supplies, thereby increasing certainty on input prices and ensuring constant access to materials that are hard to substitute for.

4. Make diplomatic and commercial efforts to strengthen trade relationships between India and Australia, Canada, Finland, Brazil, the Philippines and Chile, to enable the diversification of India's critical mineral supply chains.

1. Introduction

As a major fossil fuel importer with abundant renewable energy resources, it is in India's interest to transition towards a low-carbon economy. At the 26th meeting of the Conference of the Parties to the UNFCCC (COP26) in November 2021, India's Prime Minister Narendra Modi committed to achieving net zero carbon emissions by 2070. Alongside its decarbonisation goals, the Indian Government also aims to attain developed nation status by 2047, which will massively increase the country's energy demand. To meet these goals simultaneously, India will need to adopt low-carbon capital at a significant scale to replace its current fossil fuel-intensive infrastructure. However, the adoption of low-carbon technologies requires substantially greater inputs of critical minerals, for which India is currently heavily import-dependent.

This report maps out India's main import partners for cobalt, copper, graphite, lithium and nickel and projects future demand for these minerals and rare earth elements under different International Energy Agency scenarios and for different low-carbon technologies before evaluating potential diversification options for India's critical mineral supply chains. It concludes with policy recommendations to enable India to strengthen its supply chain resilience.

Context

In recognition of its decarbonisation and developed nation status goals, the Indian Government set interim nationally determined contribution (NDC) targets in 2022, such as having 50% of its installed power capacity from non-fossil fuel-based sources by 2030. While the country's overall energy mix remains heavily dependent on fossil fuels — coal accounted for nearly 60% of the country's energy supply in 2023–24 (NITI Aayog, 2025) — it has made some headway in building power capacity in non-renewable energy sources. As of June 2025, 49% of the country's total capacity was in the form of non-fossil fuel sources (Press Information Bureau, 2025a).

Low-carbon technologies such as EVs, solar PV and wind turbines will play an instrumental role in balancing rising energy demand with the net zero transition. Alongside renewable energy technologies such as solar PV, EVs are expected to play a central role in India's decarbonisation pathway. The transportation sector alone is responsible for 14% of India's total direct (Scope 1) emissions, particularly from land transport, which comprises 90% of the emissions within the sector (Kumar et al., 2022). To that end, the government has outlined ambitious EV targets for 2030: 30% of total sales of private cars, 70% of commercial vehicles, 40% of buses and 80% of two- and three-wheelers (Press Information Bureau, 2023).

However, the adoption of low-carbon technologies requires substantially higher inputs of critical minerals such as lithium, copper, cobalt, graphite, nickel and rare earth elements. For example, EVs require six times more minerals than their conventional counterparts (IEA, 2021), demonstrating the scale of India's needs. Despite having reserves, India currently lacks domestic production capacity for many of these minerals, and is instead heavily import-dependent. Several factors constrain India's ability to scale up domestic production, including uncertainties in mineral reserve data, technological gaps in extraction and processing capacities, and cost competitiveness (Konda and Rakheja, 2024).

According to the Ministry of Mines (2023a; 2025a), India is reliant on imports for 10 critical minerals, representing a major potential vulnerability for the success of the country's low-carbon transition. Existing studies have highlighted India's growing exposure to geopolitical risks due to the high geographical concentration of upstream sectors in a small number of countries. This, in turn, gives a substantial amount of economic leverage to mineral producing countries (Chadha et al., 2025). Resulting supply chain risks have already started to materialise — for example, China recently imposed global export restrictions on rare earth elements in response to US tariffs. As a result, Indian automakers reportedly experienced supply disruptions and struggled to import essential components for EVs, such as permanent magnets, leading one company to cut back production (*The Times of India*, 2025).

The Indian Government is aware of these risks and has introduced a series of domestic reforms to bolster its critical minerals sector. In 2025, the Government launched the National Critical Mineral Mission (NCMM) to oversee the entire value chain, from exploration to end-of-life recycling (Press Information Bureau, 2025b). Amendments have also been made to the Mines and Minerals (Development and Regulation) Act to incentivise private sector participation by cutting red tape, streamlining the auction-based licensing process and granting new exploration licences.

India's critical minerals strategy also encompasses international trade. It has begun forging bilateral partnerships, including with Australia through the 2022 Critical Minerals Investment Partnership, and through Khanij Bidesh India Ltd (KABIL), a joint venture under the Ministry of Mines, which signed a US$24 million deal for a lithium exploration pact with Argentina in 2024. India has also joined multilateral efforts, such as the US-led Minerals Security Partnership (MSP) which aims to create a more secure and resilient global supply chain for critical minerals (Jayaram and Ramu, 2024).

However, given the long average lead time of 18 years that a mining project requires from discovery to extraction (Manalo, 2025), some of these initiatives may take decades to reap the benefits. In the meantime, India should explore strategies to further diversify and strengthen its critical mineral supply chains to securely transition away from carbon-intensive energy sources.

Aims and structure of the report

This report provides new insights regarding India's current and future critical mineral dependencies, as well as some potential solutions to the country's heavy import reliance on specific partner countries so that it can guarantee it has access to the raw materials necessary for producing low-carbon technologies. Although the NCMM lists around 30 minerals as being critical for India, due to a lack of available data, special attention is given here to the minerals necessary for the deployment of EVs, solar PV and wind turbines.

The report is structured as follows:

- **Section 2** provides context on the domestic regulatory landscape of Indian critical minerals mining and discusses why it has impeded the industry's growth.
- **Section 3** presents India's main import partners for cobalt, copper, graphite, lithium and nickel between 2017 and 2023.
- **Section 4** projects future critical minerals demand under different International Energy Agency scenarios and for the above-mentioned technologies. Rare earth elements are also considered in this part of the analysis.
- **Section 5** evaluates potential foreign partnership options for diversifying India's critical minerals sourcing strategy for cobalt, copper, lithium and nickel through the lens of project profitability, country-level risk scores and existing trade relationships.
- **Section 6** provides conclusions and policy recommendations.

2. Policy challenges

India faces several domestic policy challenges in securing critical mineral supplies. This section introduces the National Critical Mineral Mission (NCMM) and examines why it may struggle to achieve its objective of developing the upstream segment of India's critical minerals industry, something that could hinder progress towards building a resilient and competitive supply chain. Specifically, the section highlights structural issues in the mining licensing framework, why fostering foreign partnerships is important, and the gaps in public financing of recycling infrastructure.

The primary focus of the NCMM, launched by the Government in 2025, is to secure India's critical mineral supply chains and strengthen its domestic value chains, partly because India is currently fully reliant on imports of all critical minerals except for copper (Chadha et al., 2023). The NCMM details an extensive critical minerals strategy for India, with several targets to be achieved by 2031. The budget outlay for the Mission is INR 16,300 crore (~US$1.9 billion) with an additional expected investment of INR 18,000 crore (~US$2.1 billion) from private and public companies (Press Information Bureau, 2025b). A significant 77% of the budget is dedicated to mineral exploration and securing mineral assets within India and abroad. The NCMM aims to support 1,200 exploration projects and the acquisition of 50 foreign mines. Mineral recycling is also an important component of the Mission, with incentives of INR 1,500 crore (~US$170 million) expected to achieve the recycling of 400 kilotonnes (kt) of critical minerals by 2031. Mineral processing has received a more limited budgetary allocation of INR 500 core (~US$57 million) to set up four critical mineral processing parks across India (Ministry of Mines, 2025a).

However, achieving the objectives of the NCMM will require significant changes to domestic policies that currently impede the growth of India's domestic mineral sector. Some shortcomings of the existing policies are presented below:

- **Investments in mineral exploration in India decreased significantly following the introduction of the auction system for mines in 2015.** Although the Government changed the previous 'first come first serve'[1] system for granting mining licences, it did not properly design the new policies it introduced, which were intended to incentivise exploration. The *composite licence* scheme, which was also introduced in 2015, provides both exploration and mining rights, but licences are only granted for brownfield mineral blocks. These types of deposits have already been developed and necessitate high capital expenditures to become profitable, rendering them less attractive to investors (Bansal and Chadha, 2025). Moreover, the *exploration licences* system, which was introduced in 2023, did not grant exploitation rights, which are auctioned off by the Government as part of a separate process. While the exploration licence holder is entitled to a share of the auction premium paid for exploitation rights in the future (Ministry of Mines, 2023b), a disconnect between exploration risk and mining reward remains, which discourages private investment.
- **Auctions have suffered from limited interest or irrationally high bids.** Five tranches of critical mineral auctions covering a total of 55 blocks have been launched, but only 34 blocks have been successfully granted (Press Information Bureau, 2025c). Of the successful auctions, winning bidders often placed irrationally high offers, such as for a graphite block which was auctioned off at a 752% premium above the reserve price (Bansal and Chadha, 2025; Hazarika, 2024). This type of speculation has led to instances of leaseholders returning their auctioned mining blocks due to their poor financial viability.

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[1] Where mining rights or licences are provided to the first party that applies for them.

- **Low domestic mineral production has negatively impacted other midstream and downstream sectors.** The mineral processing sector is highly dependent on domestic mineral resources or cheap imports. Indian processing capacity for minerals like lithium, nickel, cobalt, silicon and magnet rare earth elements is very limited. Even copper, a base mineral that has been mined and processed in India for thousands of years, faces challenges due to the lack of competition and the small scale of operations. As a result, a significant share of India's domestic copper demand is still met through imports (Ministry of Mines, 2025b). Given the expected rise in demand for many of these minerals by 2030, a lack of domestic processing capacity could become a critical risk for other downstream sectors.

The procurement of foreign mining projects has been touted as a potential solution to the lack of domestic production, but it should ideally be done in partnership with host countries. KABIL, for example, has successfully signed exploration and development contracts and memorandums of understanding (MoUs) with different mineral-rich countries. Consequently, it has obtained exploration and development rights for lithium blocks in Argentina, initiated joint projects with the Australian Government for investing in lithium and cobalt mining projects, and has also taken up exploration efforts for lithium brine deposits in Chile. Going forward, the Indian Government could consider developing a state-backed investment vehicle that facilitates holding equity in foreign mining projects. This would help to derisk projects, leverage private investment and positively shape project outcomes (Moerenhout et al., 2025).

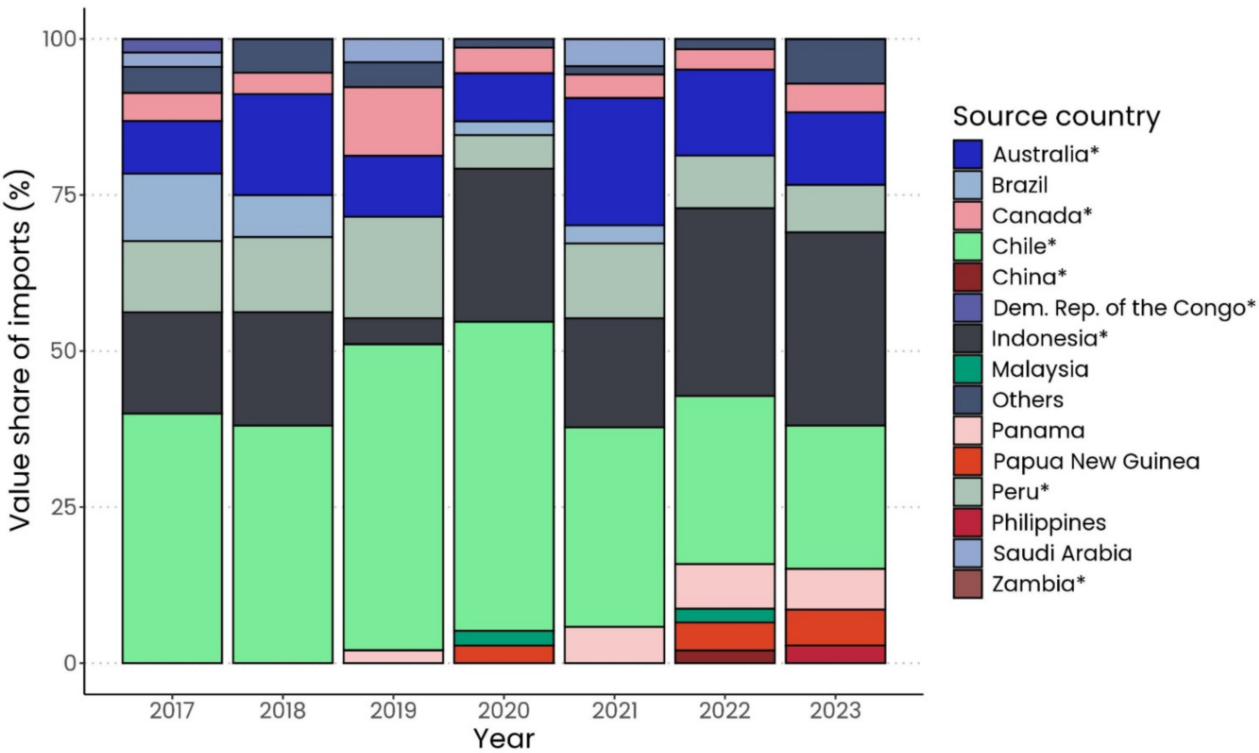
Reassuringly, mineral recovery and processing from recycling end-of-life technologies have attracted large investments in India. Domestic companies are recovering and processing minerals like cobalt, nickel and lithium from end-of-life batteries. These recycling companies are also looking to further invest in the upstream and midstream stages of the value chain since vertical integration can improve profitability (Moerenhout et al., 2025). However, even if the acquisition of mining assets and investments in manufacturing can help to integrate the supply chain, further supportive policies and financial backing from the Indian Government are still necessary. This is because the economic viability of recycling remains unclear due to the price volatility of primary metals and the high recovery costs involved (IEA, 2024a).

3. India's critical minerals import partners

Despite the NCMM and the earmarked financial resources for developing India's critical minerals value chain, complex policy challenges remain which will require years, if not decades, to resolve. In the short- to medium-term, critical mineral availability for midstream and downstream industries will continue to rely heavily on imports (Chadha et al., 2023). A thorough mapping of India's main import partners, as covered in this section, is therefore helpful to identify vulnerabilities and opportunities.

Previous work by Konda and Rakheja (2024) mapped India's imports of cobalt, graphite, copper and nickel products, most of which are already processed and ready for end-use applications. The following analysis is complementary to theirs because it focuses on the raw versions of the minerals, namely ores and concentrates,[2] and it extends coverage from the year 2017 through to 2023 (see Figure 3.1). Ultimately, the development of green supply chains will depend on reliably sourcing these raw materials so that they can be refined and then transformed into low-carbon technologies.

Figure 3.1. India's import partners for copper ores and concentrates



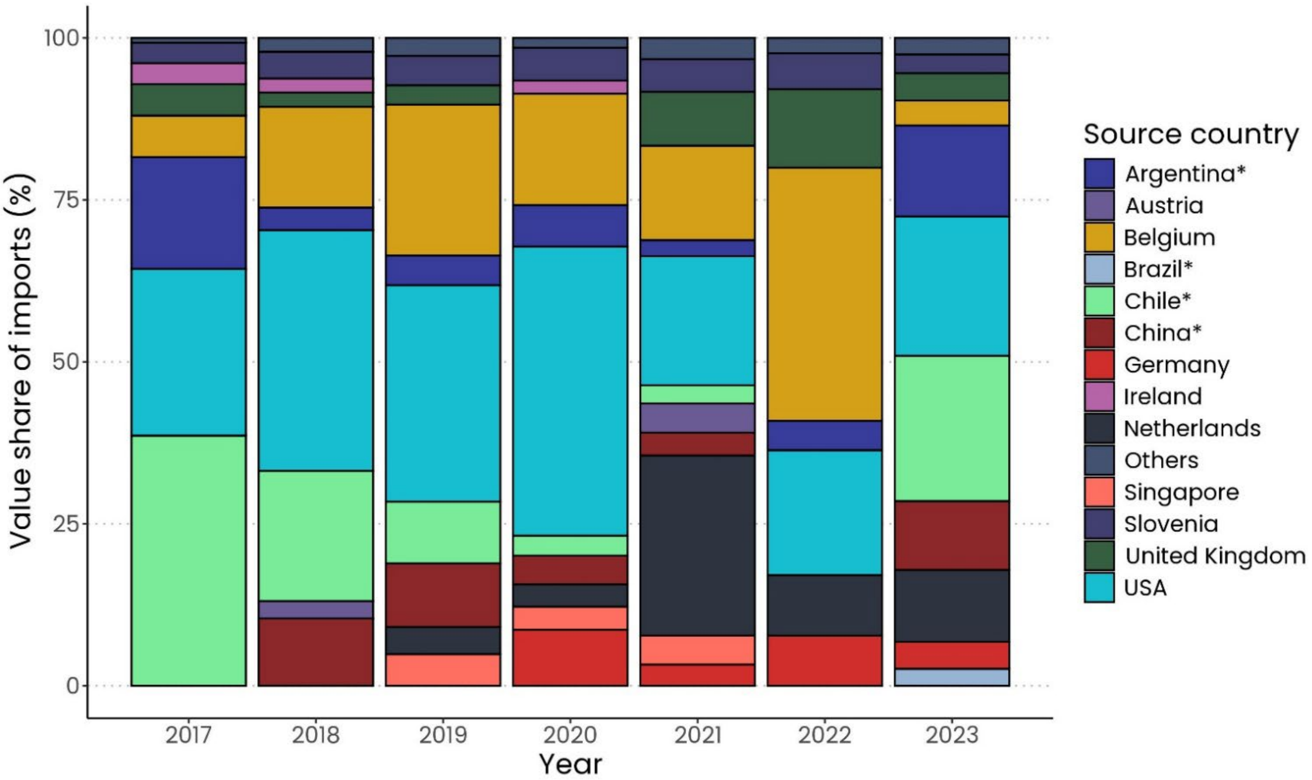
Notes: Harmonized System (HS) code 260300 (see Appendix Table A1 for a full list of employed HS codes). *Country has mining activity as per the U.S. Geological Survey (2025).
Source: Authors' calculations using data from Gaulier and Zignago (2010)

[2] Except for lithium, for which trade of concentrates is rare. Hence, the analysis is conducted for lithium carbonate which is more actively traded. Trade flow classifications impede the tracking of other forms of lithium, such as hydroxide.

Copper ores and concentrates are mainly sourced from Chile, Indonesia and Australia. Additionally, Peru and Canada are significant suppliers of these products to India, especially in 2019. Copper sourcing is well-diversified, with at least 14 import partners across the study period. Half of the countries India sources its copper ores and concentrates from have mining activity, which is a less common characteristic for other metals analysed in this report, but also common for graphite. Reassuringly, some of the world's leading producers, such Australia, Chile, Indonesia and Peru, cover more than half of India's imports across the study period. Chile supplies an average of 37% of total imports, followed by Indonesia and Australia, which represent 20% and 12%, respectively. However, between 5.4% and 15.7% of copper ores are bought from countries that do not have mining activity — such as Saudi Arabia or the Philippines — due to the re-export of the ores. For example, Chilean ores are sometimes traded with the Philippines first before being re-exported to India.

Lithium carbonate imports are also well-diversified, with at least eight different sources each year between 2017 and 2023 (see Figure 3.2). A significant volume of the material was sourced from the United States until 2020, a year in which 44% of the imports were of American origin. Between 2017 and 2023, the US supplied an average of 29% of Indian imports of lithium carbonate. In 2021 and 2022, imports were led by the Netherlands and Belgium, respectively. At its peak, Dutch supply accounted for 28% of total imports, whereas Belgian lithium carbonate had a market share of 39% by 2022. Finally, in 2023 Argentina, Chile and China gained a more significant role, with 14%, 22% and 10%, respectively.

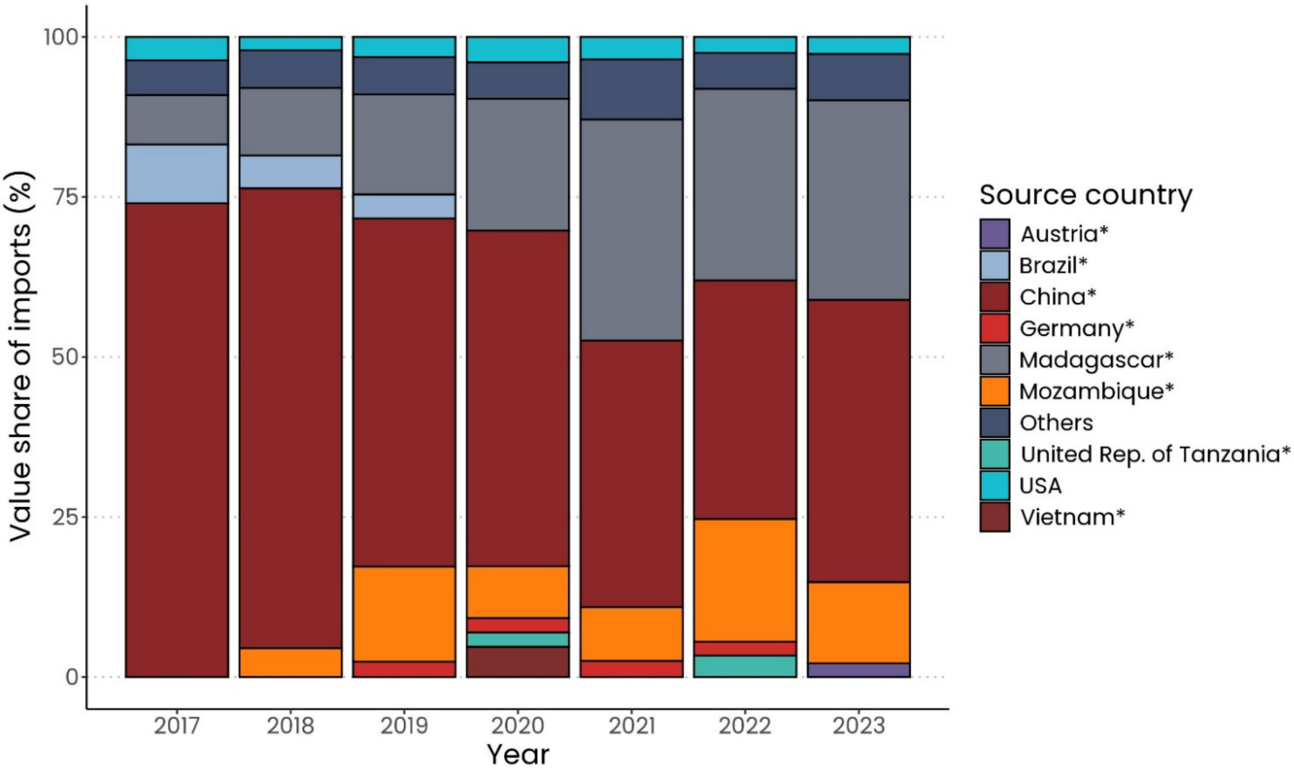
Figure 3.2. India's import partners for lithium carbonate



Notes: HS code 283691. *Country has mining activity as per the U.S. Geological Survey (2025).
Source: Authors' calculations using data from Gaulier and Zignago (2010)

By contrast, natural graphite imports were more concentrated across the study period (see Figure 3.3). In 2017, more than 90% of imports were sourced from just three countries, with China accounting for roughly three-quarters of total imports, and Madagascar and Brazil supplying 9% and 7%, respectively. In general, Chinese natural graphite dominates Indian imports throughout the period, although the share declines from 74% to 44%, reflecting some level of diversification. Natural graphite sourced from Brazil gradually vanishes as a source of imports over the period. By contrast, imports from Madagascar and Mozambique start playing a more significant role from 2018 onwards. The share of imports from Madagascar grew from less than 10% in 2017 to over 30% by 2023, while imports from Mozambique, which in 2017 were not significant, represented 19% of total imports in 2022.

Figure 3.3. India’s import partners for natural graphite



Notes: HS codes 250410, 250490. *Country has mining activity as per the U.S. Geological Survey (2025).
Source: Authors’ calculations using data from Gaulier and Zignago (2010)

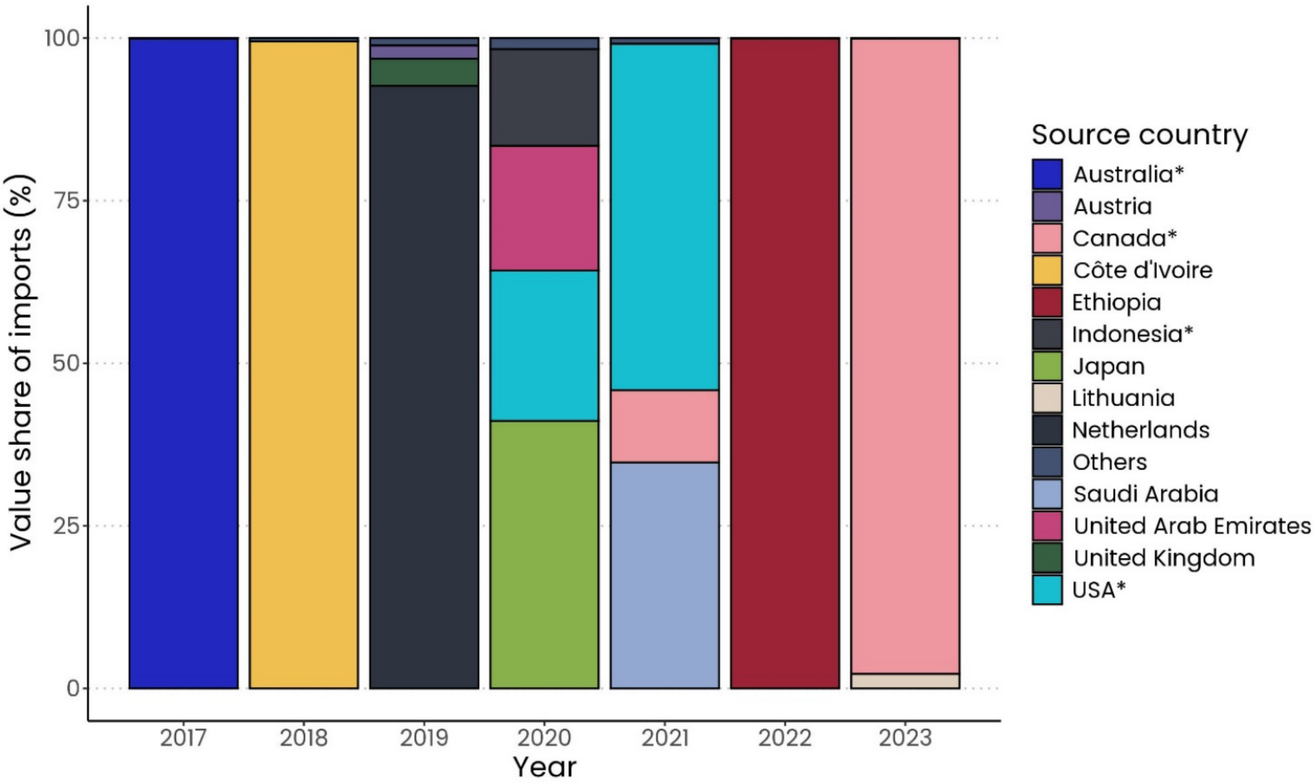
Import origins of nickel and cobalt are extremely concentrated in specific years, resulting from a low import base (see Figure 3.4 and Figure 3.5). Indian demand for raw nickel and cobalt is almost non-existent. Imports of nickel and cobalt ores and concentrates represented less than 0.1% of global production during the study period.[3] This, in turn, reflects the lack of refining capacity for these minerals. Most nickel imports were sourced from a single country at the beginning and the end of the sample, whereas from 2019 to 2021 nickel was bought from at least three different countries. Similarly, India’s cobalt imports from 2017 through to 2023 mostly came from the United Kingdom, except for 2017 and 2023, where Belgium and Malaysia took a larger market share.

Overall, India imports copper and lithium from several countries, whereas graphite, nickel and cobalt imports originate from a small number of partners. In addition, some import partners have no mining activity.4 The latter observation may result from how the underlying data is reported and constitutes one of the limitations of the analysis. For instance, the Netherlands and Belgium represent a high share of India’s lithium carbonate imports despite their lack of mines. However, the two largest European ports belong to these countries, meaning that trade flows may not necessarily reflect the country where the lithium carbonate was produced. This misreporting can also arise if some materials are only transiting through ports.

[3] Trade flow data for quantities tends to be unreliable, which is why most shares are presented as import values. However, where available, quantities were compared to the U.S. Geological Survey (2025). Throughout the study period, Indian imports of nickel and cobalt ores amounted to 38.7 kt and 0.03 kt, respectively. Global supply of each of the minerals was of the order of 19,200 kt and 1,120 kt.

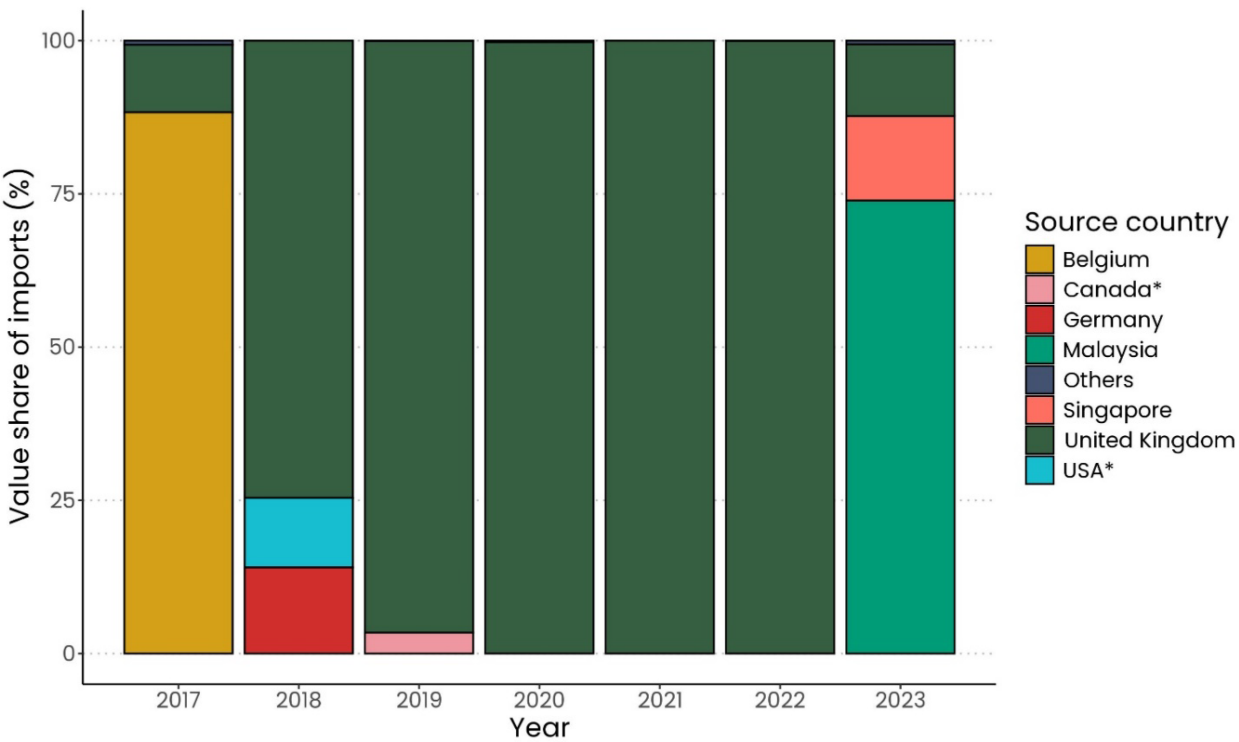
[4] Mining activity was tracked by means of the U.S. Geological Survey (2025). Earlier versions of the survey were also employed to identify producers in each year.

Figure 3.4. India's import partners for nickel ores and concentrates



Note: HS codes 260400. *Country has mining activity as per the U.S. Geological Survey (2025).
Source: Authors' calculations using data from Gaulier and Zignago (2010)

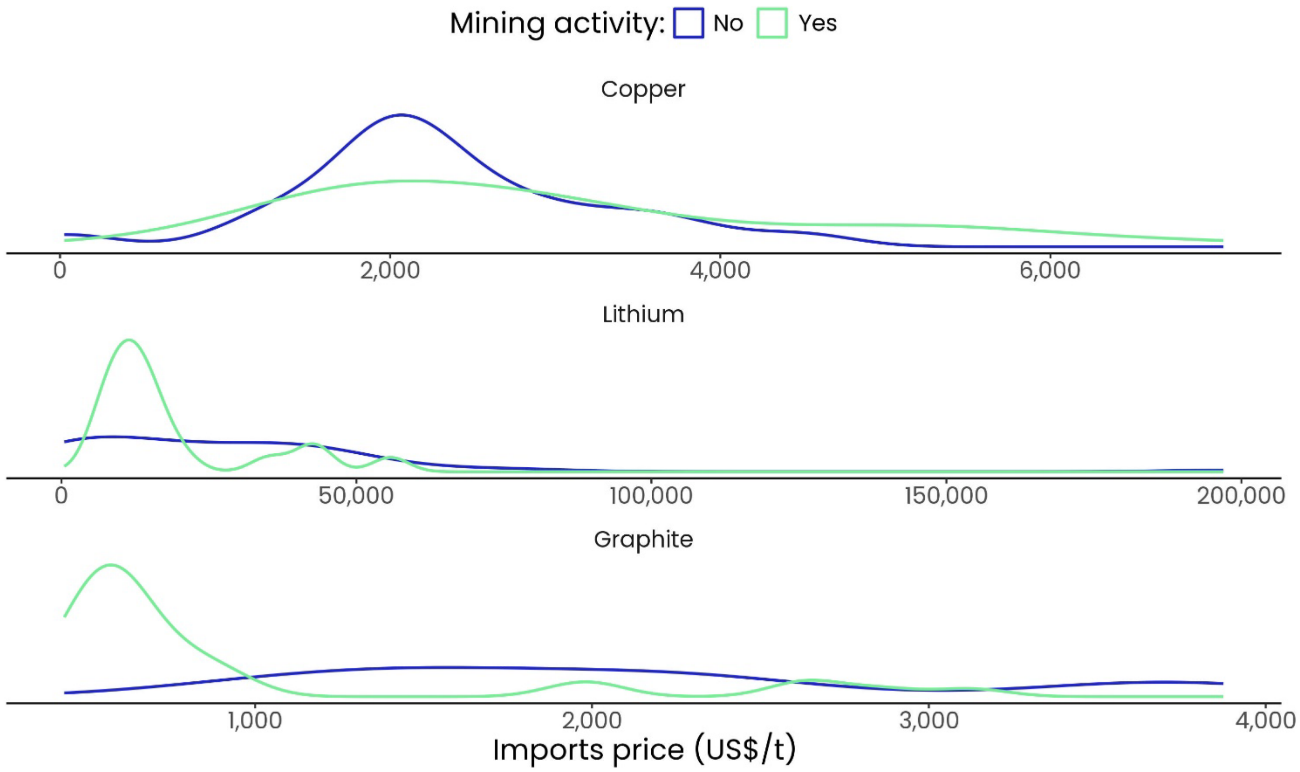
Figure 3.5. India's import partners for cobalt ores and concentrates



Notes: HS codes 260500. *Country has mining activity as per the U.S. Geological Survey (2025).
Source: Authors' calculations using data from Gaulier and Zignago (2010)

Lack of diversification and purchasing from countries without deposits and mining activity could affect supply chain vulnerability and the price stability of inputs. Due to geopolitical tensions, the risk of unexpected trade restrictions and disruptions is high, which may limit access to critical mineral commodities. Moreover, purchasing from non-producing countries may result in double marginalisation if India sources more expensive inputs from these countries, compared to sourcing them directly from producing nations. This issue is significant for lithium carbonate and graphite, for which median import prices from countries where there is mining activity compared to countries where there are no active mines are 68% and 42% lower, respectively. When comparing the price densities of these two minerals, it is evident that import prices from countries where there is mining activity are more concentrated and lower, whereas import prices from non-producing sources are more dispersed. Interestingly, this pattern is not present in copper imports — prices from mining countries are more dispersed and sometimes higher (see Figure 3.6).

Figure 3.6. Import price densities from countries with and without mining activity



Note: Mining activity recorded by the U.S. Geological Survey (2025).
Source: Authors' calculations using data from Gaulier and Zignago (2010)

4. India’s future critical minerals demand

India’s commitment to reach net zero by 2070 will necessitate a vast deployment of low-carbon technologies. Replacing high-carbon vintages while supporting economic growth will gradually decrease the Indian economy’s carbon intensity while increasing its mineral intensity (IEA, 2024b). This section projects future critical minerals demand under different IEA scenarios and for EVs, solar PV and wind technologies. Rare earth elements are also considered.

Estimating mineral demand under different scenarios is key to assessing the implications of different decarbonisation targets and to benchmark the NCMM’s ambitions (see Figure 4.1). The International Energy Agency’s (IEA) three scenario framework[5] — Stated Policies Scenario (SPS), Announced Pledges Scenario (APS) and Net Zero Emissions (NZE) — can help in understanding how different decarbonisation pathways affect mineral requirements. Each scenario reflects varying levels of policy ambition, from current trajectories (SPS) to full NDC compliance (APS) and deep decarbonisation (NZE).

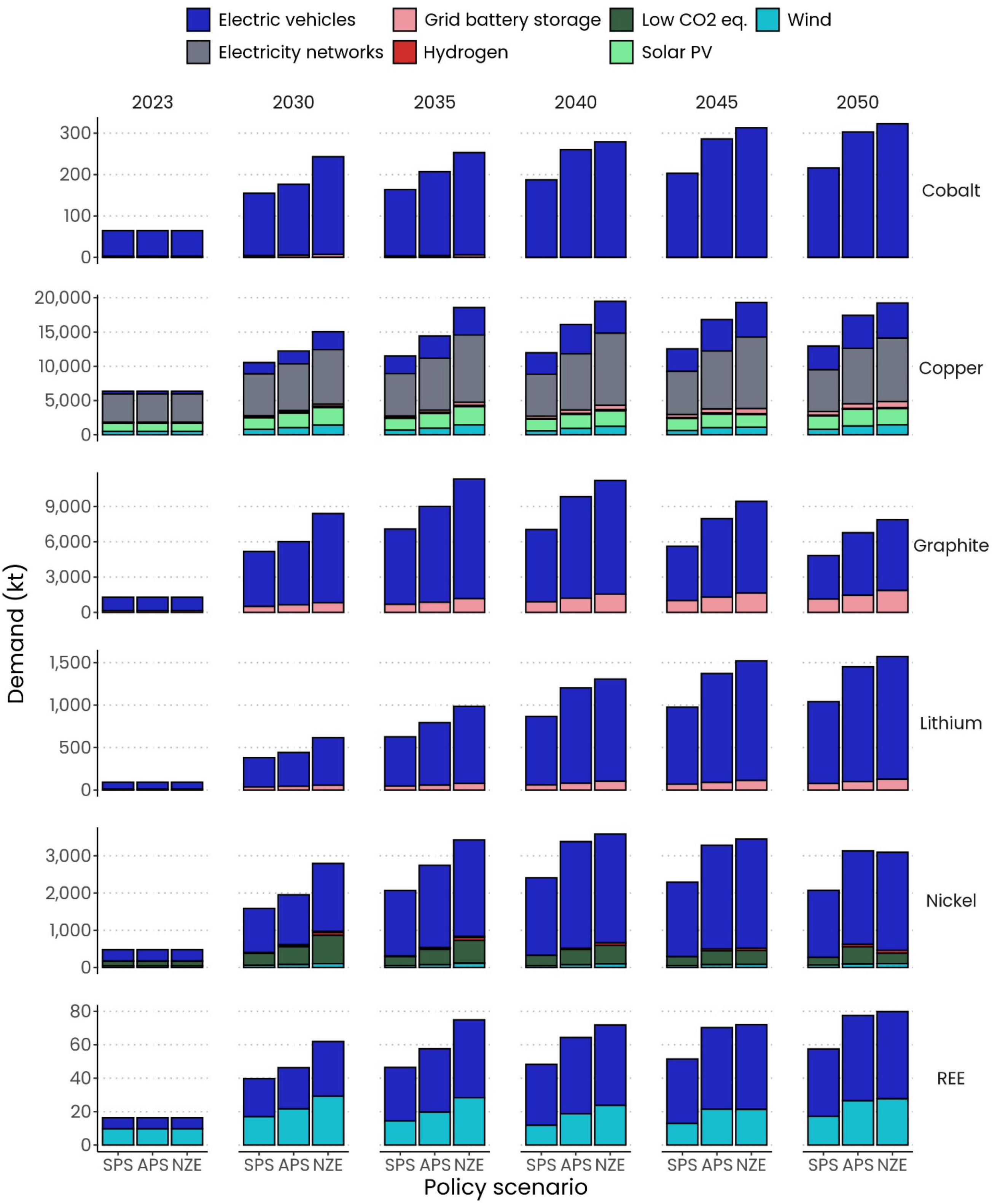
Across the IEA’s three scenarios covering cobalt, copper, lithium, nickel and rare earth elements, EVs are the main driver of demand growth. Current storage technologies are an amalgamation of these minerals — different proportions of them are employed to produce batteries with heterogeneous energy densities, (dis)charge efficiencies and longevities. Moreover, most electric motors require special magnets, which will require increased use of rare earth elements. Added to this, each low-carbon technology is intensive in at least one mineral. For example, the expansion of the electricity grid, in part due to the widespread adoption of solar PV, will require substantial amounts of copper. In contrast, wind technologies are intensive in rare earth elements, which are required to produce magnets.

The analysis in this report computes India’s demand for critical minerals with a top-down method. It relies on the forecasted demand presented in Figure 4.1 coupled with the IEA’s (2024c) *World Energy Outlook*. The latter report has regional forecasts under the SPS and APS, which depict the role of each green technology within India’s energy matrix. The proposed top-down approach contrasts with a more common bottom-up method that assumes different penetration rates of sub-technologies — such as thin-film solar cells versus wafer-based crystalline silicon solar cells — and then aggregates depending on the mineral intensity of each of them. This top-down method is complementary to the one employed, for instance, by Chadha and Sivamani (2024), insofar as it is based on the IEA’s Global Energy and Climate Model (2024c), which considers prices and therefore better mimics economic processes. However, it comes at the cost of losing granularity in terms of sub-technology types.

In the following sub-sections, India’s future demands for cobalt, copper, graphite, lithium, nickel and rare earth elements are presented (see also Figure 4.2). The results only refer to the SPS and APS, given that the IEA’s (2024b) *Critical Minerals Outlook* does not provide estimates under the NZE scenario. In addition, the projections only focus on demand driven by the projected adoption of wind, solar PV, low CO_2 eq. technologies and EVs. For EVs, only figures until 2035 can be presented due to lack of projections until 2050.

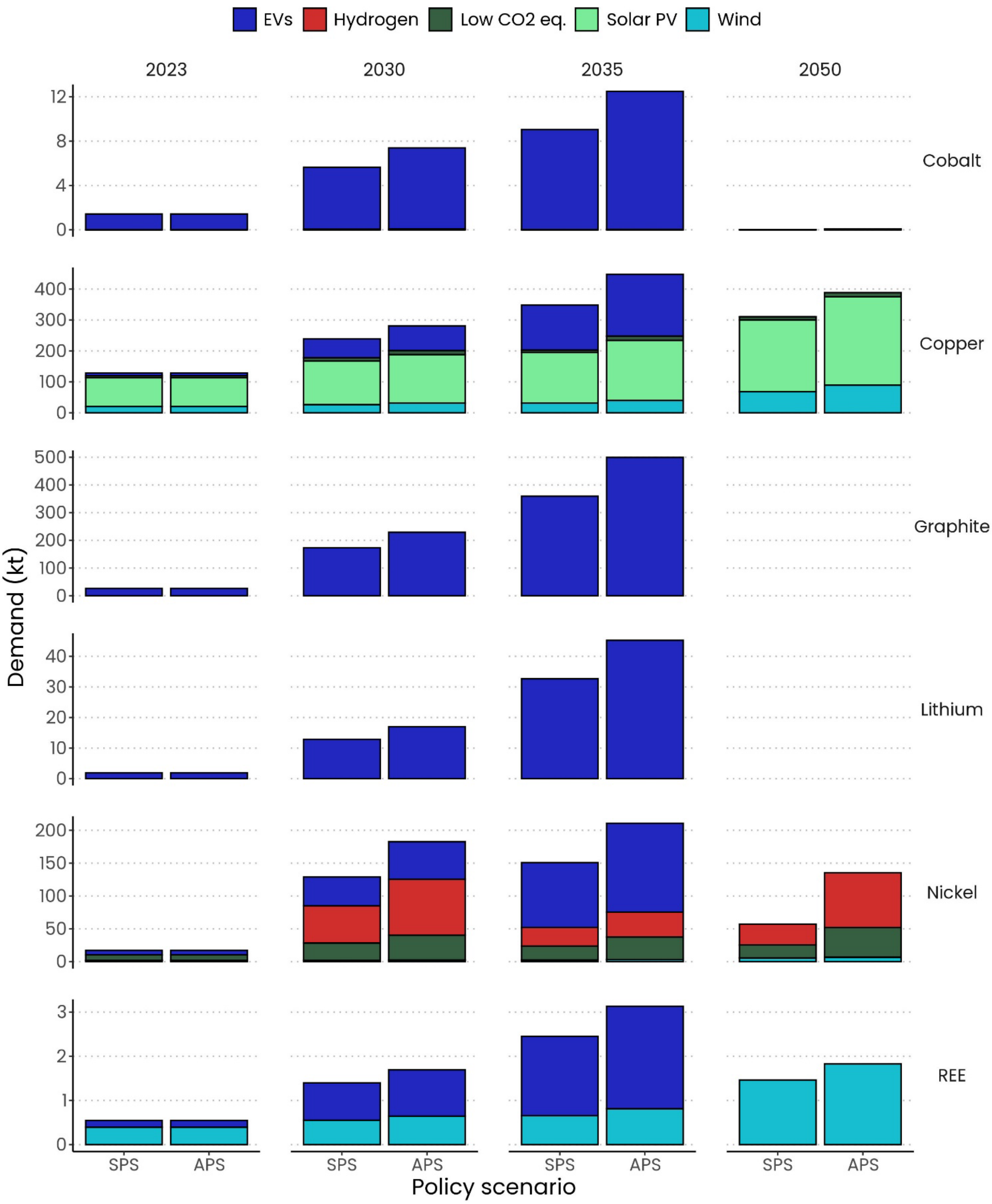
[5] These scenarios are explained further in the Appendix alongside the methodology for projecting India’s future demand based on the IEA’s global estimates.

Figure 4.1. Global demand for critical minerals from the IEA's policy scenarios



Notes: REE: magnet rare earth elements; SPS: Stated Policies Scenario; APS: Announced Pledges Scenario; NZE: Net Zero Emissions by 2050 Scenario. Low carbon dioxide equivalent (CO_2 eq.) technologies comprise nuclear, and modern liquid, gaseous and solid bioenergy.
Source: Adapted from IEA (2024b)

Figure 4.2. India's demand for critical minerals by green technology



Notes: **REE**: magnet rare earth elements; **SPS**: Stated Policy Scenario; **APS**: Announced Pledges Scenario. EV deployment figures were only available until 2035, which explains the sudden disappearance in 2050. Low CO_2 eq. technologies comprise nuclear, and modern liquid, gaseous and solid bioenergy.
Source: Authors' calculations using IEA data (2024b, 2024c)

Cobalt

India's cobalt demand linked to EVs was about 1.4 kt in 2023.[6] By 2030, demand is expected to rise to 5.65 kt under the SPS and to 7.39 kt under the APS. Demand for cobalt will mainly be driven by EV adoption since it is necessary for nickel-based battery technologies. That is, the current policy path will increase cobalt demand by 292%, and if India were to meet its announced pledges, consumption of this mineral would increase by 412% in the next five years. Also, in 2035 demand is projected to be 9.02 kt and 12.4 kt under the APS and the SPS respectively. These scenarios therefore translate to demand multipliers of about five and seven times the baseline 2023 levels. Though not perceptible in Figure 4.2 due to the scale, cobalt demand will also be marginally driven by the deployment of hydrogen and low CO_2 eq. solutions. However, due to the nascent development of these technologies, the projections are relatively uncertain.

Copper

Total demand in 2023 was 128.7 kt, and by 2030 it is expected to rise by 86% (to 238.8 kt) under the SPS and 118% (to 281.1 kt) under the APS. Initial demand is mostly driven by the expansion of solar PV (73%), followed by wind (16%). EVs and low CO_2 eq. technologies account for 7% and 4%, respectively. These splits change by 2030 under both scenarios, where solar PV's share of total demand decreases to 59% (141.4 kt) under the SPS and 56% (156.9 kt) under the APS. However, it is important to note this technology presents a net increase in both scenarios when compared to 2023 levels. Within 10 years, current policies generate a solar PV expansion that will necessitate 164.1 kt of copper, and if India were to meet its pledges, demand would be 30.2 kt higher (194.3 kt). Finally, by the middle of the century, demand increases by 148.3% in the SPS and 205.9% in the APS.

Similarly, EV deployment will increase demand by 2030 — under the SPS, demand will multiply by 5.6, and under the APS by 7.7 compared to the initial period. Within 10 years, EV adoption is expected to increase substantially, thereby pushing copper demand to 145.6 kt and 199.9 kt under the SPS and APS, respectively. These figures imply demand multipliers of around 15 and 21 under each scenario, when compared to 2023 levels. In both scenarios EVs drive over 40% of total copper demand by 2035.

Interestingly, low CO_2 eq. technologies will marginally contribute to demand — they are expected to represent between 2% and 4% of total copper demand across the study period. The most substantial increase will occur in the next five years, when copper demand under the SPS increases by 73.6% (10.15 kt) and under the APS it grows by 119.7% (12.9 kt). Depending on the scenario, demand then either shrinks to 7.2 kt (23.2% of the baseline) or marginally grows to 13.5 kt (131.5% of the baseline, or 4.6% of overall demand in 2030).

Finally, by 2030, the expansion of wind power generates demand increases of 28.6% (26.1 kt) and 54.1% (31.2 kt) under the SPS and the APS, respectively. Within 10 years, deployment of wind turbines will require 31.3 kt of copper under the former scenario, while in the latter demand amounts to 39.8 kt, which should translate to increases of either 54.4% or 96.3% with respect to 2023. In 2050, the SPS leads to copper demand of 68.3 kt (236.8% of the baseline), while the APS will require 98.27 kt of copper (340% of the baseline). Hydrogen deployment never attains more than 0.08% of total copper demand and is therefore not a prominent contributor.

Graphite

EV adoption will drive all the demand for graphite, which in 2023 was at 26.5 kt. By 2030, graphite consumption will increase by 555% under the SPS, and 767% under the APS. This is equivalent to consumption levels of 173.4 kt and 229.4 kt, respectively. Five years later, in 2035, graphite demand due to EV deployment would further grow by 107% under the SPS to 359.4 kt, and by 118% under the SPS,

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[6] 2023 is taken as the baseline reference for expressing multipliers and percentage increases. Notice that the bars in Figure 4.2 are of equal height under both scenarios. All multipliers per technology and scenario are presented in Appendix Figure A1.

equivalent to 499.72 kt. Relative to the baseline, these demand levels represent a growth in demand of 1,258% and 1,788%.

Lithium

Demand for this metal, as for graphite, will be entirely driven by EV deployment, growing by 573% under the SPS and 788% under the APS by 2030. India's current demand for lithium stands at 1.9 kt, yet in 2030 it will be about 10.9 kt higher (12.9 kt) under the former scenario, and 15.1 kt higher (16.9 kt) under the latter. By the middle of the next decade, lithium demand will further grow 153% under the SPS to 32.6 kt, and by 166% under the APS, implying consumption of 45.2 kt. These represent increases of 1,608% and 2,266% compared to the baseline. Note, however, that initial consumption is relatively low.

Nickel

Expansion of nickel demand will be mainly driven by EV adoption and expansion of the hydrogen industry, each one increasing in five years to 43.9 kt and 56.8 kt under the SPS, and 57.1 kt and 85.3 kt under the APS. Hydrogen-driven consumption in 2023 is nil, meaning it is not possible to generate growth rates from the baseline. By contrast, EV-linked consumption amounts to 6.9 kt in the baseline. Hence, the aforementioned quantities represent an increase of 536% and 727% for each scenario. Interestingly, nickel consumption due to hydrogen deployment shrinks by the middle of the next decade — by 28.3 kt under the SPS, whereas under the APS it decreases to 37.9 kt. On the other hand, the greater penetration of EVs will more than double nickel consumption. Under the SPS, 98.8 kt of nickel will be needed (1.24 times 2030 levels), while under the APS consumption will grow to 135.3 kt (1.37 times 2030 levels). Finally, hydrogen-driven consumption grows again by the middle of the century — 31.58 kt of nickel will be needed under the SPS and 83.61 kt under the APS, situating this demand closer to 2030 levels.

Rare earth elements

Rare earths are needed for EV motors and wind turbines. These two technologies will require 393 t and 151 t in 2023, respectively. In 2030, their demand will have increased by 40.3% and 456% under the SPS, and by 66.1% and 591% under the APS. These percentages translate into demand levels of 552 t and 644 t under each scenario for wind turbines, and 845 t and 1,048 t for EVs. By the middle of the next decade, the consumption of rare earths associated with wind power will further grow to 654 t and 812 t under each scenario, and EV deployment causes demand levels to grow to 1,797 t and 2,321 t. Compared to the baseline, the latter figures represent increases of 66.1%, 106%, 1,084% and 1,429%, respectively. Finally, wind turbines will require 1,461 t of these metals in the SPS, and 1,827 t in the APS, translating to increases with respect to 2023 of 271% and 364%.

Benchmarking supply chain development with projections

This analysis provides estimates for future critical mineral requirements under different energy transition scenarios. The estimates illustrate the final consumption of the commodities that result from low-carbon capital deployment. This demand could be met with Indian production if the supply chains existed and grew in India, or indirectly if the capital goods were imported from abroad. Naturally, the former case is more compatible with the NCMM's objectives of supply chain development as well as the Indian Government's goal to become self-reliant.

The estimates should be treated as upper bounds of commodity demand under absolute self-sufficiency. Namely, that India produces the entirety of its green capital. The transition will most likely be a mix of Indian and foreign green technologies, and the projections can be a benchmark for any share of indigenisation of the supply chain. For instance, if a policymaker is interested in understanding the amount of critical minerals necessary in a 50% self-reliance scenario, they should halve all the absolute estimates presented in Figure 4.2 and included in Appendix Table A2.

Moreover, the projections can also help benchmark mineral demand from Production Linked Incentive (PLI) schemes — for example, the 2022 solar PV PLI will need 14 kt of copper and 51 t of nickel, or almost 10% of the projected needs by 2030. PLI schemes are a government initiative to boost domestic manufacturing capacity. They consist of financial incentives for manufacturers based on output and value addition (Ministry of New and Renewable Energy, 2023). This solar PV PLI tranche allocated funds to develop 39,600 megawatts of production capacity (Solar Energy Corporation, 2022), of which around 50% is eligible for claiming the PLI aids. This means that approximately 9.65% of the necessary installed capacity[7] by the 2030 SPS projection is subsidised by the scheme. For this tranche of the PLI to be effective, the abovementioned quantities of minerals should be secured.

Finally, demand for critical minerals can fall substantially as a result of technological progress. Research and development may lower mineral intensity or skew demand towards a particular mineral. The IEA's (2024b) projections already capture the roles of prices and technological change, yet for the latter they are rather conservative in terms of the improved productivity and reduced mineral intensity of new technologies. If mineral intensities were to lessen drastically, or a particular technology became more dominant, demand projections could diminish or be dominated by a particular mineral. For example, lithium-ion batteries could become a leading technology for EVs instead of nickel-based NMC batteries, implying that nickel needs are replaced by higher lithium demand. Similarly, there is substantial uncertainty regarding the long-term production and consumption of green hydrogen. For example, there is not full clarity about the cost structure of low-emissions hydrogen production and how it will evolve, making it prohibitively expensive at present. Moreover, some of hydrogen's applications, such as freight and electricity storage, are still in the demonstration stage (IEA, 2024d). Consequently, the associated demand for critical minerals might evolve in different ways depending on whether hydrogen technologies become cost-competitive and more widely adopted.

[7] Production capacity must be translated into actual generation for later comparison to the projected demand. Solar PV generation under the SPS in 2030 is expected to be 539 terawatt hours (TWh). Assuming a capacity factor of 30% yields $(50\% * 39{,}600MW * 30\% * 8{,}760h) \div 539TWh \ = 9.65\%$

5. Diversification opportunities

The options presented in this section are grounded in three key considerations. First, a country-level risk assessment evaluates geopolitical stability, regulatory predictability and exposure to trade disruptions. This ensures that diversification does not substitute one vulnerability for another. Second, the analysis incorporates mine-level profitability, estimated through net present value (NPV) projections based on each mine's cost structure and expected future cash flows. This approach helps identify mining projects that are not only technically feasible but also potentially profitable. Third, the roadmap accounts for India's existing trade relationships, as mapped in Section 3, to prioritise countries where commercial ties already exist and to highlight jurisdictions where new partnerships or deeper engagement may be necessary. By combining these dimensions, this section outlines a strategic roadmap for investment opportunities and partnership development.

Countries with low-risk profiles, competitive cost structures, and that are currently India's trade partners emerge as immediate candidates for upstream diversification. Conversely, where promising projects exist in jurisdictions with limited trade engagement, India may need to pursue diplomatic and commercial initiatives to secure access. This integrated approach ensures that diversification strengthens supply chain resilience while aligning with India's broader trade and industrial policy objectives.

Country-level risk scores provide a comprehensive measure of the strategic and operational risks that enterprises face when operating in each jurisdiction. These scores are provided by S&P Global (2025a), which explores six major categories of risk: political, economic, legal, tax, operational and security. Each category captures a distinct dimension of the investment environment. For example, political risk reflects government stability and policy predictability, while economic risk considers factors such as inflation, currency volatility and sovereign default. Legal risk focuses on contract enforcement and expropriation, tax risk on fiscal consistency, operational risk on infrastructure reliability and corruption, and security risk on threats like terrorism or civil unrest (S&P Global, 2025b).

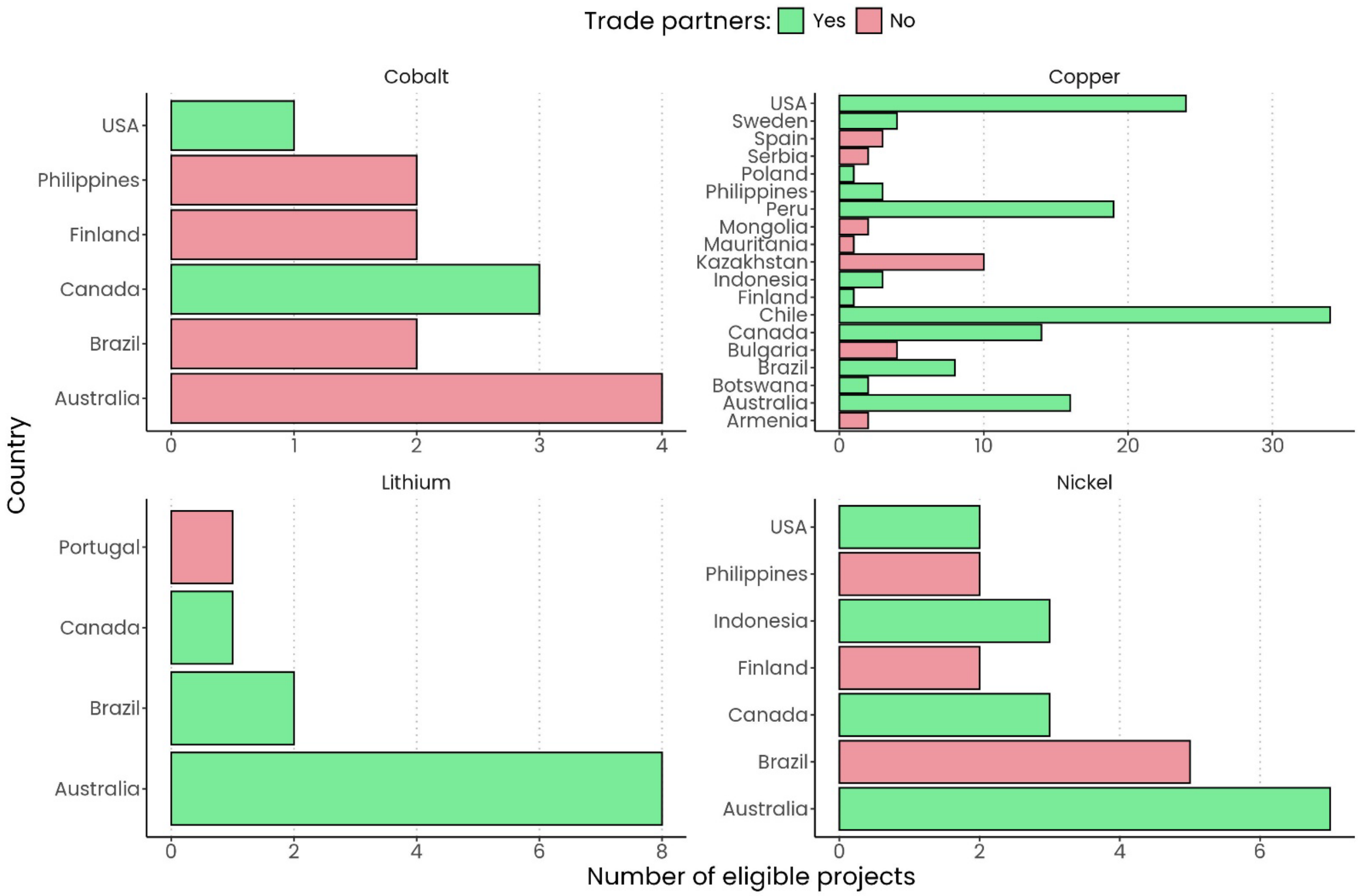
The scoring process combines qualitative analysis and forward-looking forecasts to produce a numeric score that represents the expected level of risk over the coming years. These scores are then translated into descriptive bands — ranging from low to extreme — to facilitate interpretation (see Table 5.1 and Appendix Table A3). Importantly, the same country-level risk score is applied across all mining projects located within that jurisdiction. This ensures consistency in evaluating geopolitical and macroeconomic exposure, regardless of individual project characteristics. While project-specific factors such as cost structure and cash flow projections determine financial viability, the overarching country risk score acts as a baseline for assessing the stability of the operating environment.

Figure 5.1 presents the number of eligible projects per country. In addition, it displays whether a trade relationship between India and the specific trade partner already exists, as per the analysis presented in Section 3. A mining project is deemed eligible if (i) the country-level risk score is lower than 2.4, or high in S&P's (2025) categorisation, and (ii) the project has positive NPV, thereby signalling expected profitability.

Australia, Brazil, Finland and the Philippines emerge as potential new diversification partners for India's cobalt supply chains, as there was no recorded cobalt ores trade with these countries between 2017 and 2023. In contrast, cobalt has in the past been sourced from Canada and the US, both of which also host eligible projects. Australia and Finland share the same moderate risk profile, making them attractive for new engagement. The Philippines, with an elevated risk score of 2.2, and Brazil, slightly higher at 2.3, offer additional opportunities but would require stronger risk mitigation strategies. This mix of low-risk and higher-risk jurisdictions would provide India with a pathway to broaden its cobalt sourcing while balancing security and cost considerations.

Countries such as Armenia, Kazakhstan, Mauritania, Mongolia, Serbia and Spain present potential diversification options, each hosting eligible copper projects. While copper sourcing for India is already relatively well-diversified compared to other critical minerals, these countries represent opportunities to deepen resilience by establishing new partnerships. The least risky option is Spain, with an elevated risk score of 1.9, followed by Bulgaria and Mongolia with scores of 2.1 and 2.2, respectively. Interestingly, countries India has historically traded copper ores with — such as Australia, Canada, Finland and Sweden — have moderate risk scores of 1.3, while Chile, a major supplier, is ranked as elevated at 1.7. This pattern suggests that, for copper, India's diversification strategy could focus on strengthening existing partnerships and securing long-term agreements rather than pursuing new, higher-risk jurisdictions.

Figure 5.1. Number of eligible mining projects per country, by mineral and trade relationship status with India



Source: Authors' calculations using data from S&P Global (2025a)

In the case of lithium, the only new partnership opportunity identified is Portugal, which hosts a single eligible project and carries an elevated risk score of 1.7. While this represents a chance to broaden India's supplier base, the strategic priority should remain strengthening existing ties with Australia, Brazil and Canada, where both project availability and established trade channels reduce entry barriers and transaction risk. These countries account for the bulk of eligible projects — Australia (8 projects), Brazil (2 projects) and Canada (1 project) — and offer relatively predictable operating environments, with Australia and Canada rated at moderate risk (1.3).

Diversification of nickel sourcing could be advanced by establishing new trade relationships with Brazil, Finland and the Philippines, which host eligible projects and carry risk scores of 2.3, 1.3 and 2.2, respectively. These jurisdictions offer potentially profitable opportunities to scale up imports of raw nickel products, though risk mitigation might be necessary in the cases of Brazil and the Philippines. At the same time, India should prioritise strengthening existing partnerships with Australia and Canada, where trade already occurred between 2017 and 2023 and where risk scores remain at a moderate level (1.3). Additional engagement with the US (risk score 1.8) and Indonesia (2.2) could complement this strategy. A balanced approach that couples deepening ties with trusted suppliers while selectively adding new partners will help India secure nickel supply for its growing industrial and energy needs.

Potential foreign direct investment levels

Table 5.1. Potential FDI levels and risk scores per country and mineral

Country	Risk score	FDI levels			
		Cobalt	Copper	Nickel	Lithium
Australia	1.3 - Moderate	868.7	10,671.6	1,064.3	60,059.6
Canada	1.3 - Moderate	949.0	6,598.2	949.0	111.0
Finland	1.3 - Moderate	748.5	310.1	748.5	–
Sweden	1.3 - Moderate	–	3,384.1	–	–
Chile	1.7 - Elevated	–	81,727.8	–	–
Portugal	1.7 - Elevated	–	–	–	29.0
USA	1.8 - Elevated	43.0	18,664.8	451.7	–
Spain	1.9 - Elevated	–	1,398.3	–	–
Poland	1.9 - Elevated	–	460.9	–	–
Botswana	1.9 - Elevated	–	1,147.9	–	–
Peru	2.1 - Elevated	–	41,308.7	–	–
Bulgaria	2.1 - Elevated	–	1,633.6	–	–
Philippines	2.2 - Elevated	1,282.2	1,194.7	1,282.2	–
Indonesia	2.2 - Elevated	–	20,657.6	11,386.8	–
Mongolia	2.2 - Elevated	–	13,213.5	–	–
Brazil	2.3 - Elevated	725.0	9,548.5	2,056.1	772.5
Kazakhstan	2.3 - Elevated	–	16,029.5	–	–
Serbia	2.3 - Elevated	–	5,030.5	–	–
Mauritania	2.3 - Elevated	–	160.4	–	–
Armenia	2.3 - Elevated	–	3,222.2	–	–

Note: FDI levels are presented in millions of 2024 US dollars. The NPV of multi-product projects was divided by the number of minerals to avoid double counting of investment levels. The risk score aggregates six main risk categories: political, economic, legal, tax, operational and security. The aggregate score is expressed numerically and translated into descriptive bands: low (0.1–0.7), moderate (0.8–1.5), elevated (1.6–2.3), high (2.4–3.1), very high (3.2–4.3), severe (4.4–6.4) and extreme (6.5–10.0). Further details regarding S&P Global's (2025a) risk scores are available in the Appendix.
Source: Authors' calculations using data from S&P Global (2025a)

The NPV projections provided by S&P (2025a) serve as a benchmark for estimating the maximum foreign direct investment (FDI) India might require to secure its critical mineral supply through full acquisition of foreign assets. Table 5.1 above presents these upper-bound figures under a hypothetical scenario where India purchases 100% of the identified projects shown in Figure 5.1. While such complete ownership is unrealistic, these estimates provide a useful ceiling for planning and can be rescaled to reflect partial ownership targets. For example, acquiring 10% of Australian cobalt assets would imply an investment of approximately US$86.9 million, compared to a full acquisition cost of US$868.7 million. Similar calculations can be applied across other minerals and jurisdictions, enabling India to align its diversification strategy with the NCMM's objective of acquiring 50 "foreign critical mineral mines" (Ministry of Mines, 2025a).

Under a full acquisition scenario, the largest FDI exposures are concentrated in lithium and copper assets, particularly in Australia (US$60.1 billion for lithium and US$10.7 billion for copper) and Chile (US$81.7 billion for copper). These figures underscore the capital intensity of securing upstream control in resource-rich jurisdictions. Countries which should be prioritised in India's roadmap include Australia, Canada and Finland, which host multi-product mines and carry moderate risk scores (1.3), making them attractive for phased investments. Developing economies also present significant project pipelines of strategic importance for securing cobalt, nickel, copper and lithium. Specifically, Brazil hosts projects across all four minerals, the Philippines offers opportunities in cobalt, nickel and copper, and Chile remains critical due to its substantial copper potential.

Risk mitigation strategies

As stated in the NCMM, India is accelerating its outward FDI strategy to acquire at least 50 strategic mineral assets abroad (Ministry of Mines, 2025a). The above-mentioned countries can be potential FDI destinations, yet they have heterogeneous risk profiles. Political instability, regulatory unpredictability, currency inconvertibility and expropriation risks in host countries may jeopardise long-term returns. To address these vulnerabilities, India can leverage an existing institutional architecture comprising the Export Credit Guarantee Corporation of India (ECGC), the Export-Import Bank of India (Exim Bank) and the World Bank's Multilateral Investment Guarantee Agency (MIGA). While some of these institutions are more focused on promoting exports, their mandates and instruments can be adapted to support resource-importing ventures.

Each institution can play a role in operationalising a risk-mitigation strategy. The ECGC could develop instruments analogous to its Export Credit Insurance, which protects exporters against non-payment. However, this should be tailored to importers needs and protect them, for instance, from non-delivery. Exim Bank can provide long-term project financing and structured credit facilities designed for overseas mineral acquisitions, reducing exposure to liquidity shocks and enabling hedging against currency and commodity price volatility. Meanwhile, the MIGA could offer multilateral guarantees against non-commercial risks, covering threats such as expropriation, currency restrictions and contract breaches, thereby enhancing investor confidence and lowering the perceived risk premium in politically unstable environments. Together, these instruments can create a layered safety net that aligns financial support with risk-sharing mechanisms, making India's outward FDI in strategic minerals more resilient.

6. Conclusions and recommendations

This report has identified some of the policy challenges that India faces in securing critical mineral supplies as it transitions towards a low-carbon future. Our projections of India's future critical mineral demand and our analysis of the profitability of mining projects combined with country-level risk assessments reveal how India could overcome its current supply bottlenecks by diversifying its critical mineral supply chains. Diversifying its imports between a mix of stable and emerging market jurisdictions would provide India with a balanced roadmap to strengthen the resilience of its critical mineral supply chains while supporting its industrial and energy transition goals. Moreover, this diversification strategy should be accompanied by policy reforms that foster the growth of domestic raw minerals production, as well as mineral recovery and recycling from end-of-life products.

India's industrial strategy to develop green supply chains will only succeed if the necessary inputs are available at an affordable price. Despite the NCMM and reforms to the Indian mining industry's regulatory framework, there are significant challenges. For one part, the existing composite and exploration licence system is imperfect and creates disincentives for investing in new mining projects. These two licensing mechanisms should be redesigned so that successful exploration is rewarded with the right to exploit. As also previously discussed by Chadha et al. (2025), companies willing to invest in geological surveys should be granted the associated mining rights or provided with other forms of compensation if those rights are granted to other companies. This could be operationalised by, for instance, expanding the scope of composite licences, so that they allow greenfield mineral reconnaissance, prospecting and exploration.

Furthermore, long-term supply chain contracts have become an impediment to companies willing to import raw materials directly from producer countries. Many mines in Australia and the Democratic Republic of the Congo have long-term contracts with processing and manufacturing companies to guarantee access to their commodities, something that creates barriers to entry for others (Bansal and Chadha, 2025). India should facilitate the same types of agreements between Indian refiners and low-carbon technologies manufacturers, and foreign mining companies. As a result, both incumbents and entrants would profit from higher certainty on input prices, as well as constant access to hard-to-substitute materials. The analysis shows that a number of India's import partners are not actual mineral producers but intermediaries, which translates into higher input prices. This can affect Indian producers' cost structure and can render India's green industries less competitive than counterparties that have direct access to raw materials. Without diversified supply chains, India's ability to access large quantities of minerals is limited, further undermining the development of downstream sectors and India's future decarbonisation targets.

These issues related to the Indian mining industry are aggravated by highly concentrated import dynamics. For instance, in the case of graphite, which is necessary to produce batteries, approximately 50% of imports originate from just two producers: China and Madagascar. Moreover, nickel and cobalt imports, also needed to produce energy storage technologies, are extremely low. Few countries sell these commodities to India, highlighting the necessity of developing ties with new foreign partners.

Both diversification and investment in foreign and domestic capacity are urgent, especially because the mineral intensity of the Indian economy is expected to grow sharply in the coming years. In the future, EVs will be the main driver of India's critical mineral demand, particularly because battery technologies are highly intensive in cobalt, lithium and nickel. Under the IEA's Stated Policies Scenario cobalt demand will triple by the end of the decade and lithium requirements will increase almost seven-fold. Moreover, all technologies are highly intensive in copper due to its conducting properties and its vital role in electrical systems. Given the lack of domestic production capacity of most minerals, India has to engage with foreign parties to diversify supply and invest in domestic capacity to avoid future supply bottlenecks, as well as strategic vulnerabilities that could derail its clean energy transition.

India's diversification roadmap for critical minerals should balance three dimensions: country-level risk, project-level profitability and existing trade relationships. The analysis shows that Australia, Canada and Finland consistently emerge as top-tier partners. These countries combine moderate risk scores (1.3) with multi-product mining portfolios and established trade ties. Their scale and stability make them ideal anchors for India's upstream strategy, offering opportunities to secure cobalt, nickel, lithium and copper through phased investments and long-term agreements.

Beyond these low-risk jurisdictions, Brazil, Chile and the Philippines stand out among developing economies as strategic complements. Brazil offers multi-metal potential, including cobalt, lithium and nickel, while Chile remains critical for copper supply. The Philippines provides cobalt and nickel opportunities, though its elevated risk score (2.2) calls for robust risk mitigation measures such as structured offtake agreements. In addition, this market-design mechanism should be complemented with the existing national and international institutional architecture to mitigate FDI risks. All in all, engagement with these countries, as well as Australia, Canada and Finland, will require diplomatic and commercial initiatives to ensure predictable operating conditions.

Finally, the FDI benchmarks derived from NPV projections underscore the capital intensity of the mining industry. While complete ownership of the critical minerals mining industry is unrealistic for India, these figures provide an upper bound for planning and can be scaled to partial stakes aligned with India's NCMM. Prioritising low-risk, multi-metal jurisdictions for initial investment, while selectively engaging with resource-rich developing economies, offers a pragmatic path to building resilient supply chains that support India's industrial and energy transition.

Summary of recommendations

To support the diversification of India's critical mineral supply chains, the Government should:

1. Diversify and invest in foreign and domestic critical minerals capacity urgently, particularly as the mineral intensity of the Indian economy is expected to grow significantly in the coming years as it transitions towards a low-carbon economy.

2. Grant companies that are willing to invest in geological surveys the associated mining rights, or provide better compensation schemes when those rights are auctioned to other companies.

3. Facilitate long-term agreements between local producers of low-carbon technologies and foreign parties with abundant mineral supplies, thereby increasing certainty on input prices and ensuring constant access to materials that are hard to substitute for.

4. Make diplomatic and commercial efforts to strengthen trade relationships between India and Australia, Canada, Finland, Brazil, the Philippines and Chile, to enable the diversification of India's critical mineral supply chains.

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Appendix

Trade flow data and employed HS codes

The trade flow data is sourced from CEPII's BACI database (Gaulier and Zignago, 2010), which is a harmonised version of the UN's Comtrade dataset. Essentially, CEPII reconciles duplicated reports that may differ because of cost, as well as insurance and freight rates. Furthermore, CEPII assesses the reliability of each country, thus systematic under reporters are down-weighted in the harmonisation.

Furthermore, the United Nations Conference on Trade and Development (UNCTAD, 2023) provides a product classification for the different mineral processing stages, particularly for lithium, cobalt and graphite. This is then complemented with the HS codes for ores and concentrates of copper, nickel and rare earth elements. All the employed HS codes available are presented in Table A1.

Table A1. Employed Harmonized System (HS) codes and descriptions per mineral

Metal	HS code	Description
Cobalt	260500	Cobalt ores and concentrates
Copper	260300	Copper ores and concentrates
Graphite	250410	Graphite: natural, in powder or in flakes
Graphite	250490	Graphite: natural, in other forms, excluding powder or flakes
Lithium	253090	Mineral substances: n.e.c. in chapter 25
Lithium	283691	Carbonates: lithium carbonate
Nickel	260400	Nickel ores and concentrates
Rare Earth Elements (REE)	280530	Earth-metals, rare: scandium and yttrium, whether or not intermixed or interalloyed

Source: Adapted from UNCTAD (2023) and World Customs Organisation (2012)

International Energy Agency scenarios description

The **Stated Policies Scenario (SPS)** tracks the current direction of the energy system, given the sector-by-sector and country-by-country enacted policies and announced projects. In short, this pathway is a baseline that aims to mimic a static world where no major energy-related policy action takes place.

The **Announced Pledges Scenario (APS)** assesses how far the energy system is from meeting decarbonisation targets. The APS assumes that the NDCs will be fully achieved on time. Therefore, the difference between the APS and the SPS serves as a benchmark for how ambitious policies must be to meet the NDCs.

The **Net Zero Emissions by 2050 (NZE)** scenario traces a pathway towards a carbon-neutral energy sector, without relying on other sectors' emissions reductions. This is the most stringent scenario because it takes for granted global cooperation and the deployment of a larger number of green technologies. In addition, it also aligns with developmental goals. For instance, it assumes universal access to modern energy by 2030.

Demand projections methodology and results

The top-down approach at the core of these projections relies on the IEA's (2024c) *World Energy Outlook* (WEO), which provides global and regional projections on electricity generation and capacity, as well as energy supply. These figures are available for different scenarios and technologies. The *Critical Minerals Outlook* (CMO), in turn, provides supply and demand projections of the specific commodities necessary for producing the technologies (IEA, 2024b).

The procedure starts by matching global figures from the WEO to the CMO. This allows us to calculate mineral intensities per technology and scenario. Formally, the mineral m intensity $\theta^m_{sk,t}$, which is associated with a scenario s, a technology k and a year t, is computed as:

$$\theta^m_{sk,t} = \frac{Q^m_{sk,t}}{X_{sk,t}}$$

Where $Q^m_{sk,t}$ is the quantity of mineral m that is required under scenario s to produce technology k. $X_{sk,t}$ refers to the global level of either electricity generation, electricity capacity or energy supply, as projected by the IEA. The next step consists of matching the mineral intensities to projected levels of $X_{sk,t}$ but for India, instead of globally — that is, $x_{sk,t}$.[8] Thus, India's mineral demand would be given by the global mineral intensity of the technology, times $x_{sk,t}$:

$$q^m_{sk,t} = \theta^m_{sk,t} x_{sk,t}$$

It is sometimes the case that $x_{sk,t}$ is not provided directly by the IEA, as in the case of nuclear, and modern liquid, gaseous and solid bioenergy. Hence, the assumption is that these energies will represent the same share of India's energy matrix as the world's. Formally, let $\omega_{sk,t}$ be the share of global energy attributed to a specific technology in a specific scenario and in a certain year:

$$\omega^{world}_{sk,t} = \frac{X_{sk,t}}{X_{s,t}}$$

The subscript k was dropped from the denominator because $X_{s,t} = \sum_k X_{sk,t}$. Assuming that $\omega_{sk,t}$ holds for India too, yields an estimate of $x_{sk,t}$ from the share identity:

$$x_{sk,t} = \omega^{world}_{sk,t} \sum_k x_{sk,t}$$

For instance, under an APS, the IEA estimates that the world's nickel demand associated with low-carbon equivalent technologies will be around 461.9 kt in 2050. This is associated with a global energy supply of 167.9 exajoules (EJ), yielding a nickel intensity of $\theta^m_{sk,t}$ = 2.749 kt/EJ. Moreover, the IEA estimates that the total energy supply will be 634.73 EJ, thus $\omega^{world}_{sk,t}$=0.265. Under the same scenario and in the same year, India's energy supply would amount to $\sum_k x_{sk,t}$=61.906 EJ. Therefore:

$$q^m_{sk,t} = \theta^m_{sk,t} \cdot \omega^{world}_{sk,t} \sum_k x_{sk,t} = \frac{2.749kt}{EJ} \cdot 0.265 \cdot 61.906EJ = 45kt$$

Which is almost equal to the underlined entry in bold in Table A2, and the difference results from rounding errors.

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[8] Global figures are presented in uppercase, whereas India's figures are lowercase.

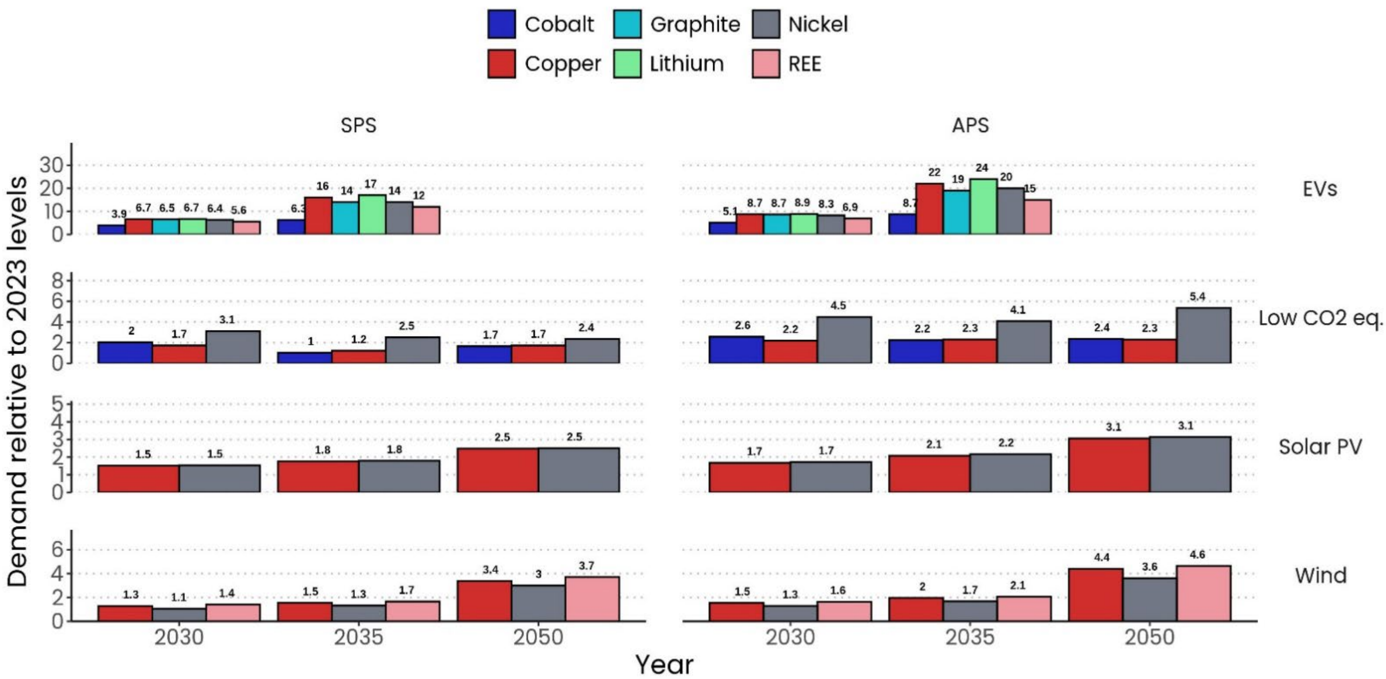
Table A2. Critical minerals demand per technology and policy scenario

Technology	Metal	SPS 2023	SPS 2030	SPS 2035	SPS 2050	APS 2023	APS 2030	APS 2035	APS 2050
Wind	Copper	20.28	26.10	31.33	68.33	20.28	31.25	39.82	89.27
Wind	Nickel	1.85	1.96	2.44	5.54	1.85	2.40	3.10	6.68
Wind	REE	0.39	0.55	0.65	1.46	0.39	0.64	0.81	1.83
Solar PV	Copper	93.40	141.41	164.13	231.90	93.40	156.91	194.30	285.72
Solar PV	Nickel	0.03	0.05	0.06	0.08	0.03	0.06	0.07	0.11
Hydrogen	Cobalt	0.00	0.05	0.02	0.03	0.00	0.07	0.03	0.07
Hydrogen	Copper	0.00	0.14	0.07	0.08	0.00	0.22	0.10	0.21
Hydrogen	Nickel	0.00	56.83	28.33	31.59	0.00	85.27	37.96	83.61
Low CO_2 eq.	Cobalt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low CO_2 eq.	Copper	5.85	10.16	7.21	10.14	5.85	12.85	13.54	13.49
Low CO_2 eq.	Nickel	8.42	26.21	21.18	19.85	8.42	37.75	34.34	**45.05**
EVs	Cobalt	1.43	5.59	9.02		1.43	7.31	12.45	
EVs	Copper	9.14	61.04	145.67		9.14	79.83	199.86	
EVs	Graphite	26.47	173.37	359.43		26.47	229.43	499.72	
EVs	Lithium	1.91	12.87	32.65		1.91	16.99	45.24	
EVs	Nickel	6.91	43.96	98.80		6.91	57.11	135.27	
EVs	REE	0.15	0.85	1.80		0.15	1.05	2.32	

Note: Quantities expressed in thousands of tonnes.
Source: Authors' calculations using IEA data (2024b, 2024c)

Demand multipliers

Figure A1. Critical minerals' demand multiplier per technology and IEA scenario



Note: **SPS**: Stated Policies Scenario; **APS**: Announced Pledges Scenario. EV deployment figures were only available until 2035, which explains the sudden disappearance in 2050. Low CO_2 eq. technologies comprise nuclear, and modern liquid, gaseous and solid bioenergy.
Source: Authors' calculations using IEA data (2024b, 2024c)

S&P Global's risk assessment

S&P Global conducts country risk analysis for over 200 countries and territories, providing a comprehensive assessment of the investment environment. The methodology aggregates six main risk categories: political, economic, legal, tax, operational and security. Each category is further subdivided into specific risk factors. For example, *political risk* includes government instability, policy instability, and state failure; *economic risk* considers inflation, currency depreciation and sovereign default; and *legal risk* evaluates expropriation and contract enforcement. Similarly, *tax risk* captures fiscal unpredictability, *operational risk* covers corruption and infrastructure disruptions, and *security risk* addresses threats such as terrorism, civil unrest and interstate conflict.

These sub-categories are scored individually and then aggregated into their respective main categories. The six category scores are later averaged into an overall strategic risk score, which reflects the expected level of risk for private enterprises operating in each jurisdiction. Scores are expressed numerically and translated into descriptive bands: low (0.1–0.7), moderate (0.8–1.5), elevated (1.6–2.3), high (2.4–3.1), very high (3.2–4.3), severe (4.4–6.4) and extreme (6.5–10.0). Table 5.1 presents these aggregated scores, while Table A3 provides the disaggregated category-level scores for the same countries. This framework ensures a standardised and forward-looking approach to evaluating geopolitical, economic and operational risks for FDI decisions.

Table A3. S&P Global's disaggregated risk scores

Country	Overall score	Political	Economic	Legal	Tax	Operational	Security
Australia	1.3 Moderate	1.5 Moderate	1.3 Moderate	1.1 Moderate	1.6 Elevated	1.3 Moderate	1.2 Moderate
Canada	1.3 Moderate	1.2 Moderate	1.7 Elevated	0.6 Low	1 Moderate	1.4 Moderate	1.6 Elevated
Finland	1.3 Moderate	1.2 Moderate	1.4 Moderate	1.0 Moderate	1.2 Moderate	1.5 Moderate	1.3 Moderate
Sweden	1.3 Moderate	1.5 Moderate	1.8 Elevated	0.7 Low	0.9 Moderate	1.2 Moderate	1.7 Elevated
Chile	1.7 Elevated	1.9 Elevated	1.3 Moderate	1.7 Elevated	1.8 Elevated	1.8 Elevated	1.9 Elevated
Portugal	1.7 Elevated	1.9 Elevated	2 Elevated	1.6 Elevated	1.8 Elevated	1.8 Elevated	1.3 Moderate
USA	1.8 Elevated	1.5 Moderate	1.3 Moderate	1.8 Elevated	1.8 Elevated	1.8 Elevated	2.3 Elevated
Spain	1.9 Elevated	1.7 Elevated	2 Elevated	1.9 Elevated	2.3 Elevated	1.7 Elevated	1.7 Elevated
Poland	1.9 Elevated	1.9 Elevated	2.4 High	1.8 Elevated	2.4 High	2.1 Elevated	0.8 Moderate
Botswana	2 Elevated	2.2 Elevated	1.9 Elevated	1.7 Elevated	2.2 Elevated	2 Elevated	1.8 Elevated
Peru	2.1 Elevated	2.9 High	1.1 Moderate	2.1 Elevated	1.9 Elevated	2.8 High	1.9 Elevated
Bulgaria	2.1 Elevated	2.7 High	2 Elevated	2.1 Elevated	1.8 Elevated	2.3 Elevated	1.6 Elevated
Philippines	2.2 Elevated	1.9 Elevated	1.5 Moderate	2.2 Elevated	2.1 Elevated	2.7 High	2.7 High
Indonesia	2.2 Elevated	2.0 Elevated	1.9 Elevated	2.2 Elevated	1.9 Elevated	2.8 High	2.3 Elevated
Mongolia	2.2 Elevated	1.9 Elevated	3.0 High	2.3 Elevated	2.6 High	2.6 High	0.9 Moderate
Brazil	2.3 Elevated	2.0 Elevated	2.4 High	1.9 Elevated	2.8 High	2.7 High	1.7 Elevated
Kazakhstan	2.3 Elevated	2.0 Elevated	2.7 High	2.7 High	2.2 Elevated	2.7 High	1.4 Moderate
Serbia	2.3 Elevated	2.3 Elevated	2.2 Elevated	2.4 High	2.1 Elevated	2.5 High	2.2 Elevated
Mauritania	2.3 Elevated	1.8 Elevated	2.5 High	2.1 Elevated	2.4 High	3.3 Very High	1.9 Elevated
Armenia	2.3 Elevated	2.3 Elevated	2.1 Elevated	2.5 High	2.1 Elevated	2.4 High	2.3 Elevated

Source: Adapted from S&P Global (2025a; 2025b)