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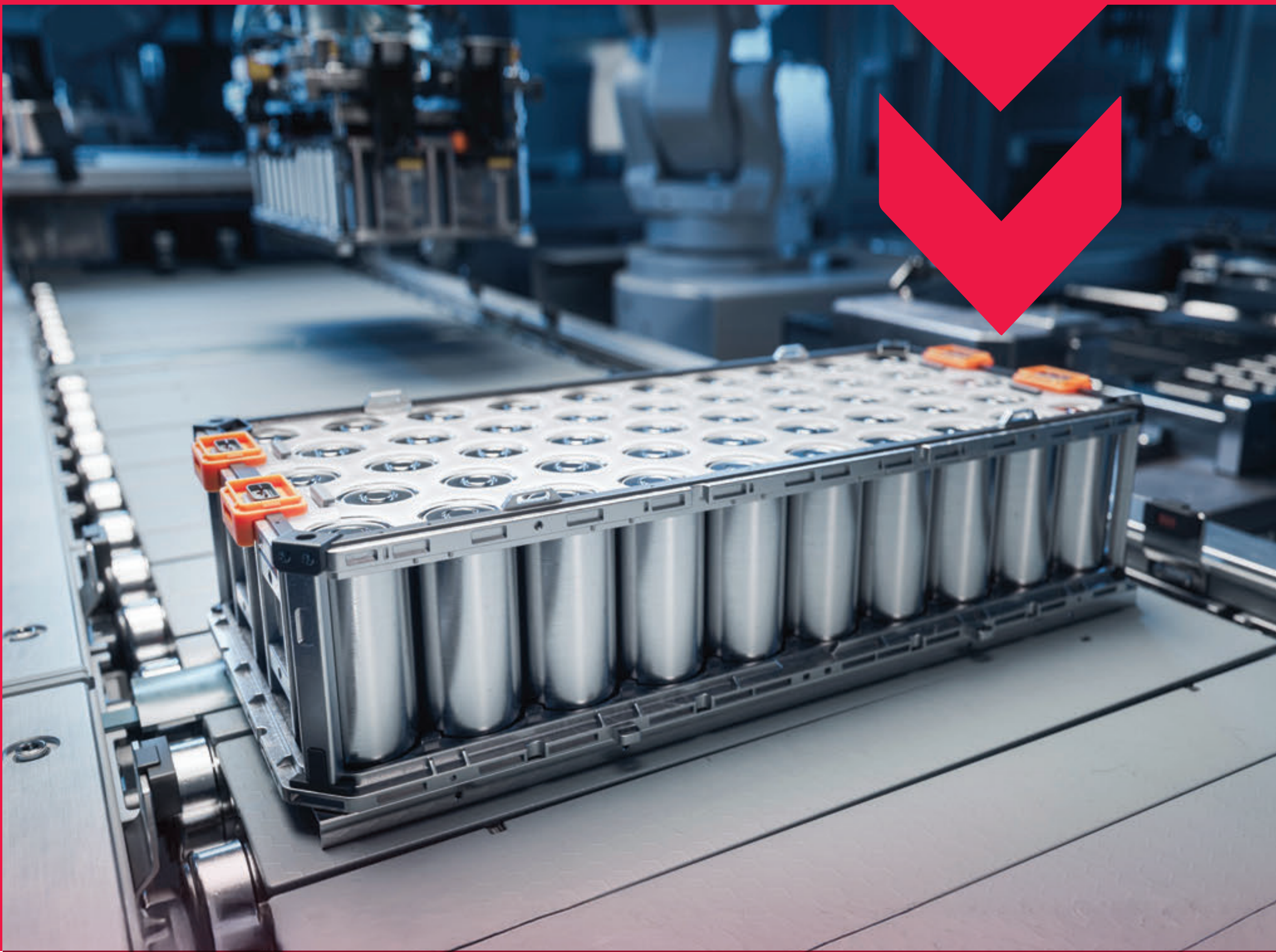

Technical and statistical report

Critical Minerals, Critical Decisions

Industrial Policy for the Energy Transition

United Nations

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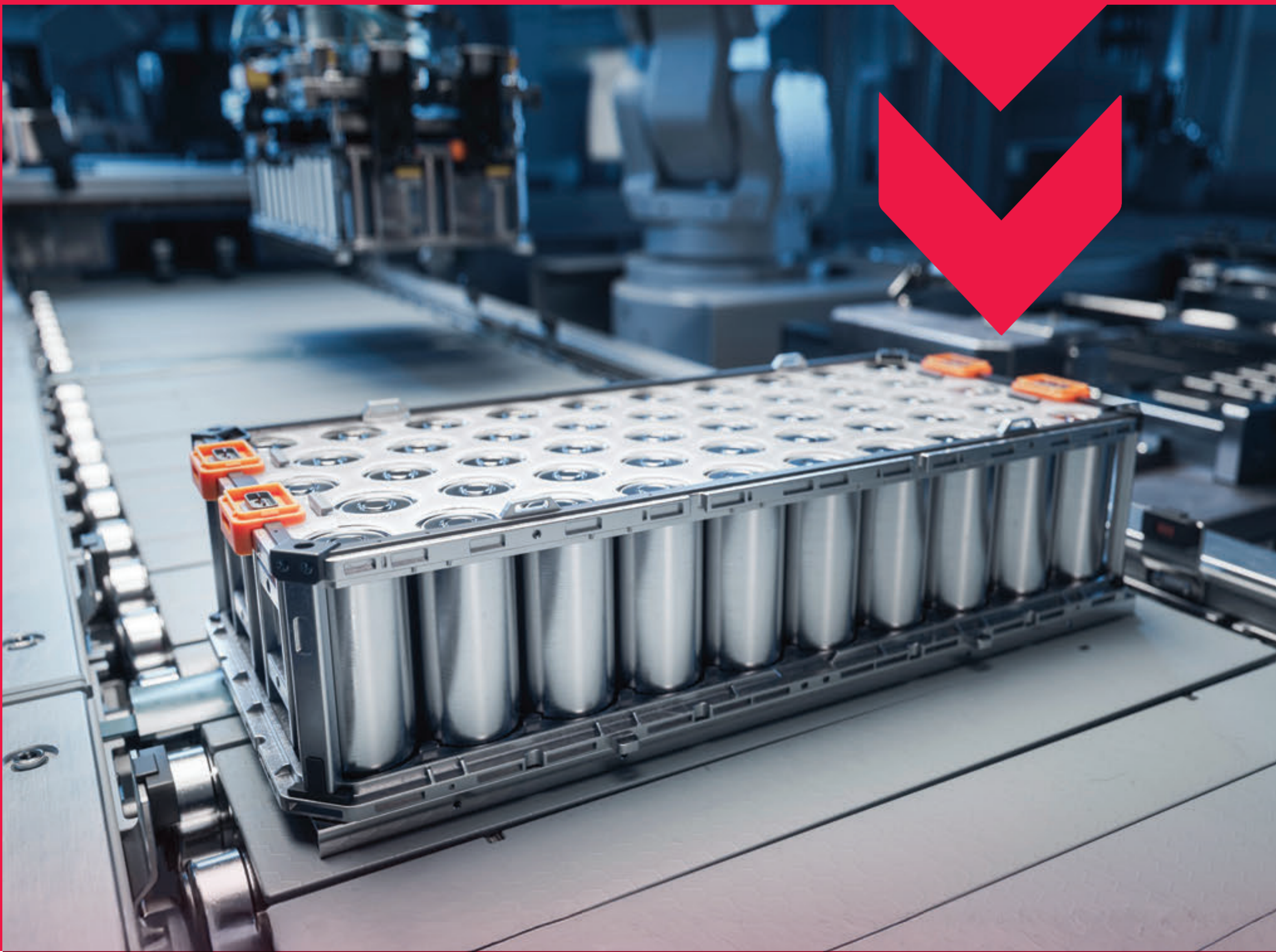

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Critical Minerals, Critical Decisions

Industrial Policy for the Energy Transition

United Nations
Geneva, 2026

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Abbreviations

ADB	Asian Development Bank
AfCFTA	African Continental Free Trade Area
ANM	Agência Nacional de Mineração (Brazil)
BITs	Bilateral Investment Treaties
CELAC	Community of Latin American and Caribbean States
CETM(s)	Critical Energy Transition Mineral(s)
Codelco	Corporación Nacional del Cobre de Chile
CORFO	Corporación de Fomento de la Producción (Chile)
CPRM	Serviço Geológico do Brasil
DLE	Direct Lithium Extraction
DRC	Democratic Republic of the Congo
ECLAC	Economic Commission for Latin America and the Caribbean
ENAMI	Empresa Nacional de Minería (Chile)
EPE	Empresa de Pesquisa Energética (Brazil)
ESG	Environmental, social and governance
EU	European Union
EV(s)	Electric Vehicle(s)
FTAs	Free Trade Agreements
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GVC(s)	Global value chain(s)
HS	Harmonized System
IBRAM	Instituto Brasileiro de Mineração
IEA	International Energy Agency
LDCs	Least Developed Countries
MFN	Most-Favoured-Nation
MME	Ministério de Minas e Energia (Brazil)
OECD	Organisation for Economic Co-operation and Development
PGMs	Platinum-group metals
PNM 2030	Plano Nacional de Mineração 2030 (Brazil)
R&D	Research and development
REE(s)	Rare Earth Element(s)
SCM	Subsidies and Countervailing Measures (Agreement)
SDGs	Sustainable Development Goals
SEIA	Sistema de Evaluación de Impacto Ambiental (Chile)
SMEs	Small and medium-sized enterprises
STEPS	Stated Policies Scenario
TBT	Technical Barriers to Trade (Agreement)
TRIMs	Trade-Related Investment Measures
TVET	Technical and vocational education and training
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNU-WIDER	United Nations University World Institute for Development Economics Research
US	United States
USGS	United States Geological Survey
WNA	World Nuclear Association
WTO	World Trade Organization

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Executive Summary

Critical energy transition minerals (CETMs)- such as lithium, copper, nickel, cobalt, graphite, and rare earth elements - are at the core of the global shift to low-carbon energy systems. For developing countries, these resources offer both a major opportunity for structural transformation and a risk of renewed dependency if managed without a coherent industrial strategy.

This study examines how countries can leverage critical minerals for sustainable growth while navigating constraints imposed by global trade rules, investment treaties, and shifting geopolitics. Regional cooperation and value-chain integration are identified as essential to expand markets, share infrastructure, and build collective resilience.

The study underscores that industrial policy must go beyond promoting value addition or moving from mining to processing. It should aim to foster broader economic diversification by strengthening backward, forward, and lateral linkages between the mining sector and other productive sectors of the economy, to harness critical minerals for structural transformation and sustainable development.

Drawing on case studies from Latin America (Brazil, Chile, Argentina) and Africa (Namibia, Zambia), the report finds converging policy priorities: capability building, value addition, sustainable governance, and institutional coordination.

Key Recommendations

To transform critical mineral wealth into sustainable and inclusive development, countries may consider adopting integrated governance and industrial policy frameworks aligned with national and regional priorities. This requires:

1. **Promoting domestic value-chain development and diversification** by strengthening mining linkages across the economy through targeted incentives, technology transfer, and skills formation.
2. **Building strategic partnerships** that expand access to finance, innovation, and markets while preserving policy space.
3. **Ensuring policy coherence** across fiscal, industrial, trade and environmental domains to link resource extraction with long-term diversification.
4. **Embedding sustainability, transparency, and community participation** in all stages of the value chain.
5. **Advancing regional cooperation** on market access, infrastructure, standards, and research to deepen value addition and diversification, and strengthen collective bargaining power.

Together, these measures can help developing economies turn critical minerals into engines of low-carbon industrialization and shared prosperity.

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I. Introduction

- **The global energy transition is fundamentally mineral-intensive,** creating new dependencies, vulnerabilities and development opportunities that differ sharply from the fossil-fuel era.
- **For developing countries, critical energy transition minerals (CETMs)** represent both a pathway to structural transformation and a risk of renewed extractive dependence if managed without an active industrial strategy.
- **Market forces alone are unlikely to deliver inclusive and sustainable outcomes,** given high concentration, geopolitical risks, and environmental and social externalities along CETMs value chains.
- **Harnessing CETMs for development** requires industrial policy embedded in broader strategies of diversification, capability-building and regional cooperation, rather than a narrow focus on extraction or processing.

The transition towards a low-carbon, sustainable economy depends on the reliable supply of critical minerals that are indispensable for renewable energy technologies, energy storage systems, and advanced manufacturing. From lithium, cobalt, and nickel used in batteries to rare earth elements (REEs) essential for wind turbines and electric vehicle (EV) motors, the new energy paradigm is strikingly more mineral-intensive than the fossil-fuel era it seeks to replace. Whereas traditional energy systems relied heavily on a narrow range of carbon-based resources, emerging clean technologies require a broader array of metallic and non-metallic minerals—often in larger quantities per unit of final output. This shift is redefining the global map of resource importance, creating new dependencies and vulnerabilities across energy, trade, and economic development dimensions. It also presents a unique opportunity for developing countries to leverage their mineral wealth to build productive capacities, diversify their economies, and accelerate structural transformation, as highlighted by recent international assessments (IEA, 2021; World Bank, 2020; UNCTAD, 2023).

However, the existence of mineral endowments alone does not guarantee development outcomes. The experience of many resource-rich developing countries underscores that extractive activity, in isolation, often yields limited local value addition and fails to generate structural transformation. Several factors can contribute to this outcome. First, market imperfections—stemming from high entry barriers to informational asymmetries and volatility of commodity prices—tend to discourage long-term investment in domestic value chains. Second, the global mining and processing industries remain highly concentrated, with a small number of firms and countries exercising oligopolistic control over key segments of production, processing, and technology (UNCTAD, 2022). This concentration amplifies price fluctuations, constrains access to technologies, and limits opportunities for new entrants. Third, considerations of national security, supply-chain resilience, and emerging geopolitical tensions are increasingly shaping policy choices in both producing and consuming countries. Export restrictions, investment screening, and arrangements to reroute supply chains to countries perceived as politically and economically safe or low risk to avoid disruptions illustrate how strategic concerns can override wider economic or developmental objectives. In such a context, reliance on market forces alone is unlikely to yield equitable outcomes or ensure that the energy transition contributes to sustainable development. Instead, proactive and strategic development policy—through industrial planning, capacity-building, and international cooperation—becomes essential to align the exploitation of critical minerals with broader economic and environmental objectives.

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This requires a deliberate effort to foster backward, forward, and sideways linkages across the economy, connecting the extractive sector to manufacturing, services, and knowledge-intensive activities. Mineral-based industrialization must be embedded within broader national development strategies that prioritize employment creation, technological upgrading, and economic diversification.

The challenge of designing such policies is compounded by ongoing debates surrounding the definition and scope of critical minerals. While the term is by now widely used, its meaning varies according to context, methodology, and institutional perspective. National and regional lists of critical minerals often reflect security of supply concerns, technological relevance, and/or economic priorities rather than uniform global standards. To address this fragmentation, the United Nations Secretary-General's Panel on Critical Energy Transition Minerals (CETMs) has proposed a harmonized framework distinguishing minerals that are critical for achieving the energy transition and the Sustainable Development Goals (SDGs) from those considered strategic for other purposes (United Nations, 2024) The Panel's definition emphasizes three interrelated criteria: (i) the essentiality of a mineral to low-carbon technologies, (ii) the vulnerability to supply disruptions due to market or geopolitical factors, and (iii) the potential for adverse social, environmental, or governance impacts if not managed responsibly.

This definitional clarity matters for policy. By focusing on CETMs rather than a broader list of "critical" minerals policymakers can more effectively target interventions that advance both decarbonization and development. It allows for prioritizing minerals whose supply stability, governance, and environmental footprint have disproportionate influence on global progress toward sustainable development. Furthermore, adopting an UN-led conceptual framework helps to anchor national and regional policies in a coherent multilateral discourse, facilitating cooperation, transparency, and shared accountability across CETMs value chains. Building on this conceptual framework, UNCTAD's List of Critical Minerals[1] sets out a review of strategic minerals for developing economies, mapping existing classifications of critical minerals. This facilitates statistical analysis of what makes minerals critical for both developed and developing economies, contributing towards a comprehensive list of critical minerals for trade and development. The approach also reinforces the importance of aligning mineral governance with the broader agenda of productive transformation, understood as the process through which economies diversify their production structures, upgrade technological capabilities, and shift labour and resources toward higher value-added activities. In line with UNCTAD's long-standing analysis in

1 https://sdgpulse.unctad.org/critical-minerals/

its Trade and Development Reports and Least Developed Countries Reports, mineral governance should therefore be embedded within development strategies aimed at structural transformation, rather than treated as a stand-alone extractive policy domain.

This report therefore adopts UNCTAD's approach to the classification of CETMs, in particular, the main elements of their value chains and the role of industrial policy in harnessing these resources for sustainable and inclusive development. Ultimately, the report aims to contribute to a more equitable and coordinated approach to CETMs, consistent with UNCTAD's mandate on trade, development and structural transformation, the findings of the United Nations Secretary-General's Panel on Critical Energy Transition Minerals, and the broader objectives of the 2030 Agenda for Sustainable Development and the Paris Agreement. It calls for an integrated governance and industrial policy framework centred on economic diversification, structural transformation, regional cooperation, and a development-oriented multilateralism, grounded in expanded policy space, coordinated industrial strategies, and international cooperation, that enables developing countries to build productive capacities, upgrade within and across value chains, and pursue sustained structural transformation (UNCTAD 2023 and 2024).

II. Mapping the Geography of Critical Energy Transition Minerals: Global Production, Value Chains and Economic Implications

- **Global production and processing of CETMs are highly concentrated geographically,** exposing supply chains to disruption and reinforcing asymmetric power relations between producers and consumers.
- **The distribution of reserves differs markedly from current production patterns,** indicating significant latent potential but also long lead times, technological barriers and investment risks.
- **CETMs exhibit distinctive economic characteristics**—such as by-product dependence, capital intensity and modest market size—that complicate supply responses and governance.
- **Participation in CETMs value chains is uneven across stages,** with processing and refining capturing a disproportionate share of value added and learning opportunities.
- **Without strong governance and environmental safeguards,** expanding CETMs supply risks reproducing extractive development patterns that undermine both sustainability and social legitimacy.

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2.1 The Global Landscape of Critical Energy Transition Minerals

The green transition relies heavily on mineral inputs that differ significantly in type and volume from those used in conventional fossil-fuel–based systems. Wind turbines, photovoltaic panels, and other renewable energy infrastructure rely heavily on copper, aluminium, nickel, and rare earth elements for their construction and operation and are significantly more mineral-intensive than fossil fuel–based technologies in terms of material inputs per unit of capacity or output (IEA, 2021; World Bank, 2020). For example, an onshore wind plant requires multiple times the mineral inputs of a natural gas plant of equivalent capacity while EVs require six times the mineral inputs of internal combustion engine vehicles, with battery production alone accounting for a substantial share of this increase (IEA, 2022, and Hund et al., 2020). Moreover, the deployment of large-scale energy storage systems—a prerequisite for balancing intermittent renewable energy generation—further amplifies the reliance on CETMs (World Bank, 2020).

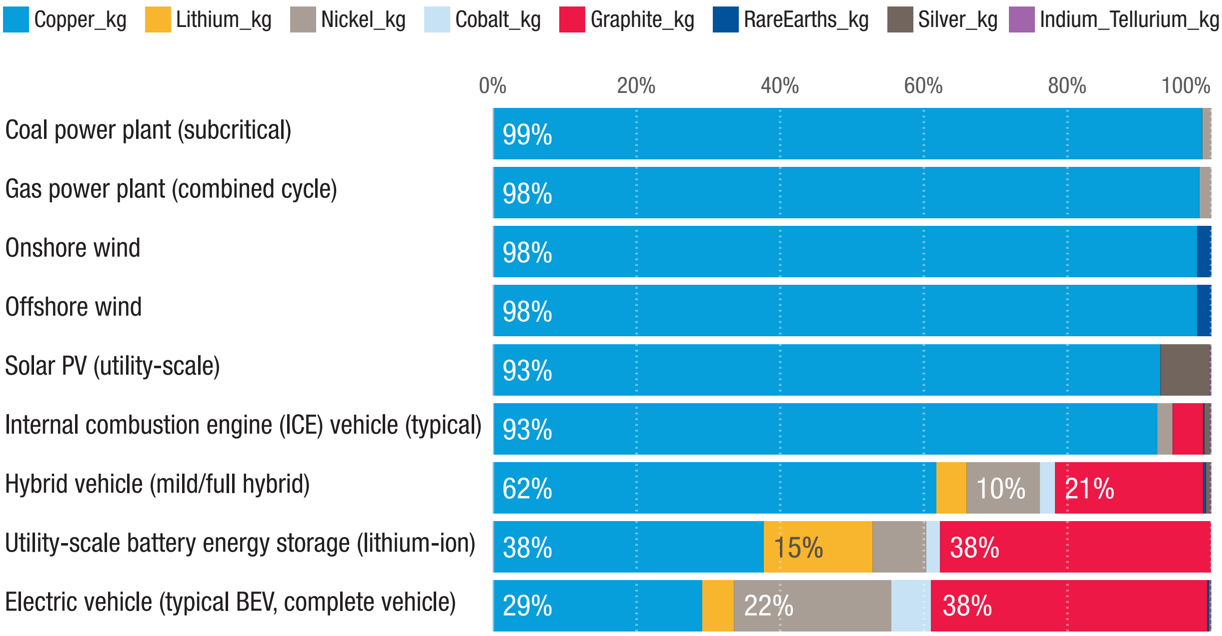
Demand dynamics

Global demand for critical energy-transition minerals is rising rapidly. In the IEA Stated Policies Scenario (STEPS) (IEA, 2025), lithium demand is projected to increase fivefold by 2040, graphite and nickel are expected to double, cobalt and rare earth elements to rise by 50–60%, and copper by about 30%, underscoring its continued importance in electrification and renewable energy infrastructure.

While certain minerals are uniquely tied to specific applications and others serve as foundational inputs across diverse technologies (see Figure 1), each critical mineral plays a distinct role in enhancing the functionality and efficiency of clean energy systems. For example, lithium, cobalt, nickel, and graphite are indispensable to produce high-performance batteries that power EVs and can store renewable energy for grid scale storage. Copper, with its superior conductivity, is essential for expanding electricity networks and integrating renewable sources into the grid. REEs, such as neodymium and dysprosium, are critical for manufacturing the permanent magnets used in wind turbines and electric motors, allowing for compact, high-efficiency designs. Similarly, geothermal energy depends on nickel and chromium to construct durable materials capable of withstanding the high-pressure, high-temperature conditions deep underground where Earth's heat is harnessed. In hydrogen technologies, platinum-group metals[2] (PGMs), such as platinum and palladium, act as catalysts in fuel cells, enabling the conversion of hydrogen into electricity with minimal emissions. Furthermore, lesser-known critical minerals like niobium and molybdenum are also essential to the energy transition. Niobium improves EV performance and safety, supports energy storage, and reinforces infrastructure, while molybdenum enables high-strength steel for wind turbines and enhances solar panel efficiency.

[2] PGMs are palladium, platinum, iridium, osmium, rhodium, and ruthenium.

Figure 1.
Selected CETMs used in selected clean energy transitions

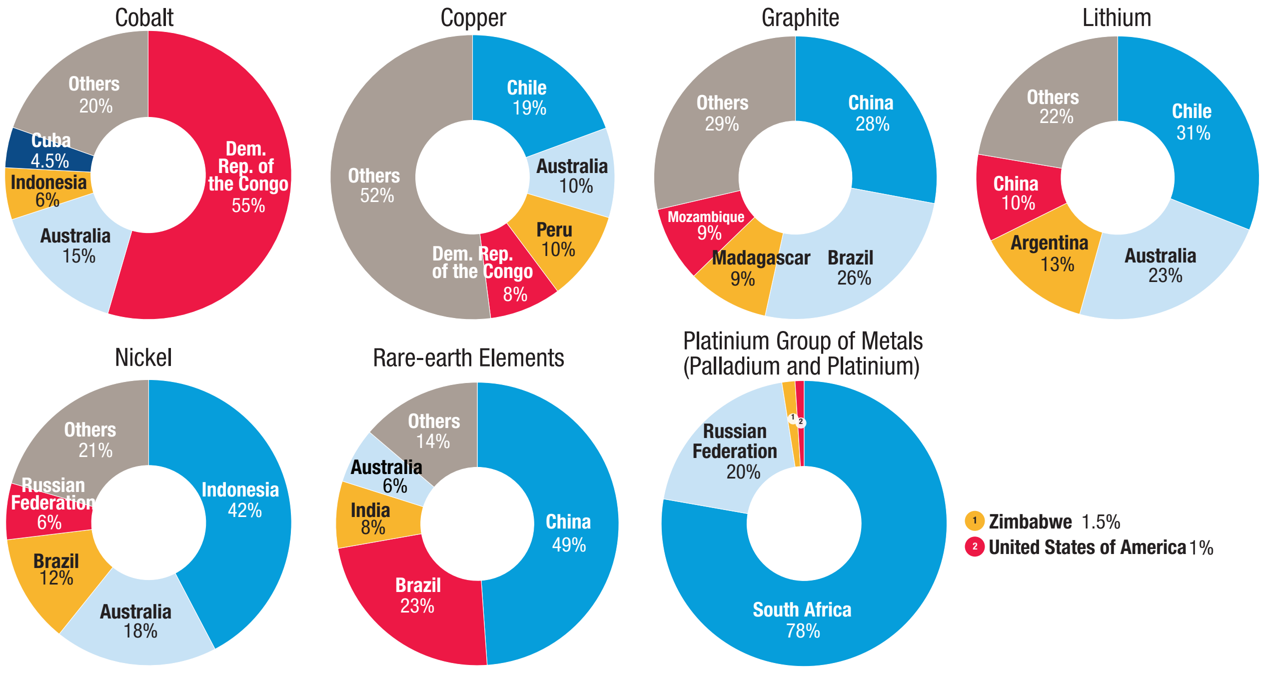


Source: IEA (2021), The Role of Critical Minerals in Clean Energy Transitions, Figures on pp. 7 and 28; WNA (2024), Mineral Requirements for Electricity Generation.

A defining feature of critical energy transition minerals (CETMs) is the high concentration of both reserves and production, albeit with important differences between the two, which create distinct vulnerabilities in global supply chains. On the production side, output of several CETMs is dominated by a small number of countries. In 2024, Indonesia and the Philippines accounted for more than two-thirds of global nickel production, while the Democratic Republic of the Congo supplied nearly three-quarters of global cobalt output. Australia and Chile together represented over half of global lithium production, and China dominated the mining and processing of natural graphite and rare earth elements (REEs). Such concentration at the production stage heightens exposure to supply disruptions arising from geopolitical tensions, trade measures, or domestic policy changes in key producer countries (USGS, 2023).

At the same time, the geographical distribution of reserves only partially overlaps with current production patterns. While some producing countries also hold large shares of global reserves—such as Chile and Australia for lithium, or South Africa for platinum group metals—significant CETMs reserves are located in countries where production remains limited or undeveloped. This includes, for example, Greenland and Ukraine for REEs and other strategic minerals, and Venezuela for certain battery-related minerals. These gaps between reserve endowment and actual production reflect technological, infrastructural, environmental, and political constraints, as well as the long lead times and high capital intensity characteristic of mining investments. Distinguishing between reserves and production is therefore essential for understanding both current supply-chain risks and the potential future reconfiguration of CETMs value chains. Figure 2 illustrates the distribution of reserves of selected critical minerals by country.

Figure 2.
Mineral Reserves by Country (2024, percentage)



Source: UNCTAD based on data from USGS (2023).

Uneven production patterns further reinforce the dominance of a few key players in the global supply of critical minerals. For example, in 2024, Indonesia and the Philippines were leading producers of nickel (68.4 per cent), while the Democratic Republic of the Congo supplied near 76 per cent of global cobalt output. Australia and Chile are top producers of lithium (57.1 per cent), with Australia leading in hard-rock mining and Chile in brine extraction. China plays a dual role as both a major producer and dominant processor of several minerals, including REEs and graphite (69.2 and 79.4 per cent of world production, respectively), giving it significant leverage across the supply chain. South Africa remains the world's largest palladium and platinum producer, accounting for over half of global output. China, Chile and the Democratic Republic of the Congo concentrate over 53 per cent of world copper. Table 1 below shows the share of leading producers of selected critical minerals.

The concentration of critical mineral reserves and production in a small number of countries raises pressing concerns about supply chain resilience and equitable access. This imbalance grants key producers considerable leverage over the flow of raw materials that are essential to advancing the global energy transition. For importing nations, reliance on a limited pool of suppliers creates vulnerabilities, requiring them to manage supply risks and intensifying competition for secure and affordable access. The uneven distribution of these resources reinforces the urgency of developing diversified, transparent, and robust supply chains. It also underscores the importance of international cooperation, the development of harmonized sourcing standards that promote responsible and transparent mineral supply chains, and the adoption of inclusive strategies to ensure that the benefits of the energy transition are shared equitably and achieved in an environmentally and socially sustainable manner across all regions.

Table 1.
Mineral production by country (2024, percentage)

Country	Metric tons	Percentage
Cobalt	**290,000**	**100.0%**
Dem. Rep. of the Congo	220,000	75.9%
Indonesia	28,000	9.7%
Russian Federation	8,700	3.0%
Philippines	3,800	1.3%
Others	29,500	10.2%
Copper	**50,000**	**100.0%**
China	13,800	27.6%
Chile	7,200	14.4%
Dem. Rep. of the Congo	5,800	11.6%
Peru	2,990	6.0%
Others	20,210	40.4%
Graphite	**1,600,000**	**100.0%**
China	1,270,000	79.4%
Madagascar	89,000	5.6%
Mozambique	75,000	4.7%
Brazil	68,000	4.3%
Others	98,000	6.1%
Lithium	**240,000**	**100.0%**
Australia	88,000	36.7%
Chile	49,000	20.4%
China	41,000	17.1%
Zimbabwe	22,000	9.2%
Others	40,000	16.7%

Country	Metric tons	Percentage
Nickel	**3,700,000**	**100.0%**
Indonesia	2,200,000	59.5%
Philippines	330,000	8.9%
Russian Federation	210,000	5.7%
Canada	190,000	5.1%
Others	770,000	20.8%
Platinum Group of Metals (Palladium and Platinum)	**360,000**	**100.0%**
South Africa	192,000	53.3%
Russian Federation	93,000	25.8%
Zimbabwe	34,000	9.4%
Canada	20,200	5.6%
Others	20,800	5.8%
Rare-earth elements	**390,000**	**100.0%**
China	270,000	69.2%
United States of America	45,000	11.5%
Myanmar	31,000	7.9%
Australia	13,000	3.3%
Others	31,000	7.9%

Source: UNCTAD based on data from USGS (2023).

Ultimately, securing adequate, affordable, and responsibly sourced critical minerals will be decisive in meeting net-zero targets and supporting the world's decarbonization trajectory (IEA, 2021; World Bank, 2020). Beyond supply concentration, policy gaps, and underinvestment, environmental risks across the entire mineral value chain—from extraction to processing and refining—pose major challenges to the sustainability of the energy transition. Mining and processing of CETMs are associated with significant environmental pressures, including water depletion, tailings management, energy-intensive refining, and biodiversity loss (IEA, 2021; UNCTAD, 2023). If not properly governed, these impacts risk undermining both climate objectives and social legitimacy, underscoring the need for coordinated action combining industrial policy, environmental regulation, and international cooperation (UNCTAD, 2023)

2.2 Key Distinctive Characteristics of CETMs

While critical energy transition minerals share a number of operational features with conventional mineral commodity ties, the mineral economics literature has long highlighted that certain minerals exhibit distinctive characteristics—related to geological concentration, capital intensity, market structure and strategic relevance—that set them apart in terms of supply dynamics, governance challenges and development implications (Humphreys, 2019; UNCTAD 2023).[3]

First, a large proportion of CETMs are not mined as primary products but rather as by-products or co-products of so-called "host metals", a well-established concept in the mineral economics literature (Frenzel et al., 2017). For instance, antimony is frequently obtained during gold or lead mining; cobalt, bismuth, and tin often occur in copper deposits; and indium is almost exclusively recovered as a by-product of zinc extraction (Nassar, Graedel, and Harper, 2015). This dependency on host-metal production complicates supply security, as the output of CETMs is closely tied to demand trends for their primary counterparts rather than their own markets (Tilton, 2003).

Second, reliable estimates of global critical mineral reserves are difficult to produce. Deposits are highly uneven in their geographic distribution, and not all ore bodies contain recoverable quantities of these secondary elements. Moreover, the technological and industrial capacity to process and refine such materials varies widely across countries, creating additional uncertainty and reinforcing global asymmetries in supply availability (McNulty and Jowitt, 2021).

Third, the overall scale of critical mineral markets remains modest for now when compared with bulk commodities such as oil, gas, or iron ore. In 2023, the combined value of major energy transition minerals was approximately $325 billion—comparable to iron ore but representing only about 5 per cent of the global oil and gas market (IEA, 2024; Kings Research, 2024). Within this aggregate, however, there is substantial variation. For example, in 2022, copper accounted for more than $180 billion in market value, while lead remained under $10 billion (World Bank, 2023; UN DESA, 2025). Such disparities highlight the heterogeneity of these markets, both in size and strategic importance.

2.3 Critical Energy Transition Minerals Value Chains

The value chain of CETMs extends across multiple stages, including geological exploration, mineral extraction, processing and refining, component manufacturing, and eventually recycling

[3] In addition, several studies suggest that CETMs tend to exhibit higher price volatility than conventional bulk minerals, reflecting thinner markets, supply concentration, inelastic short-term supply, and demand shocks driven by rapid technological change and policy shifts (IEA, 2023).

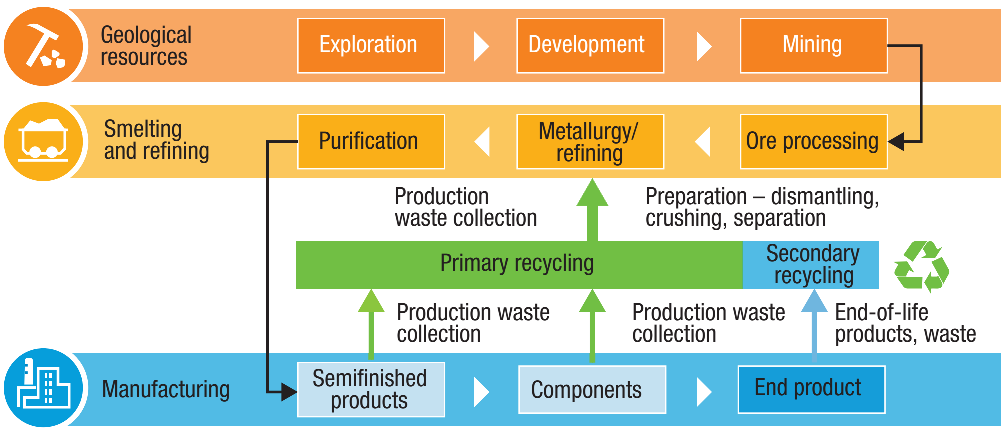
and end-of-life management. Each stage of the chain requires distinct capabilities, infrastructures, and governance frameworks, and the degree of participation by producing countries varies widely.

While the production of CETMs differs in its specific outputs and end uses, its operational dynamics share many similarities with conventional mining activities. Both are highly capital-intensive industries characterized by long project development horizons, often spanning several years before profitability is realized. Moreover, mining enterprises generally operate as price takers within global commodity markets, exposing them to substantial risks associated with volatile price movements, abrupt shifts in demand arising from macroeconomic fluctuations or policy interventions, and the inherent rigidity of supply-side responses (Daly et al., 2022).

Equally important are the socio-economic and environmental implications of critical mineral value chains, which can be substantial and, in some cases, severe. While critical minerals are indispensable for low-carbon technologies, their extraction, processing and refining entail significant environmental risks and social costs if not properly governed. Mining and processing activities can lead to deforestation, land degradation, soil erosion, water depletion and contamination, and the generation of hazardous waste, including radioactive by-products in the case of some rare earth elements. These environmental pressures often have direct social and economic consequences for local communities, including loss of livelihoods, health impacts, displacement, and heightened social conflict, particularly in regions with weak regulatory frameworks and limited institutional capacity (IEA, 2021; World Bank, 2020; UNCTAD, 2023; UNEP, 2023).

Beyond local effects, the environmental footprint of critical mineral value chains extends to downstream stages, notably through energy- and water-intensive processing and refining, which can generate substantial greenhouse gas emissions and pollution if reliant on fossil-based energy systems. As a result, without strong environmental standards, transparency, and lifecycle-based governance approaches, the expansion of critical mineral supply risks reproducing extractive development patterns that undermine both environmental sustainability and inclusive development, even as it supports global decarbonization objectives.

Figure 3.
Schematic Representation of Critical Mineral Value Chain



Source: Asian Development Bank (ADB). Building Resilient and Responsible Critical Minerals Supply Chains for the Clean Energy Transition. ADB Brief No. 298, May 2024, pp. 9 (Figure 1).

The upstream segment begins with geological exploration, which involves the identification and assessment of mineral deposits through geological mapping, geochemical surveys, and advanced remote sensing. This stage is highly capital-intensive and risk-prone, typically dominated by specialized exploration companies or public geological surveys. The quality and accessibility of geoscientific data, as well as the efficiency of licensing systems, play a decisive role in attracting investment and reducing exploration risk.

Following discovery and feasibility studies, the extraction phase converts resources into economically recoverable reserves through mining or brine operations. This stage generates the highest export revenues in many resource-rich economies yet often captures only a modest portion of the total value created along the chain. Extraction technologies differ according to mineral type—ranging from open-pit mining and underground operations for copper and nickel to evaporation and emerging direct extraction processes for lithium. Environmental management, water use, and waste disposal are critical governance concerns at this stage, given the high ecological and social sensitivity of many mining areas.

The midstream stage encompasses refining, chemical processing and the production of intermediate materials, transforming mined concentrates or brines into higher-purity compounds and metals suitable for downstream industrial applications. In many critical mineral value chains, this segment has emerged as a key locus of technological capability and coordination, as it requires advanced metallurgical know-how, reliable energy and water infrastructure, and stable regulatory and investment frameworks.

Empirical evidence suggests that participation in refining and processing remains highly concentrated geographically, with many mineral-producing countries—particularly in the Global South—continuing to export raw or semi-processed materials while higher-value processing activities are located elsewhere. This pattern has contributed to a persistent asymmetry between mineral endowment and industrial integration along critical mineral value chains.

Importantly, however, the developmental significance of the midstream does not lie solely in processing per se, but in its potential to generate backward, forward and lateral linkages with other productive sectors, including manufacturing, services, infrastructure and knowledge-intensive activities. As highlighted in the literature on resource-based industrialization and global value chains, strengthening domestic participation in processing can support learning, capability accumulation and diversification when embedded in coherent industrial policy frameworks and supported by complementary investments in skills, technology and institutions (Pietrobelli et al., 2024). Enhancing participation in this segment therefore depends not only on attracting processing capacity, but on coordinated policies that connect mineral processing with broader strategies for structural transformation.

Beyond refining, the downstream segment uses processed minerals in manufacturing industries, such as batteries, renewable energy components, electronics, and high-performance alloys. These stages typically capture a larger share of total value added along the value chain, reflecting higher levels of product differentiation, branding, and market power (Gereffi et al., 2005; IEA, 2021). They are also associated with significant opportunities for technological learning, particularly in system integration, product design, and incremental innovation. At the same time, important learning dynamics also occur at the processing and refining stages, especially where advanced metallurgical, chemical, and environmental management capabilities are required. The distribution of value added and learning across midstream and downstream segments thus depends critically on the technological intensity of processes, firm capabilities, and the broader industrial ecosystem.

Firms operating in the downstream segment rely on secure supply chains of critical inputs, high standards of material quality, and substantial research and development investment. Countries able to integrate into these segments—through joint ventures, technology transfer, or local manufacturing—capture greater developmental benefits and are concentrated in industrial economies with large-scale technological infrastructures, particularly in Eastern Asia, North America, and Europe.

This spatial fragmentation means that the journey of a single mineral from extraction to final use spans multiple continents. For instance, lithium extracted in Chile may be refined in China, incorporated into a battery cell in the Republic of Korea, and assembled into an EV in Europe or the United States.

Overall, the globalized and fragmented structure of CETMs value chains exposes them to multiple vulnerabilities, including geopolitical tensions, trade restrictions, price volatility, and environmental and social externalities at extraction sites. At the same time, it highlights their strategic role in the energy transition, as no single country controls the full spectrum of activities from resource extraction to high-tech manufacturing.

2.4 Transforming Resource Endowments into Development Gains

Countries endowed with significant critical mineral reserves can, in principle, harness these resources to drive economic growth, attract investment, generate employment, and bolster fiscal revenues. However, this potential does not automatically translate into developmental gains but requires careful managing at macroeconomic and sectoral levels.

2.4.1 Macroeconomic and Distributional Challenges

For resource-rich developing economies, mining often forms a substantial share of exports and GDP. In some developing countries—such as the Botswana, Democratic Republic of Congo, Guinea, Mauritania, Mongolia, Namibia, Peru, and Zambia—it contributes over 50 per cent of merchandise exports and typically between 10 and 20 per cent of GDP. These contributions increase further when indirect upstream and downstream linkages are taken into account, including demand for mining-related inputs and services, as well as activities that use mineral outputs as intermediate inputs across the wider economy. Mining, as a key source of foreign exchange and fiscal revenues, can therefore ease balance of payment as well as wider structural constraints on economic growth and industrial transformation. Increased access to foreign exchange facilitates the import of capital goods, intermediate inputs, and advanced technologies that are essential for industrial upgrading. Similarly, increased fiscal space can help to boost domestic demand and investment and to support economic diversification strategies, provided that mineral revenues are managed in a way that addresses intergenerational equity concerns, given the non-renewable nature of mineral resources.

At the same time, and as the vast literature on commodity dependency in developing countries suggests (e.g. Mohtadi et al, 2021, Van Arnim et al, 2018), high exposure to price volatily in commodity markets, the production structure of commodity sectors and distributional patterns associated with commodity dependency can offset some or all of potential developmental gains. Understanding these dual dynamics—macroeconomic opportunity and structural vulnerability—is therefore central to designing policies that turn mineral wealth into sustained and inclusive development.

As has been pointed out, in the context of CETMs, global demand for minerals such as lithium, copper, nickel and REEs is expected to expand rapidly in response to decarbonization efforts and digitalization (see also, World Bank, 2020). As figures 6 and 9 (see boxes 1 and 2) show, nevertheless this does not mean that price fluctuations for core CETMs, such as Lithium and REEs, do not affect GDP growth in core CETMs-exporting economies with high reserves and production shares for these minerals.

Similarly, other more structural factors that generally affect mineral dependent developing countries also apply to those that are endowed with CETMs. This includes highly centralised production structures for capital-intensive and geographically centred CETMs mineral operations, their dominance by foreign direct investment by few large corporations and societal income and wealth distributional patterns that favour the participation of small segments of society in the use of resource rents (UNCTAD, 2024).

This underscores the importance of industrial and fiscal policy strategies that strengthen production linkages within the mining sector and between mining and other domestic activities, rather than targeting domestic demand in a generic sense. Key channels include fostering backward and forward linkages between extractive activities and local manufacturing and services, promoting infrastructure and logistics development around mining regions, and using public procurement and local supplier development programmes to create stable demand for domestically produced inputs and intermediate goods.

In resource-rich economies, fiscal policy has traditionally been the primary instrument for managing mineral rents, often through taxation and revenue redistribution. While such measures can expand fiscal space and support public investment, experience shows that fiscal tools alone are insufficient to generate sustained structural transformation. Well-designed fiscal instruments—such as stabilization funds, public investment programmes, and time-bound, performance-based incentives—are most effective when embedded within a broader industrial policy framework aimed at building productive capacities, facilitating learning, and supporting diversification beyond extraction (van der Ploeg, 2011; UNCTAD, 2023; UNCTAD, 2024).

The core challenge therefore lies in balancing short-term macroeconomic objectives with long-term industrial upgrading, ensuring that mineral-related foreign-exchange earnings are channeled into productive investment and capability formation rather than remaining confined to consumption smoothing or enclave-type development patterns.

Effective management of CETMs revenues is also essential to prevent macroeconomic distortions. Large inflows from resource exports can lead to an appreciation of the real exchange rate, a phenomenon known as the Dutch disease, that undermines the competitiveness of manufacturing and other tradable sectors (Corden and Neary, 1982; Mien and Goujon, 2022). Sustaining a competitive and stable exchange rate is therefore a cornerstone of a strategy that ensures that resource rents strengthen, rather than erode, the foundations for productive diversification (UNCTAD, 2022; UNCTAD, 2023). Policy tools such as sovereign wealth funds, export taxes, or partial sterilization of inflows can help maintain an industrial equilibrium exchange rate and preserve incentives for innovation and value addition.

2.4.2. Sectoral Opportunities for CETMs

Opportunities for expanding extraction and processing extend beyond traditional mining-dependent economies. Nations, including Brazil (REEs, nickel), Viet Nam (bauxite, REEs), the United Republic of Tanzania (graphite), Mexico (copper), and India (REEs) hold large, untapped reserves, yet contribute modestly to global production (USGS, 2024). This positions them to leverage CETMs for sustainable development and economic diversification.

The sector is also a growing source of employment. Between 2019 and 2022, the workforce in copper and cobalt mining expanded by approximately 8 per cent annually, with projections suggesting a doubling by 2030 (World Bank, 2022); IEA, 2023). While many emerging tasks require high-skilled labour—engineers, environmental specialists, and data analysts—the trend across both developed and developing economies is a shift from routine manual work toward cognitively demanding, non-routine positions (Daly et al., 2022). In lower-income developing countries, however, the expansion of critical mineral extraction may also increase demand for low-skilled labour, including informal or artisanal mining. While such activities provide important sources of income and employment, they are frequently associated with unsafe working conditions and labour risks, underscoring the need for formalization and the enforcement of basic labour standards.

The growth of the CETMs sector can additionally generate opportunities for local businesses and entrepreneurs, particularly in areas such as logistics, equipment supply, and business services (Moritz et al., 2017). Estimates suggest that government revenues from CETMs could reach between $5 billion and $25 billion annually by 2040, with Latin America and the Caribbean and sub-Saharan Africa poised to benefit most, potentially accounting for roughly 1.2 per cent and 0.76 per cent of regional GDP, respectively (UNCTAD, 2024b).

To maximize these development benefits, resource-rich economies should foster productive linkages and expand midstream and downstream activities, including processing and manufacturing. Moving further along the value chain—for instance, into EV battery or photovoltaic module production—offers countries the chance to diversify their economies, increase value-added output, and enhance technological capabilities. Notably, the market value of processed CETMs significantly exceeds that of their raw forms: refined lithium, graphite, nickel and cobalt command prices three to four times higher than unprocessed material (see Table 2).

Table 2.
Added value from extracting to processing selected CETMs, 2022

	Weighted average unit price (US$/kg)		Total value of exports (US$ bn)		
	Raw wmaterials	Processed materials	Raw materials	Processed materials	Battery materials
Cobalt	6.6	20.8	0.2	9.9	10.5
Graphite	0.7	3.3	6.6	2.4	3.7
Lithium	1.7	5.7	20	7.3	51
Nickel	0.1	14.7	4.1	10.4	2.8

Source: UN DESA (2025), Table 3 pp. 16.

Enhancing both upstream and downstream linkages within critical mineral value chains can yield substantial economic benefits, yet many developing countries face significant barriers in realizing this potential. The limitations often stem from gaps in technological expertise, insufficient infrastructure, and constrained access to international markets (UNCTAD, 2021). These challenges are compounded by the fact that processing and manufacturing capacities remain heavily concentrated in a small number of countries, which dominate key stages of the value chain. As a result, resource-rich developing economies may struggle to capture higher value-added opportunities, integrate into global supply networks, and fully leverage their natural endowments to drive industrial diversification and sustainable growth. Addressing these structural bottlenecks through targeted investment, capacity-building, and international partnerships is therefore critical to transforming raw resource advantages into broader economic and technological development.

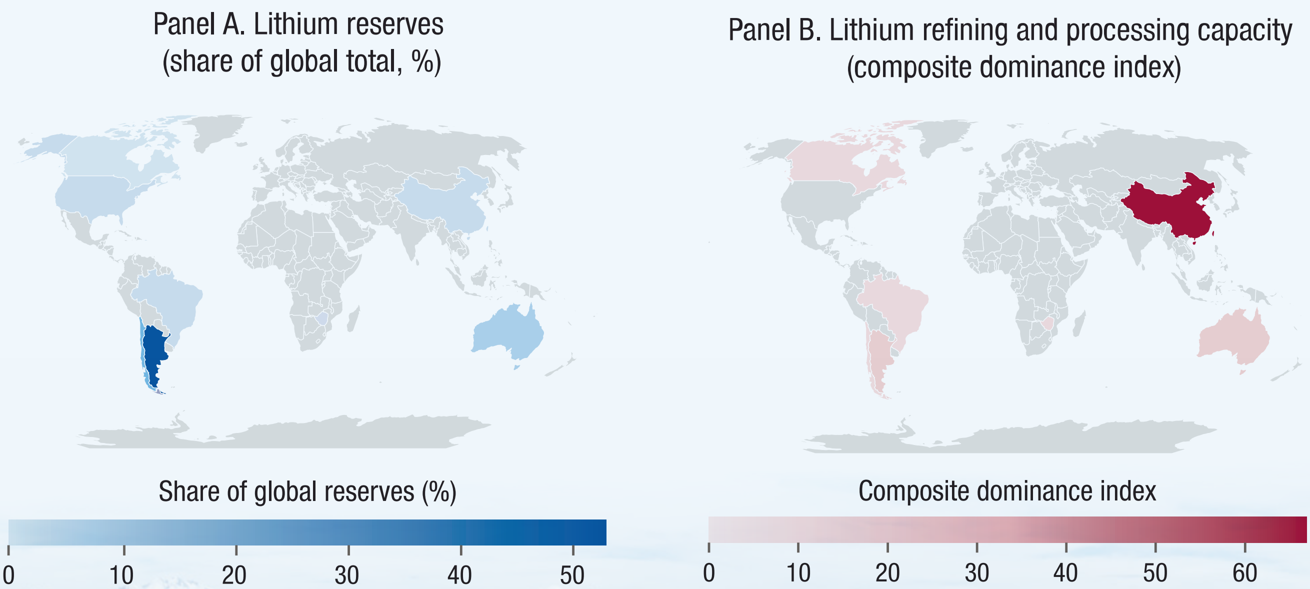
Evidence from a range of country experiences indicates that commodity-rich countries that succeed in moving beyond primary extraction to develop domestic refining and downstream processing tend to achieve markedly higher levels of manufacturing value-addition, more sustained structural transformation and greater resilience to commodity price volatility (see Box 1 and 2). By capturing successive stages of the value chain—smelting, chemical processing, component manufacture and recycling—these economies retain a larger share of rents, foster linkages with local suppliers and service firms, and create more diverse and higher-skilled employment. The consequent multiplier effects stimulate demand for domestic inputs and services, expand the tax base, and catalyse investment in complementary capabilities such as logistics, energy and skills development.

Importantly, countries with integrated downstream capacity are less exposed to the full amplitude of raw-material price swings: refined and manufactured outputs typically enjoy differentiated market positions, longer contractual horizons and greater pricing power than unprocessed ores, thereby stabilising export revenues and public finances. This structural upgrading also facilitates technology absorption and innovation, enabling firms to move up the learning curve and to participate in higher-value segments of regional and global value chains. While the scale and speed of these benefits depend on sound policy design, institutional quality and responsible resource governance, the broad pattern is consistent: beneficiation and domestic processing are powerful drivers of transformation, providing a pathway from resource dependence toward sectorally diversified growth and enhanced economic resilience.

The case of Lithium

Lithium has become a strategic mineral of global importance, underpinning energy transition through its central role for rechargeable batteries in electric vehicles and stationary storage. Demand for lithium has grown steeply over the past decade and is projected to expand further as electrification accelerates. Yet both reserves and production remain highly geographically concentrated, creating structural vulnerabilities for producers and consumers alike. As shown in Figure 4, global reserves are primarily located in the “lithium triangle” of Chile and Argentina where brine-based resources dominate, and in hard-rock deposits in Australia. Although Chile and Australia account for most extraction, downstream refining and processing are even more concentrated, with China holding by far the largest share of global refining capacity despite relatively modest reserves (Figure 4, Panel B). This asymmetry underscores the importance of industrial capabilities for shaping countries’ strategic positions in the battery value chain.

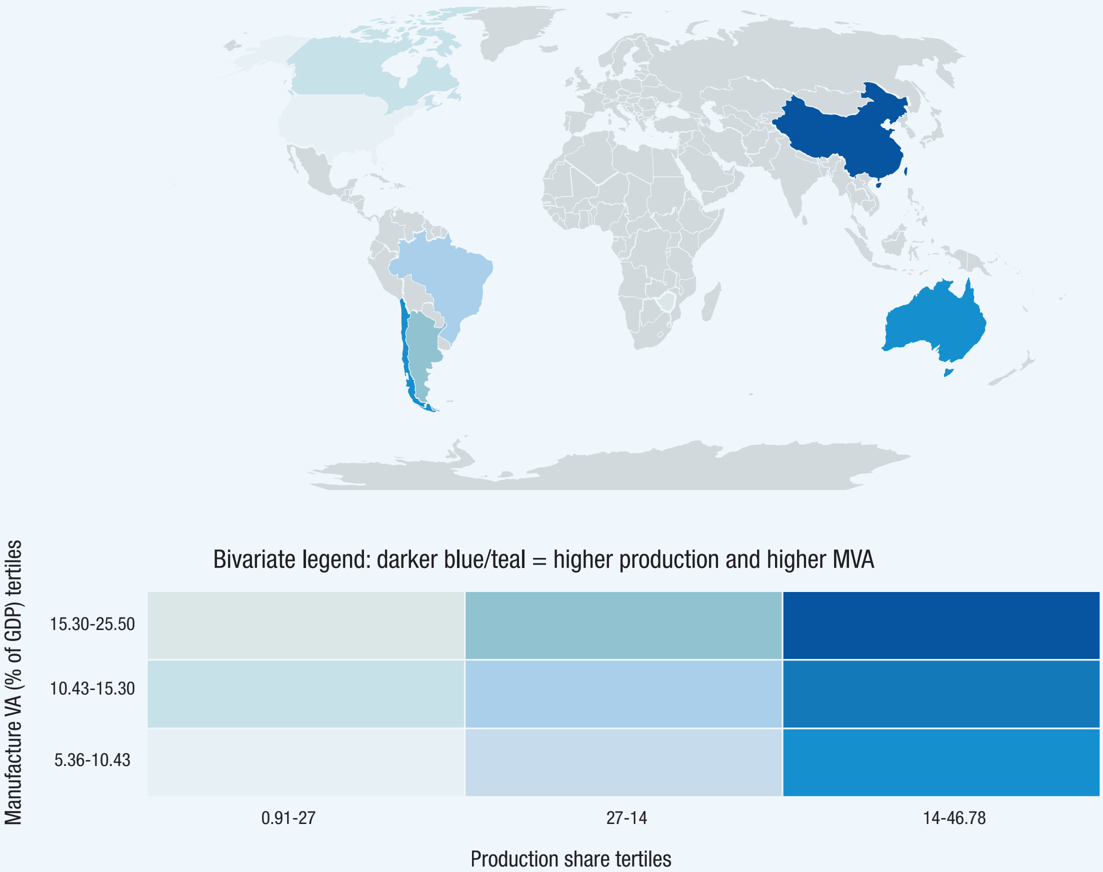
Figure 4.
Share of global lithium reserves and refining and processing capacity, 2023.



Source: U.S. Geological Survey (2023 and 2024).

Figure 5 combines country-level lithium production shares with data on manufacturing value added as a share of GDP. The figure reveals that only China—and to a lesser extent Australia—combines high output with a sizeable manufacturing base. Other major producers, including Chile and Argentina, exhibit relatively low manufacturing intensity. This implies that, while they are resource-rich, their ability to capture domestic value from the lithium economy remains constrained by limited industrial depth (UNCTAD, 2023; IEA, 2023). Strengthening processing, materials transformation and cell manufacturing capacity thus represents an important policy frontier.

Figure 5.
Mined lithium production (share of output, 2023) and manufacturing value added (percentage of GDP, 2022)



Source: World Bank indicators, U.S. Geological Survey (2023 and 2024) and BGS (2023). Bivariate choropleth combining country tertiles for (i) production shares and (ii) manufacturing value added.

Implications for domestic policy support.

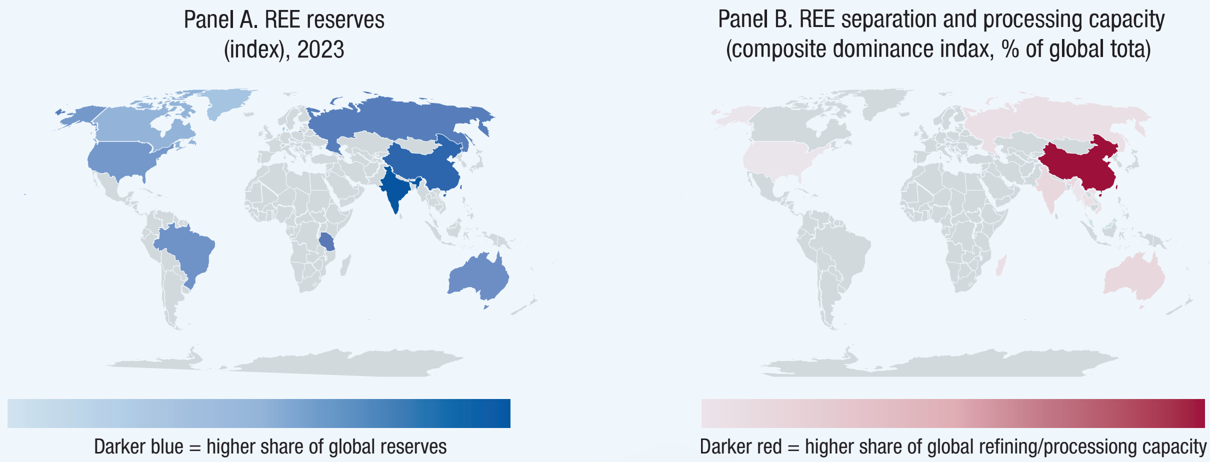
For lithium-rich developing countries, the central challenge lies not only in expanding extraction, but in building upstream and downstream capabilities that reduce vulnerability to price volatility and enhance domestic value addition. This includes investment in refining and processing, incentives for battery-adjacent industries, and the development of skills and technological capabilities needed to participate in higher-value segments of emerging green value chains.

The case of Rare Earth Elements

Rare earth elements (REEs) are indispensable inputs in a broad set of strategic technologies, from electric motors and wind turbines to advanced electronics, defense systems and high-performance magnets. Although REEs are relatively abundant in the earth's crust, economically viable deposits are limited, and extraction and processing are technologically complex and environmentally demanding. As a result, the REE value chain remains highly geographically concentrated.

Figure 6 illustrates this concentration. China accounts for roughly 70 per cent of global REE mining output and over 85 per cent of refining and separation capacity. Other countries with notable reserves—including Viet Nam, Brazil, India and the United States—contribute modestly to global extraction and even less to downstream processing. This concentration heightens the risk of supply disruptions and exposes dependent economies to price volatility and geopolitical constraints.

Figure 6.
Rare Earths mined reserves and refining and processing capacity as a share of the global total, 2023



Source: U.S. Geological Survey (2024).

Figure 7 overlays REE production shares with country-level manufacturing value added. As with lithium, China stands out as the only major REE producer with a comparatively strong manufacturing base. Most other producers—such as Myanmar or Malysia—rank lower in terms of industrial intensity. This structural asymmetry shaping the REE economy demonstrates that resource endowment alone does not confer strategic advantage; industrial capabilities play a central role.

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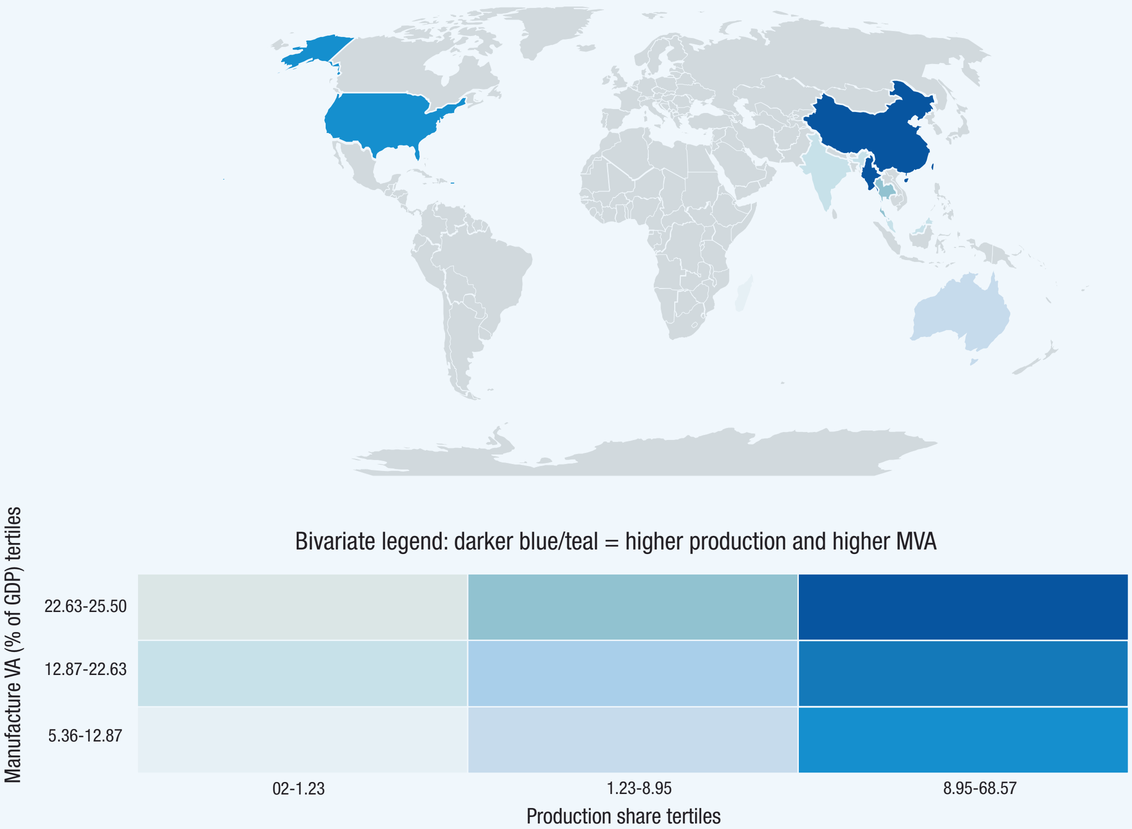
Figure 7.
REE mined production (share of global total, 2023) and manufacturing value added (percentage of GDP, 2023)



Source: World Bank indicators, U.S. Geological Survey (2024); USGS (2023); BGS (2023). Bivariate tertile classification of production and manufacturing intensity.

Implications for domestic policy support.

For REE-rich economies, strengthening domestic capabilities in processing, separation technologies, materials engineering and magnet manufacturing is essential to reducing vulnerabilities, for example to price volatility. Industrial policies fostering research, skills development and environmental management—including solutions to radioactive waste—are critical to building resilient and sustainable REE supply chains. In the case of REEs, recent technological developments may also reshape the strategic landscape of REEs. Several firms, including manufacturers in Europe, are advancing commercial-scale production of electric motors that do not require rare earth permanent magnets, relying instead on alternative motor designs and improved materials engineering. Should such technologies achieve widespread diffusion, dependency on REEs for key segments of the green transition—particularly electric mobility—could diminish. While this does not eliminate the importance of REEs in other strategic sectors, it underscores the dynamic nature of technological change and the need for policy approaches that remain flexible and responsive to shifting industrial demand patterns.

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III. Industrial Policy and the Governance of Critical Energy Transition Minerals

- **CETMs offer a unique opportunity to foster resource-based industrialization,** but only if industrial policy deliberately targets linkages, learning and diversification beyond extraction.
- **Successful strategies require** coherent policy packages combining fiscal, industrial, trade, innovation and skills policies, rather than isolated instruments.
- **Global value chain structures in mining are highly concentrated and hierarchical,** limiting automatic spillovers and reinforcing the need for targeted, coordination-intensive industrial policy.
- **A wide range of supply-side and demand-side instruments remains available,** but their effectiveness depends on policy coherence, institutional capacity and bargaining power.
- **International trade and investment rules constrain some traditional industrial policy tools,** making policy space, sequencing and international cooperation central to CETMs governance.

3.1 The Case for Industrial Policy

Developing countries and emerging market economies could leverage their critical mineral endowments to establish a new developmental energy–mineral complex by diversifying both upstream and downstream into related industries. Backward linkages can emerge through the development of capital equipment manufacturing and mining-related services, while forward linkages can be built through processing, refining, and the production of intermediate and final goods linked to energy transition technologies. Exploiting these linkage opportunities requires cross-cutting industrial, trade, and innovation policies, including skills development, infrastructure provision, and targeted investment support. Such policies need to be embedded within coherent national development strategies that prioritize structural transformation and regional value chain integration.

Transformative opportunities associated with critical minerals and the green transition do not automatically translate into sustained development outcomes. Historical experience shows that, in the absence of a coherent and coordinated policy framework, mineral-led growth strategies have often resulted in enclave-type production structures, limited domestic value addition, and weak employment creation. Past approaches have typically relied on a combination of foreign-led investment, fiscal incentives, and export-oriented extraction, with limited emphasis on building domestic capabilities, infrastructure linkages, or technological learning.

A central constraint has been the high cost, risk, and long-time horizons associated with mineral exploration and development. Exploration activities involve substantial sunk costs, capital-intensive equipment, and lengthy licensing and permitting processes, with mine development cycles often extending over a decade (Wårell & Lundmark, 2008; UNCTAD, 2025). Many developing country governments have faced binding constraints in terms of technical expertise, geological information, and access to long-term finance, limiting their ability to play an active role in early-stage prospecting and project development. As a result, reliance on a small number of large multinational firms has been common, contributing to industry concentration through mergers and acquisitions and reinforcing asymmetric bargaining positions along mineral value chains.

Recent literature highlights that overcoming these structural constraints requires moving beyond narrowly fiscal or investment-led approaches toward integrated strategies that combine industrial policy, competition policy, and regulatory frameworks with targeted investments in infrastructure, skills, and institutional capacity (e.g. Weldegiorgis et al., 2021). Without such an approach, green-transition-related mineral booms risk reproducing patterns of dependent growth rather than supporting durable structural transformation.

Recent structural shifts—greater fragmentation, increasing servicification, and a stronger reliance on localised solutions—have expanded the policy space, creating both opportunities and challenges. While demand for tailored engineering services, processing technologies and capital goods can, in principle, stimulate domestic linkages, these opportunities are often constrained by weak coordination among governments, multinational mining firms and local suppliers. In addition, pronounced price volatility and long investment cycles characteristic of critical minerals complicate investment planning and limit the effectiveness of market-led upgrading strategies. Evidence from critical mineral and rare earth supply chains suggests that participation alone does not automatically generate technological spillovers, as governance structures remain highly concentrated and technology-intensive segments—particularly processing and advanced materials—are frequently retained outside producing countries. These features underscore the need for targeted industrial and coordination policies tailored to the specific organization of critical mineral value chains, rather than reliance on generic export-oriented or Global Value Chains (GVCs)-integration strategies (Morrison et al., 2008; Pietrobelli et al., 2018, 2024).

Experiences with industrial and innovation policies over past decades—marked by both progress and shortcomings—have highlighted several prerequisites that can help foster diversification, structural transformation, and growth. While these factors alone do not guarantee success, they remain extremely relevant when designing policy approaches for the CETMs sector.

The first factor is the extent to which governments recognise the strategic value of these CETMs for domestic and regional industrialisation and production linkages development. By locating domestic strategies as part of regional industrial development plans, countries can exert more bargaining power and realise greater cluster and scale economies.

Second is the extent to which governments are willing and capable to negotiate mineral rights conditions as part of a domestic industrial policy for sustainable structural transformation. In this respect, the introduction of conditionalities on localisation, technology sources and complementary investments are essential.

Third is the capacity to reconcile the short time horizons of political cycles with the much longer periods required for the design and effective execution of industrial and innovation strategies.

Fourth, coherence across the policy framework is indispensable, as policy interventions rarely operate in isolation and their outcomes are often shaped by how they interact with complementary measures (Andreoni and Chang, 2019; Anzolin and Pietrobelli, 2021). Indonesia provides a telling example. Progress in building downstream capacity within the electric-vehicle supply chain has been driven not only by restrictions on nickel ore exports, but also by complementary policy measures, including coordinated investments in energy and transport infrastructure, incentives for processing and battery manufacturing, support for research and skills development, and the creation of dedicated industrial zones (UNCTAD, 2023).

Finally, the extent of bargaining power available to a resource-rich country significantly influences its capacity to engage with foreign governments and mining corporations, thereby conditioning the outcomes of its industrial policy strategies. Once again, we can consider Indonesia that offers a contrasting pair of cases in this respect: the ban on nickel ore exports generated notable downstream gains, whereas a similar restriction on bauxite was far less effective. These divergent results demonstrate that leverage, often derived from the scale and strategic importance of mineral reserves, can be decisive in shaping policy trajectories. Yet resource abundance on its own does not guarantee developmental success. The Democratic Republic of the Congo, despite producing more than 60 per cent of the world's cobalt ore, has struggled to convert this dominance into broader industrial upgrading.

3.2 Industrial Policy for Critical Energy Transition Minerals: A Taxonomy

Beyond mitigating distortions and curbing negative externalities such as pollution, governments may directly shape industrial outcomes through procurement strategies. Yet, effective policy design requires moving beyond a narrow, sector-specific lens. Sustainable development in resource-rich economies depends not only on activities within mining but also on fostering diversification into adjacent industries and knowledge-intensive services, where linkages and spillovers are more likely to stimulate broad-based growth (Dietsche, 2018; Mancini & Paz, 2016).

Rather than treating sectors as monolithic, GVC-oriented approaches highlight the distribution of tasks, the depth of backward and forward linkages, and the power asymmetries between lead firms and suppliers (Pietrobelli et al., 2021). Viewing the mining sector through a GVC lens highlights three characteristics that are central to industrial policy design.

First, mining projects demand large, long-term investments and often rely on imported technologies, making the development of human capital a strategic priority (ICMM, 2018; OECD, 2019). Skills must be cultivated not only through formal education but also through workplace training, with an emphasis on anticipating uncertain technological trajectories. Effective coordination between industry, government, and training institutions is therefore essential (Fessehaie & Rustomjee, 2018).

Second, the sector is characterized by a high degree of concentration and hierarchical value chain governance, in which lead firms exercise significant control over production standards, technology choices, and market access. Such governance structures can limit the scope for supplier entry and learning-based upgrading, particularly for firms in developing economies. Although these barriers discourage inter-firm collaboration, emerging technological niches and localized applications create potential entry points for domestic firms, particularly in supplier markets linked to innovation-driven activities.

Third, the industry's ongoing technological renewal has increased the demand for context-specific process and organizational innovations. Unlike sectors driven by new product development, innovation in mining typically targets efficiency and cost reduction (Andersen, 2012; Iizuka et al., 2022; Fusillo et al., 2024). Building such capabilities rarely occurs autonomously and instead requires selective industrial policies capable of addressing power asymmetries and fostering capability accumulation.

Table 3 introduces the taxonomy of industrial policy instruments for mining global value chains proposed by Anzolin and Pietrobelli (2025). While structural transformation ultimately requires building linkages between the mining sector and a broader set of manufacturing, services and infrastructure activities, such transformation is mediated through concrete policy instruments. The taxonomy does not conceptualize the development of mining GVCs as an end in itself. Rather, it provides an analytical framework to classify the range of supply-side and demand-side instruments that governments can deploy to promote both intra-sectoral upgrading within mining-related activities and inter-sectoral linkages with the wider economy. In particular, demand-side measures—such as public procurement, local content requirements and skills obligations—highlight channels through which mining activities can stimulate broader productive capacities beyond the extractive sector. In this sense, the taxonomy is introduced here as an operational bridge between sector-specific interventions and wider strategies of structural transformation.

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Table 3.
A taxonomy of policy instruments for industrial policies for mining GVCs

	Supply side	Demand side
Market-based interventions	▶ Tax incentives (on capital) ▶ Tax concessions (R&D) ▶ Access to venture capital and grants to overcome the 'valley of death' for small local suppliers	▶ Demand from large firms through: • (i) Local content policies • (ii) Rebate policies on local production ▶ Incentives to mining exports ▶ Public procurement
Public goods and skills development	▶ Training centers ▶ Specific degree programs (on mining, geology & engineering...) ▶ Skill councils	▶ Local employment targets ▶ Local training required to mining companies
Innovation infrastructure and R&D platforms	▶ Suppliers/business incubators ▶ Support to collaborative R&D projects	▶ Match-making platforms to meet demand and supply (to include potential suppliers)

Source: Anzolin and Pietrobelli (2025)

The scope of instruments encompasses both market-oriented measures and public goods provisions. Market-based tools refer to policies that modify relative prices or incentives for particular activities or actors—such as tax relief, subsidies, export regulations, or targeted procurement rules. In contrast, public or "club" goods policies involve the creation of enabling infrastructures, institutional frameworks, regulatory systems, and human capital, including education, technical training, and research platforms.

From a functional perspective, supply-side policies seek to strengthen firms' productive capacity and competitiveness. They include measures that enhance access to technology, finance, skilled labour, and innovation infrastructure, as well as those influencing the broader industrial environment through fiscal and financial reforms (Criscuolo et al., 2022). Demand-side instruments, by contrast, aim to expand or stabilize markets for goods and services, providing firms with predictable demand that facilitates capital investment, scale economies, and productivity growth. Typical examples include public procurement programs and product standards or regulations that stimulate market development.

Crucially, the effectiveness of industrial policy depends not only on the design of individual instruments but also on their alignment and coherence—that is, the extent to which supply- and demand-side measures reinforce rather than offset one another.

3.3 Beyond Extraction: Strategic Diversification

Recent work in the product space and related diversification literature provides a useful analytical lens to situate mining activities and assess realistic pathways for structural transformation in resource-dependent economies. This literature shows that diversification is strongly path-dependent: countries tend to expand into new products that are technologically and organizationally related to their existing productive structures, because these activities draw on similar skills, inputs, institutions, and infrastructure (Hidalgo et al., 2009; Hausmann et al., 2014). From this perspective, mining activities occupy specific—and often relatively peripheral—positions in the product space, with limited direct proximity to complex manufacturing activities unless deliberate policies are adopted to build bridging capabilities.

For economies specialized in extractive activities, diversification opportunities are therefore most viable in activities that are closely connected to mining through input–output linkages, shared capabilities, or common infrastructure. These include mining services, capital goods, basic processing and refining, environmental services, logistics, and selected downstream manufacturing segments where technological and organizational proximity exists. Empirical applications of the product space framework suggest that moving into such "related" activities offers a more feasible route to upgrading than attempting to leapfrog into technologically distant sectors, while also expanding the density of the productive structure and increasing future diversification options (UNCTAD, 2022; UNCTAD, 2023).

Against this backdrop, strategic diversification beyond extraction does not imply abandoning the mining sector but rather using it as a platform to build adjacent capabilities and inter-sectoral linkages. The remainder of this section therefore examines how CETMs can serve as an entry point for related diversification, provided that industrial policies deliberately target capability accumulation, learning, and linkage creation consistent with the economy's position in the product space.

The experience of commodity-dependent economies shows that natural resources should serve as a starting point for diversification, not its endpoint. The economic opportunities arising from CETMs are accompanied by risks of new forms of dependency if countries remain confined to raw material exports. Therefore, the challenge is to leverage the technological and market dynamics of the green and digital transitions to build productive sectors that are knowledge-intensive, integrated into regional and global value chains, and capable of continuous learning and upgrading.

Diversification is a cumulative and path-dependent process: what an economy produces today shapes what it can produce tomorrow. Productive capabilities, comprising knowledge, skills, infrastructure, supply chains, and institutions, develop around specific products and are difficult to redeploy across unrelated sectors. Countries and regions tend to diversify into products that are technologically or organizationally related to their current specializations, sharing complementary capabilities. This pattern of related diversification has proven to be the most successful route to upgrading, as it leverages existing strengths, lowers entry barriers, and supports higher productivity and competitiveness.

However, diversification does not automatically lead to structural transformation or inclusive development. Market forces may direct investment toward related but less complex activities, particularly when short-term profitability outweighs long-term potential for learning and innovation. Strategic policy intervention is therefore needed to influence the direction of diversification, encouraging movement toward products that add technological upgrading, create spillovers and open pathways for further upgrading. diversifying into dense areas, where multiple related opportunities exist, expands future options and fosters dynamic industrial ecosystems, whereas entering sparse areas may generate limited growth prospects.

The quality of diversification determines its developmental outcomes. If driven solely by market incentives, diversification can reinforce inequality and environmental degradation, especially when it concentrates in capital-intensive or polluting sectors. To be inclusive and sustainable, diversification must create decent employment, promote gender and youth participation, and align with low-carbon and resource-efficient trajectories. In an era shaped by climate imperatives and technological change, guiding diversification toward, inclusiveness, and sustainability is essential to ensure that it contributes not just to growth, but to lasting structural transformation.

Therefore, strategic diversification requires an intentional approach. Diversification policies must identify specific products and activities that can generate linkages across sectors, facilitate innovation, strengthen domestic production systems, and steer the economy towards sectors that yield higher social and economic gains without compromising the environment. The goal is to expand into related products that use similar inputs, skills, and technologies. This process builds on existing capabilities while incrementally increasing economic.

3.4 Policy Space for Sustainable Critical Energy Transition Minerals Development

The evolving global environment—shaped by the proliferation of green industrial strategies in advanced economies, the expansion of new trade, investment, and cooperation frameworks, and emerging geopolitical tensions—has generated an increasingly complex policy context for developing countries. For resource-endowed economies, the central challenge lies in balancing three objectives: securing stable market access for their exports, attracting foreign investment and technology, and preserving sufficient policy autonomy to pursue domestic development goals. Achieving this balance, however, is often constrained by asymmetries in bargaining power.

Furthermore, many bilateral investment treaties (BITs), or investment chapters in Free Trade Agreements (FTAs), contain strong protections (e.g. “fair and equitable treatment,” “full protection and security,” provisions on direct and indirect expropriation) and typically allow covered foreign investors to bring arbitration claims via investor–state dispute settlement clauses against host governments (UNCTAD, 2022b; UNCTAD, 2023c). When governments seek to introduce measures such as localization requirements, performance requirements (including mandatory domestic processing or beneficiation), export quotas, or preferential support to domestic firms in the CETMs sector, these measures may be subject to challenge under existing trade and investment agreements, depending on treaty provisions and their interpretation (UNCTAD 2023d). The fear of costly arbitration claims could deter some ambitious industrial interventions even when justified by broader public-interest goals, resulting in a “regulatory chill”. In addition, broadly worded “national treatment” and “most-favoured-nation” clauses in investment treaties or chapters in FTAs that are not accompanied by exceptions or clarifications can potentially restrain differentiated support for domestic firms, joint ventures, or technology partnerships. Rules of origin in FTAs may also influence where processing occurs, sometimes favouring raw-material exports over regional value addition (Cadot et al., 2007). Newer trade and investment agreements tend to contain more safeguards for regulatory space as well as proactive clauses on investment facilitation, promotion and cooperation. However, decades-old agreements without such content by far outnumber new ones (UNCTAD, 2023).

In addition, developed economies, have begun to go beyond traditional FTAs by pursuing bilateral agreements with several CETMs-rich developing countries. This includes, for example two strategic partnerships on Critical Raw Materials value chains, signed by the EU Commission in 2023 with the Democratic Republic of Congo (DRC) and Zambia, as well as a Memorandum of Understanding (MoU) the EU signed with the US, Angola, the DRC, Zambia, the African Development Bank, and the Africa Finance Corporation in 2022 for the development of the Lobito Transport Corridor (Neema, 2024, Vandome, 2024).

The multilateral trade framework can impose significant constraints on industrial policy making in the critical minerals sector (Cadot et al., 2006). Recent bilateral initiatives by the United States further illustrate how critical minerals are increasingly governed through strategic trade and cooperation frameworks outside the WTO. The 2023 U.S.–Indonesia Comprehensive Strategic Partnership and the U.S.–Malaysia

Critical Minerals Dialogue aim to secure supply chains for battery and energy-transition minerals through cooperation on investment, processing and standards, while stopping short of granting full free-trade preferences. These arrangements reflect a growing trend toward selective, geopolitically motivated agreements that may reshape policy space and competitive conditions for critical mineral producers.

Under World Trade Organization (WTO) rules, the Agreement on Trade-Related Investment Measures (TRIMs) prohibits investment measures inconsistent with GATT Articles III (national treatment) and XI (quantitative restrictions). However, special and differential treatment provisions apply to least developed countries (LDCs). In particular, Annex F of the 2005 WTO Hong Kong Ministerial Declaration allows LDCs temporary derogations from certain TRIMs obligations, recognizing their development needs, although these flexibilities are time-bound and subject to periodic review.

In practice, the TRIMs has restricted the use of key industrial-policy tools such as local content requirements, trade-balancing obligations, and export-performance conditions (UNCTAD, 2020). Governments are thus often constrained in their ability to require investors in mining or processing to use domestic inputs or sell a share of output locally through binding multilateral disciplines, limiting direct incentives for value addition. Nevertheless, some countries—most notably Indonesia—have pursued alternative policy pathways, combining regulatory measures with investment coordination and infrastructure development, to promote downstream processing within existing legal constraints.

TRIMs is often criticized for its breadth and asymmetry, as it links virtually any investment condition “related to” goods to core GATT disciplines (UNCTAD 2022b). This broad interpretation has constrained late-industrializing economies seeking to use commodity sectors to develop midstream and downstream capabilities—options that earlier industrializers freely exercised. The interaction with the Subsidies and Countervailing Measures (SCM) Agreement further compounds the problem, since targeted incentives may be treated as prohibited or actionable subsidies if tied to domestic use or exports (Hoekman, 2020). Together, these rules discourage the selective, time-bound interventions typically required for industrial upgrading (World Economic Forum, 2022). Recent trade disputes and policy developments suggest, however, that the interpretation of WTO rules is evolving. In particular, cases related to industrial subsidies—such as those linked to climate and security objectives—indicate that GATT Articles XX and XXI may provide legal space to justify targeted industrial measures pursued for

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public policy purposes. This reflects growing recognition, including among advanced economies, of the need for policy space to support strategic industrial transformation.

The constraints outlined above map directly onto the policy instruments summarized in Table 3. Demand-side measures such as local content requirements, public procurement, export restrictions and performance obligations—often central to fostering linkages and upgrading—are precisely those most exposed to disciplines under WTO rules and investment agreements. Similarly, supply-side interventions related to skills development, public goods provision or innovation support face fewer formal restrictions but may be constrained indirectly through subsidy disciplines or investment protections. Linking international commitments to specific instruments helps clarify not only where policy space is restricted, but also where scope remains for strategic, development-oriented action within existing rules.

Additional WTO provisions also narrow policy space. Export restrictions are generally discouraged under GATT Article XI, while many developing countries have bound export duties at negotiated ceiling rates rather than eliminating them altogether. In practice, this preserves some scope to use export taxes—historically an important instrument for promoting domestic processing and capturing resource rents—as illustrated by continued use in sectors such as agriculture and mining in several countries. However, bindings, bilateral commitments, and investment agreements can still significantly limit the effective deployment of such measures in CETMs sectors. The Technical Barriers to Trade (TBT) Agreement allows challenges to standards that might indirectly favour local inputs. Moreover, exceptions such as those in GATT Articles XVIII and XX are limited, focusing on conservation or balance-of-payments rather than development. At the same time, commitments under the General Agreement on Trade in Services (GATS) may constrain certain performance requirements in mining-related services, but can also liberalize access to inputs, expertise, and technology, potentially supporting industrial upgrading when aligned with domestic policy objectives.

For many developing economies, however, the geopolitical urgency to build domestic supply chains is weaker. High capital costs, technological barriers, and modest profitability make large-scale processing investments less attractive, leading governments to treat CETMs mainly as export commodities. Yet their developmental value lies in industrial transformation—building processing capacity can foster learning, infrastructure, and linkages essential for diversification and technological upgrading (UNCTAD, 2023b).

The challenge is to balance strategic dependence with developmental opportunity. While advanced economies frame CETMs as national security assets, many developing producers approach them as commercial goods. This asymmetry risks deepening global concentration in high-value segments (UNCTAD, 2023).

Recent export controls introduced by China on selected critical minerals and rare earth elements further illustrate how policy space is being actively used by major producers to pursue strategic objectives. Measures affecting gallium, germanium, graphite and rare earth processing technologies have highlighted the growing intersection between industrial policy, trade governance and national security considerations. These actions underscore both the vulnerability of globally concentrated supply chains and the uneven distribution of policy autonomy across countries. They also highlight ongoing debates about how producer countries can engage in international cooperation while managing dependence risks and preserving policy autonomy in the context of expanding global demand for CETMs (Mildner and Schmucker, 2023).

Even within these constraints, however, there remains scope for constructive adaptation. Several governments are pursuing treaty revisions or new trade and investment frameworks that explicitly safeguard the right to regulate in the public interest, including for strategic and environmental objectives. By embedding carefully drafted exceptions, performance-based clauses, or transparent subsidy regimes, states can reconcile industrial policy ambitions with international commitments under trade and investment agreements (Hoekman and Nelson, 2020). Regional cooperation and South-South partnerships are also emerging as pragmatic avenues to restore balance: through shared standards, joint processing ventures, or coordinated negotiation platforms, producer countries can strengthen their bargaining position and promote fairer value distribution along mineral supply chains.

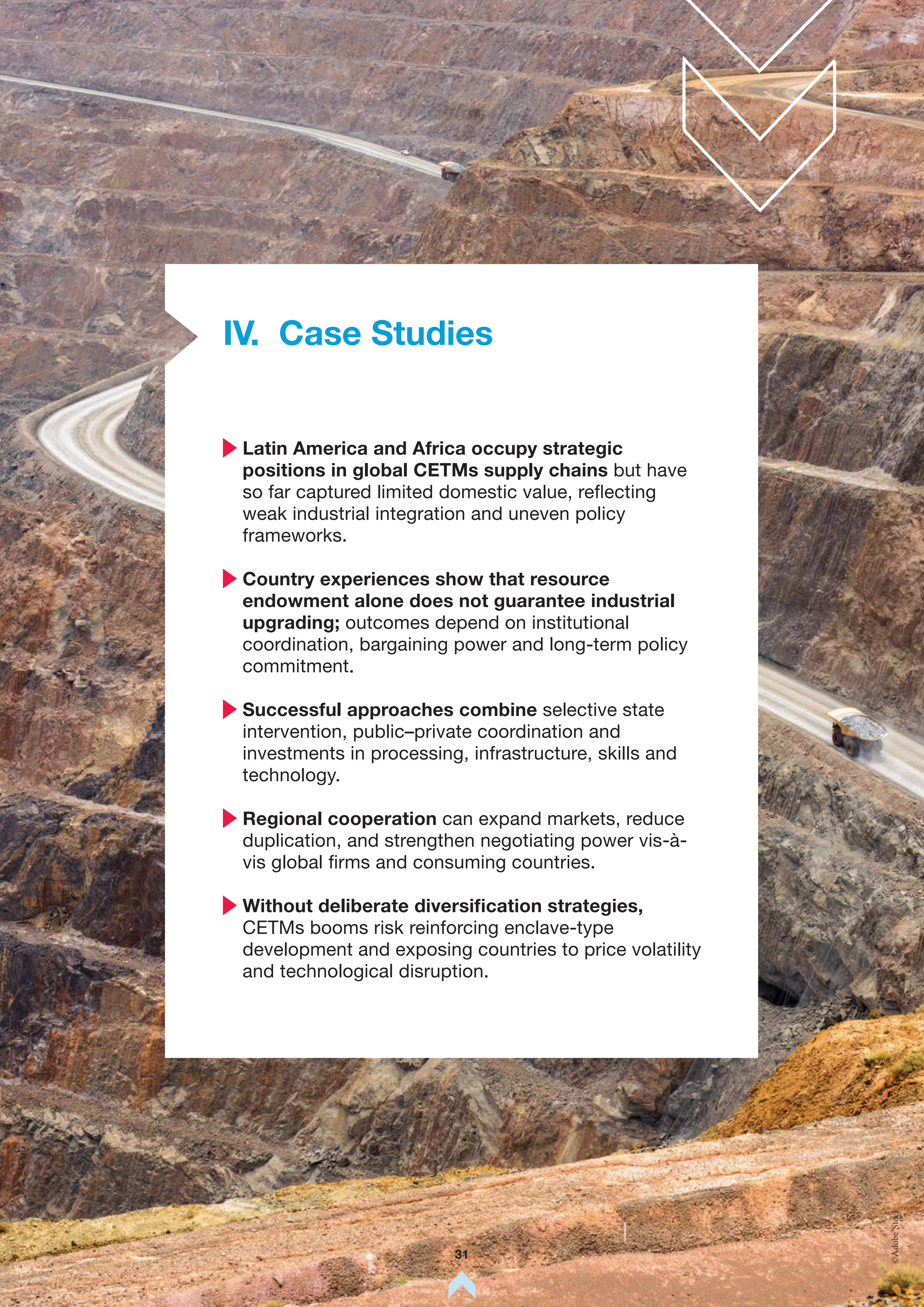
Ultimately, the preservation of policy space for CETMs industrialization requires a recalibration of global economic governance. Multilateral fora, including the United Nations and its regional commissions, are well placed to facilitate dialogue on aligning trade rules with the imperatives of sustainable development and strategic autonomy. The challenge ahead is to ensure that international disciplines evolve to accommodate industrial policy while maintaining transparency and predictability in the global system. A balanced framework—one that safeguards both development aspirations and cooperative interdependence—will be essential to realizing the promise of CETMs for an inclusive, low-carbon future.

In this context, the role of maritime transport is fundamental. It plays a central role in enabling the extraction, processing and global distribution of critical minerals and constitutes the backbone of mineral value chains. Most of these minerals, whether in raw or processed form, are shipped across the oceans from geographically concentrated producers to a broader base of industrial consumers (UNCTAD, 2025). Seaborne trade thus serves as the backbone of mineral value chains, connecting resource-rich economies with global refining hubs and end users.

For developing countries, maritime logistics, including port infrastructure, shipping services and trade facilitation, are pivotal to harness opportunities in critical minerals, support domestic processing, and integrate into higher-value segments of mineral supply chains. However, persistent constraints such as high transport costs, limited port capacity and underdeveloped intermodal connectivity continue to hamper their ability to move beyond raw material exports. Addressing these challenges requires more than infrastructure upgrades. It demands strategic alignment between logistics development and industrial policy. Experiences from regions such as Suape in Brazil and the Lobito Corridor in Africa suggest that when port infrastructure is linked to targeted sectoral strategies (such as processing zones for chemicals, machinery or battery components in port-proximate zones), countries can attract investment, promote value addition and generate employment (Monie and Vidal, 2010; World Bank, 2024).[4]

Coordinating maritime logistics with broader industrial objectives creates conditions for structural transformation, allowing mineral-rich economies to leverage their resources for sustained, inclusive growth (UNCTAD, 2025).

[4] These examples are illustrative and do not imply an assessment or endorsement of the performance, conduct, or outcomes of specific private entities involved in these initiatives.



IV. Case Studies

- **Latin America and Africa occupy strategic positions in global CETMs supply chains** but have so far captured limited domestic value, reflecting weak industrial integration and uneven policy frameworks.
- **Country experiences show that resource endowment alone does not guarantee industrial upgrading;** outcomes depend on institutional coordination, bargaining power and long-term policy commitment.
- **Successful approaches combine** selective state intervention, public–private coordination and investments in processing, infrastructure, skills and technology.
- **Regional cooperation** can expand markets, reduce duplication, and strengthen negotiating power vis-à-vis global firms and consuming countries.
- **Without deliberate diversification strategies,** CETMs booms risk reinforcing enclave-type development and exposing countries to price volatility and technological disruption.

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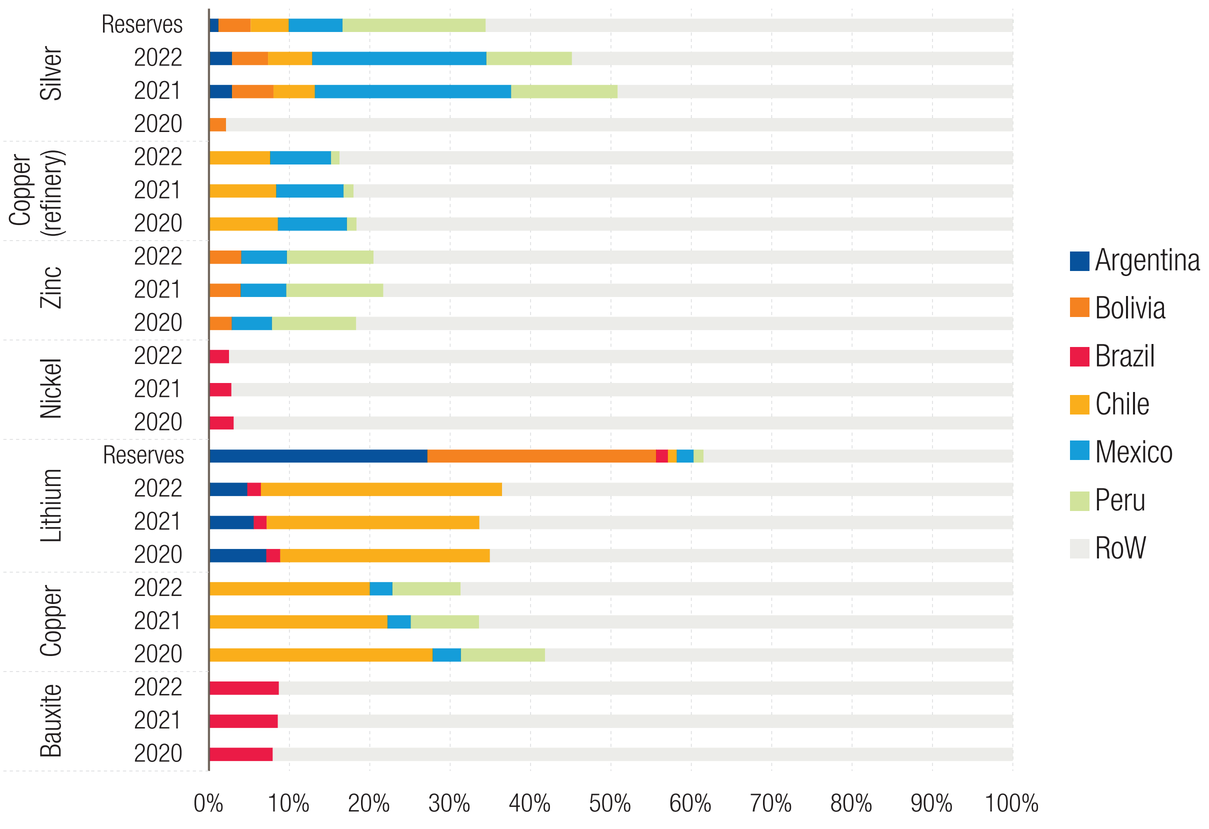
Building on the conceptual and analytical framework outlined in the preceding section, the analysis now shifts from theory to practice, focusing on how the dynamics of critical energy transition minerals unfold in concrete regional contexts. The following section examines the experiences of Latin America and Africa, two resource-rich regions that occupy strategic positions in global supply chains for energy transition minerals. By exploring their respective policy approaches, institutional arrangements, and industrial strategies, the analysis highlights how differing resource endowments, governance capacities, and development priorities shape each region's pathway toward leveraging critical minerals for sustainable economic transformation. This transition from conceptual foundations to applied regional perspectives provides the basis for assessing how theoretical principles translate into practice across distinct developmental settings.

4.1 Latin America's Role in the Global Critical Mineral Supply Chain

Latin America holds a central position in the global production and reserves of several CETMs essential for the clean energy transition and advanced manufacturing. The region accounts for the production of more than half the world's lithium, over a third of its copper, and more than half its silver (see figure 8). This places the countries of the region in an excellent position to embark on a green transition and leverage their minerals reserves to accelerate economic progress.

Figure 8.
CETMs production-reserves in selected Latin American countries, percentage of total world production



Source: UNCTAD (2025b) based on USGS (2023).

The region's geological diversity underpins its strategic relevance; however, policy frameworks governing these resources remain uneven across countries. With the exception of Brazil, which formally defined a list of CETMs in 2020, most countries in the region have not yet established comprehensive strategies for the governance, industrial integration, and sustainable development of critical mineral value chains (ECLAC, 2023). Existing efforts are often fragmented or oriented toward specific commodities rather than part of a coordinated, long-term approach.

From a production perspective, Brazil, Chile, Peru, Mexico, and Bolivia collectively account for a significant share of global output in critical minerals such as copper, lithium, silver, molybdenum, tin, and niobium (USGS, 2025). Brazil stands out as one of the most diversified producers, and its dominance in the niobium market is particularly notable: in 2024, the country accounted for over 90 per cent of global production and held approximately 94 per cent of known reserves. Brazil also contributed 4 per cent of global lithium output, with reserves representing around 1.3 per cent of the world total, and possesses substantial potential in REEs, hosting more than 23 per cent of global reserves despite negligible current production (USGS, 2024).

Chile remains the region's principal copper producer and a major global supplier. In 2024, it produced roughly 23 per cent of global mined copper and 7 per cent of refined copper, with reserves equivalent to nearly 20 per cent of the global total. Chile is also the world's second-largest lithium producer, responsible for one-fifth of global output and controlling about 31 per cent of reserves. Moreover, the country ranks third in molybdenum production, contributing nearly 15 per cent of global supply and holding more than 9 per cent of global reserves.

Peru has consolidated its position as another major producer of base and precious metals. In 2024, it accounted for approximately 11 per cent of global mined copper and 1.5 per cent of refined copper, supported by reserves equivalent to 10 per cent of the world total. The country also contributed 16 per cent of global molybdenum output and holds nearly 13 per cent of global reserves. In addition, Peru remains one of the largest silver producers globally, representing over 12 per cent of production and 21 per cent of reserves.

Mexico continues to play a prominent role in both base and precious metals. In 2023, it supplied around 3 per cent of mined copper and 1.3 per cent of refined copper, with reserves exceeding 5 per cent of the global total. Mexico also accounted for almost 7 per cent of global molybdenum output and was the world's leading silver producer in 2024, responsible for 25 per cent of global production and nearly 6 per cent of known reserves.

Bolivia, is an important producer of tin and silver, accounting in 2024 for 7 and 5 per cent of global output respectively and holding about 10 and 3 per cent of world reserves. The country also possesses considerable lithium resources—estimated at 23 million metric tons—as part of the "lithium triangle" shared with Argentina and Chile. However, Bolivia's lithium production remains at an early stage compared with its resource potential.

Despite these strong geological endowments and established production profiles, the region's policy landscape has not yet fully matched its growing global importance in critical mineral markets. Existing comparative assessments suggest that, in several Latin American economies, policy frameworks continue to treat critical minerals primarily as export commodities, with limited integration into broader strategies for domestic value addition, innovation systems, and industrial development (ECLAC, 2023). While a small number of countries—most notably Brazil—have begun to articulate more comprehensive approaches linking mineral extraction to industrial policy and technological upgrading, such strategies remain uneven across the region. The following country-specific sections therefore examine in greater detail how selected national experiences are attempting to address these gaps, and where institutional coordination, regulatory predictability, and investment in processing, refining, and technology transfer could further strengthen the contribution of critical minerals to sustainable structural transformation.

There are, moreover, important risks on the horizon. Beyond the environmental risks of mining in terms of deforestation, water and air pollution, erosion of soil and damage to marine ecosystem, the IEA suggests that significant uncertainty characterizes the long-term outlook for CETMs, given potential technological disruption amid global research and development efforts globally to generate alternative technologies that rely on substitute materials (such as phosphate-based or hydrogen-based batteries to replace lithium-ion batteries). Furthermore, acquiring the capacity to add value along potential value chains, and replicating successful experiences such as Indonesia's management of its nickel deposits remain challenging. When it comes to negotiating contracts with leading multinationals and fostering technology transfer, market size and effective bargaining power matter (UNCTAD, 2025). Finally, the risk remains of repeating the history of resource-dependent enclave economies that fail to build a wider productive base, resulting in economic gains being channelled to a privileged minority of the population.

4.1.1 Industrial Policy Approaches to CETMs in Latin America

Across Latin America, the governance of CETMs has increasingly become a focus of industrial policy discussions, reflecting the region's strategic position in global energy and technology transitions. While mineral extraction has long underpinned export revenues and foreign investment, the recent surge in demand for minerals such as lithium, copper, nickel, and REEs has renewed debates on how to leverage these resources for structural transformation, value addition, and sustainable development.

To date, industrial policy approaches remain heterogeneous and at varying stages of maturity. Only a limited number of countries—most notably Brazil—have formalized policy instruments explicitly addressing critical or strategic minerals. Brazil's 2020 National Mining Plan identified a list of CETMs and emphasized technological upgrading, research and development, and the integration of domestic industries into global supply chains. Other countries, such as Chile, Argentina, and Bolivia, have advanced partial frameworks or sector-specific strategies, often linked to lithium and copper value chains. These initiatives typically focus on increasing state participation, promoting domestic processing, and attracting foreign investment aligned with sustainability and innovation objectives.

However, in most Latin American countries, policy approaches to critical minerals remain largely focused on extraction and primary export, with limited integration into broader industrial, innovation or value-addition strategies . Policy coordination across ministries and agencies remains limited, and comprehensive strategies that link mining to broader industrial and technological development goals are still emerging. Institutional capacity constraints, regulatory uncertainty, and insufficient investment in innovation ecosystems further limit the ability of states to capture greater value from mineral production.

Recent regional initiatives, including cooperation under the Community of Latin American and Caribbean States (CELAC) and joint policy dialogues facilitated by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), have emphasized the need for a coordinated regional vision (ECLAC, 2022). Such efforts seek to promote knowledge sharing, harmonize standards, and strengthen the region's bargaining position within global supply chains. From a policy perspective, the challenge lies in balancing the imperatives of competitiveness and sustainability while ensuring that the exploitation of CETMs contributes to inclusive growth, decarbonization objectives, and long-term resilience.

Review of policies for critical energy transition minerals in selected countries[5]

Argentina.

Argentina's mining policy for CETMs is shaped by its federal constitution, which assigns ownership of natural resources to the provinces (Constitution, Art. 124). As a result, the national government sets framework rules (e.g. the Mining Code and investment regime), while provinces control concessions, environmental permits, and many fiscal instruments. This division has produced a multi-speed governance landscape in the lithium-bearing northwest, where provincial authorities play a primary role in licensing and local content arrangements.

In the lithium value chain, Argentina has pursued a largely open, private-investment model, with provincial leadership complemented by national initiatives in technology and downstream pilots. The provinces of Jujuy, Salta, and Catamarca formed the Interprovincial Mesa del Litio/Región Minera del Litio to coordinate standards, infrastructure, and promotion, reflecting the regional concentration of salars. At the same time, public research and energy entities (Y-TEC/YPF Litio) have advanced battery-cell pilots and R&D partnerships, including efforts to evaluate Direct Lithium Extraction (DLE). These initiatives aim to build local technological capabilities even as most production remains oriented to exports.

The policy stance emphasizes macroeconomic stabilization and investment attraction, with mining framed as a driver of exports and foreign currency. Authorities project rapid scaling of lithium capacity alongside the emergence of copper, supported by new investment frameworks (e.g. Régimen de Incentivo a las Grandes Inversiones (RIGI)) and project-specific approvals—such as the Rincón development. Nonetheless, inflation, FX regulations, and social-environmental debates around water governance and community consent continue to influence timelines and costs.

Three features define Argentina's trajectory. First, provincial primacy produces agility where local institutions are strong but also results in heterogeneity of standards; harmonization via interprovincial coordination is advancing but incomplete. Second, investment-led growth has prioritized upstream production; early steps toward downstream and technology (battery pilots, DLE trials) are promising but nascent relative to the pace of resource development. Third, social and environmental governance—particularly water management in arid salars—remains a focal point for long-term legitimacy and requires reinforced monitoring, transparency, and benefit-sharing mechanisms.

Brazil.

Brazil's mineral policy framework has evolved from a primarily extractive orientation to a more strategic agenda that links geology, industrial transformation, and sustainability. The anchor is the national mining plan, Plano Nacional de Mineração 2030 (PNM-2030), launched in 2011, which articulated a long-term vision around three pillars: stronger public governance, expansion of geological knowledge and domestic

5 The country analyses are based on a desk-based synthesis of publicly available policy documents, official strategies, legislation and regulatory announcements, complemented by UNCTAD analytical work and insights from technical assistance, policy dialogues and expert engagements. Key sources include Argentina's federal mining governance framework and lithium coordination mechanisms (EY, 2023), Brazil's Plano Nacional de Mineração 2030 (MME, 2011; IEA, 2023b), and Chile's National Lithium Strategy (Gobierno de Chile, 2023), as well as related investment and policy monitoring materials produced by UNCTAD (2023e).

value addition (transformação mineral), and environmental and social sustainability. While programmatic rather than prescriptive, PNM-2030 established a durable reference for subsequent initiatives in regulation, mapping, and institutional capacity (IEA, 2023).

More recently, Brazil has begun to frame critical and strategic minerals as part of its energy transition and industrial policy. Government and public research entities (notably EPE and SGB/CPRM) have published assessments that identify minerals of interest—such as niobium, graphite, REEs, nickel, lithium—and link them to domestic manufacturing prospects (e.g. magnets, batteries, alloys). Although Brazil's current REEs output remains limited, the policy narrative emphasizes leveraging geological potential with technology partnerships and downstream incentives. Industry associations (e.g. IBRAM) have also proposed guidelines for a national critical minerals policy, underscoring R&D, Environmental, social and governance standards (ESG), and enabling infrastructure.

Despite progress, structural constraints are still slowing down progress. Licensing remains complex due to overlapping mandates; fiscal and industrial instruments aimed explicitly at domestic processing are still incipient; and social-environmental conflicts in sensitive territories challenge implementation. Monitoring and adaptive review mechanisms, envisaged in PNM-2030, have not always been systematic, suggesting scope for an updated plan that directly reflects the post-2020 surge in demand for battery and magnet minerals and embeds measurable targets for local content, innovation ecosystems, and regional development.

Taken together, Brazil's approach exhibits three salient traits. First, strategic continuity: PNM-2030 remains the conceptual backbone for governance, even as policy instruments evolve. Second, institutional layering: newer programs and analyses on CETMs are grafted onto existing geological and regulatory institutions (MME/SGM, ANM, CPRM, EPE). Third, gradual industrialization: the policy goal of moving "beyond extraction" is clear, but requires sharper incentives for beneficiation, targeted infrastructure (power, logistics, water), and risk-sharing mechanisms to crowd in private capital for processing and advanced materials.

Chile.

Chile's critical minerals policy rests on decades of copper governance combined with a new strategic approach to lithium. In April 2023, the Government announced the National Lithium Strategy, establishing a state-led, public-private partnership model for new projects, with the state holding controlling positions in strategic salars (via

Codelco and ENAMI), while opening other areas to competitive private development. The strategy links resource stewardship with environmental safeguards and community participation, aiming to raise value addition and technology adoption across the chain.

Concurrently, Chile enacted a new mining royalty framework for large copper producers, combining an ad-valorem component with a margin-based tax and capping the overall tax burden at 46.5 per cent of pre-tax profits. The reform seeks to balance fiscal revenues with competitiveness and predictability. Although primarily targeted at copper, the royalty reform updated Chile's broader fiscal stance on mining and interacts with lithium via overall investor expectations and fiscal design coherence.

Operationalization of the lithium strategy has proceeded through state-company mandates and negotiated partnerships. A landmark Codelco–SQM agreement will consolidate state participation and extend operations in the Salar de Atacama—Chile's flagship lithium brine—while enabling increased output under stricter environmental parameters and higher public revenue shares. The government has also moved to open new areas for exploration and development through competitive processes, including salars and non-brine resources (e.g. clays and geothermal fluids), accompanied by Indigenous consultation where applicable.

Institutionally, the strategy relies on Codelco as the principal state partner for the Atacama and other strategic salars, with ENAMI leading earlier-stage development in additional basins. CORFO retains roles in contract management and innovation promotion, while environmental oversight is conducted through Chile's established SEIA system. The policy narrative emphasizes environmental thresholds, water stewardship, and scientific monitoring—responding to concerns about brine-aquifer dynamics—while encouraging technology upgrades, potentially including DLE where appropriate.

Three elements stand out. First, strategic state stewardship: the state defines the development model and reserves strategic salars for majority public control, while partnering with private firms for capital, know-how, and market access. Second, fiscal and contractual recalibration: royalty reform and new contract terms aim to capture a greater share of rents while preserving investment signals. Third, environmental governance is embedded into contracts and permitting, with explicit commitments to monitoring and Indigenous engagement under international standards. Effective delivery will depend on timely tenders, regulatory clarity on "strategic" designations versus open areas, and the scaling of monitoring capacity in sensitive ecosystems.

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4.1.2 A Comparative Perspective: Converging Goals, Divergent Pathways

Despite contrasting institutional architectures, the three countries share convergent strategic objectives:

1. To secure and expand production of CETMs,
2. To promote greater domestic value addition, and
3. To ensure environmental sustainability and social inclusion.

The means through which these objectives are pursued differ markedly. Brazil emphasizes institutional planning and long-term governance, leveraging its broad geological base but still seeking to strengthen incentives for processing industries. Argentina prioritizes investment attraction and provincial autonomy, enabling rapid project pipelines but limiting the coherence of a unified national strategy. Chile, in turn, has adopted a state-stewardship model that integrates fiscal reform, environmental safeguards, and public-private partnerships within a clear strategic framework. The regional challenge remains to translate resource endowment into long-term industrial transformation—a process that will require shared standards, technological cooperation, and alignment of critical-minerals strategies with broader climate and development goals.

Table 4.
Policy Instruments for CETMs in Brazil, Argentina and Chile

Dimension	Brazil	Argentina	Chile
Governance model	Centralized national policy (PNM 2030); strong federal institutions (MME, ANM, CPRM)	Federal system; provincial ownership of mineral rights; national investment law	Centralized with state enterprises (Codelco, ENAMI); defined national lithium strategy
Main legal framework	PNM 2030; Mining Code (1967); PMD 2020–2023	Law 24.196 on Mining Investment; provincial mining codes and royalties	Mining Code; National Lithium Strategy (2023); Mining Royalty Law (2023)
CETMs focus	Niobium, lithium, REEs, nickel, graphite	Lithium, copper (emerging), potential nickel and cobalt	Lithium, copper, molybdenum
Industrial policy orientation	Emphasis on mineral transformation, R&D, and mapping	Export-oriented with emerging technology pilots (YPF Litio)	State-led partnerships; local processing and DLE promotion
Environmental governance	Federal-state licensing; sustainability pillar in PNM 2030	Provincial EIA systems; increasing public scrutiny of water use	Centralized SEIA; Indigenous consultation; strict aquifer monitoring
Institutional capacity	High; strong technical agencies	Uneven; provincial disparities	High; long-standing mining institutions
Key challenge	Translating planning into incentives and downstream investment	Policy fragmentation and macroeconomic instability	Implementation pace and maintaining investor confidence

Source: UNCTAD

A coordinated regional approach to CETMs could amplify Latin America's strategic position in the global energy transition. Building on national experiences, regional cooperation—through ECLAC, CELAC, or the Inter-American Development Bank—could promote shared standards on sustainability, technology transfer, and fiscal transparency. Cross-border collaboration in research, value-chain development, and skills formation would strengthen the region's capacity to capture greater economic and social benefits from its exceptional mineral endowment.

4.2 The African Experience based on UNCTAD's Rapid Assessment Project[6]

For many countries endowed in CETMs, the primary challenge is not a lack of resources but rather the limited capacity to transform them into productive opportunities. These economies often struggle to identify realistic paths for diversification within and beyond mineral value chains. They have analytical gaps, weak institutional coordination, and limited information about what products can be feasibly developed. As a result, they remain dependent on raw material exports and exposed to external shocks, while the potential of critical minerals to support structural transformation remains untapped. The Rapid Assessment approach was developed to address this problem in a practical way.

4.2.1 UNCTAD's Rapid Assessment Approach

The Rapid Assessment approach starts by identifying specific products that combine three conditions: growing market demand, technological proximity to existing capabilities, and potential to strengthen domestic production systems. These product opportunities derive from an empirical analysis of each country's export basket using economic complexity and product-space techniques.[7] The analysis maps what the country already produces and exports and identifies nearby products that have been successfully exported by countries with similar capabilities.

Once the opportunities are identified, they are validated with local industry stakeholders. Through interviews and workshops, firms, business associations, and technical institutions review the feasibility of producing each product and highlight concrete constraints. This step transforms the analysis from a statistical exercise into a dialogue between data and practice. It reveals the real bottlenecks, such as skills shortages, access to inputs, standards, finance, or infrastructure, that prevent industries from diversifying toward promising products.

Unlike conventional approaches that begin by listing generic gaps, this method begins with the opportunities. By starting from feasible and market-relevant products, it allows policymakers to focus on solving problems that matter for real diversification. The solutions are therefore targeted: each policy instrument is designed to remove a specific obstacle faced by firms in moving toward those identified products. This makes diversification not a theoretical aspiration but a sequence of practical, achievable steps.

The approach integrates quantitative and qualitative methods. Economic complexity and product-space analysis provide the quantitative foundation, while structured stakeholder engagement adds contextual intelligence. The quantitative analysis is highly granular, disaggregating products within six-digit HS codes by unit price and quantity to capture differences in value and specialization. The qualitative phase ensures that statistical proximity is matched with industrial reality.

Four complementary scenarios guide the identification of opportunities. The first focuses on global export potential; the second, on regional opportunities within subregional blocs; the third, on continental trade under the African Continental Free Trade Area (AfCFTA); and the fourth, on domestic import substitution. Each scenario highlights a different market horizon and helps

6 See UNCTAD, Critical energy transition minerals: Rapid assessment of value addition and diversification capacity in Southern Africa (accessed February 2026).

7 For details about these techniques, see UNCTAD (2024). Uncovering Suape's potential: Strategic pathways to economic complexity and global competitiveness. UNCTAD/TCS/DITC/INF/2024/10.

governments prioritize between export-oriented and inward-looking strategies according to their development goals.

Finally, the Rapid Assessment translates analytical results into policy design. Together with national counterparts, UNCTAD co-creates a portfolio of policy instruments organized around core functional domains: skills, innovation, finance, enterprise support, infrastructure, procurement, and sustainability. This structure enables governments to build coherent, problem-driven interventions that respond to the specific constraints of each product cluster. The process thus connects opportunity identification with institution-building and policy coherence.

Through this approach, UNCTAD turns the discussion on value addition and diversification from broad strategy into concrete action. It provides governments with an operational tool to link the wealth generated by critical minerals to productive transformation, industrial employment, and long-term economic resilience.

4.2.2 Key Insights from Target Countries

The rapid assessments in Namibia and Zambia illustrate how mineral-dependent economies more broadly—rather than CETMs leaders per se—are grappling with the challenge of moving from resource dependence toward productive diversification. Through consultations with government agencies, industry associations, firms, financial institutions, and academia, local stakeholders identified practical measures to strengthen linkages between extractive activities and the wider economy. While the two countries differ in their current relevance for specific critical energy transition minerals, the assessments provide transferable insights into governance, capability-building, and policy coordination challenges that are common across resource-rich developing economies seeking to leverage mineral sectors as catalysts for structural transformation.

On the supply side, participants in both countries stressed the need to reinforce productive capabilities through skills, infrastructure, and access to finance. In Namibia, stakeholders called for the expansion of technical education and the creation of new testing and training centres, including shared facilities for copper-based engineering and a testing laboratory for the chemical sector in Erongo. The stakeholders proposed short training programmes in electrowinning, toolmaking, and steel processing, as well as gender-sensitive machine-shop facilities and stronger university–industry partnerships. Participants also suggested innovative financing tools such as sovereign-wealth-fund allocations, diversification or green bonds, and dedicated sectoral funds for SMEs.

In Zambia, stakeholders emphasized similar priorities but placed stronger focus on financial intermediation and skills upgrading. They proposed a “Finance Window” within the Zambia Credit Guarantee Scheme to provide 50–70 per cent loan guarantees for equipment leasing, together with capacity-building programmes to improve MSME financial management. In the chemical sector, participants suggested sector-specific special-purpose vehicles and offtake agreements with mines to unlock finance for local suppliers. For the electrical and electronics industries, they recommended a regional “Incentives and Offtake Compact” to reduce component tariffs, provide VAT exemptions for accredited assemblers, and establish a supplier register with standards and type-approval. Across sectors, participants called for the expansion of technical and vocational education and training (TVET) and in-house training, the recognition of private certification, and an increase in the Skills Development Levy to sustain training funds.

On the demand side, participants in both countries viewed public procurement and quality standards as essential to stimulate domestic production and regional trade. In Namibia, proposed measures included integrating local-content provisions into the

Procurement Act guidelines, mapping entry points for developmental procurement, creating a national catalogue of locally produced goods, and reinforcing the "Buy Local, Grow Namibia" initiative through branding and labelling. Stakeholders also recommended shorter regulatory approval times for domestic pharmaceutical products and the development of a national online marketplace for industrial information.

In Zambia, participants identified the need to strengthen standards enforcement and buyer awareness for diversified copper products, benchmark and update rebar standards, and coordinate regional certification with professional bodies. They also proposed preferential public procurement for locally produced electrical and electronic equipment, alongside utility and mining offtake agreements to secure markets for local suppliers. Broader logistics and infrastructure measures were discussed, including upgrading the railway network, aligning incentives along the Lobito Corridor, and linking industrial parks and multi-facility economic zones to downstream copper and steel production.

Overall, the assessments highlight that stakeholders in both Namibia and Zambia have a clear vision of the interventions needed to move from raw-material exports to value-added production. Supply-side measures are well articulated and often supported by ongoing initiatives, while demand-side instruments, particularly procurement reform, market creation, and enforcement of standards, require institutional strengthening.

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Table 5.
Supply-side strength, demand side gaps: Policy priorities for diversification in Nambia and Zambia

Scope / Category	Supply-Side Instruments	Demand-Side Instruments
Market-Based Instruments	**Namibia**	
	Proposals for sovereign-wealth-fund allocations and creation of diversification / green bonds to finance industrial projects; rebates and financing mechanisms to offset local-content costs; supply-development programmes linking mining companies to domestic suppliers; tax incentives for machinery and chemical equipment; lower interest rates for green-bond financing.	A mix of industrial policy instruments aimed at strengthening domestic linkages and supplier capabilities, including local-content provisions in public procurement guidelines; revisions to procurement laws to allow preferences for domestic suppliers; the establishment of a national catalogue of locally produced goods; branding and labelling initiatives (“Made in Namibia”); streamlining of regulatory timelines in selected sectors; and targeted regional trade and supplier-development workshops. These measures are better understood as selective industrial policy instruments—rather than purely market-based tools—designed to shape demand, support domestic suppliers and build productive capabilities, even where they may interact with or test the limits of existing trade and investment disciplines.
	Zambia	
	Creation of a dedicated “Finance Window” under the Zambia Credit Guarantee Scheme with partial guarantees for long-term loans and leases; sector SPVs and offtake agreements with mines for MSME chemical producers; VAT exemptions and 0 per cent component tariffs for accredited assemblers; fiscal incentives for copper-based manufacturers; alignment of SEZ / MFEZ incentives with product-line diversification.	Zambia has adopted a set of industrial policy–oriented measures aimed at strengthening linkages between copper mining and domestic manufacturing. These include preferential public procurement for locally produced electrical and metal products, the use of offtake agreements with utilities and large mining operators to support local suppliers, and the benchmarking and domestication of technical standards for products such as rebar and fabricated metal goods. Trade measures, including the maintenance of higher MFN tariffs on selected finished products, have been used selectively to support local assembly and manufacturing activities. Together, these instruments combine demand-side policies and regulatory measures to promote value addition, rather than purely market-based interventions.
Public Goods and Capability-Building Instruments	**Namibia**	
	Establishment of shared testing and training centres in Erongo and Okahandja; expansion of TVET and university programmes in copper electrowinning, machinery fabrication, and steel processing; gender-sensitive facilities in regional machine shops; investment in desalination and railway modernization to support industrial development; creation of an online market-intelligence portal for SMEs.	Strengthening of the Namibia Standards Institute; creation of sectoral conformity-assessment laboratories; expansion of mining supplier databases to other sectors; awareness campaigns under “Buy Local, Grow Namibia”.
	Zambia	
	Expansion of TVET and in-house training for instrumentation and processing; recognition of private certification; increase in the Skills Development Levy to 1 per cent; targeted scholarships and employer placements in metallurgy and mechanical engineering; coordinated curriculum design between universities and industry; upgrading industrial parks and clusters in iron & steel, machinery, and electronics; coordination of standards enforcement through professional bodies.	Strengthening of the Zambia Bureau of Standards (ZABS) and expansion of standards enforcement; regional harmonization of conformity assessment; implementation of e-waste regulations for the electrical and electronics sector; public awareness to counter substandard imports.

Source: UNCTAD

4.2.3 Policy Coherence and Sequencing

A central finding is that both Namibia and Zambia already possess the foundation for a more diversified production structure, but these foundations remain fragmented. Each country has developed isolated initiatives (e.g. training programmes, special economic zones, supplier development efforts, and standards institutions) that operate in parallel rather than in coordination. The rapid assessment highlighted the need to integrate these initiatives within a unified policy framework, ensuring that supply-side capacity-building is complemented by demand-side market creation.

The coherence between supply and demand measures is what gives these proposals their transformative potential. Skills and finance policies without markets would lead to underutilized capacity; procurement without local capabilities would increase costs and import dependence. When designed together, however, these instruments can reinforce one another: training programmes aligned with industrial clusters feed into supplier development schemes; financial incentives leverage offtake contracts; and standards help translate local production into regional competitiveness.

Institutionally, both countries face a similar challenge of coordination. Industrial policy functions, usually spread across ministries of trade, industry, mining, finance, and education, need stronger mechanisms for joint planning and monitoring. Stakeholders suggested the creation of inter-ministerial coordination mechanisms or task forces to oversee implementation of diversification measures, ensuring alignment between investment promotion, procurement policy, and skills development. The assessments also showed the value of maintaining continuous dialogue between government and industry, as many of the most concrete policy ideas emerged directly from practitioners.

The rapid assessments also reveal that diversification is not only a matter of industrial instruments but also of sequencing. Some actions, such as expanding training capacity or reforming procurement guidelines, can be implemented immediately, while others, like developing regional value chains or upgrading transport infrastructure, require medium-term coordination and investment. Recognizing this sequencing helps policymakers balance ambition with feasibility, turning the long-term vision of structural transformation into a series of achievable steps.

4.3 Converging Lessons for Industrial Policy: Latin America and Africa

Although the Latin American and African case studies differ methodologically, they converge in substance. The Latin American analysis, based on data and policy documentation, illustrates how CETMs fit within national industrial strategies. The African perspective, drawn from UNCTAD's Rapid Assessment approach, reflects how stakeholders themselves identify practical pathways for diversification. While the former defines what policy priorities should guide mineral-based industrialization, the latter reveals how they can be implemented, highlighting real-world constraints and feasible solutions.

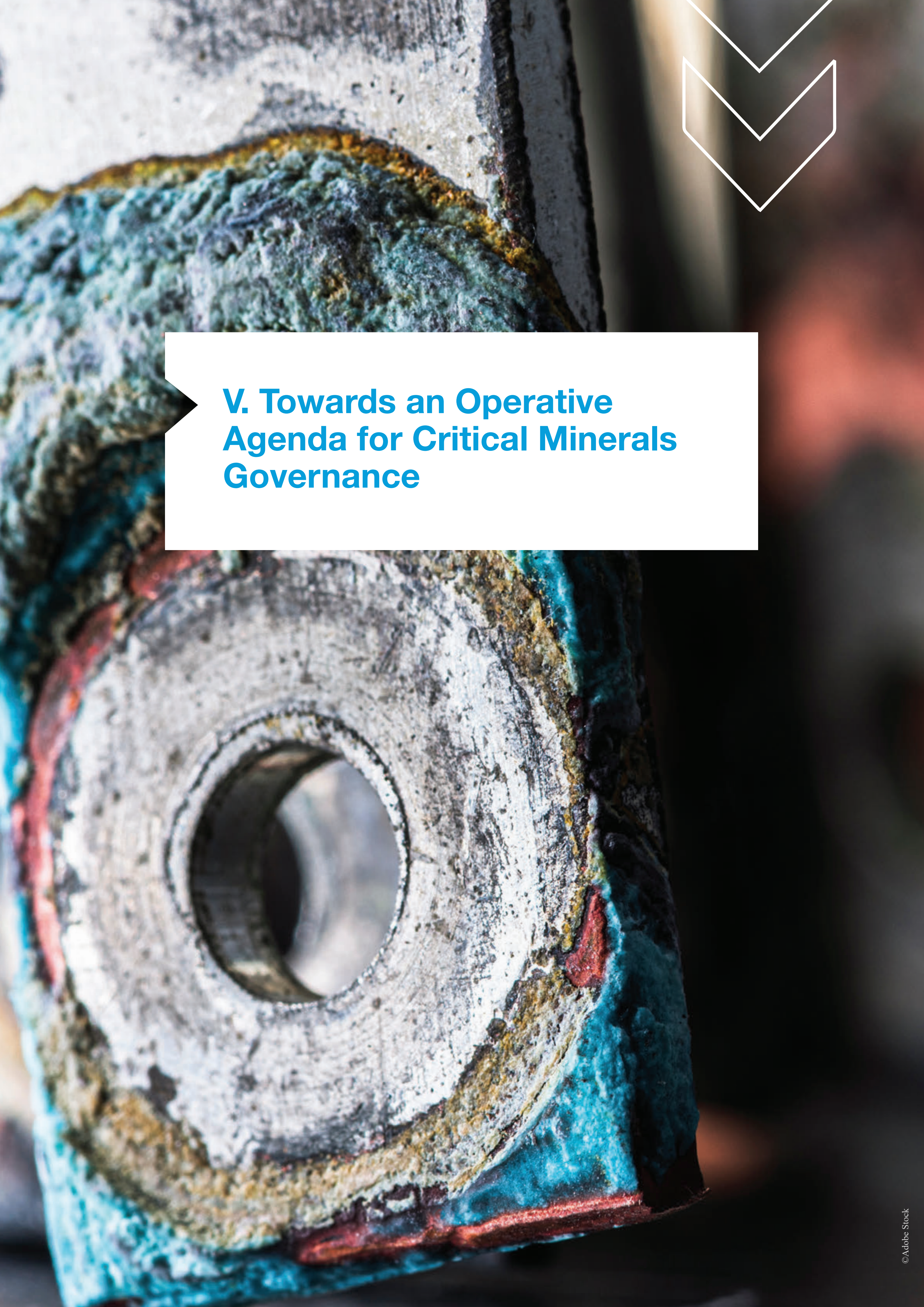
Despite differing contexts, both regions converge on a common objective: leveraging the mining and critical minerals sectors as entry points for broader productive transformation. In both cases, the emphasis is on aligning mining policies with industrial, fiscal, skills, and innovation strategies to ensure that extractive activities generate durable linkages and capabilities beyond the resource sector itself.

A shared feature is the combined use of supply- and demand-side instruments to stimulate upgrading within and around mining value chains. In Latin America, this takes the form of investment incentives, downstream processing initiatives, and technology partnerships; in Africa, complementary demand-side tools—such as public procurement, offtake agreements, and standards—play a more prominent role. These approaches underscore that supply-side measures (skills, finance, infrastructure) are most effective when paired with policies that create predictable demand for local firms.

Ultimately, both experiences illustrate that capability formation within mining-related activities—through skills development, standards, and innovation systems—is a necessary condition for translating mineral endowments into wider diversification and productivity gains. In this sense, the mining sector functions not as an end in itself, but as a platform through which broader processes of structural transformation can be initiated.

Overall, Latin American and African approaches reveal a coherent mix of industrial policies. Market-based interventions combine fiscal and financial incentives with demand-side instruments such as procurement and standards. Public goods and skills measures include education, laboratories, and supplier-development initiatives. Innovation platforms encompass pilot plants, research consortia, and regional clusters linking local firms to global technology networks. Across these pillars, environmental sustainability, community engagement, and transparency operate as cross-cutting enablers of legitimacy and durability.

V. Towards an Operative Agenda for Critical Minerals Governance



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Given the pivotal role of critical minerals as both a catalyst for structural transformation and a cornerstone of the global climate transition, developing countries are encouraged to pursue a comprehensive governance agenda that translates strategic vision into actionable policy. This agenda must not only address governance and sustainability but also provide the policy tools needed to move from extraction to transformation.

In this regard, on industrial policy for mining global value chains offers a useful taxonomy for operationalizing such an agenda. It distinguishes three complementary categories of instruments—market-based interventions, public goods and skills development, and innovation and R&D platforms—which together underpin the structural transformation of mineral economies. The five governance principles outlined below can be seen as the institutional and strategic architecture through which these policy instruments are deployed effectively and coherently.

1. First, domestic **value-chain development, local content and diversification** correspond closely to market-based interventions. They involve targeted incentives and regulatory instruments that promote investment in processing, refining, and recycling while strengthening linkages between global investors and domestic firms. These measures can include local-content frameworks, performance-based fiscal incentives, blended-finance mechanisms, and public procurement strategies that stimulate domestic demand for processed mineral products. When embedded within regional cooperation mechanisms, such policies reinforce backward, forward, and sideway linkages across sectors—allowing spillovers into manufacturing, agriculture, and services.

2. Second, **strategic partnerships and multilateral engagemen**t Partnerships can catalyze market-based interventions through joint ventures and regional value chains, enhance public goods and skills development through shared training and research infrastructure, and support innovation platforms by pooling resources for R&D. Such alliances—whether regional, South–South, or multilateral—are essential for access to technology, concessional finance, and standards development, while safeguarding national policy space in a context of geopolitical competition.

3. Third, **policy coherence and strategic planning** serve as the enabling condition across all instrument categories. Integrating extractive, industrial, fiscal, environmental, and social policies within a unified national framework ensures that supply- and demand-side measures operate in concert rather than in isolation. National critical minerals strategies—with measurable targets, interministerial coordination mechanisms, and periodic reviews—provide the planning infrastructure needed to link market incentives, capability formation, and innovation ecosystems in a mutually reinforcing manner. International trade and investment commitments should be aligned with national critical minerals strategies and should ensure country's right to regulate while promoting and facilitating sustainable trade and investment.

4. Fourth, **sustainability and community rights** align primarily with the public goods and skills pillar. Social legitimacy and environmental stewardship are prerequisites for durable mineral development. Embedding robust environmental standards, lifecycle management, and consent-based community engagement ensures that value-chain development is inclusive and resilient. Equitable benefit-sharing arrangements, social investment plans, and support for community-based enterprises extend the developmental impact of the sector, anchoring industrial growth in local participation and human capital formation.

5. Fifth, **transparency and accountability** cut across all dimensions of the framework. Predictable, transparent legal and fiscal systems—supported by open data, independent audits, and accessible grievance mechanisms—enhance trust among citizens, investors, and international

partners. These governance standards reduce uncertainty, prevent elite capture, and ensure that market and innovation incentives contribute to public welfare rather than narrow rent capture.

Taken together, these five principles form the institutional scaffolding Table 6 below summarizes the main priority areas, corresponding policy domains, and indicative lead institutions for implementing an integrated governance agenda for critical minerals.

Table 6.
Operational Priorities for Strengthening Critical Minerals Governance

Priority Area	Corresponding Instrument Category	Operational Focus	Lead Institutions / Partners
1 **Domestic value chains, local content & diversification**	Market-based interventions	**Promote** processing, refining, and recycling; support technology transfer, skills, and SME linkages; foster regional and South–South cooperation.	Industry, Trade & Mining Ministries; Development Banks; Regional Economic Communities.
2 **Strategic partnerships & multilateral engagement**	Cross-cutting (market, skills, innovation)	**Build** regional value chains and joint ventures; engage in global rule-making and standards; secure finance and technology via multilateral platforms.	Foreign Affairs & Trade Ministries; Regional Dev. Banks; UNCTAD, UNIDO, AU, ECLAC.
3 **Policy coherence & strategic planning**	Enabling framework (links all categories)	**Prepare** national critical-minerals strategies; align extractive, industrial, and climate policies; establish coordination and monitoring mechanisms; ensure international trade and investment commitments are aligned with such strategies.	Planning, Finance, Industry & Environment Ministries; Cabinet Offices.
4 **Sustainability & community rights**	Public goods & skills development	**Enforce** environmental and social standards; ensure consent and benefit-sharing; support local enterprises and supply chains.	Environment & Labour Ministries; Local Governments; Indigenous & Civil Society Orgs.
5 **Transparency & accountability**	Cross-cutting enabler	**Publish** contracts and revenues; ensure audits and open data; align with EITI and anticorruption standards.	Finance & Justice Ministries; Audit Agencies; Civil Society; EITI Secretariat.

Source: UNCTAD

Effective implementation of this integrated governance and policy framework will require sustained political commitment, coherent interministerial coordination, and continued investment in institutional capacity. International cooperation—through technology transfer, concessional finance, and multilateral partnerships—will be critical to support these national efforts and ensure that developing economies can fully benefit from the emerging critical minerals economy. By aligning governance, industrial policy, and sustainability objectives, countries can turn their mineral endowments into lasting engines of structural transformation and inclusive, low-carbon development.

Appendix: Data, Methods and Construction of Figures 4-7

This appendix provides a consolidated description of the data sources, methodological procedures and analytical choices underlying Figures 4 to 9. It is intended to ensure full transparency and reproducibility of the empirical material supporting Boxes 1 and 2.

Data Sources and Coverage

The information on lithium and rare-earth reserves and mined output is taken from the United States Geological Survey (USGS) Mineral Commodity Summaries (2024 edition). These sources provide internationally comparable estimates of economically recoverable reserves and annual mined output for 2023, expressed as shares of the global total.

Manufacturing value added (MVA) is drawn from the World Bank's World Development Indicators (series NV.IND. MANF. ZS). Because international coverage is most complete in 2022, this year is used as the reference point for the manufacturing variable, with China's MVA updated to 15.2 per cent of GDP in 2023 based on official national statistics.

Construction of Figures 4 and 6

Figures 4 and 6 display reserves and refining and processing capacity for lithium and rare earth elements, respectively. For both minerals, Panel A presents an index of reserves constructed from harmonised USGS estimates and normalised to allow cross-country comparison. Panel B presents a composite refining, separation and processing dominance index, reflecting each country's estimated share of global downstream capacity. Because no single harmonised dataset exists for these stages of the value chain, the index combines the most recent and authoritative estimates from the IEA Global Critical Minerals Review, the USGS Mineral Commodity Summaries, BloombergNEF, Roskill/ Adamas Intelligence and national mining authorities. These sources consistently

show that China commands by far the largest share of global processing capacity—around 65 per cent for lithium refining and close to 90 per cent for REE separation—while other producers such as Chile, Argentina, Malaysia, the United States and Australia hold much smaller shares.

For mapping purposes, each country's process index is expressed as its percentage share of global refining or separation capacity. Countries are then classified into five fixed dominance categories widely used in critical-minerals market analysis: 0–1, 1–10, 10–20, 20–50 and above 50 per cent of global capacity. These thresholds avoid over-precision (given data uncertainty in downstream capacity estimates) and ensure that countries with genuinely dominant roles—most notably China—are visually distinct. Darker green shades therefore represent greater downstream processing dominance, while very light shades correspond to countries with limited or no refining or separation capacity. This method provides a transparent and reproducible way to compare strategic positions across the lithium and REE value chains.

Construction of Figures 5 and 7

Figures 5 and 7 combine mineral production shares with manufacturing value added using a bivariate mapping technique. Each variable—production share and MVA as a percentage of GDP—is divided into three groups (low, medium and high) based on tertile thresholds. These classifications generate nine possible combinations of production intensity and industrial capacity.

The resulting 3 by 3 classification is then visualised through a bivariate colour palette. In line with the analytical focus of the paper, the palette emphasises the degree of industrial capability: darker, more saturated tones indicate stronger manufacturing bases, regardless of production level. This approach makes it possible to distinguish resource-abundant economies with limited industrialisation from those that combine mineral endowments with downstream production capabilities. Countries with no commercial production (for example Portugal in the case of lithium) are not included in the bivariate grid.

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