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TESS Forum on Trade, Environment, & the SDGs

GENEVA GRADUATE INSTITUTE

GENEVA PLATFORM RESILIENT VALUE CHAINS

Critical Minerals

Trade, Climate, and Net Zero Pathways: Scenarios and Implications for Developing Countries and Climate-Resilient Development

Peter Wooders & Simon Lobach

TESS Forum on Trade, Environment, & the SDGs

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About This Series of Sectoral Briefing Notes

This briefing note is part of a series of sectoral notes commissioned by TESS intended to inform a final report on *Trade and climate scenarios on the road to 2050: Implications for developing countries and climate-resilient development*.

The series and the report aim to provide an overview of current and anticipated transformations in trade on the road to 2050 in the context of the unfolding climate crisis and the international community's climate action agenda and to discuss potential scenarios and implications for developing countries.

A wider objective of the series is to contribute to a better understanding of emerging trade and trade policy trends and dynamics and their implications within the various sectors, with a focus on supporting developing countries in identifying and advancing their climate change trade-related interests and priorities in international discussions.

The sectors covered in the series include agriculture, carbon markets, critical minerals, digital trade, fisheries, energy transition, heavy industries, shipping, and textiles, each authored by experts in these respective fields.

Abbreviations

CBAM	Carbon Border Adjustment Mechanism
CTIP	Clean Trade and Investment Partnership
ESG	Environmental, Social, and Governance
EU	European Union
GHG	Greenhouse Gas
ICMM	International Council on Metals and Mining
IEA	International Energy Agency
OECD	Organisation for Economic Co-operation and Development
US	United States
WO	World Trade Organization

1. Critical Minerals and Mining in the Context of Climate Change

The energy transition is having an enormous impact on the demand for critical minerals. Mineral demand is expected to double, or even quadruple, by 2040, depending on the stringency of climate action adopted (IEA, n.d.-a).[1]

Half of the increase in critical mineral demand is projected to come from the electrification of personal vehicles (see Figure 1) and the production of batteries (for use in electric vehicles, electricity grid storage, and other purposes). At the 2023 United Nations Climate Change Conference, over 130 parties pledged to triple their renewable power capacity by 2030 (COP28 UAE, 2023)—which automatically translates into higher demand for critical minerals. Other energy transition activities that will lead to significant hikes in mineral demand include power generation (especially offshore wind but also solar), electric cabling, and hydrogen production.

Simultaneously, there is little sign that mineral demand from sectors not related to the energy transition will go down. Critical minerals are essential to semiconductors and defence industries, for example, and the extraction of minerals required for the energy transition is thus expected to occur in addition to existing mineral demand.

Additionally, as the ores with the highest metallic content are the first to have been mined and exhausted, mining companies are forced to move to increasingly low-grade ores, which further increases the total ore volume that our economies require (Rötzer & Schmidt, 2018).

Figure 1. Minerals and Metals Required for the Production of Electric Vehicles and Their Source

27 58.933 **Co** Cobalt	**Cobalt** 13.3 kg DR Congo 73.9%, Indonesia 7.4%, Russia 3.8%, Australia 2.0%
3 6.9410 **Li** Lithium	**Lithium** 8.9 kg Australia 47.8%, Chile 24.4%, China 18.3%, Argentina 5.3%, Brazil 2.7%
28 58.693 **Ni** Nickel	**Nickel** 39.9 kg Indonesia 50.0%, Philippines 11.1%, France (New Caledonia) 10.6%, Russia 5.6%, Canada 5.0%
25 54.938 **Mn** Manganese	**Manganese** 24.5 kg South Africa 36.0%, Gabon 23.0%, Australia 15.0%, Ghana 4.2%, China 3.7%, Brazil 3.1%
6 12.011 **C** Carbon	**Graphite** 66.3 kg China 76.9%, Madagascar 6.3%, Mozambique 6.0%, Brazil 4.6%.
26 55.845 **Fe** Iron	**Iron ore** Australia 39.3%, Brazil 18.7%, China 11.3%, India 11.3%.
57-71 89-103 **REE** Rare Earths	**Rare Earths** 0.5 kg China 68.6%, USA 12.3%, Myanmar 10.9%, Australia 5.1%.
29 63.546 **Cu** Copper	**Copper** 53.2 kg Chile 22.7%, Peru 11.8%, DRC 11.4%, USA 5.0%, Russia 4.1%.

Note: The figure indicates the minerals and metals for electric vehicles by weight (in kg) and leading producing countries (in percent of production). For graphite, only natural (mined) graphite is included in this percentage, even though electric vehicles may also contain synthetic graphite. For iron, the iron content in raw ore has been used for calculating the percentages. For copper, raw unprocessed ore has been used

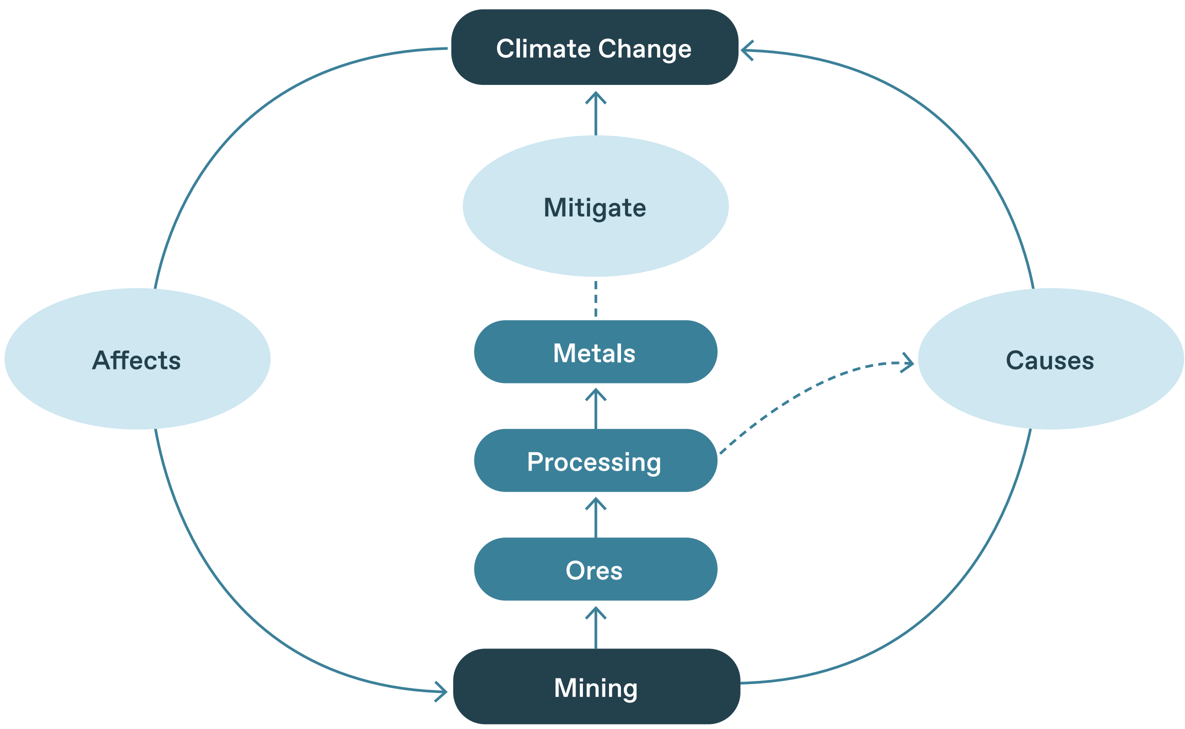
Source: Compiled from Hendriwardani and Ramdoo (2022) (metals used in EV production); USGS (2024) (cobalt, lithium, nickel, manganese, natural graphite, iron ore, and copper); and USGS (n.d.-a) (rare earths).

1. Section 2 of this paper discusses critical minerals in detail, including how they are defined and where they are mined and processed.

Interlinkages Between Critical Minerals and Climate Change

The positioning of the mining sector in environmental debates is two-sided. The mining industry is actively associating itself with a "green" image, given the importance of critical minerals for the energy transition (Archer & Calvão, 2024). At the same time, mining itself has important environmental impacts. The expansion of mining worldwide leads to the generation of mining waste, greater energy use, and increased greenhouse gas (GHG) emissions. Figure 2, schematically illustrates the interlinkages between mining and processing of critical minerals and climate change.

Figure 2. Interlinkages Between Mining and Processing of Critical Minerals and Climate Change



Source: Authors' elaboration.

While most of the emissions resulting from the mining sector are caused by iron and steel production, the role of critical minerals in GHG emissions is significant. In recent years, the production of critical minerals has represented approximately 4% of total global emissions, mainly attributable to aluminium production (2.8%—calculated on the basis of International Aluminium Association (n.d.)), followed by nickel (0.3%) (CarbonChain, 2024), and copper (International Copper Association, 2022). A large share of these emissions derives from the processing of mined ores (Lehne, 2024). Additionally, coal is used to process some critical minerals, including significant shares of copper and aluminium output; and the use of coal for these purposes is rising. Due to these and other factors, GHG emissions from critical mineral production for the energy transition are rising consistently (Fahimi Bandpey et al., 2024). Although the mitigation of GHG emissions from technologies using critical minerals tends to be much larger than the emissions from critical mineral production, net zero scenarios require the progressive elimination of all sources of GHG emissions.

Mitigating the Climate Impact of the Mining Sector

International commitments for the mining sector to contribute to mitigation, adaptation, and loss and damage with regards to climate change have been made at the multilateral level (among states) and at the sector level (industry standards).

In order to meet climate agreements and national net zero pledges, governments have created a range of mechanisms for mining companies to phase out their GHG emissions. These include rules and regulations, fiscal measures, subsidies, and investments in research and technology. Several countries have outlined these policy choices in their nationally determined contributions (Schaap & Karamira, 2024).

Reducing GHG emissions from critical mineral production should be obtained through changes in production processes and efficiency gains (including through circularity and recycling), while the use of critical minerals for products unrelated to the energy transition should be reduced to the extent possible. Colombia, for example, in its National Mining Policy ("A new vision of mining in Colombia"), highlights the objective of considerably expanding its mining activities to meet demand for critical minerals, but in a way that lowers the carbon intensity of its mining sector as a whole (Government of Colombia, 2023).

The industry is also adopting voluntary standards, and several mining companies are experimenting with technologies to ultimately eliminate GHG emissions from their operations, including through: on-site renewable energy generation and storage (including through pumped hydro); electrification of mining equipment and processing; process optimization (including through digital technologies); using hydrogen; carbon capture and storage; and replacing diesel-power crushing and grinding with hydrometallurgy and biomining and relying on living organisms to retrieve metals from deposits (Ahmad et al., 2024; Kaksonen & Petersen, 2023).

Not all mining companies are moving at the same pace, however, with some companies operating internationally having made voluntary commitments to achieve net zero by 2050 while others have not. As a result, a divide is starting to appear within the sector. Organizations like the International Council on Metals and Mining (ICMM) require their members to strive to net-zero by 2050 (ICMM, 2021).[2] Additionally, price premiums exist for low-carbon aluminium (Argus Media, 2024), and the London Metal Exchange is exploring the possibility of implementing a similar premium for nickel (LME, 2024). This divide may become more pronounced as a result of trade measures specifically directed at carbon-intensive goods, such as the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM), which specifically targets aluminium as one of its focus sectors.

Adaptation of the Mining Sector to Climate Change

The mining industry also needs to implement measures to adapt to climate change (Bellois, 2022b). Mining-related adaptation challenges can be divided into three broad categories:

1. *Climate-related direct threats to mining operations.* Examples include: mines at risk from flooding during extreme weather events (BHP, 2019), mines in coastal regions prone to sea level rise, and mines in permafrost regions where global warming may cause soils to become unstable. Extreme weather events and sea level rise may also endanger transportation facilities used for trade in minerals, such as ports or railways for example.

2. *Risks to local communities caused by a combination of mining and climate change*. This can occur, for example, when extreme weather events cause failure in tailing dams, which can endanger human lives and ecosystems in across a vast area (as happened in the Mariana (2015) and Brumadinho (2019) disasters in Brazil).

2. The ICMM is a collaborative group of leading mining and metals companies created to strengthen the industry's contribution to sustainable development.

3. *Water scarcity caused by a combination of mining and climate change*. Climate change may reduce water availability in a given area. If mining operations are also contributing to water stress in this area, this can lead to water disputes between local communities and mining operations, for example in evaporation-based lithium production (Lakshman, 2024).

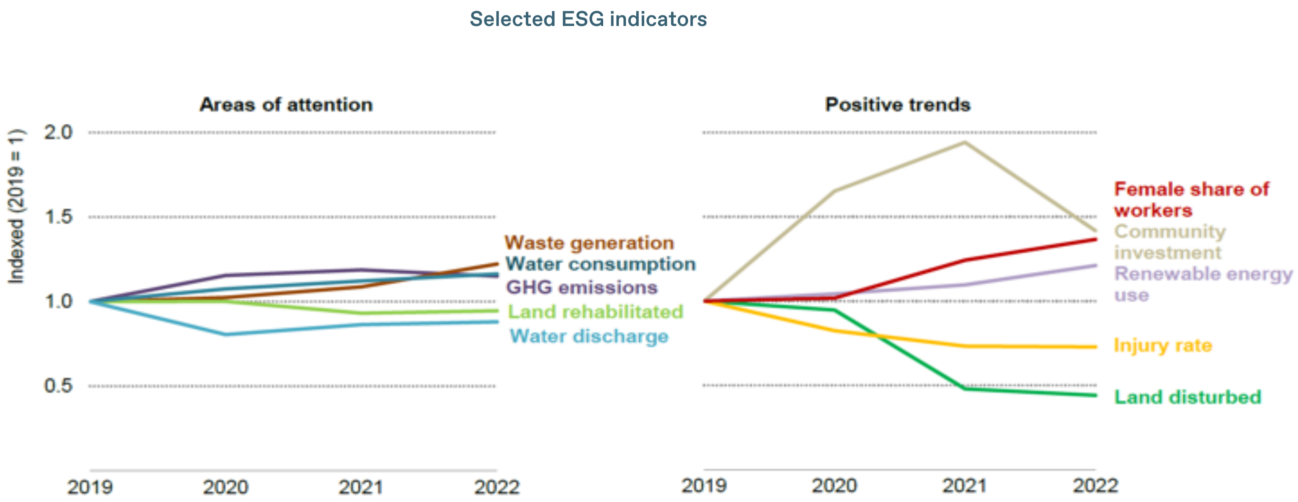
Mining is currently mentioned in only a small share of the national adaptation plans submitted to the United Nations Framework Convention on Climate Change, often together with oil and gas activities. The National Adaptation Planning Global Network has reviewed 59 national adaptation plans and found that only 8 of them (13.5%) include "Mining and/or oil and gas" as a priority sector for climate change adaptation (NAP Trends Platform, n.d.).

Developing countries may have less resources available to ensure that their mining ambitions are climate-resilient, while high levels of dependence on a limited number of minerals may decrease their ability to adapt. Conversely, successful expansion of economic activities linked to critical minerals can allow for increased investments in climate adaptation and mitigation and help address social and other environmental challenges.

Broader Environmental and Social Impacts of the Mining Sector

Sustainability reporting by companies with a strong presence in critical minerals supply chains paints a mixed picture with regards to environmental, social, and governance (ESG) performance. Based on self-provided sustainability reports by some of the main mining companies, Figure 3 illustrates the evolution of mining's ESG impacts between 2019–2022. There are several environmental issues where companies (on average) are not improving their performance, including around water, land rehabilitation, and GHG emissions.

Figure 3. Self-Reported Evolution of Social and Environmental Impacts of Mining (2019-2022)



Notes: Aggregated data for 25 major companies that have a strong presence in critical minerals supply chain. Considers reported data for all operations. Indicators are calculated per tonne of mineral produced—except for injury rate, water recycling, and female share of workers—which reflect the weighted average of production.

Source: IEA (2024).

Sustainability standards help provide a framework for the assessment of performance. However, the large number of competing standards in the mining sector creates complexity, and in recent years there has been a growing chorus of calls for greater harmonization or convergence of ESG standards and sustainability initiatives. In this context, the ICMM, The Copper Mark, the Mining Association of Canada, and the World Gold Council announced in November 2023 that they will seek to consolidate their individual standards into one global responsible mining standard with a multistakeholder oversight system (ICMM, 2023). This collaboration aims to simplify the landscape of standards and sustainability initiatives and drive performance improvements at scale.

Box 1. Summary of the Mining Sector's Net Zero Challenges

1. To significantly increase metal output, especially for the green transition
2. To do so from ores that are increasingly low-grade
3. To do so without causing any GHG emissions by 2050
4. To adapt its operations to reduce climate change vulnerabilities

2. What Are Critical Minerals and Where Are They Produced?

Which Minerals are Critical?

There is no generally accepted definition or list of "critical minerals." The term is often used interchangeably with "critical raw materials," "strategic minerals," and "energy transitions minerals," even though these terms may designate very different things depending on the context in which they are used (Hendriwardani & Ramdoo, 2022). Examples of national and regional definitions include:

- The Chinese government uses an undisclosed list of materials that it considers critical under its 14th Five Year Plan (2021–2026). It can be observed, however, that China's trade policies give special consideration to certain minerals (Andersson, 2024).
- The United States (US) regards as "critical minerals" those minerals that are "essential to the economic or national security of the United States" (USGS, n.d.-b).
- Similarly, for the EU, "critical raw materials" have "economic importance, high risk of supply disruption [...] and [a] lack of affordable substitutes." The EU also distinguishes a subset of critical raw materials that it considers "strategic" based on their expected supply growth and complex production pathway.
- India, in 2025, adopted a National Critical Mineral Mission. This framework, encompassing all stages of the value chain, aims to secure the supply of critical minerals resources vital to green technologies (Prime Minister of India, 2025).

Criticality is thus country- and context-specific and depends on factors such as mineral endowment (including whether the country is a producer or consumer), strategic importance, supply risks, and volatility (Hendriwardani & Ramdoo, 2022).

International organizations like the International Energy Agency (IEA) and the World Bank tend to emphasize the link between critical minerals and the energy transition more explicitly (IEA, n.d.-b; World Bank, n.d.).

Box 2. Definition of Critical Minerals and Minerals Generally Recognized as Critical

This briefing note adopts the definition used by Hendriwardani & Ramdoo (2022), according to which critical minerals can be defined as: "the raw materials—minerals and metals—that are necessary for renewable energy, clean technology, and our transition to a more sustainable, low-carbon future."

Cobalt, copper, lithium, nickel, and graphite are generally recognized to be critical minerals. They are important inputs into renewable energy technologies, batteries, and electric vehicles. In addition, generally included are the 17 "rare earth" elements: a fixed set of metals with similar properties, which are found concentrated in certain locations and used in a variety of clean energy technologies (Alves Dias et al., 2020). Other elements (such as aluminium and manganese) are also often included due to their use in green technologies.[3]

Where are Critical Minerals Mined and Processed?

Large-scale mining occurs in a range of countries, but the location of mines does not necessarily correspond to their ownership. Companies from the Global North play a predominant role in mining worldwide, while China is increasing its influence. For example, Indonesia is the largest processor of nickel, but many of the plants are owned or controlled by Chinese interests (C4DS, 2025).

Moreover, even if mining activity takes place in a variety of countries, mineral processing capacity is often far more concentrated. As illustrated in Figure 4, China dominates global processing of many critical minerals, currently refining a large majority of graphite, rare earths, cobalt, and lithium.

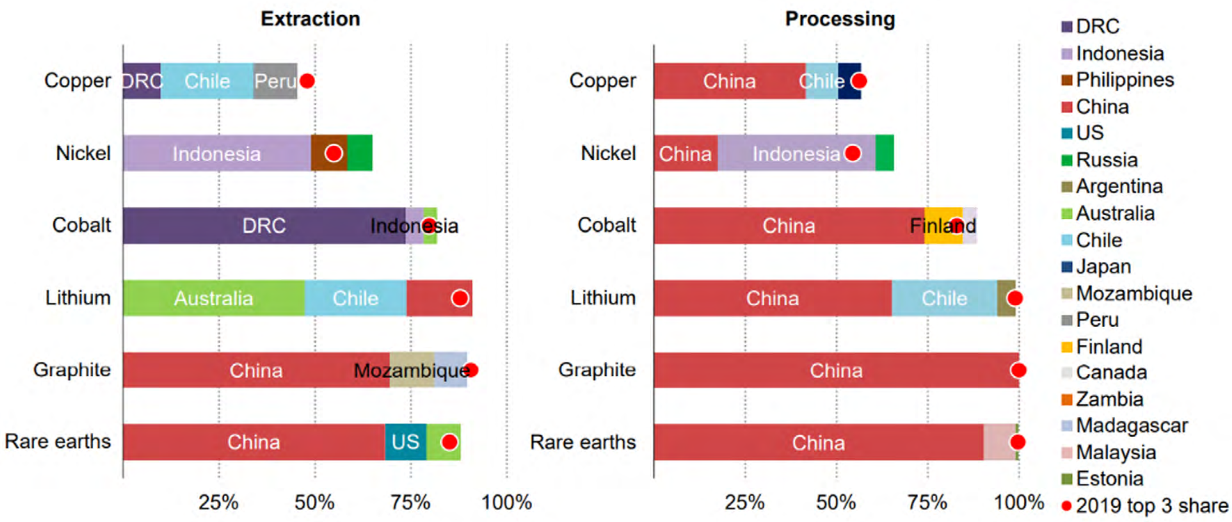
As noted in section 1, demand for critical minerals is projected to rise, with some seeing significant hikes in production. Lithium production, for example, is projected to increase sevenfold, from 0.2–1.4 million tonnes per year between 2025–2040, primarily for use in batteries. Cobalt production, after having doubled over recent years to meet demand for batteries, is expected to continue to grow at an annual rate of over 5% (Jenns, 2025). Copper, aluminium, nickel, and graphite production are projected to double by 2040 for uses related to green energy generation, batteries, and electricity cables (IEA, 2024a).

Where mining and processing will be located to serve this demand is not fixed. Kulik et al. (2025) estimate that 20% of the critical minerals needed in 2035 have yet to be found. At a regional level, the IEA (2024a) projects that the "benefits of market expansion are shared across different regions, especially for mining. Latin America captures the largest amount of market value for mined output with around USD 120 billion by 2030. Indonesia sees the fastest growth, doubling its market value by 2030 due to its burgeoning nickel

3. This sectoral briefing note is part of a series, which includes analysis of the energy transition and heavy industries sectors. There are some overlaps—for example Lehne (2024) on heavy industries includes aluminium—and the briefing note should be read in conjunction with these papers.

production. Africa witnesses a 65% increase in market value by 2030." Investments of around $800 billion will be required "to get on track for a 1.5 °C scenario to 2040." The IEA further projects little change in processing share by location in the period to 2040, despite current government concerns over the need to diversify critical minerals supply chains.

Figure 4. Share of Extraction and Processing of Material Production by Country (2022)



Notes: DRC = Democratic Republic of the Congo. Graphite extraction is for natural flake graphite. Graphite processing is for spherical graphite for battery grade.

Source: IEA (2023).

3. Overview of International Trade in Critical Minerals

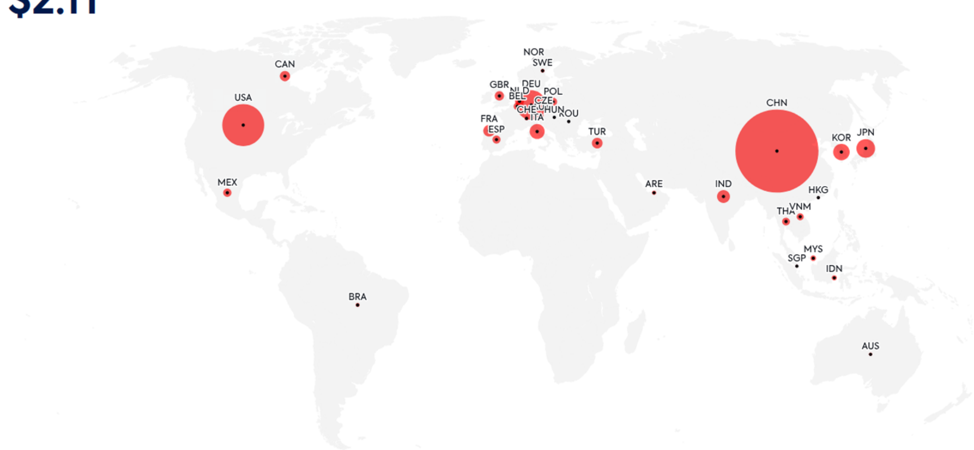
Trade in critical minerals is highly globalized and growing quickly. The World Trade Organization (WTO) estimates that annual trade in energy-related critical minerals has increased from $53 billion to $378 billion between 2002–2022; an average annual growth rate of 10% (Snoussi-Mimouni & Avérous, 2024). In 2022, China accounted for 33% of global total in unprocessed critical minerals, followed by the EU at 16% and Japan and the US both at 11%. Figures 5 and 6 show the total import and export values of all minerals (including critical minerals) in 2022, indicating the main import and export destinations and the top mineral imports and exports that year.

Ores are heavy and bulky and therefore rely on bulk transport solutions: large ships, rail, and large road vehicles. Bulk transport prices have seen high levels of volatility in recent years (UNCTAD, 2024). There are also increasing efforts to decarbonize transport in the transition towards net zero. For example, members of the International Maritime Organization reached an agreement in April 2025 focused on "setting mandatory fuel standards and introducing an industry-wide carbon pricing mechanism" (Mishra, 2025).

Figure 5. Global Mineral Imports and Exports (2022)

Total import value
$2.1T

Imports



Displaying 33 of 145 importers

Top 5 importing countries

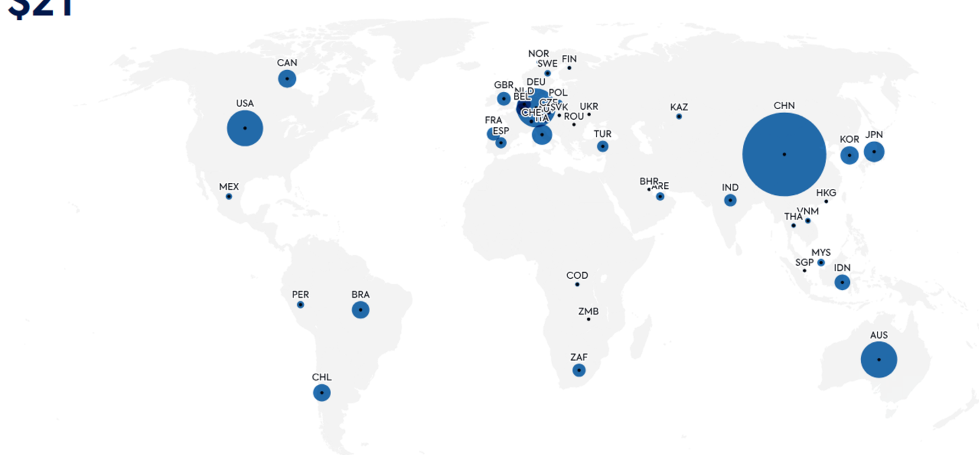
China	$413B
USA	$209B
Germany	$147B
Japan	$93B
Rep. of Korea	$82B

Top 5 mineral related commodities imported

Iron	$1.1T
Copper	$325B
Aluminium	$296B
Nickel	$54B
Zinc	$39B

Total export value
$2T

Exports



Displaying 42 of 145 exporters

Top 5 exporting countries

China	$284B
Germany	$131B
Australia	$123B
USA	$122B
Japan	$71B

Top 5 mineral related commodities exported

Iron	$1.1T
Copper	$287B
Aluminium	$283B
Nickel	$44B
Silver	$35B

Source: Critical Minerals Monitor (n.d.).

Future trends in critical minerals trade will depend on many factors, including the degree of international cooperation and environmental ambition. Kulik et al. (2025) note that 30% of critical mineral flows could be disrupted by geopolitical realignments, which, in turn, will depend on the ability of countries to build up domestic, regional, or "friend-shored" supply chains.

Import and Export Tariffs and Restrictions on Critical Minerals

Import tariffs and restrictions on critical mineral imports tend to be low. Snoussi-Mimouni and Avérous (2024) note that the most-favoured-nation tariffs applied to imports of critical minerals in 2022 were around 4%

while bound tariffs were on average 26%, "indicating significant room for manoeuvre for WTO members to increase their applied tariffs should they need to do so."

There are few examples of significant tariffs or quantitative restrictions on critical minerals imports—the EU's CBAM levied against embodied carbon emissions is an outlier and currently only applies to aluminium within the set of critical minerals. Import tariffs on batteries—which to a large extent are embedded critical minerals—are generally low but some developing countries levy tariffs in the range of 10–20% on imports from China and other producers. Rather, countries have put in place a range of incentives to encourage domestic mining and processing. For example, under former US President Biden, the Inflation Reduction Act and the Infrastructure Investment and Jobs Act granted a range of financial and other incentives to encourage local mining and production of critical minerals, including for semiconductors and defence.[4] The EU is also operationalizing its supply chain diversification strategy, including through the identification of "strategic projects" similarly aimed to "secure and diversify access to raw materials" (European Commission, 2025).

Tariffs and restrictions on critical mineral exports are often much higher than on imports. Much of the current concern around critical minerals is on the ability of import-dependent countries to obtain them reliably and at acceptable prices. In contrast to imports, there are many instances of export tariffs or quantitative restrictions being employed, mainly for economic or geopolitical reasons. The OECD (n.d.) maintains a database on export restrictions of critical raw materials, which "shows a five-fold increase in the export restrictions of CRMs [critical raw materials] since the OECD began collecting data in 2009, with 10% of global trade in CRMs now facing at least one export restriction measure." Export tariffs are the most common measure employed, but there are also examples of quantitative restrictions (e.g. bans, quotas, licencing restrictions), some of which have been implemented in retaliation for other trade policies (Lederman & Barattieri, 2024).[5]

OECD (n.d.) note that "while export taxes and licensing requirements remain the most common restrictive measure for critical raw materials, recent years have seen a sharp increase in quantitative restrictions such as export prohibitions and quotas. Since 2019, export bans have become increasingly prominent, reflecting more assertive policies and efforts to retain value domestically." In 2025, restrictions on exports of rare earth elements from China have received considerable global attention (CSIS, 2025).

International Partnerships and Agreements to Secure Access to Critical Minerals

As countries around the world seek to secure access to critical minerals, many have developed strategies for that purpose and are using trade agreements, foreign investment, and a range of other mechanisms (IEA, n.d.-b). Examples include:

- Chinese institutions and companies have invested significantly in foreign mining and processing, including through the Belt and Road Initiative (Chatham House, n.d.).
- The EU passed its Critical Raw Materials Act in 2023, aiming "to ensure secure and sustainable supply of critical raw materials for Europe's industry and significantly lower the EU's dependency on imports from single country suppliers" (European Commission, n.d.). The bloc has also announced: (i) the first Clean Trade and Investment Partnerships (CTIP), a "mini-trade deal" with South Africa focused on "investment, the clean energy transition, skills and technology, and on developing strategic industries along the entire supply chain" (European Parliament Think Tank, 2025); (ii) a Partnership on Sustainable Raw Materials Value Chains and Renewable Hydrogen with Namibia (European Commission, 2022) and a strategic partnership on raw materials with the Democratic Republic of Congo (European Commission, 2024) ; and (iii) 47 "strategic projects to secure and diversify access to raw materials in the EU" within and outside the EU's

4. At the time of writing (July 2025) both of these initiatives faced an uncertain future as the Trump administration had ordered federal authorities to freeze the disbursement of related funds (Guarna & Turner, 2025; Archer, 2025).
5. Some of these measures have led to legal challenges at the WTO.

territory designed to "boost domestic strategic raw material capacities" (European Commission, 2025). The EU also continues to incorporate sustainability chapters, including provisions on critical minerals, in its trade agreements with partners.

- The US is looking to conclude trade deals to consolidate supply chains for critical minerals feeding industries including defense (Boudreau, 2025). The US has recently signed a memorandum of understanding with the Democratic Republic of the Congo and Zambia for the development of value chains for battery-grade materials and is looking to deepen its cooperation on minerals supply with other African countries through its Minerals Security Partnership Forum (Tucker, 2025).

Groups of countries with common interests have also formed partnerships and cooperation agreements. Beuter et al. (2025) identify almost one hundred bilateral agreements in Africa alone, noting their diversity; with some emphasizing direct state cooperation and others simply seeking to foster an enabling environment for example. A number of these agreements cover social and environmental standards while others do not. An example of note is the cooperation agreement between the Democratic Republic of the Congo and Zambia, which, in the context of rising demand from the battery sector, is based on adding value to the vast cobalt and copper reserves that the countries respectively hold (UNECA, 2022). The Lithium Triangle is another illustration where Argentina, Bolivia, and Chile are cooperating in a variety of ways to realize greater value from their resources.

Table 1 lists a selection of key multi-country partnerships and agreements. These are often reached between developed and emerging economies looking to gain preferential access to the minerals produced in resource-rich developing countries, sometimes with provisions on financial and other resources to increase production.

Table 1. Selection of Critical Minerals Partnerships and Agreements

Partnership or Agreement	Description/Objective*
Australia-Japan-India-US (Quad) critical minerals initiative	Collaboration between the four partners to bolster supply chains for critical minerals and reduce reliance on single countries (e.g. China)
China's Belt and Road Initiative	Mining, processing, and infrastructure investments in a range of countries
EU Critical Raw Materials Act & Global Gateway	EU developing projects and access with a range of partners**
India's Critical Mineral Alliances	Secure access to minerals from countries other than China
Latin America's Lithium Triangle (Argentina, Bolivia, and Chile)	Regional processing in lithium mining and (downstream) battery manufacturing
Minerals Security Partnerships	US, EU, and a range of developed countries aim to develop projects in developing countries through this forum
US-Canada Joint Action Plan on Critical Minerals	Strengthen supply chains between the US and Canada (e.g. to support electric vehicle production)
US-Japan Critical Minerals Agreement	Secure access to critical minerals for both countries

* Beuter et al. (2025) note that "lack of transparency means that the specific provisions of agreements are often difficult to ascertain."

** In its Critical Raw Materials Act, the EU stipulates that no more than 65% of any key raw material should come from a single country (Lee, 2023).

Source: Authors' elaboration based on IEA (n.d.-b).

4. Critical Minerals and Climate-Resilient Development: Key Considerations for Developing Countries

Developing countries' critical minerals strategies can include increasing any or all of extraction, processing, and downstream activities using processed minerals (e.g. the production of batteries or battery components). Imports of critical minerals can create opportunities to expand economic activities, as can circularity and recycling. Greater production can lead to higher exports and/or lower imports. Finally, there are opportunities for countries to increase the provision of services they offer to the mining and critical minerals sectors—this has been an important part of the strategies followed by a number of countries, including Chile's national lithium strategy (Government of Chile, n.d.).

Developing countries need to critically assess whether in their specific circumstances greater engagement in critical minerals production will support climate-resilient development.[6] Benefits and costs should be assessed across economic, social, and environmental dimensions, informed by a range of possible future scenarios and risk assessments. Table 2 provides a list of questions, grouped into five main categories, which can help guide such an assessment.

Table 2. Guiding Questions to Assess Whether Critical Minerals Strategies Will Support Climate-Resilient Development

Economic Case	▪ What are the financial, trade, and geopolitical conditions and considerations around the investment? ▪ How much risk will the country take? ▪ How volatile are product markets? ▪ What incentives could competitors offer? ▪ Are there substitutes which could erode market value?* ▪ Are there downstream opportunities, for example manufacturing of batteries or their components? ▪ How would extraction affect the macroeconomy, for example exchange rates and credit ratings?
Technology and Infrastructure	▪ Does the country possess the necessary technology and infrastructure? ▪ If not, with whom should it partner to get these? ▪ What are the terms and conditions of technology transfer? ▪ Does the implementation of necessary supporting infrastructure (e.g. harbours, roads, electricity generation and grids) require the country to borrow money? If so, under what conditions?
Employment	▪ How many jobs will be created? ▪ Are locals or expats being employed? ▪ What are the points in the project timeline when employment is higher and lower?
Fairness	▪ Does the country receive a fair price for the minerals that it is allowing to be extracted? ▪ How is the revenue being reinvested into the economy? ▪ Who benefits the most from this revenue? Who does not benefit? ▪ Who sees an increase/decrease in their living standards? ▪ What kind of regulatory regimes are needed to make sure that mining-based development is inclusive?
Local Environmental and Health Impacts	▪ Will the project exacerbate local climate impacts? ▪ Does the project take place on land used by local communities, including Indigenous and/or tribal groups? ▪ If so, how will they be affected/compensated? ▪ Are there any other environmental impacts, such as emissions or depositions of toxic substances, flood or earthquake risks related to mineral extraction, or environmental impacts of energy generation (e.g. hydro reservoirs)? ▪ Are there potential human health impacts that need to be considered?

* For example, LFP (lithium iron phosphate) batteries now account for around 40% of the market. They do not need the nickel, manganese, or cobalt required in the competing NMC (lithium nickel manganese cobalt oxides) chemistry. This diversifies the options for battery makers but constitutes a risk for countries that have invested in mining of nickel, manganese, or cobalt.

Source: Authors.

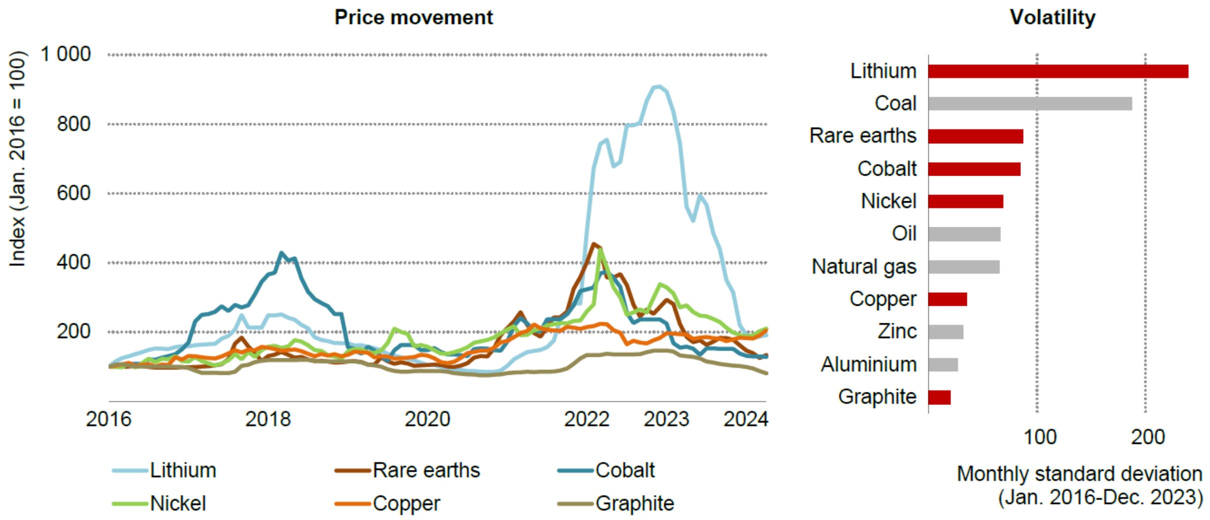
6. The Intergovernmental Panel on Climate Change, in their 6th Assessment Report, define climate-resilient development as "a solutions framework that successfully combines strategies to deal with climate risks (adaptation) with actions to reduce greenhouse gas emissions (mitigation) which result in improvements for nature's and people's well-being – for example by reducing poverty and hunger, improving health and livelihoods, providing more people with clean energy and water and safeguarding ecosystems on land, in lakes and rivers and in the ocean" (IPCC, 2022).

Accounting for Price and Price Volatility

Concerns over the ability of critical minerals supply to meet future demand are often raised. For example, looking to 2035, the IEA (2024a) notes that "[t]here is a significant gap between prospective supply and demand for copper and lithium: Anticipated mine supply from announced projects meets only 70% of copper and 50% of lithium requirements. Balances for nickel and cobalt look tight relative to confirmed projects, but better if prospective projects are included".

However, it should not be assumed that such concerns around future demand and supply of critical minerals will necessarily translate into high prices or profits. The prices obtained for critical minerals may eventually disappoint. The lithium market offers clear recent examples of countries generating lower than expected returns, partially explained by the strong downward trend in battery prices, a sector prone to fierce competition (BMI, n.d.). Moreover, critical mineral prices, notably lithium, have exhibited strong volatility in recent years, more so than for oil and natural gas (Figure 6). Volatility increases uncertainty around investment returns and future prices.

Figure 6. Price Movement and Volatility of Selected Commodities



Notes: Assessment based on the London Metal Exchange (LME) Lithium Carbonate Global Average, LME Nickel Cash, LME Cobalt Cash, LME Copper Grade A Cash prices, China flake graphite (-194 free on board), and neodymium oxide 99.5-99.9% Min China prices.

Source: IEA (2024a).

Increasing Value Addition From Critical Minerals

Although critical minerals are increasingly seen as strategic, standard mining and processing considerations and concerns around greater activity still apply: capital costs are high, markets are volatile and competitive, social and environmental risks are considerable, and new production takes a long time to get online and requires large amounts of capital and know-how (Omonube & Mataba, 2024). Additionally, most developing countries are marginal producers and lack market power (Gaylor et al., 2024).

Table 3 lists the strategies that developing countries can consider to support value addition from critical minerals (see Table 4 for a detailed description of possible trade policy tools and options for international cooperation for each strategy).

Table 3. Strategies to Support Value Addition from Critical Minerals in Developing Countries

Provide incentives for domestic mining, processing, and manufacturing
Promote downstream industries (e.g. metals, batteries, electric vehicles)
Invest in infrastructure (e.g. ports, railways, energy supply)
Strengthen legal and regulatory frameworks (e.g. fiscal regimes, mining codes)
Build human capacity and technology absorption
Promote circularity and recycling
Diversify supply chains and build up strategic reserves
Ensure environmental sustainability and social responsibility

Source: Authors.

One strategy governments can pursue is to encourage foreign investment. Multinationals and sovereign investors have many options and competing countries often need to create attractive investment and regulatory environments to access finance and associated expertise. Stable, predictable, and transparent rules are generally valued by foreign investors. Multiple governments providing incentives for critical minerals production can drive down prices, increasing risks for newcomers in the market, especially countries with limited financial resources. As noted, there are many possible scenarios regarding the future trajectory of critical mineral prices, influencing the profitability of future investment projects—developing country governments must prepare for the full range of possibilities. Efforts among consumers of critical minerals to diversify their supply chains, particularly to reduce their dependence on Chinese minerals, could open opportunities for developing countries to exploit.

Moving downstream of the value chain—into mineral processing, battery production, or associated activities for example—is a strategy that is widely proposed.[7] Some of these industries (e.g. batteries and their components) are highly competitive and mature. Any such strategy should carefully asses the extent to which these markets are accessible. It should also gauge the potential to contribute positively to socio-economic development and state revenues and negatively to pollution and other externalities. Some minerals have substitutes, including for example minerals used in battery cathodes. If a country decides to invest in producing such minerals, it may need to generate a return relatively quickly or risk seeing demand evaporate because of evolving technology choices.

To support value addition, a range of industrial policies (including subsidies and local content requirements) are being tested around the world. These should be carefully considered using the list of guiding questions to assess whether critical minerals strategies will support climate-resilient development identified in Table 2.[8] In addition, some countries have introduced export bans on unprocessed critical minerals in order to incentivize a

7. In considering the use of fiscal incentives as an investment promotion tool, "the increased demand for critical minerals, which could result in some producing countries having more bargaining power than previously, could offer an opportunity to remove overly generous, poorly targeted fiscal incentives. Whereas in the past, incentives have largely been used to encourage investment in mineral extraction (the upstream part of the business), this could be a moment for countries to think more about incentivizing processing, or value addition more broadly, through such measures as performance-based incentives to increase processing capacity" (IGF, 2024).
8. Local content requirements in the mining sector generally means requiring that a percentage of processing is done in a country. This can be successful, but only if the country has the industrial capacity, infrastructure, and skills, and a guaranteed market (e.g. backed-up offtake contracts)—otherwise there are many examples where such measures have not achieved their aims (Ramdoo, 2018).

domestic processing industry.[9] It is too early to assess the effectiveness of such policies, but an important factor to consider is a country's potential market share in any given mineral—without market power, export restrictions are less likely to achieve their policy objectives.

Circularity and recycling can help developing countries comply with external standards and also increase access to critical materials. Battery recycling is becoming a key sector and developing countries should assess their options in this regard and the policies and frameworks—trade and otherwise—needed to support the sector. This may also include the transport and trade of wastes.

Working to high sustainability standards provides another opportunity to enhance value addition. Sustainability standards—many linked to carbon intensity—exert growing influence over critical minerals supply chains, and complying with them will increasingly become a requirement to access markets and, potentially, charge premium prices compared to products that do not meet these standards. However, compliance with such standards can be a challenge for developing countries.[10]

Climate resilience and wider development goals can also be achieved through seeking or requiring mining and processing companies to make specific investments, or use appropriate taxes and royalties, towards these ends (e.g. investments in electricity access, water circularity or desalination, road and rail infrastructure, or infrastructure to support local trade and industrial clustering).

Implementation of a critical minerals strategy needs policy support, including in relation to industry and trade. The development of the critical minerals sector often requires active state involvement, which can come with risks. If policies are "poorly designed and implemented, expanded state participation could result in adverse unintended consequences, including corruption, operational inefficiency, and knock-on impacts on investor confidence" (Omonbude & Mataba, 2024).

5. Options for Trade-Related Policies and Cooperation to Support Climate-Resilient Development

While developing countries have varied experiences in mineral policy, critical minerals are distinctive due to their growing strategic importance and rising demand, which could alter the balance of power and strengthen the negotiating positions of resource-rich countries.

As noted, the appropriate policies to promote value addition are context-specific and depend on factors such as a country's role in the mineral value chain, market conditions, resource scale, infrastructure, investment appeal, and the existence of trade agreements among others. As such, there is no one-size-fits all approach or generic advice on the best mix of policies or measures—both trade and non-trade related—any given country should follow. In addition, countries will seek to pursue varying objectives, including to increase any or all of extraction, processing, downstream industries, critical minerals access, or exports.

Table 4 provides different types of trade and trade-related policy tools developing countries could employ as well as options for trade policy engagement and international cooperation to help achieve three overarching objectives: increase economic activity in the critical minerals sector; increase access to critical minerals; and reduce impacts and support access to export markets.

The strategies to support value addition from critical minerals identified in Table 3 are grouped under these three objectives, and each strategy is associated with a set of trade and trade-related policy tools for consideration and options for international cooperation.

9. This is the case, for example, of Indonesia's nickel policy (IEA, 2024b).
10. "Demonstrating how mineral development will bring positive social benefits on the ground not only for the elites is a must—not only because it is the right thing to do but because it will strengthen the resilience of resource security" (Lee, 2023).

Table 4. Potential Trade Policy Tools and Options for International Cooperation to Support Climate-Resilient Development and Value Addition in Critical Minerals

Objective	Strategy	Potential Trade and Trade-Related Policy Tools	Options for International Cooperation
Increase economic activity in the critical minerals sector	Promote upstream activities in the mining sector, including extraction and related services	Subsidies (including tax breaks and low-interest loans), special economic zones, regulatory measures, public–private partnership (PPP)s, price floors, preferential offtake agreements	▪ Bilateral or regional trade and investment or access agreements (e.g. EU CTIPs), involving, for example, premium prices, offtake agreements, new investments, or technology transfers ▪ Joint investment frameworks with blended finance mechanisms that reduce risk and the cost of capital that would help spearhead and sustain investments in new projects extracting and processing critical minerals
	Promote downstream activities, including domestic transformation and value addition	Industrial policies (e.g. subsidies, local content requirements, export restrictions or taxes, intellectual property rights, standards and regulations), public–private partnerships, public procurement of manufactured goods	▪ Regional integration schemes (e.g. AfCFTA) to foster the development of regional supply chains allowing for transformation and value addition ▪ Bilateral or regional trade and investment or access agreements involving support measures for local transformation and value addition (e.g. joint investment frameworks with blended finance mechanisms or public-private partnerships that reduce risk and the cost of capital for investment in processing critical minerals) ▪ Clarifying international disciplines applicable to subsidies and trade-related investment measures (e.g. on local content requirements), intellectual property rights, and export restrictions and prohibitions and how they should be allowed/applied (with a view to minimizing trade distortions)
	Invest in infrastructure (e.g. ports, railways, energy supply)	Government subsidies and more general expenditure Trade and investment facilitation measures aimed at improving infrastructure for critical mineral trade routes and energy supplies	▪ Regional trade infrastructure initiatives and integration schemes (e.g. the Lobito Corridor between Angola, Democratic Republic of the Congo, and Zambia) to foster modernization of transport and logistics, linking mineral-rich regions to global markets and promoting value chains. ▪ Investment from multilateral development banks, international financial institutions, multinational firms (where investments in infrastructure can be conditional on wider agreements granting access to resources), export credits
	Strengthen legal and regulatory frameworks (e.g. fiscal regimes, mining codes); and build human capacity and technology absorption	Stable, predictable, and transparent trade rules, ideally accompanied by participatory processes Trade focus in R&D, education, and training	▪ Regional trade integration schemes to help upgrade regulatory frameworks and develop consistent and transparent fiscal and regulatory regimes across different jurisdictions ▪ Establish regional R&D centres
Increase access to critical minerals	Promote circularity and recycling	Recycling programmes and infrastructure development, regulations including enhanced producer responsibility, standards, waste transport, trade regulations	▪ Rules negotiations for cross-boundary transfer of key waste streams, notably used batteries, in line with the Basel Convention and the application of its rules ▪ Regional and global approaches can reduce costs and improve security for all
	Diversify supply chains and build up strategic reserves	Regulations, subsidies, investment in further infrastructure, trade agreements, stockpiling	▪ Regional integration schemes to promote diversification and help develop regional value chains.
Reduce impacts and support access to export markets	Ensure environmental sustainability and social responsibility	Regulations and standards to drive progress towards environmental and social sustainability, and make provisions for end-of-life decommissioning of mines and facilities	▪ Promotion of harmonization, equivalence, or mutual recognition of rules of origin and use of international standards in bilateral and regional agreements ▪ Technical assistance and capacity building to support compliance with emerging ESG requirements ▪ Engagement in development and implementation of private and public standards and technology hubs, pools, and partnerships for sustainable mining and processing technologies

Source: Authors.

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