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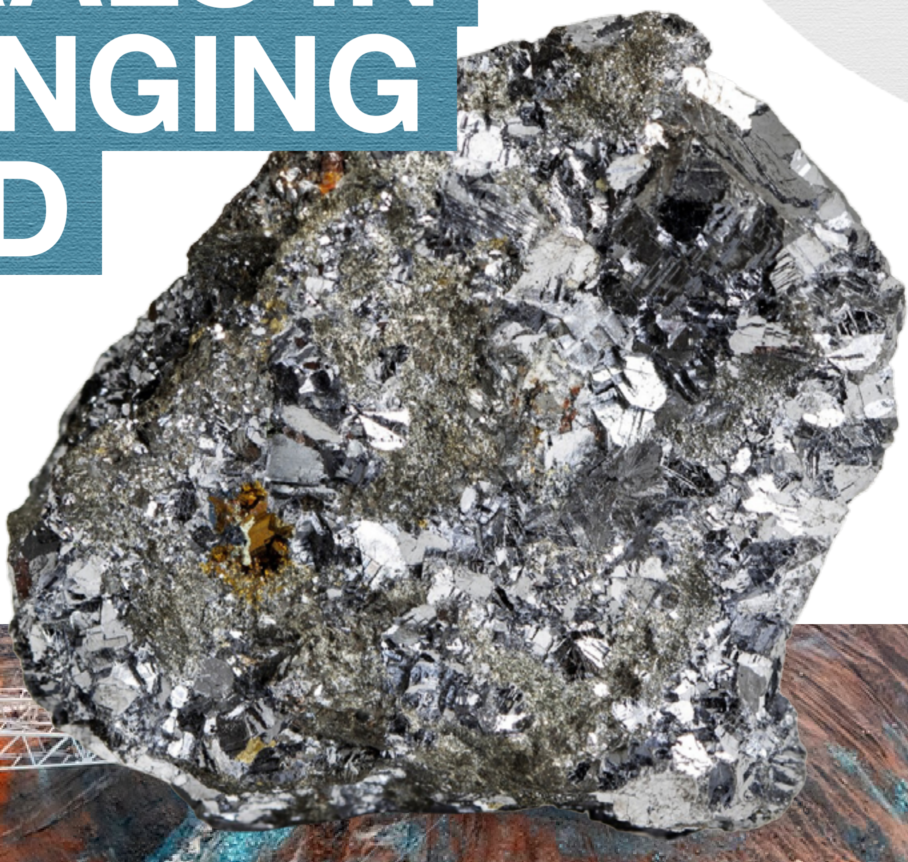
BRAZIL'S CRITICAL AND STRATEGIC MINERALS IN A CHANGING WORLD



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Executive Summary

This strategic paper examines Brazil's critical and strategic minerals amid growing global demand as foreign governments and multinational companies seek new supplies to fuel the transition to green and digital technologies. Brazil has a rich and diversified supply of minerals critical to the development of these new technologies, including niobium, graphite, rare earths, and nickel, and is a major exporter of iron ore, manganese, tantalum, niobium, and bauxite. As Brazil explores *friendshoring*[1] arrangements, it still plays a less prominent role on the global stage when it comes to other types of mineral ore.

This strategic paper highlights potential tensions and pressure points around the country's critical and strategic minerals regarding public and private sector actors, society, foreign policy, and nature. It concludes with five key takeaways, the first of which concerns Brazil's unclear role in the green and digital transitions, to the extent that the terms of engagement with global markets are still being defined. Secondly, Brazil's troubled history of tension and conflict over the ownership and control of its mineral resources, coupled with the uneven distribution of the country's geological knowledge, can lead to conflicts between different stakeholders, both within and outside the country.

Thirdly, the emphasis on economic gains in the discussions and policies concerning critical and strategic minerals often overshadows environmental and social issues. This approach could have global consequences, especially considering the ongoing climate change agenda and the transition towards sustainable practices. Fourth, without government aid or a domestic market, the private sector is unlikely to invest in the *downstream and midstream*[2] processing of critical minerals.

This strategic paper emphasizes the need for wide social agreement on environmental and cultural protections for critical and strategic mineral extraction. Notwithstanding the President Luiz Inacio Lula da Silva administration's pledge to reinstate relevant environmental and indigenous safeguards, consensus remains crucial.

This strategic paper demonstrates that Brazil has the potential to strategically position itself as a responsible and trusted critical minerals partner, leveraging its diverse portfolio and protecting the Amazon, while also influencing global social and environmental norms in the critical minerals market.

Introduction

Global demand for critical and strategic minerals (CSMs) is growing. Rare earths, lithium, graphite, cobalt, copper, nickel, and dozens of others are increasingly vital to the global economy as many countries transition to digital and green technologies. This shift is driven in part by unpredictable rates of technological development and the adoption of carbon-reducing energy technologies, which often require more minerals to produce the same energy output as fossil fuels.

As the production of these technologies increases, so does the demand for many of these minerals.[3] Photovoltaic power, for example, requires up to 40 times more copper than burning fossil fuels, while wind power requires up to 14 times more iron.[4] It takes two tonnes of rare earths to make a single wind turbine.[5] In the next 25 years, demand for copper is expected to reach 550 tonnes, equivalent to the amount produced in the last 5,000 years.[6] By 2050, the demand for lithium is expected to increase by 965%.[7]

According to World Bank projections, green energy technologies alone will require more than 3 billion tonnes of CSMs by 2050.[8] However, today's global supply chains are dependent on a few exporting countries – notably the People's Republic of China, the Democratic Republic of Congo, Chile, and South Africa.[9] The geographic concentration of supply chains makes them vulnerable to market shocks, geopolitical events, and logistical disruptions.

Market pressures increased in 2020 when China implemented a new law restricting the flow of CSMs to foreign countries.[10] The Asian country's dominance in processing, including rare earths, influences global prices.[11] With persistent questions about whether there are enough mineral resources in the world to meet expected demand, the availability and affordability of CSMs cannot be guaranteed. This is likely to increase geopolitical competition as countries scramble for access to these minerals.

Given the geopolitical complexities, Western countries are already trying to reduce their dependence on China. In the coming years, the United States is likely to accelerate its efforts with *onshore* and *friendshore* strategies (with countries such as Australia, Canada, and possibly Brazil) to develop new supply chains.[12] To date, Brazil's role has been relatively minor, but with heightened confidence from investors and policymakers, it has the potential to emerge as a significant player.

Brazil is already considered a mining superpower – in addition to high-quality iron ore, the country also supplies 9% of the world's aluminum and bauxite, 7% of its graphite, and 90% of its niobium (Annex 2). It also has great potential for the production of copper, lithium, nickel, phosphate, potassium, uranium, and rare earths. As Latin America's largest economy begins to attract the attention of global investors,[13] the government of President Lula is confronted with pivotal decisions regarding the strategic positioning of Brazil in the fast-evolving CSM market.

The development of new supply chains for Brazilian CSMs raises important social, environmental, and governance issues. Mining activities can trigger risks related to various issues, including indigenous autonomy, illegal economies, armed conflicts, and environmental destruction.[14] Given that approximately 30% of known CSM reserves in Brazil are located in the Legal Amazon,[15] there is a real risk that the energy transition could trigger a deeper climate crisis.

This strategic papert offers an initial analysis of the dynamics surrounding Brazil's CSMs and connects them to the country's potential role in the new global architecture for digital and green transitions.

Definition of critical and strategic minerals (in Brazil and other countries)

This strategic paper explores "critical" and "strategic" minerals, terms that lack global consensus and whose definition is subject to ongoing debate as technological innovations, disruptions, and global crises reshape supply chain structures.[16] A mineral that is considered critical or strategic for the economy of one country may be perceived differently by another.

Annex 1 shows the minerals considered critical and strategic for Brazil, China, the United States, and the European Union (EU).

Table 1. Definition of "Critical" and "Strategic" Minerals by Country

CHINA	"Strategic" minerals "ensure national economic security, national defense, and the security and development needs of strategic emerging industries."[17]
UNITED STATES	"Critical" minerals have the following characteristics: (i) Non-fuel mineral or mineral material essential to the economic and national security. (ii) Supply chain is vulnerable to disruptions. (iii) Serves an essential function in the manufacture of a product, the absence of which would have significant consequences for the economy or national security.[18]
EUROPEAN UNION	(i) "Critical" raw materials: "Raw materials of high importance to the economy and whose supply is associated with a high risk." (ii) "Strategic" raw materials: "Key raw materials for technologies that support the twin green and digital transition, and defense and aerospace objectives."[19]

continuation

AUSTRALIA	"Critical minerals" are metals and non-metals deemed "essential to the functioning of our modern technologies, economies or national security," and where "there is a risk that its supply chains could be disrupted."[20]
CANADA	"Critical" minerals are: (i) Essential to Canada's economic security and its supply is threatened. (ii) Required for the national transition to a low-carbon economy. (iii) Sustainable sources of highly strategic critical minerals for partners and allies."[20]
UNITED KINGDOM	"Critical" minerals are those "with high economic vulnerability and high global supply risk."[22]

In Brazil, Resolution 2 of the "Pro-Strategic Minerals Policy"[23] provides a precise definition of "strategic minerals," divided into three categories:

- **Category 1:** Minerals with a high percentage of imports, and necessary to supply vital sectors of the economy.
- **Category 2:** Important minerals for use in high-tech products and processes.
- **Category 3:** Minerals with comparative advantages that are essential to the economy because they generate a surplus in the country's trade balance.

Table 2. Minerals defined in Resolution 2 of Brazil's "Pro-Strategic Minerals Policy"

CATEGORY 1	CATEGORY 2			CATEGORY 3
• Sulfur • Phosphate • Potassium • Molybdenum	• Cobalt • Copper • Tin • Graphite • Platinum - Iridium - Osmium - Osmium-iridium - Palladium - Platinum - Platinum-iridium - Platinoids - Rhodium - Ruthenium • Lithium	• Rare Earths - Monazite - Scandium - Yttrium - Lanthanum - Cerium - Praseodymium - Neodymium - Promethium - Samarium - Europium - Gadolinium - Terbium - Dysprosium - Holmium - Erbium - Thulium - Ytterbium - Lutetium	• Niobium • Nickel • Silicon • Thallium • Tantalum • Titanium • Tungsten • Uranium • Vanadium	• Aluminum - Bauxite • Copper • Iron • Graphite • Gold • Manganese • Niobium • Uranium

Category 1 minerals are those with a high percentage of imports and limited mining potential in Brazil. Most of these minerals are demanded by the Brazilian agricultural sector for use in domestic fertilizers, given the importance of soy, beef, and other agricultural exports. In this strategic paper, they are referred to as **agrominerals.**

Category 2 minerals are important for applications in high-tech products and processes, including batteries (especially lithium, cobalt, rare earths, nickel, and copper) and green and digital technologies. These minerals are generally exported from Brazil for processing and used for production purposes in global value chains. In this strategic paper, they are referred to as **technological minerals.**

Category 3 minerals are those that provide Brazil with a comparative advantage and are economically important because they contribute to the country's trade surplus. They are minerals of high quantity, such as iron ore, or high value, such as gold. In this strategic paper, they are referred to as **commercial minerals.**

As this strategic paper focuses on the dynamics of minerals in Brazil, the study is limited to the minerals listed in the Pro-Strategic Minerals Policy (2021) (Table 2). However, given that the document is intended for policymakers around the world – with variations on what is understood as "critical" and "strategic" – we adopt a broad perspective on such minerals, referred to here as "critical and strategic minerals" (CSMs).

Location and Quantity of Critical and Strategic Minerals in Brazil

Brazil has a rich and diverse geological makeup, consisting of several fertile volcanic-sedimentary, volcanic, and plutonic sequences. These formations underlie two different geographic environments: the Amazon in the west and the Atlantic in the east.[24]

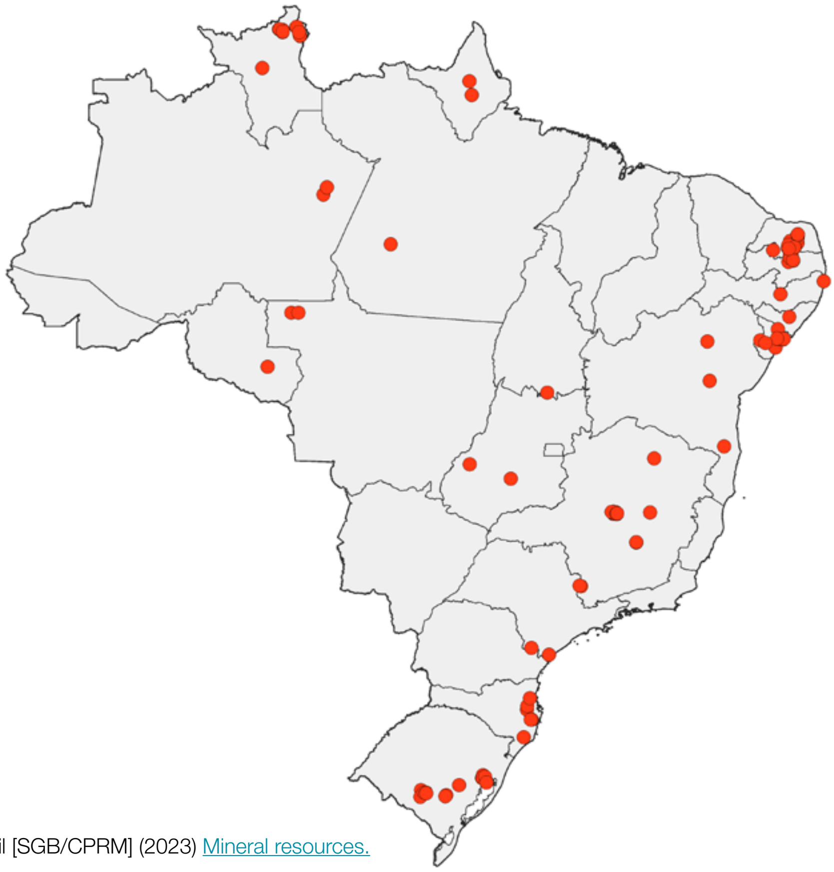
Category 1 agrominerals (Figure 1) are mainly distributed along the Atlantic coasts with some smaller and more sparsely scattered reserves inland.

Category 2 technological minerals (Figure 2) are more plentiful and can be found in three broad areas:

1. Northern Goiás and Southern Tocantins.
2. Scattered throughout the Brazilian Legal Amazon.
3. Minas Gerais, North and Western Bahia, Southeastern Piauí, Western Pernambuco, and Southern Ceará.

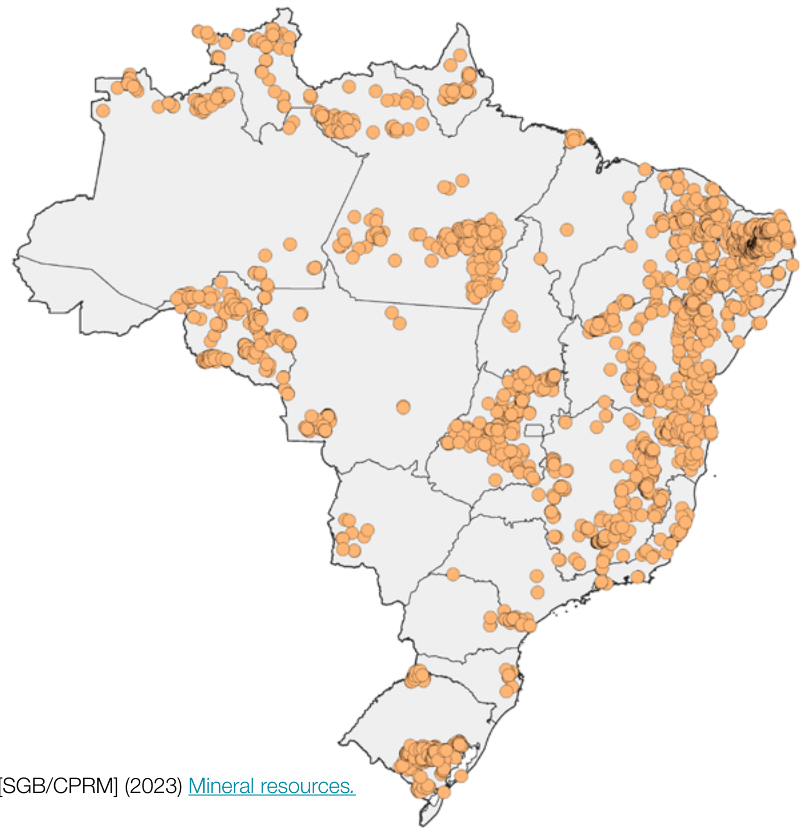
Category 3 commercial minerals (Figure 3) are abundant in much of the country.

Figure 1. Official occurrences of Category 1 agrominerals



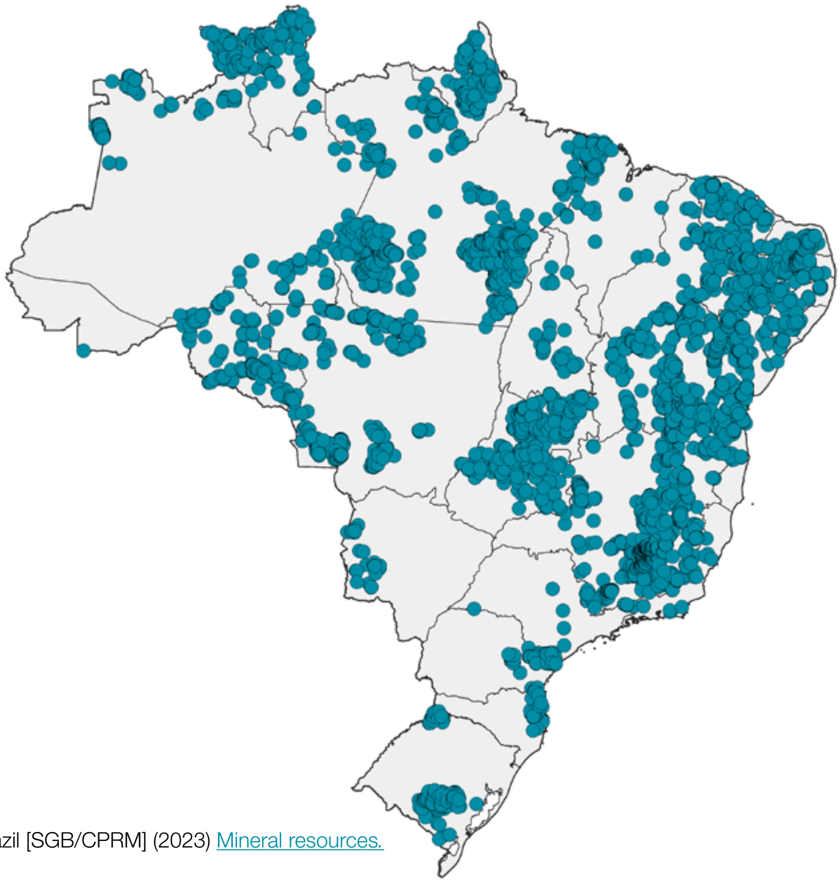
Source: Geological Survey of Brazil [SGB/CPRM] (2023) [Mineral resources.]

Figure 2. Official occurrences of Category 2 technological minerals.



Source: Geological Survey of Brazil [SGB/CPRM] (2023) [Mineral resources.]

Figure 3. Official occurrences of Category 3 commercial minerals.



Source: Geological Survey of Brazil [SGB/CPRM] (2023) Mineral resources.

Brazil has a substantial number of known reserves of Category 2 technological minerals for which global demand is growing (Table 3). The country has 94.12% of the world's niobium, 22.42% of its graphite, 16.15% of its rare earths, and 16% of its nickel.

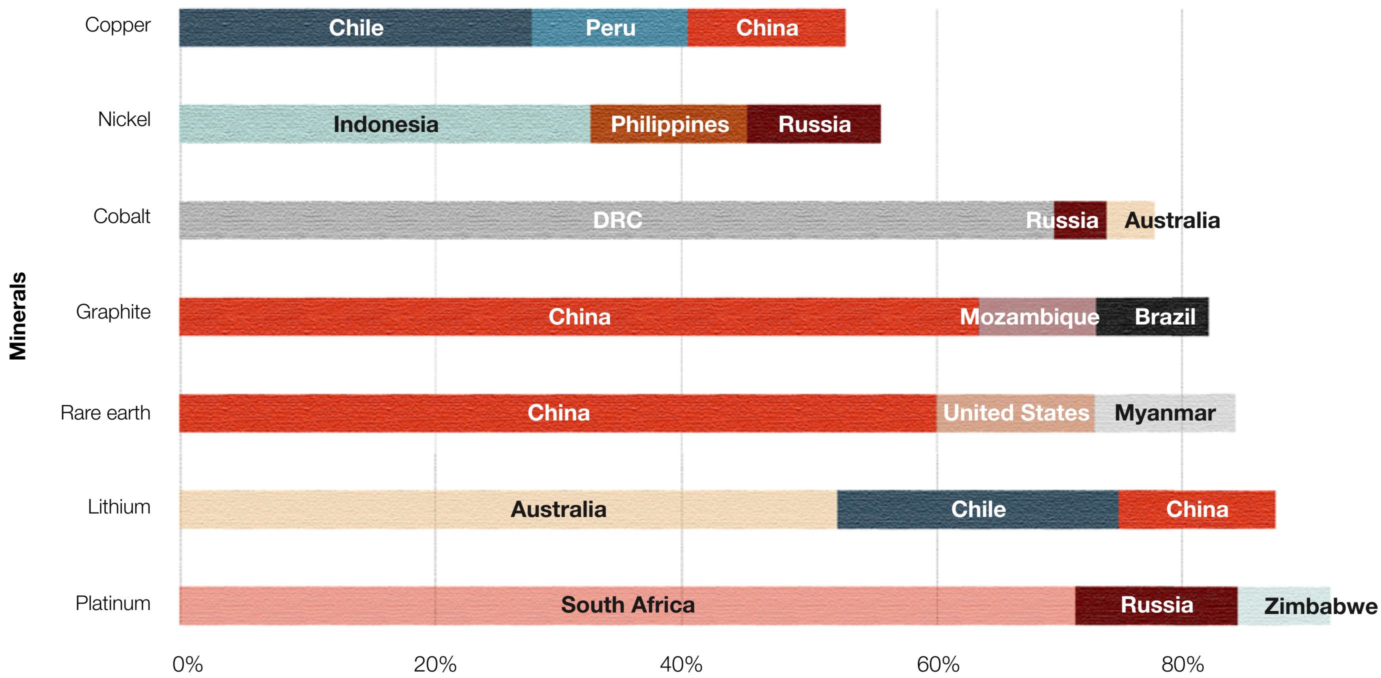
Table 3. Known reserves of Category 2 technological minerals.

	BRAZIL'S RESERVES (TONNES)	GLOBAL RESERVES (TONNES)	BRAZIL'S PARTICIPATION IN GLOBAL RESERVES
ALUMINUM (INCLUDING BAUXITE)	2,700,000	31,000,000	8.71%
COBALT	85,000	8,300,000	1.02%
COPPER	9,664,000	890,000,000	1.09%
TIN	420,000	4,600,000	9.13%
GRAPHITE	74,000,000	330,000,000	22.42%
PLATINUM GROUP	99	173,200	0.057%
LITHIUM	250,000	26,000,000	0.96%
NICKEL	16,000,000	100,000,000	16.00%
NIOBIUM	16,000,000	17,000,000	94.12%
SILICON[25]	No data	No data[26]	N/A
RARE EARTHS	21,000,000	130,000,000	16.15%
TANTALUM	40,000	No data[27]	N/A
THALLIUM[28]	N/A	N/A	N/A
TITANIUM[29]	43,000	650,000	6.62%
TUNGSTEN	28,000	3,800,000	0.74%
URANIUM	244,788	N/A	N/A
VANADIUM	120	26,000	0.46%

Sources:
- Lima, F. S. & Filho, W.S. S. (2021). Uranific potential in Brazil: a bibliographic review. Brazilian Journal of Development, 7(6), 58852–58867.
- U.S. Geological Survey [USGS] (2021). Mineral commodity summaries 2021.
- USGS (2023). Mineral commodity summaries 2023.

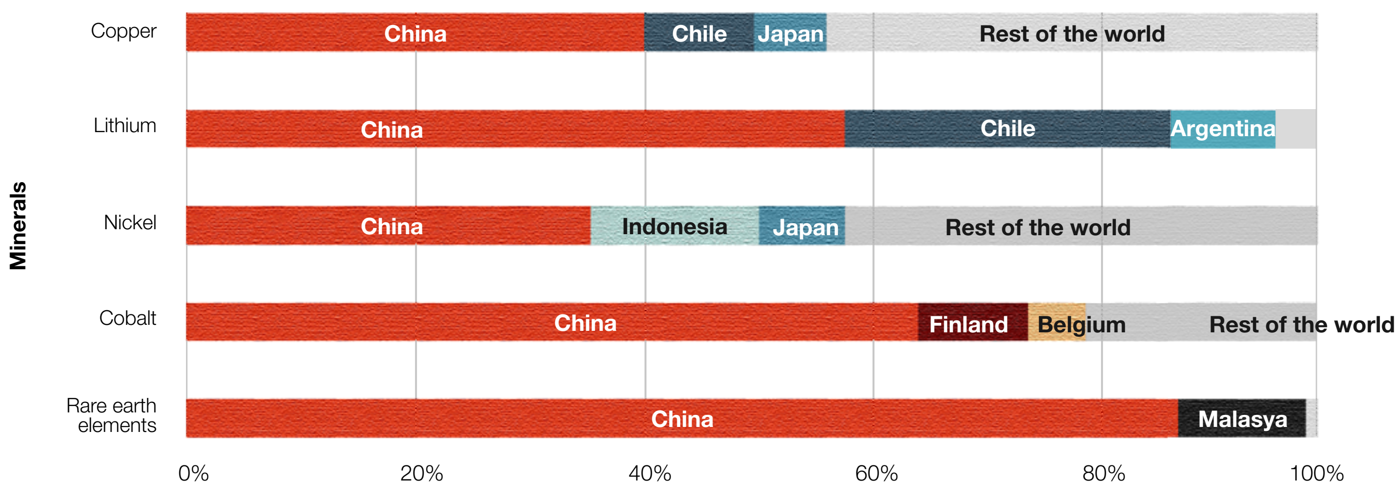
However, despite its abundant reserves and production potential for Category 2 Technology minerals, Brazil is not currently a major player in global markets. Compared to countries such as the Democratic Republic of Congo, Chile, China, Indonesia, Australia, and South Africa, Brazil's share of global reserves is relatively small (Figure 4a). China is the clear leader in processing, with Chile, Japan, and Indonesia also playing important roles (Figure 4b).

Figure 4a. Share of top producing countries in total production of selected technological minerals (2019).



Source: IEA (2021). The Role of Critical Minerals in Clean Energy Transitions.

Figure 4b. Share of processing volume by country for selected technological minerals (2019).

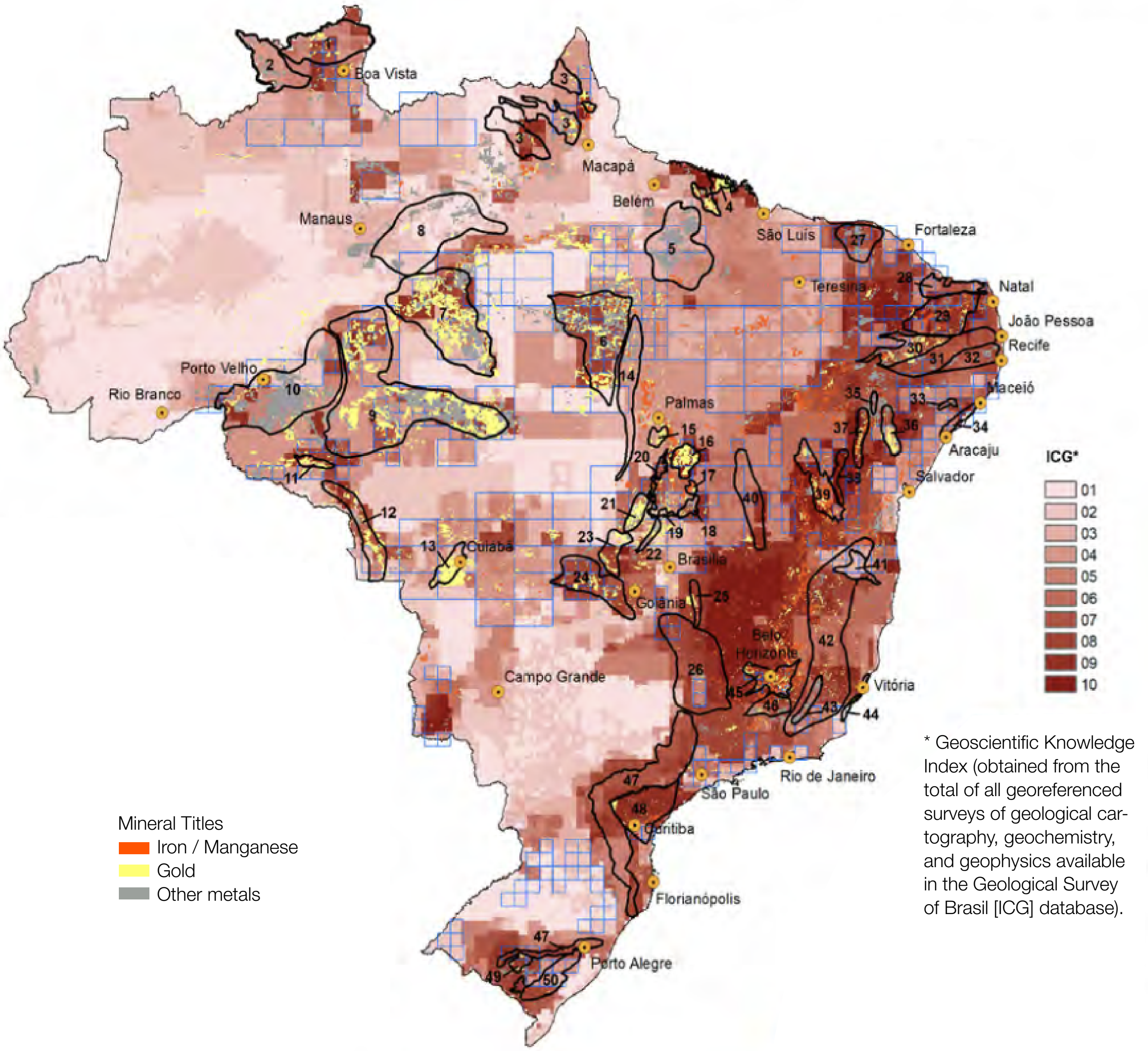


Source: IEA (2021). The Role of Critical Minerals in Clean Energy Transitions.

Traditional metrics, like a country's market share size, can sometimes distort the true picture. In the global mining sector, Brazil's mineral reserves are valued more for their variety than their volume.[30]

One of the main challenges in extracting CSMs is locating them. The Geological Survey of Brazil (SGB/CPRM)[31] states that inconsistent geological knowledge is a persistent issue for both government authorities and private firms. Figure 5 shows the country's Geoscientific Knowledge Index, with dark red representing high geoscientific knowledge density and light red indicating low density.

Figure 5. Map of Brazil's Geoscientific Knowledge Index



* Geoscientific Knowledge Index (obtained from the total of all georeferenced surveys of geological cartography, geochemistry, and geophysics available in the Geological Survey of Brasil [ICG] database).

Source: SGB (s.d.). Notebook I - Geological Knowledge.

Less than half of Brazil's territory has been geologically explored and mapped.[32] The southeastern Atlantic coast is well-explored, resulting in extensive geological knowledge. However, exploration and surveying are extremely challenging in the northern and northwestern Amazon due to limited access and the need to understand tectonomagmatic events, geotectonic environments, and geochemical origins.

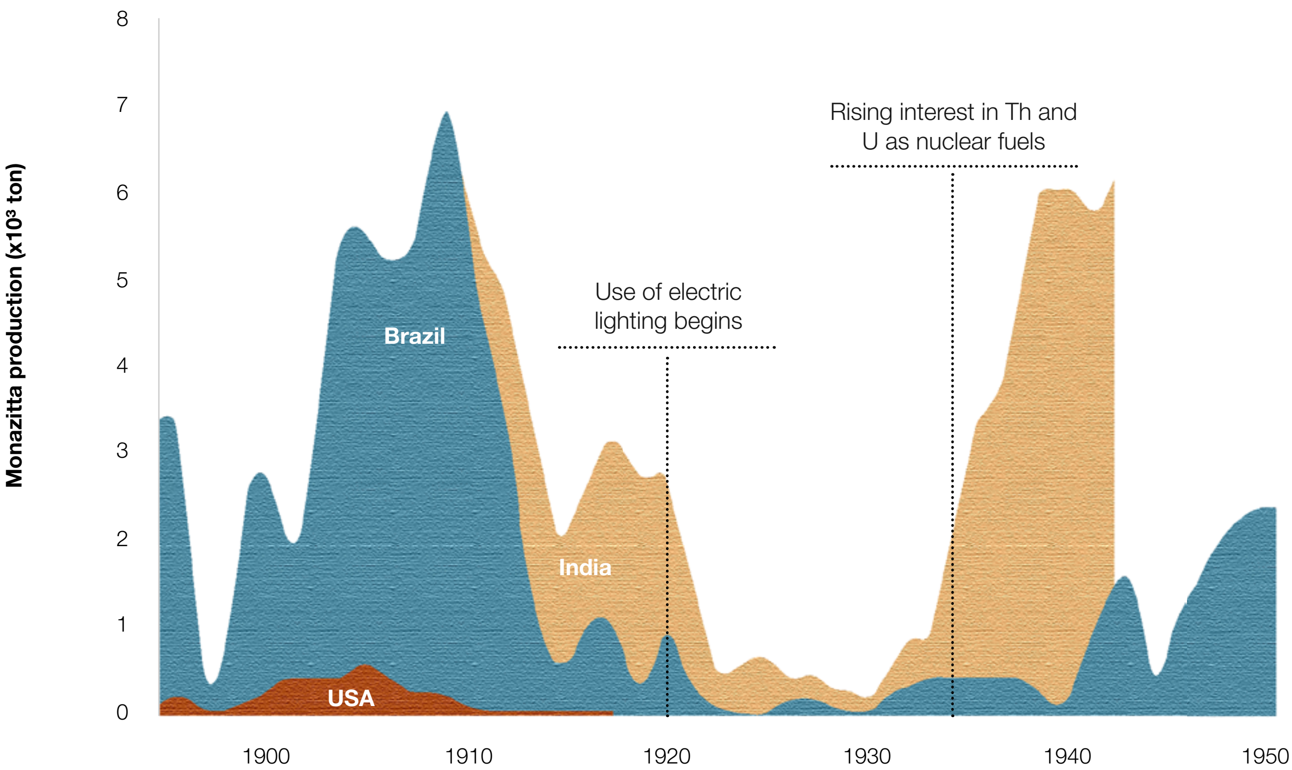
Some minerals (e.g., gold) are easier to identify and extract than others, and local actors living in the regions generally know the territory and location of minerals much better than public officials, or private companies. This can create risks for local communities, who are often vulnerable to co-option or coercion by external parties seeking knowledge and information in remote regions or outside legal or government channels.

Historical Overview of “Strategic” Minerals in Brazil

Starting with Portuguese colonial settlements in the mineral-rich region of Minas Gerais, Brazil’s economic growth has long been linked to the extraction of raw materials and minerals. Over the centuries, Brazil’s abundant resources have attracted the interest of international imperial powers, whose geologists and miners have established strong ties with the country’s mining companies.[33] In addition, global geostrategic factors – such as technological advances and world wars – have shaped global demand and influenced mining activities in Brazil.

Monazite, a mineral compound that contains rare earth elements, thorium, and uranium, was added to the list of essential minerals in 1885 when it was identified in Bahia and Espírito Santo.[34] With the advent of new technologies, particularly lampshades in the 1880s, global demand for rare earths increased, and Brazil quickly became the world’s largest supplier of raw and processed rare earths (Figure 6).[35]

Figure 6. Evolution of global monazite production (1890-1950)



Source: Sousa Filho, P.C., Galaço, A.R.B.S, & Serra, O.A. (2019). Rare Earths: Periodic Table, Discovery, Exploration in Brazil and Applications. *New Chemistry 42 (10).*

The main monazite processing company in Brazil, Orquima, was founded in 1942 in São Paulo.[36] In the 1960s, the Brazilian government nationalized the company and renamed it "Administration of Production of Monazita" to focus on the production of minerals considered strategic by the government. In the 1970s, Nuclebrás Monazita acquired the company. However, its inferior quality rare earths couldn't compete with those from the U.S. and China, leading to a significant market share loss for Brazil.[37] By the 1980s, international companies were looking to Brazil for other minerals, such as tungsten, niobium, manganese, molybdenum, nickel, and titanium – in part due to U.S. sanctions against South Africa during *apartheid*[38] –, and supplies were limited.

At the time, some politicians and businessmen saw in Brazil's undeveloped mineral production chains an opportunity to streamline operations, promote technology transfer, and invest in skilled labor.[39] Others were reluctant to encourage foreign participation in Brazil's resources and expressed concern about the return of extractive and exploitative relations.[40]

Meanwhile, China was investing heavily in its strategic mineral capabilities. By the 1950s, the Chinese state had established the State Reserves Bureau to manage reserves of strategic materials, and high-grade rare earths were a topic of considerable interest in the Chinese media.[41] China came to dominate the global rare earths market in the 1990s, while Brazil's rare earths production virtually ceased from 2002 to 2005.[42]

In the 2000s, China shifted its focus to strategic planning of mineral resources, making it a political priority. By 2009, it controlled 97% of the global rare earth market.[43] In 2010, it tightened its export quotas for rare earths, leading to a sharp rise in prices in 2011 and a global crisis in the supply chain.[44] Trade conflicts over rare earths between China and Western countries emerged in 2011,[45] with China implementing protective measures that included banning foreign investment in mining, restricting participation in rare earth smelting and separation, encouraging the export of finished products, and banning the mining of monazite containing radioactive elements.[46]

Against this geopolitical backdrop and amid growing awareness of the imperatives of the transition to green energy, policymakers in Brazil have begun to reshape the national strategy for minerals.[47] As a result, initiatives, policies, and regulations have been adopted that focus on the development of mineral extraction, production, and supply chains – particularly for rare earths, niobium, and lithium (Annex 3).

This new phase in Brazil's mineral policy reflects recognition of the potential of mineral resources to help the country gain traction in global markets.

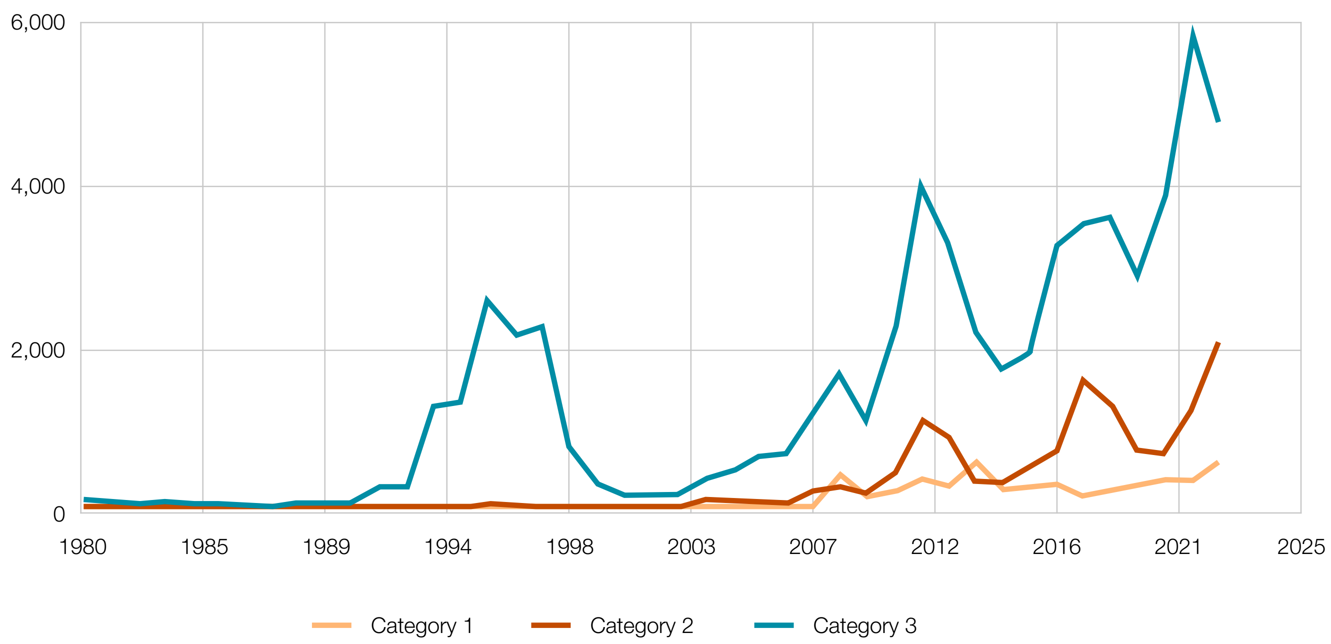
Governance and Regulation of Critical and Strategic Minerals

On March 24, 2021, the government of former President Jair Bolsonaro announced a controversial policy known as the Pro-Strategic Minerals Policy (Law 10,657/2021). This policy aims to prioritize and focus the federal government's efforts on CSM production projects. The initiative is notable for its articulation with the Investment Partnership Program (PPI) law, which includes the Policy to Support Environmental Licensing for Investment Projects (Law 13,334/2016).[48] The PPI law requires the State to act to ensure that investment projects are completed promptly and following their priority status.[49]

A critical aspect of the law is the suggestion that obtaining licenses related to regulatory, environmental, indigenous, urban, water, and cultural heritage protection aspects, among others, can be circumvented in the name of the "national interest." [50]

Since the intensification of the debate on CSMs in Brazil and the emergence of political initiatives in the late 2000s, the number of licenses issued and the active mining processes for the three categories have increased (Figure 7).[51] In Category 1, phosphate and potassium have driven the steady increase seen in mining processes since 2007. Category 2 minerals driving the peak from 2020 to 2022 are cobalt, copper, lithium, niobium, nickel, rare earths, and tantalum. Between 2021 and 2022, there was a drop in active Category 3 mining processes, due to a decrease in the amount related to iron and gold.

Figure 7. Number of active mining processes for CSMs in Brazil (1980-2022)



Source: National Mining Agency (2023). Mining Registry.

These changes are likely to be driven by a combination of market factors – global price, availability, and demand – and variation in the number of approvals issued by the National Mining Agency (ANM), the institution responsible for the management of mining activities and mineral resources, and the Ministry of Mines and Energy.[52]

The changes may also have been partly driven by the creation in 2021 of the Interministerial Committee for the Analysis of Strategic Mineral Projects (CTAPME). Coordinated by the Ministry of Mines and Energy (MME), the CTAPME aims to expedite the processing of CSM-related mining license applications for research and extraction.[53] As per Federal Decree 10.657/2021, CTAPME members also include representatives from the Ministry of Science, Technology, and Innovation (MCTI), the Institutional Security Office of the Presidency of the Republic (GSI-PR), the Special Secretariat for the Program of Investment Partnerships of the Ministry of Economy (SPPI), and the Special Secretariat for Strategic Affairs of the Presidency of the Republic (SAE-PR).[54]

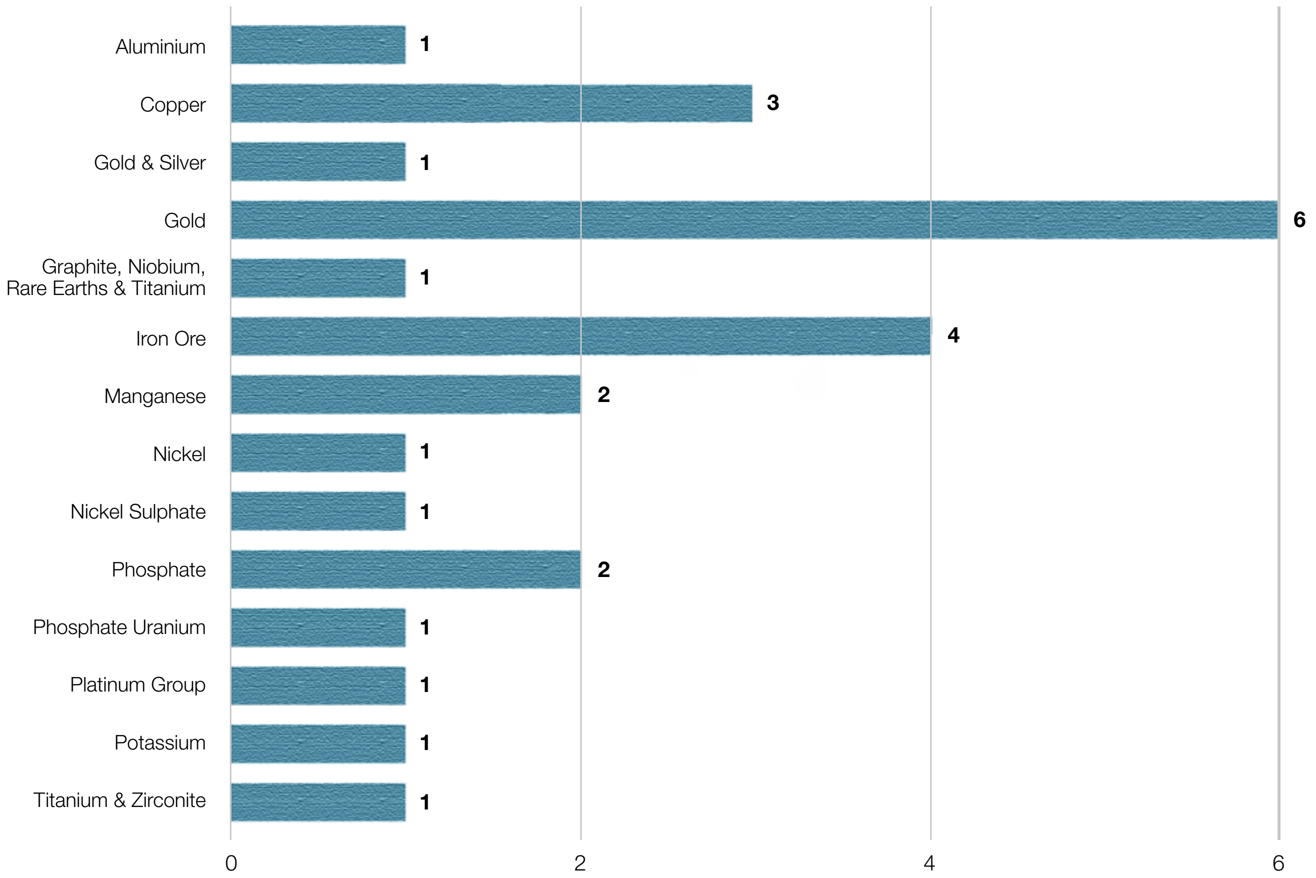
The committee emphasizes that its role is to help companies navigate through bureaucracy and synchronize the progress of environmental and mineral licenses, state checks, and public consultations.[55] In practice, this also involves addressing "obstacles" which may include environmental protections and the opposition of local communities to mining projects.[56]

Of the 25 projects reviewed by the committee through December 2022, 19 were approved for support,[57] including a proposed gold mine by the Canadian company Belo Sun that was halted in 2017 due to opposition from local communities and land use issues.[58] As shown in Figure 8, approved projects appear to prioritize Category 3 commercial minerals (cited in 13 out of 19 projects), with less focus on Category 2 technological minerals (cited in 8 out of 19 projects) and Category 1 agrominerals (cited in 3 out of 19 projects).

These priorities can raise questions about the inner workings, composition, and objectives of the CTAPME, but also about the country's broader governance priorities linked to its "strategic" minerals. In particular, limited stakeholder involvement in decision-making mechanisms for project approval through the CTAPME could reveal the priority of facilitating license approvals rather than thoughtfully mediating different stakeholder opinions.

As the global race for critical minerals gathers speed, it will be important to demand responsible action and monitor which minerals gain strategic importance under the guise of the "national interest" and energy transition.

Figure 8. Minerals mentioned in projects approved by CTAPME up to December 2022



Source: Ministry of Mines and Energy (undated). Interministerial Committee for the Analysis of Strategic Minerals Projects (CTAPME).

In 2022, the National Mining Plan 2050 was launched, focusing on the CSM production chain, which is essential for the energy transition. The plan is based on three pillars: exploitation of mineral resources, competitiveness, and sustainability.[59] In 2022, the then-Minister of Mines and Energy of the Bolsonaro administration, Pedro Paulo Dias Mesquita, proposed that the plan include initiatives to link Brazil's mineral production to the technologies needed for the energy transition (specifically wind turbines and electric car batteries), as well as to address urban e-waste recycling issues.[60]

It is also worth noting the progress of the New Mining Code and an amendment by its working group, submitted in the last days of the Bolsonaro administration, in December 2022, which is provoking political debate.[61] The amendment proposed the financing of mining titles and rights, in line with the Bolsonaro government's emphasis on developing financing initiatives for exploration and production. This was also demonstrated by a cooperation agreement between the Ministry of Mines and Energy and the Brazilian Development Bank (BNDES) in 2022.[62]

The Special Projects and Strategic Minerals Division (DIPEME) of the SGB/CPRM has been particularly active on the global stage in 2023, with marketing campaigns and visits to international mining forums to promote the exploration and extraction of niobium, lithium, graphite, cobalt, uranium, phosphate, and rare earths. However, the SGB/CPRM reports also acknowledge that outdated or incomplete geological data (especially in the Amazon) prevents Brazil and global markets from making a fully informed assessment of the country's energy-related minerals.[63]

New production and consumption models, such as the circular economy for the reuse of minerals and components, have received limited attention from Brazilian policymakers. Important political decisions are required to allocate resources to these initiatives, which in some ways contradict the significant and long-term investments already made in the exploration and extraction of minerals. However, the National Confederation of Industry (CNI) is working to develop business models and promote the adoption of circularity.[64] International organizations, such as the European Union's EITRawMaterials, have already begun to consider partnerships with Latin American countries, but these proposals are still in the early stages.[65]

How the CSM sector develops in the future will depend on key policy decisions on strategy, investment, and sector development. In August 2023, the Ministry of Mines and Energy announced that it is about to launch a national strategic minerals plan.[66] The new plan is expected to include the restructuring of the ANM and the strengthening of the SGB to accelerate mining processes and map the remaining territory of Brazil at an appropriate scale. It should also expand financing for mineral research and exploration, which in turn will be regulated by environmental, social, and governance (ESG) criteria. In addition, the plan should lay the groundwork for the development of an industrial chain associated with the exploration of strategic minerals.

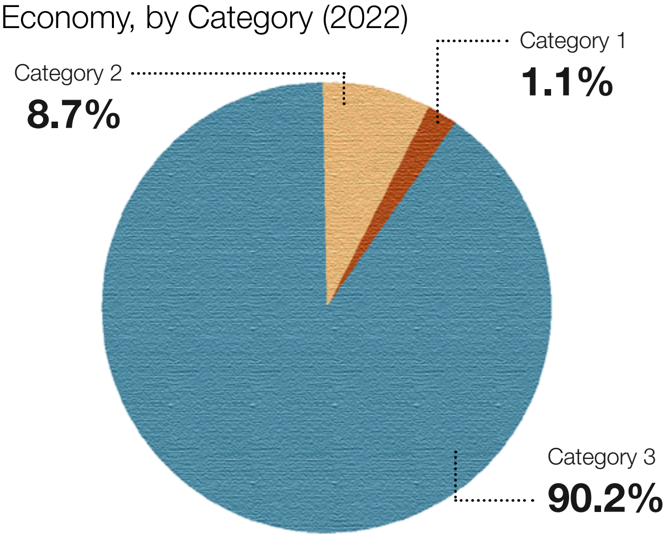
Early indications suggest that a more state-led development strategy for the mining and production sector may be on the horizon, in contrast to the previous liberal vision of reducing economic policy barriers introduced by then-president Jair Bolsonaro and his finance minister Paulo Guedes. Important questions remain about how this approach will play out, including how the priorities of different stakeholders related to CSMs will be balanced over the long term, alongside electoral pressures, and global market demands.

Critical and Strategic Minerals Sector in Brazil

Although mining has played an important historical and cultural role in Brazil, its overall contribution to the economy is relatively limited, accounting for approximately 3.1% of Brazil's Gross Domestic Product (GDP) in 2020.[67] Industry groups and lobbyists have expressed their goals to increase this contribution,[68] but the economic incentives vary significantly by mineral.

There are clear dividing lines in the economic contributions of distinct categories of CSM, suggesting that investment decisions will vary. As shown in Figure 9, Category 1 minerals contributed R$ 3.71 billion to the country's GDP in 2022.[69] Category 2 minerals contributed R$ 28.97 billion, of which copper accounted for 62% of this total (R$ 18 billion), followed by nickel with 23.5% (R$ 6.8 billion), tin with 5 .5% (R$ 1.6 billion) and niobium with 3.8% (R$ 1.1 billion).[70] Category 3 minerals contributed the most to the economy, with R$ 300.87 billion.[71]

Figure 9. Contribution of CSMs to the Brazilian Economy, by Category (2022)



Source: National Mining Agency (2023). Brazilian Mineral Yearbook.

Figure 10 shows that Category 3 minerals have consistently contributed most of the value of raw mineral production. Meanwhile, the processed value of Category 2 minerals has shown a small but steady increase (Figure 11), reflecting investment in technology, research, and development.

Figure 10. Value of Raw CSM Production (2010-2021)

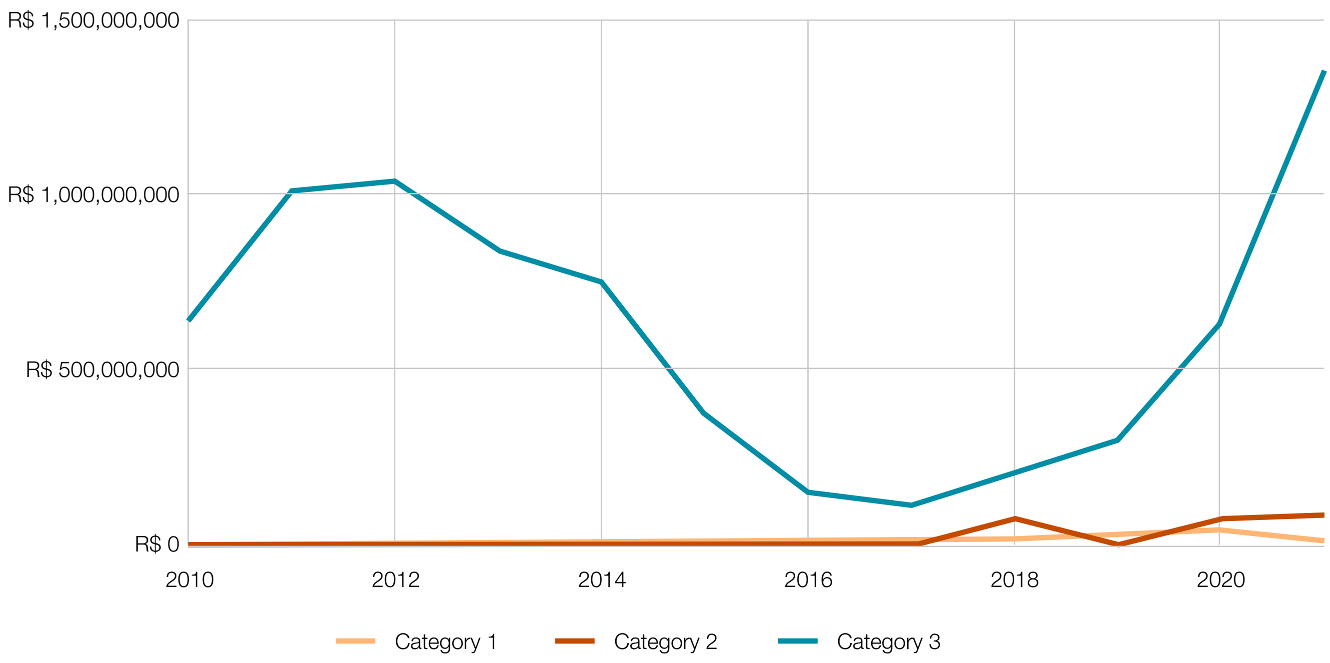
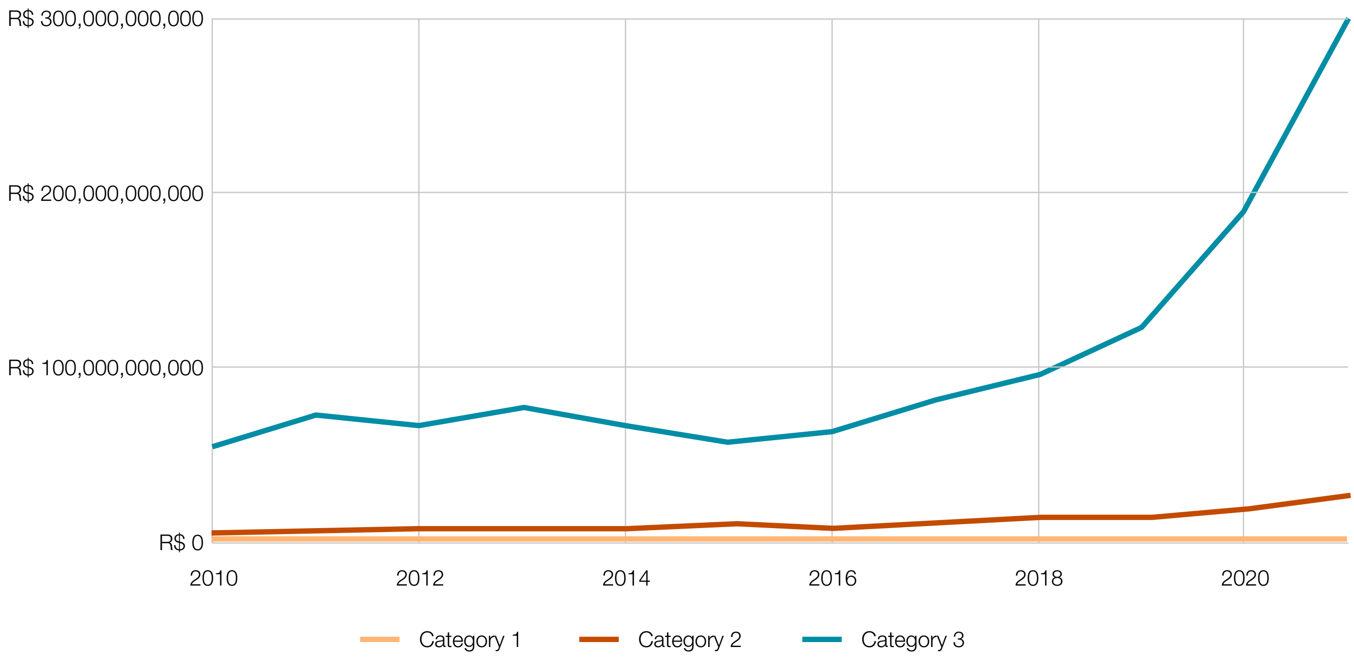


Figure 11. Value of Processed CSM Production (2010-2021)



Source: National Mining Agency (2023). Brazilian Mineral Yearbook.

CSM reserves in Brazil have attracted significant interest from global investors and mining companies.[72] The focus on energy transition is also affecting other extractive companies, such as Petrobras, the largest state-owned oil company in Brazil, which recently created a Directorate for the Energy Transition.[73]

However, Brazil lags behind other countries and territories in terms of ease of doing business. The country ranks 124th out of 190 countries in the Ease of Doing Business Index[74] and 51st out of 84 jurisdictions (countries and subnational territories) in the Mining Investment Attractiveness Index.[75] Concerns about contractual rights, business continuity and legal certainty, political instability, and social unrest – such as protests and blockades by local communities – make investors wary. Although the WTW Political Risk Index rates Brazil as "average," political polarization may remain a source of concern for stakeholders.[76]

The revision of the Mining Code is under discussion, but there is a long consultation process ahead. The Brazilian mining sector is dominated by a small group of very large companies (the top five are detailed in Table 5), especially in the extraction phase. Small and new companies are active in the sector but are generally focused on the exploration and research phases.[77] After determining the viability of sites and the economic feasibility of mineral extraction minerals, smaller companies often sell mining rights to larger companies that handle extraction and production.[78]

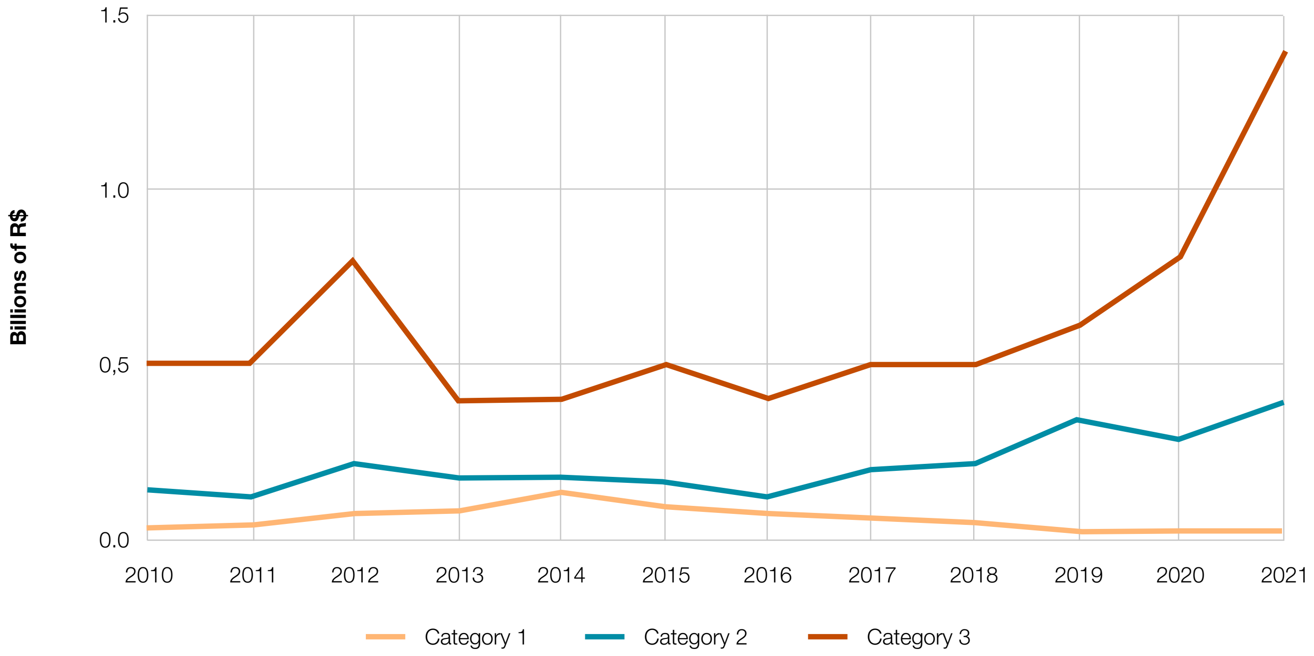
In the research phase, the exploration of CSMs has changed over the past decade (Figure 12):

- Category 1 minerals experienced a peak in mineral research in 2014, with phosphate and potash attracting the most investment. Since then, there has been a sustained decline in research investment.

- Category 2 minerals, on the other hand, have seen a steady increase in research investment, with the latest year of available data (2021) showing the highest figure to date. Cumulatively over this period, copper attracted more investment (64%), with nickel (17%), titanium (3.59%), rare earths (2.54%), niobium (2.31%), and tin (2.13%) also attracting notable investment.

- Category 3 minerals followed a similar trend to Category 2 but on a much larger scale. In Category 3, gold attracted more research investment (48%), followed by copper (22%) and iron (20%).

Figure 12. Investment in CSM Research in Brazil



Source: National Mining Agency (2023). [Interactive Brazilian Mineral Yearbook.]

Despite Brazil's significant CSM inventory, the country's investment remains below its production potential, even with the increased interest in research. This is partly due to the average lead time of 17 years from exploration to production,[79] but also because Brazil receives only a small share of global exploration budgets. For example, only 7% of the global nickel and rare earth exploration budget is spent in Latin America.[80]

Investments in infrastructure, research, development, and exploration for specific minerals show significant imbalances, with some minerals projected to attract much larger investments than others (Table 4). In the coming years, iron ore is expected to receive the largest investment in the sector, with copper, aluminum/bauxite, and fertilizers also proving attractive.

Table 4. Expected Investments in the CSM Sector in Brazil Between 2023 and 2027

MINERAL	MILLIONS OF US$
Manganese	$225
Zinc	$113
Iron ore	$16,921,90
Fertilizers	$5,222
Aluminum/Bauxite	$4,962
Copper	$4,474,30
Gold	$2,847
Nickel	$2,338
Other minerals	$1,933

Source: IBRAM (2023). Mining Sector Investment Plan and Focus on Reducing Emissions.

The five largest mining companies in Brazil (Table 5) extract several CSMs, with gold and iron ore being the most robust activities. Vale is the world's largest exporter of iron ore,[81] while three of the other five largest companies mine and export iron ore to global markets, contributing to Brazil's position as the world's second-largest exporter of iron ore, behind Australia.[82]

Vale and Anglo-American have diversified portfolios and also process critical minerals (Category 2). Anglo American is also involved in agrominerals (Category 1). Kinross Brasil, CSM Mineração, and Usiminas Mineração all have single-product portfolios focused on iron ore and gold (Category 3).

Table 5. Brazil's top five mining companies

COMPANY NAME	CSMs EXPLORED IN BRAZIL	2021 SALES (BILLIONS OF BRL)	PROPERTY PROFILE
Vale	Iron ore (C3) Nickel (C2) Manganese (C3) Copper (C2, C3)	286	Headquartered in Brazil, the company has several shareholders on global stock exchanges. Four shareholders with more than 5% of the total capital are Previ (Brazil), BlackRock, Inc. (USA), Capital Group Companies (USA), and Mitsui & Co. (Japan). The Brazilian government holds 12 "Gold Shares" (with veto rights).[83]
Anglo American	Iron ore (C3) Phosphate (C2) Niobium (C2) Nickel (C2)	3.83	Headquartered in the United Kingdom, the company has several shareholders on global stock exchanges. BlackRock, Inc. (US), Public Investment Corporation (South Africa), and The Vanguard Group, Inc. (U.S.) are the three largest shareholders (each owning less than 10% of the shares).[84]
CSN Mineração	Iron ore (C3)	3.57	Headquartered in Brazil, the company has limited shareholders. CSN (79.8%, Brazil), Brazil Japan Iron Ore Corporation (9.2%, Japan), POSCO (1.9%), (South Korea) and China Steel Corporation (0.4%, China).[85]
Kinross Brasil Mineração	Gold (C3)	5.16	The company operates as a subsidiary of Kinross Gold Corporation, a Canadian-based gold miner.[86]
Usiminas Mineração	Iron ore (C3)	12.8	Result of a 2010 joint venture between Usiminas and Sumitomo Corporation of Japan.[87] Ternium (Argentina) and Nippon Steel (Japan) are the most influential shareholders.[88]

Vale is also the world's largest producer of nickel and has signed a long-term supply agreement with Tesla through 2022.[89] Leveraging its copper and nickel operations in Brazil and Canada, it recently announced the creation of a spin-off company (Vale Base Metals) for its metals used in batteries (copper and nickel), with the expectation of further growth in these markets.[90]

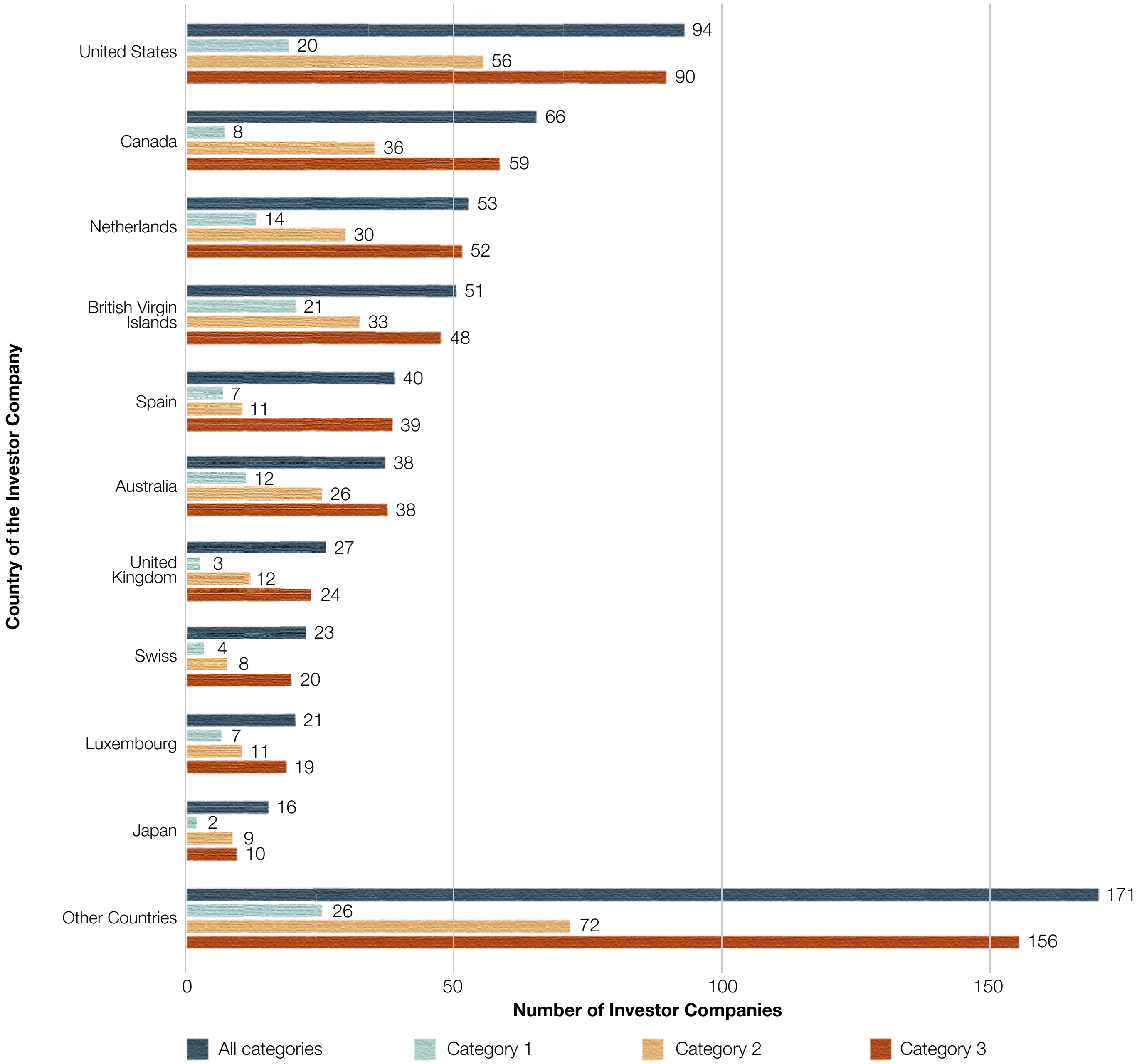
Anglo American is also looking at critical minerals globally. In February 2023, the CEO publicly called for further liberalization of the sector to meet the growing global demand for critical minerals.[91] The company is also diversifying its portfolio by acquiring stakes in critical minerals companies such as Canada Nickel.[92]

Other companies are interested in expanding CSM production in Brazil, such as SIGMA (Canada) and its recently approved lithium mine in Minas Gerais.[93] AMG Lithium Brasil, a subsidiary of the German parent company, also announced its plans to build a lithium precursor plant, which is expected to be operational in the second quarter of 2026.[94]

Chinese companies have also shown interest in Brazilian CSMs. For example, China Molybdenum's acquisition of Nióbio Brasil Ltda. and Fosfatos Brasil Ltda. from Anglo-American in 2016[95] made it the second-largest producer of niobium in the world and the second-largest supplier of phosphates in Brazil.[96] Earlier, in 2011, a consortium of five Chinese state-owned companies bought a 15% stake in Companhia Brasileira de Metalurgia e Mineração (CBMM), the world's largest niobium producer.[97]

Figure 13 shows the number of foreign companies that invested in Brazilian companies with active mining processes related to strategic minerals between 2011 and 2022. Many of these investor companies are based in the United States, Canada, and the Netherlands.

Figure 13. Foreign Companies that Invested in Brazilian Companies with Active Mining Processes Related to Strategic Minerals (2011-2022)



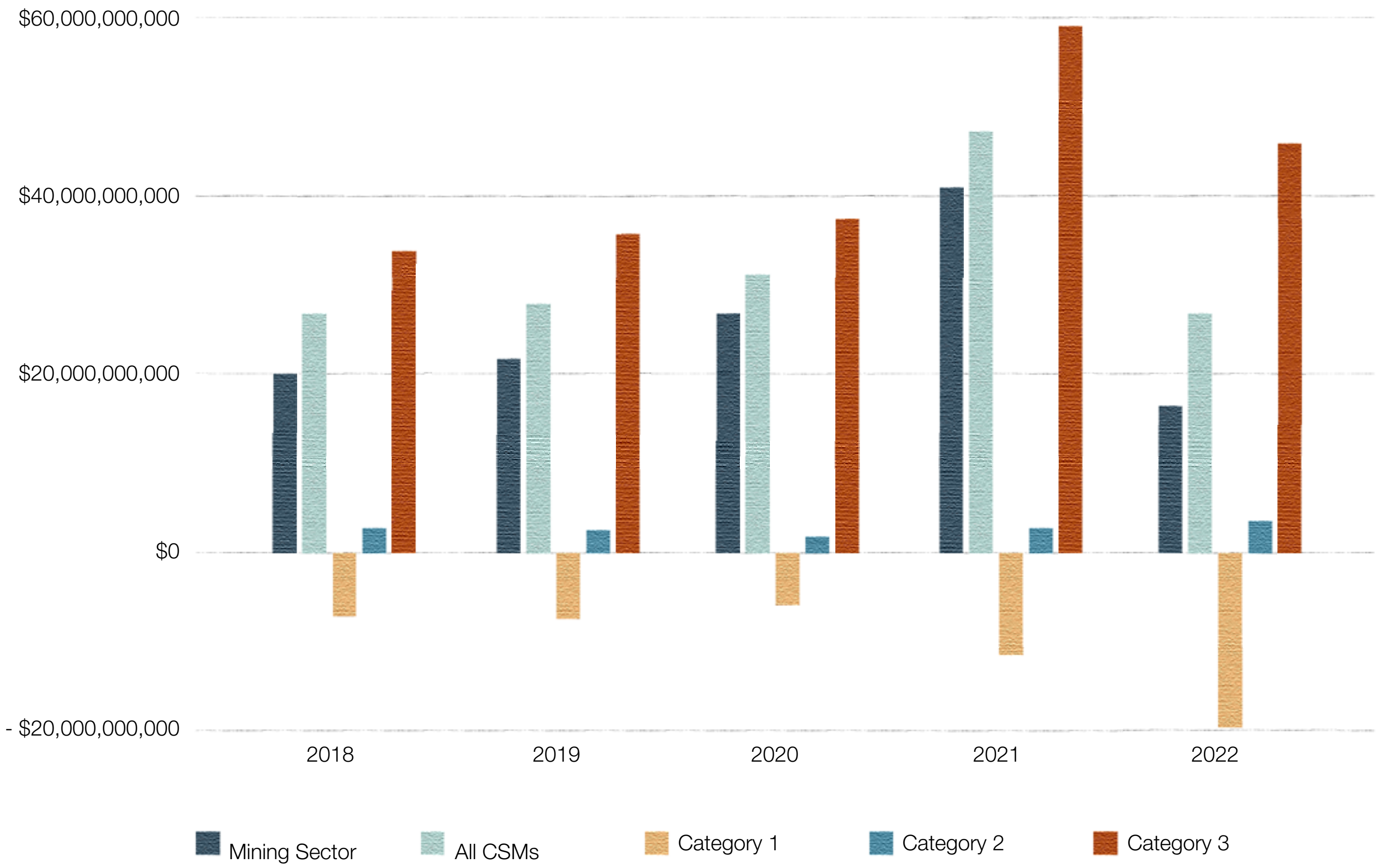
Sources: Central Bank of Brazil (2023). Declaratory Records of Direct Foreign Investment; National Mining Agency (2023). Mining Registry.

In general, future investments by Western countries in Brazilian CSMs are expected to involve partnerships and government-led strategic investments, such as the U.S. government's financing initiative for a cobalt and nickel mine in Piauí.[98]

Brazil's Critical and Strategic Minerals on the International Scene

Brazil is a consistent exporter of unprocessed mineral commodities as primary goods, although it is also dependent on imports of processed minerals or products manufactured from minerals. In 2022, Brazil's CSM trade surplus was US$ 27.9 billion, with CSM exports having a gross value of US$ 449.59 billion, including US$ 408.2 billion for extraction activities and US$ 41.39 billion for processing activities (Figure 14). However, CSM exports have declined from 2021 to 2022, largely due to a 24% decline in Category 3 exports, mainly driven by a 24% drop in iron ore exports.

Figure 14. Trade Balance for CSMs in Brazil



Source: National Mining Agency (2023). Foreign trade in the mineral sector.

Category 2 CSMs have consistently increased in export value since 2020. However, not all of these minerals have also increased in terms of exported quantities, suggesting that price fluctuations have affected the trade balance. During this period, the export value of lithium increased by 407% (+12.5% in volume). The export value of cobalt increased by 55.4% (+132% in volume). Rare earths increased by 87.8% in export value (+86.6% in volume). And there was a 58.8% increase in the value of tungsten exports (+26.1% in volume). Copper (-17.1%) and platinum (-37.77%) were the only Category 2 minerals to decrease in export value.

All Category 1 minerals increased in export value and decreased in exported volume, suggesting a positive price-related change. Category 3 experienced significant decreases in both the value and volume of exports for almost all of its minerals.

China is the largest importer of CSMs from Brazil, receiving US$ 20.73 billion in Brazilian exports in 2022, mostly iron ore. The United States is the second largest export partner, receiving US$ 9.6 billion in exports, followed by Canada with US$ 3.7 billion. The Netherlands, Germany, Belgium, and other EU countries have a smaller presence, but together CSM exports to the EU total US$ 8.26 billion.[99]

China is the largest importer of Brazil's main Category 2 minerals – including niobium, nickel, lithium, and manganese – and the second-largest importer of copper and titanium. The Netherlands, Germany, Canada, the United States, and Belgium are the main trading partners for the remaining Category 2 minerals.[100]

Processed minerals account for the largest share of Brazil's mineral imports. In 2022, imports of processed Category 1 minerals were valued at US$ 19.84 billion, with significant amounts coming from Russia (US$ 4.71 billion) and Canada (US$ 3.74 billion) – mainly phosphate and potash.[101] Imports of processed Category 2 minerals totaled US$ 5.89 billion, mostly from Chile and China, consisting mainly of copper and, to a lesser extent, silicon. Category 3 imports were valued at US$ 13.15 billion and consisted mainly of processed iron, aluminum, and copper, mostly from China.[102]

The intricate web of trade relationships in the global mineral supply chain underscores the complexity of Brazil's role as a supplier of Category 2 and 3 raw minerals. China remains Brazil's main partner for Category 1 minerals. Brazil consistently exports raw minerals to China and imports processed minerals from China. Meanwhile, Western countries are looking for ways to develop new supply chains for critical minerals from mineral-rich countries, due to the changing geopolitics and fractured relationships with Russia and China.[103]

European Union

Although the European Union has established mineral alliances with countries like the U.S., Canada, and Ukraine, the bloc's strategic negotiations with Brazil remain modest.

The Critical Raw Materials Act, announced in October 2022, outlines ambitions for a program to create strategic reserves, particularly for lithium and rare earths. Specific measures were announced on March 16, 2023,[104] including the promotion of supply chains with designated funding; reduction of licensing conditions; increased monitoring and auditing requirements; investment in skills and training; and an emphasis on recycling and circularity.

The EU is also funding the EU-Latin America Mineral Development Network Platform[105] as part of its strategy for the region, through ongoing partnerships and its annual implementation program (*Policy Dialogue Support Facility*). On July 19, at the EU-Celac Summit, € 45 billion in EU investment for Latin America and the Caribbean was announced, including projects related to the extraction of critical minerals.[106]

While not specifically referring to CSMs, the EU's diplomatic service shared a memorandum that encouraged a "qualitative leap in relations" with Latin America and the Caribbean, and the conclusion of the trade agreement with Mercosur in 2023.[107] Bilateral relations between Brazil and the EU countries are still in the diplomatic phase, including talks about critical mineral supply chains between the German Chancellor Olaf Scholz and President Lula in January 2023,[108] as well as the interest in lithium declared by the German Foreign Minister during her visit to the country in June 2023.[109] During a recent visit to Portugal, Alexandre Silveira, Minister of Environment and Climate Action, made a point of strengthening ties with Lisbon, not only as a bridge for relations with the European Union, but also as a source of investment in mining activities in Brazil.[110]

United States

In 2020, the Trump and Bolsonaro administrations jointly launched the U.S.-Brazil Critical Minerals Working Group.[111] To date, however, the group's meetings have been irregular, and little concrete action has been taken. Although Brazil is not yet an official partner in the U.S.-led Minerals Safety Partnership, the country has participated in meetings to discuss how to ensure that critical minerals are produced, processed, and recycled in ways that support economic development.[112]

President Biden's invocation of the Defense Production Act of 1950 to promote domestic production of critical minerals could harm Brazilian exports. In March 2023, an envoy confirmed the U.S. intention to invest in the extraction of CSMs in Brazil, although the details of this policy are unclear.[113] The Inflation Reduction Act is being widely seen as a game-changer for the U.S. electric vehicle industry and CSM supply chains.[114] While this policy has the potential to directly impact mineral-producing countries such as Canada, Australia, and Peru, with which the U.S. has a free trade agreement, the impact in Brazil is likely to be indirect due to the lack of such an agreement with the country.

China

In recent years, China, like other global powers, has shifted its focus to domestic issues, with a nationalist discourse on resources and the development of technologies to serve the local market using its mineral resources.[115] At the same time, Chinese companies continue to invest and expand their presence in certain extractive markets in Brazil, such as renewable energy, oil, and gas. Although Brazil is not part of China's Belt and Road Initiative, China has a significant presence in Brazil in terms of infrastructure, finance, and trade.

In December 2021, China implemented new rules that apply to companies involved in the mining or processing of rare earths, tungsten, and radioactive minerals.[116] These rules include restrictions on foreign direct investment (FDI) in these markets, as well as requirements for companies to obtain government licenses if they want to operate overseas or issue shares abroad. These regulations were introduced as part of China's efforts to exert greater control over its CSMs and prevent their exploitation by foreign agents. Although it does not specifically mention Brazil, China's National Mineral Resources Plan (2021-2025) focuses on developing regional capacity in resource-rich areas, increasing exploration, establishing strategic reserves, and safeguarding resources.[117]

Since the beginning of President Lula's third term, the president's visits to Beijing have signaled that relations with the Asian country are a priority for Brazil's foreign and trade policies. President Lula's last visit to China, in April 2023, was accompanied by a delegation of businesspeople and politicians, during which 20 new agreements and 40 new partnerships were signed.[118]

For example, Vale Indonesia, Tisco (Baowu Group), and Xinhai have agreed to jointly invest in the construction of an RKEF nickel processing plant in Indonesia.[119] In addition, the state of Rio Grande do Norte and the Chinese-owned Brazilian Sino Mining Association (ASBM) have agreed to work together to facilitate investment in the state's mineral sector.[120]

There have also been discussions on mining infrastructure, leveraging previous investments[121], and the acquisition of transportation infrastructure.[122] The Ministry of Infrastructure, the National Waterway Transport Agency (Antaq), and the Port Authority of Santos signed an agreement with Terminal Export COFCO to further develop the Port of Santos, one of the most important export hubs in Brazil.[123]

Latin America

Compared to major economic partners, regional dialogue on CSMs has been relatively limited. Governments in the region have held high-level discussions on regional coordination and supply chains for CSMs, but little policy action has been taken.

During the 2021 Conference of Ministries of Mines of the Americas, government representatives from 23 countries in the Americas and the Caribbean discussed the potential for regional supply chains to support minerals critical to the energy transition.[124] Brazil expressed interest in expanding trade relations with the region and collaborating in the industrialization chain.[125]

Although Brazil is not located in the "Lithium Triangle" of South America, the possibility of the country joining Chile, Argentina, and Bolivia in an OPEC-inspired "Lithium Cartel" to coordinate lithium production, pricing, and practices was raised.[126] Despite its modest lithium reserves, Brazil's contribution would be based on its significant experience in automotive manufacturing and advanced low-carbon mobility technologies, such as cars powered by ethanol, biofuels, and natural gas.[127]

However, the likelihood of this happening in the short to medium term is limited due to Australia's dominance of the global lithium market and the relatively nascent nature of metal mining in Bolivia, despite attempts by Chinese investors to catalyze the local market.[128]

Chilean President Gabriel Boric's decision to nationalize Chile's lithium production in April 2023 could impact regional supply chains and partnerships for the mineral, as Latin American countries with leftist governments seek to build a regional alliance and consolidate political ties.[129]

Finally, Brazilian foreign policy and trade in CSMs are intrinsically linked to an active strategy of non-alignment.[130] As a major global player in the production and trade of CSMs, Brazil is pursuing an independent foreign policy and constructive solutions that serve national interests without automatically yielding to pressure from dominant powers.

Highlight: Rare Earths in Brazil

Rare earths are among the CSMs most vulnerable to supply chain disruptions. The global supply of neodymium, praseodymium, dysprosium, and terbium oxide is expected to decrease as a result of a process starting in 2022, which implies a restriction in the production of neodymium alloys and powders needed for magnetic components used in electric vehicles and wind turbines.[131] As a result, the shortage of these materials must reach 66,000 tonnes per year by 2030 and 206,000 tonnes per year by 2035, representing almost a third of the total market.[132]

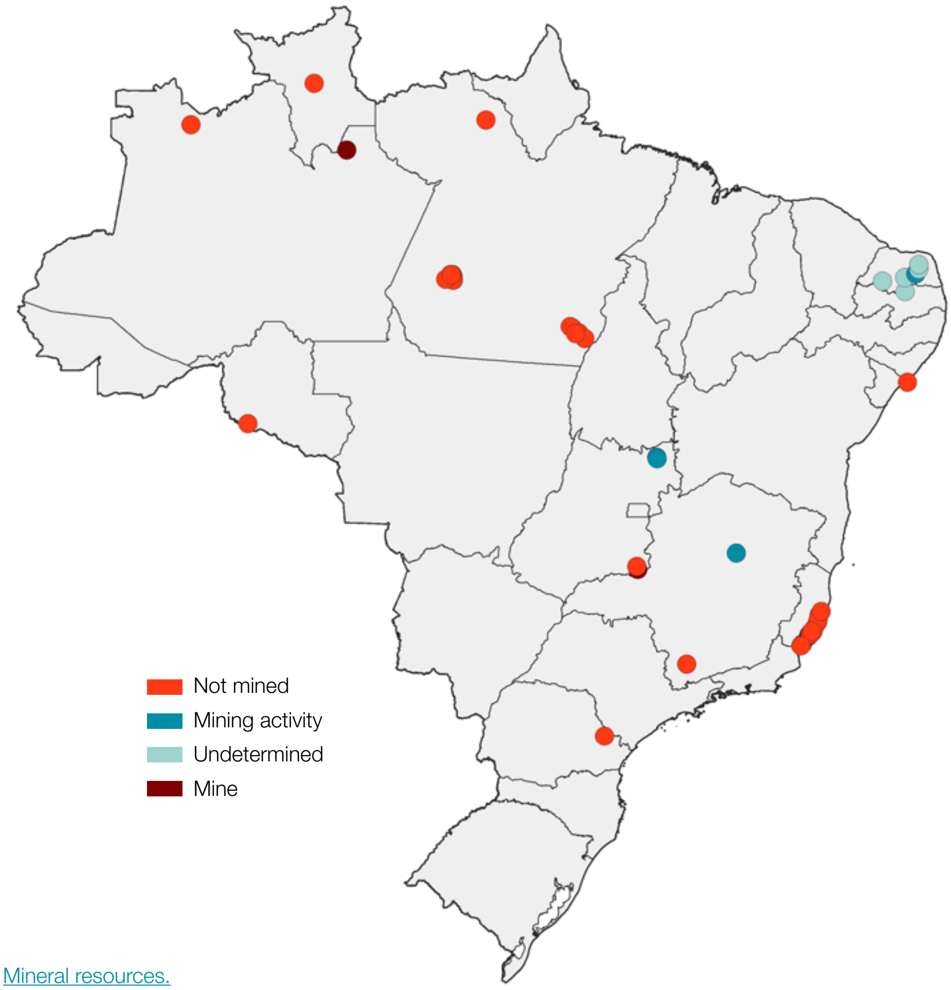
Although the global market for rare earths was relatively small in 2022 (US$ 6.58 billion)[133] – compared to other commodities such as oil (over US$ 3 trillion)[134] or iron ore (US$ 405 billion)[135] – the criticality of these elements far outweighs their economic importance. China's strategic dominance of global rare earth supply chains, particularly in midstream and downstream[136] capabilities, is perceived as one of the greatest strategic vulnerabilities for the United States.[137] China currently accounts for 60% of global rare earth production and nearly 90% of rare earth refining.[138]

Despite the abundance of rare earths in countries such as China, Vietnam, Brazil, and Russia, it can be difficult to identify economically viable deposits.[139] Brazil, with the world's third-largest reserve of rare earths (21 million tonnes), is gaining attention as a potential future source of rare earths.[140]

Research and exploration conducted by the SGB/CPRM indicate that the reserves and deposits of rare earths in Brazil are relatively well known (Figure 15). In particular, significant reserves have been discovered in alkaline-carbonatitic rocks at several locations, including Araxá, Poços de Caldas, and Tapira, the three of them in Minas Gerais state, Jacupiranga, in São Paulo state, and Catalão and Itapirapuã, in Goiás state.[141] Rare earths are also found in granitic formations, although in smaller quantities, in places such as the Pitinga mine, in Presidente Figueiredo, in Amazonas state, and Minaçu and Montividiu do Norte, in Goiás state.[142]

In addition, the sedimentary deposits in the regions of São Gonçalo do Sapucaí (Minas Gerais state) and São Francisco de Itabapoana (Rio de Janeiro state) contain rare earths, although in smaller quantities.[143] Despite studies indicating the presence of deposits in Morro dos Seis Lagos biological reserve (São Gabriel da Cachoeira, Amazonas state) and Serra do Repartimento (Roraima state), legal barriers in the protected areas have prevented new research in these areas.[144]

Figure 15. Occurrences of Rare Earths in Brazil.



Source: SGB (2023) [Mineral resources.]

Table 6 shows the distribution of active research rights for monazite and rare earths currently spread across 138 Brazilian municipalities. This shows an active rare earths sector, especially in the research phase.

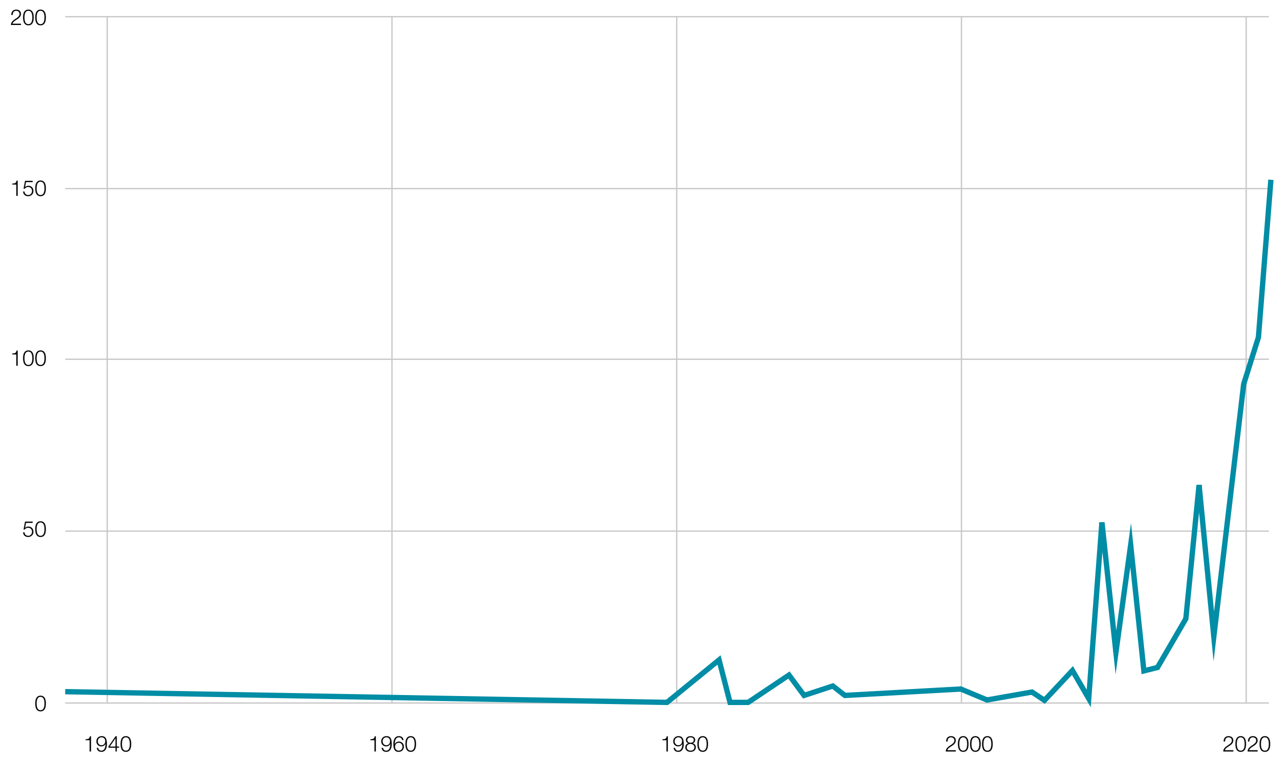
Table 6. Current and Selected Active Mining Processes for Rare Earths in Brazil (until April 2023)

PHASE	NUMBER OF PROCESSES (COMPANIES)
Research request	178
Research	467
Active mining	28

Source: National Mining Agency (2023). [Mining Registry.]

This activity is shown in Figure 16, which shows a sharp increase in the number of active rare earth mining processes.

Figure 16. Active Mining Processes for Monazite and Rare Earths (1937-2022)



Source: National Mining Agency (2023). Mining Registry via SGB/CPRM (2023). Plataforma P3M.

Several of these processes are linked to companies receiving investments from foreign agents. In 2021, there were 108 active mining processes linked to companies linked to foreign agents. In 2022, there were 175, and in May 2023 there were 111 active mining processes, suggesting that this year may surpass previous ones in terms of international interest in rare earths in Brazil.[145]

Table 7. Largest Rare Earth Projects in Brazil

NAME OF THE RESERVE	COUNTRY	ESTIMATED RESOURCES (TONNES)	INDEXES	STATUS
Tapira	Mosaic (USA)	5.8	1 a 10%	Operating
Catalan II	CMOC (China)/ Mosaic (USA)	25	0.98%	Operating
Maicuru	Mosaic (USA)	Not reported	0.49-4.79%	Not viable
Catalan I	Mosaic (USA)	78.9	8.67%	Operating
Araxá	Mosaic (USA)	0.546	4.40%	Operating
Distribution	Distribution	Not reported	5%	Not viable

continuation

NAME OF THE RESERVE	COUNTRY	ESTIMATED RESOURCES (TONNES)	INDEXES	STATUS
Poços de Caldas	Mineração Terras Raras (Brazil)	3.55	3.90%	Exploration
Barra do Itapirapuã	Barra do Itapirapuã	44.8	0.70%	Exploration
Mato Preto	Nossa Senhora do Carmo Ltda (n/a)	not reported	7.70%	Operating
Seis Lagos	CPRM (Brazil)	43.5	1.50%	Not viable
Minaçu (Serra Dourada)	Mineração Serra Verde (Brazil, controlled by Denham Capital, U.S.)	300	0.15%	Exploration
Pitinga	Mineração Taboca (Peru)	2	0.16%	Operating
São Francisco do Itabapoana	Vale (Brazil)	2.7	60%	Operating

Sources: Silva, G.F., Cunha, I.A., & Costa, I.S.L. (Orgs.) (2023). An Overview of Critical Minerals Potential of Brazil. SGB/CPRM.

A sizable portion of Brazil's rare earths production comes not from new excavation of *greenfield*[146] mines but from complex extraction processes using tailings and waste from other mining activities. For example, at the Araxá mine, CBMM developed the technology to extract rare earth sulfate from niobium mining tailings.[147] Similar projects are also being carried out in Catalão, in Goiás state, Poços de Caldas, Mata da Corda, and Tapira – all three in Minas Gerais state – and Pitinga, in Amazonas state.[148] In Bom Futuro deposit, in the Rondônia state, cassiterite mining tailings from artisanal mines were recently sold to the Canada Rare Earth Corporation.[149]

The discovery of ionic clays in Minaçu in 2015 opened up a promising opportunity for rare earths production in Brazil, especially since these clays have low radioactivity, in addition to a simple extraction and processing process.[150] Serra Verde mining company will begin production in the second half of 2023 to become "the third major non-Asian producer and the first to produce all four critical rare earth magnetic elements."[151]

However, Brazil is still struggling to significantly increase its rare earth production. The Brazilian government has already made some attempts to correct this situation by promoting a domestic market. For example, the state-owned company Companhia de Desenvolvimento de Minas Gerais (CODEMGE) has established LabFabITR, a pilot laboratory-factory dedicated to the production of magnets and alloys using processed rare earths, with a special focus on neodymium magnets.[152] Although the magnets produced by LabFabITR are more expensive than those imported from China, Brazilian customers benefit from shorter delivery times, lower transportation costs, and higher quality.[153]

Indeed, going forward, the government will play a critical role in providing funding and strategic vision for multi-sector collaboration to develop viable technologies for rare earths mining and processing.

While China's control over rare earth processing remains a significant vulnerability for global supply chains, its recent inward pivot also presents an opportunity for Brazil. Since 2018, Brazil's production of unprocessed rare earths and consumption of processed rare earths have shifted significantly (Table 8).

Table 8. Brazilian Exports of Unprocessed Rare Earths and Imports of Processed Rare Earths

	2018	2019	2020	2021	2022
Tonnes of exported raw rare earths	800	300	608	400	892
Main destination country of exported raw rare earths	China (100%)	China (100%)	China (100%)	China (100%)	Canada (100%)
Tonnes of imported processed rare earths	2,312	471	358	1,377	1,618
Main country from which Brazil imported largest amount of processed rare earths	China (69.15%)	China (61.74%)	China (53.24%)	China (54.49%)	China (57.23%)

Source: National Mining Agency (2023). Foreign trade in the mineral sector.

In 2022, new questions arose when Canada replaced China as the exclusive buyer of Brazil's rare earths.

This delicate geopolitical situation has led some investors to reconsider rare earth reserves that were previously ignored due to logistical challenges and high extraction costs.[154]

Socio-environmental Risks of Mining Critical and Strategic Minerals in Brazil

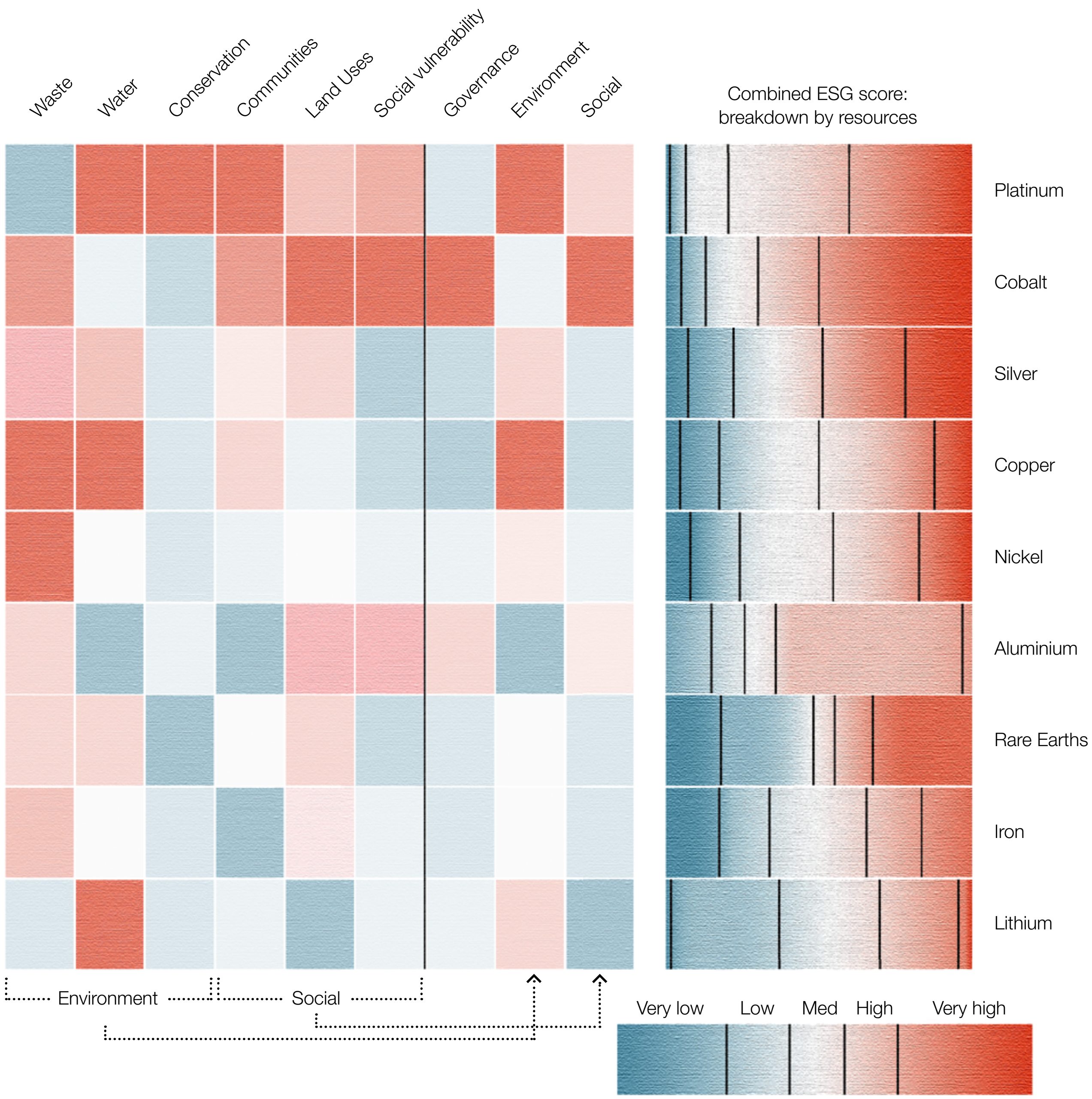
While the focus on CSMs often revolves around their location and accessibility to address "supply-side issues," it is also critical to consider the significant social and environmental risks that can lead to tipping points and instability.[155]

Table 9. Social and Environmental Risks of Mining CSMs in Brazil[156]

WASTE	Improper waste management during the mining and processing of CSMs (especially rare earths, nickel, and copper) can cause serious environmental damage due to the presence of toxic substances and heavy metals.[157]
WATER	The extraction and processing of CSMs can severely contaminate water sources with toxic chemicals. The production of lithium, used in electric vehicle batteries, requires significant water use that can exacerbate water stress and balance,[158] while gold mining can contaminate water sources with cyanide and mercury, posing a significant threat to humans and ecosystems.[159]
CONSERVATION	Mining activities can cause deforestation, soil degradation, and loss of biodiversity, significantly impacting local ecosystems and threatening the survival of plant and animal species.[160]
COMMUNITIES	The arrival of temporary workers during mining activities can disrupt the traditional lifestyles and cultural practices of indigenous communities, lead to social conflicts and tensions, and threaten the preservation of cultural heritage and traditional knowledge.[161]
LAND USES	The interplay between mining, agriculture, agribusiness, and logging can produce contradictory land uses, thus increasing complexity and the potential for conflict.[162]
SOCIAL VULNE-RABILITY	Mining can exacerbate social vulnerabilities such as poverty, inequality, and exclusion, and is often associated with increased rates of alcoholism, drug abuse, and sexual abuse in nearby areas. In addition, child labor is a concern, and there is a risk of exploitation or recruitment of local populations into the mining workforce.[163]
GOVERNANCE	Inadequate governance and regulatory oversight of CSM mining can exacerbate the threat of environmental damage and social risks due to the lack of effective enforcement of environmental and social standards.

The different processes associated with different CSMs present different social and environmental risks (Figure 17), highlighting the significant implications of prioritizing specific minerals in policy decisions.

Figure 17. Risk Profiles for Nine Energy Transition Metals



Sourcee: Lèbre, É. et al. (2020). The social and environmental complexities of extracting energy transition metals. Nature Communications, 11(1), p.4823.

However, the impacts of increased mining of CSMs in Brazil have the potential for a greater global impact due to the importance of the Amazon biome to the planet's climate. Approximately 30% of the known occurrences of strategic minerals are located in the Brazilian Legal Amazon, with 4.4% of these in indigenous lands and 14.9% in conservation units throughout Brazil.[164]

Table 10 shows the degree of overlap between active mining activities for different CSMs and these protected areas throughout Brazil. The mining processes included in this analysis were in one of the following stages: Mining concession (*Concessão de lavra*), Artisanal mining (*Lavra garimpeira*), Licensing (*Licenciamento*), and Research permit (*Autorização de pesquisa*).

Table 10. Location of Active Mining Processes Related to CSMs (as of March 2023)

	C1	C2	C3	AREA IN BRAZIL (KM²)	% IN LEGAL AMAZON	% IN INDIGENOUS LANDS	% IN CONSERVATION UNITS	% IN QUILOMBO TERRITORIES
Tin		✓		12,216	**89.71**	0	12	0
Potassium	✓			10,388	**88.84**	0	13	0
Aluminum			✓	43,738	**83.18**	0	16	1
Gold			✓	225,601	**68.87**	0	16	0
Copper		✓	✓	132,359	**64.78**	0	11	0
Tungsten		✓		1,295	**59.60**	0	25	0
Tantalum		✓		4,119	**58.61**	0	5	1
Titanium		✓		4,339	**50.20**	0	7	0
Silicon		✓		62	**47.81**	0	22	0
Platinum		✓		1,447	**38.88**	0	10	0
Manganese			✓	57,034	**35.79**	0	6	0
Niobium		✓		4,329	**35.54**	2	9	0
Phosphate	✓			58,554	**32.91**	0	4	0
Iron			✓	116,853	**31.97**	0	10	1
Nickel		✓		17,166	**29.47**	0	3	0
Molybdenum	✓			222	**16.44**	0	17	0
Rare-Earths		✓		3,369	**15.40**	0	7	9
Vanadium		✓		418	**2.29**	0	2	0
Graphite		✓	✓	3,076	**1.32**	0	2	0
Lithium		✓		3,349	**0.00**	0	2	0
Sulphur	✓			20	**0.00**	0	100	0

Sources:

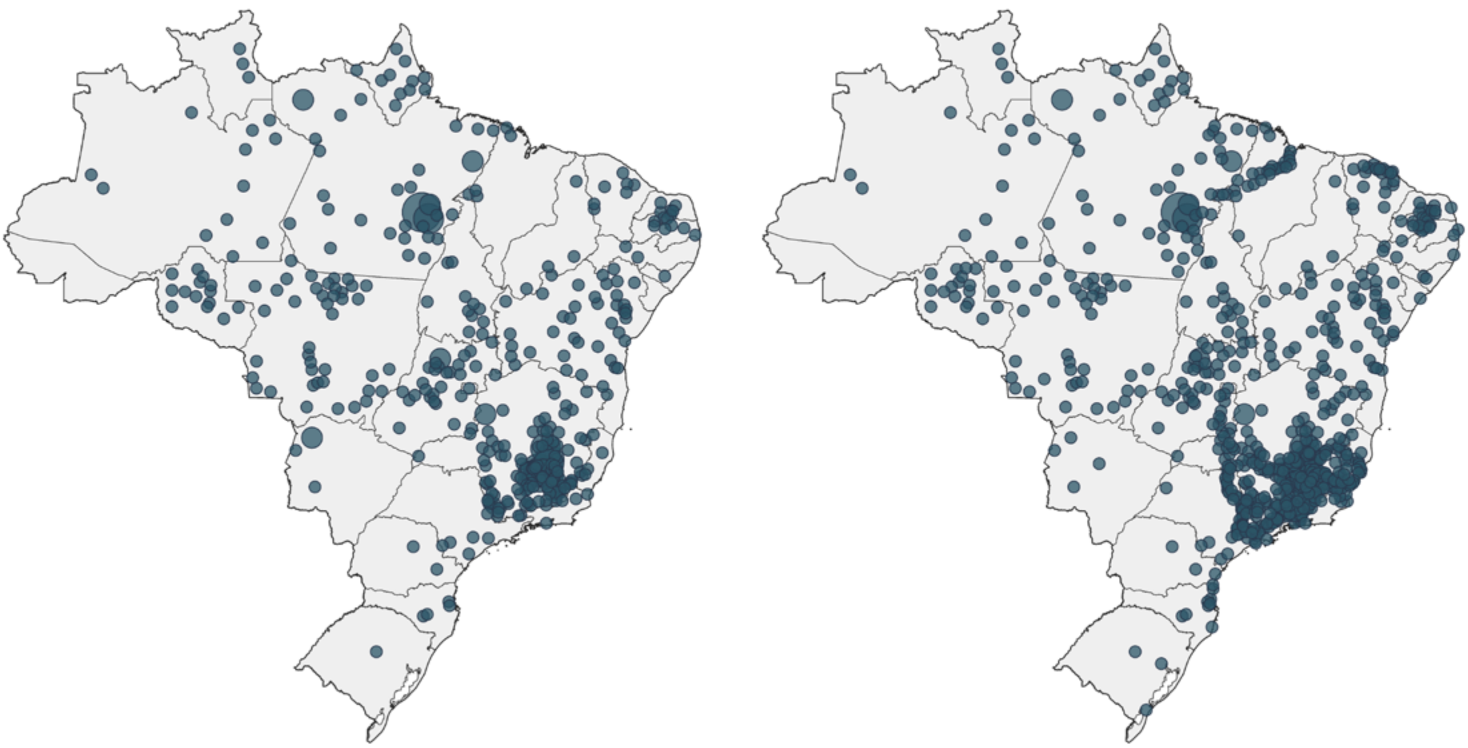
- National Mining Agency (2023). Mining Geographic Information System (SIGMINE)
- National Foundation of Indigenous Peoples (2023). Geoprocessing and Maps.
- Ministry of the Environment (2023). Conservation units.
- National Institute of Colonization and Agrarian Reform (2023). Quilombola areas.

Gold and copper account for most of the area occupied by mining operations in the Brazilian Amazon. Other minerals have higher concentrations of mining in the Amazon, such as tin, potash, and aluminum, although the geographic area they occupy is much smaller.

However, the impact of mining extends far beyond the excavation site.[165] For example, the construction of new access roads and water supply pipes can have significant environmental and community impacts. The research shows that there is a potential for impacts up to 70 km around the mines.[166]

The magnitude of these impacts creates the need for instruments such as the Financial Compensation for the Exploitation of Mineral Resources (CFEM), which regulates the collection and distribution of mining royalties. Figures 18a and 18b show the national panorama of CFEM between 2008 and 2022, which shows a concentration in the southeast and coastal regions, with some points of concentration in Pará. Royalties, taxes, and revenues from mining have different impacts on local communities, with 60% of royalties allocated to the mineral-producing municipality, 15% to the producing state government, 15% to other affected municipalities, and 10% to the federal government.[167]

Figures 18 a e b. Collection (a) and Distribution (b) of CFEM (2008-2022)



Sources: National Mining Agency (2021). [Financial Compensation for Exploitation of Mineral Resources (CFEM).]

A larger number of municipalities receive CFEM royalties compared to those where these royalties are collected, due to factors such as the rail infrastructure that passes through non-mining municipalities in Maranhão[168] and the proximity of certain municipalities in Minas Gerais to those with mines affected by tailings dams, processing plants, waste deposits, and water treatment plants.[169]

The widespread impacts of mining, coupled with a perceived lack of local benefits, can lead to conflict, social unrest, and protests, undermining the "social license" to mine.[170] In 2020 alone, there were multiple conflicts associated with 144 companies in 564 locations.[171]

CSMs can be particularly vulnerable to conflict due to their "critical" or "strategic" importance. Increased mining activity and the involvement of government agencies or the private sector can potentially lead to conflicts with communities. These conflicts can arise from disputes over access to land, the impact of mining practices on communities, and the equitable distribution of mining benefits to affected communities.

Stakeholder engagement and consultation, as well as ESG management practices, can offer some ways to mitigate conflicts involving industrial mining companies. Although the Bolsonaro administration undermined some stakeholder consultation guidelines, the Lula administration seems intent on reinstating these protocols. The ratification of the Escazú Agreement – an international treaty on environmental rights signed by 25 Latin American and Caribbean countries in 2018, will help institutionalize these processes. On May 11, 2023, after several years of delay, the Brazilian government finally sent the agreement to the National Congress for ratification.[172]

The Risks for the Amazon

When formal institutions and processes are absent or viewed by communities as illegitimate or irrelevant, mining-related conflicts are often resolved through violence. Studies of resource governance in remote regions of the Amazon indicate that violence plays a significant role in resource management.[173] This is consistent with the growing consensus on the link between violent conflict and mineral-rich areas, particularly in the context of illegal and informal mining activities.[174]

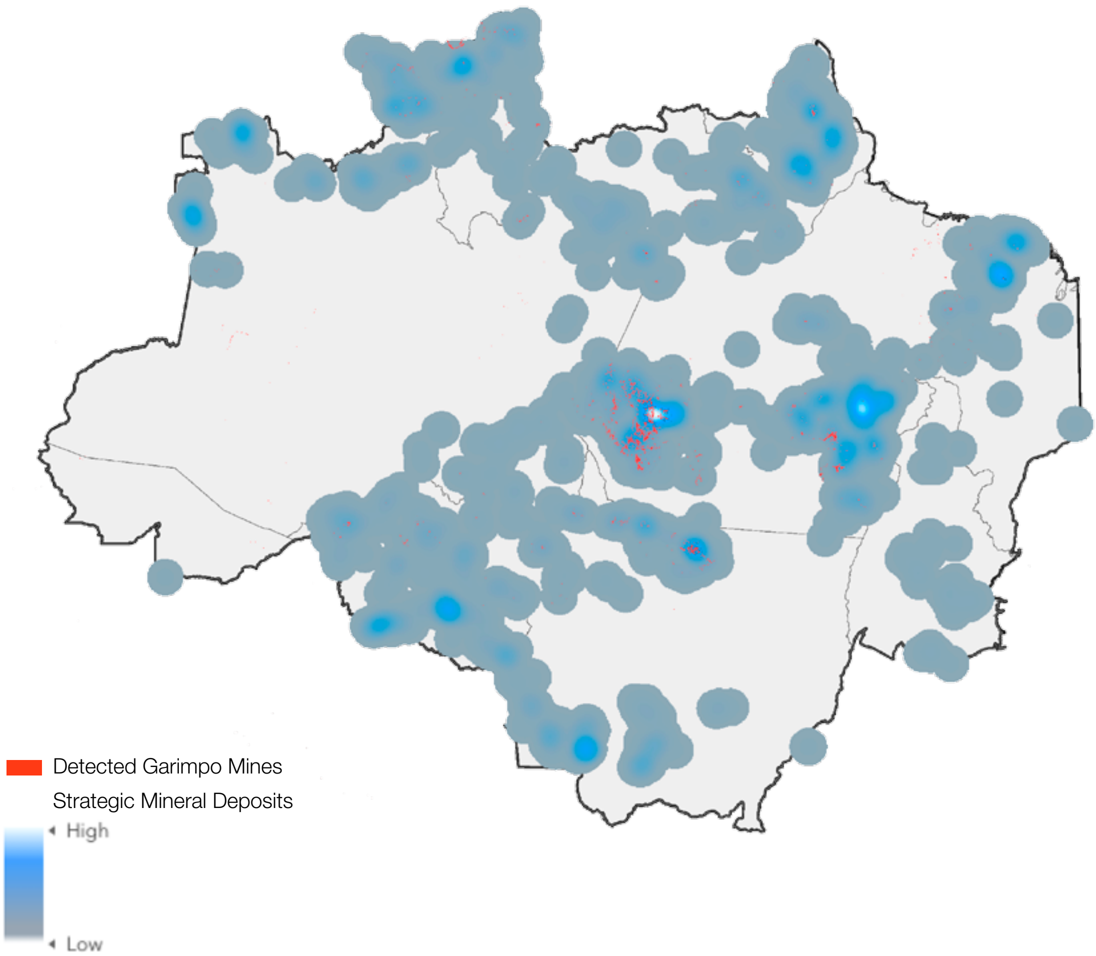
Indeed, large, organized criminal groups that dominate drug trafficking in southeastern Brazil, have seen an opportunity to expand their illicit activities into the Amazon region by exploring illegal gold mines in the forest. The Comando Vermelho (CV) and the Primeiro Comando da Capital (PCC) are among the groups that have begun to diversify their activities.[175] The presence of criminal organizations has been noted in at least two of Brazil's largest indigenous reserves in Brazil – the Yanomami reserve, in Roraima state, and Munduruku, in Pará state.[176] In addition, paramilitary networks[177] made up of ex-policemen and members of extinct criminal organizations – with links to the state apparatus – are also involved in various forms of environmental crime. [178] [179]

These actors and groups often use their access to the means of violence to engage directly in mining activities or partner with subsistence miners to extract, process, and smuggle minerals.[180] In Figure 19, there is considerable overlap between regions full of CSMs and areas of open-pit mining activity in the Brazilian legal Amazon.[181]

Gold appears to be the most commonly illegally mined mineral, possibly because of its relative ease of extraction and high economic value.[182] Reports suggest that up to 17% of Brazil's gold market may come from illegal mining.[183] The tendency of literature and research efforts to focus on gold is likely due to its economic importance and potential links to illicit financial flows, while the visibility of open-pit gold mining compared to underground mining of other minerals allows for detection by remote sensing technologies.

Although less discussed, there is also illegal mining of copper,[184] tin[185], and manganese.[186] These minerals can be more difficult and expensive to mine than gold, requiring advanced extraction technologies and processes. However, there are reports of minerals being smuggled out of Brazil for processing.

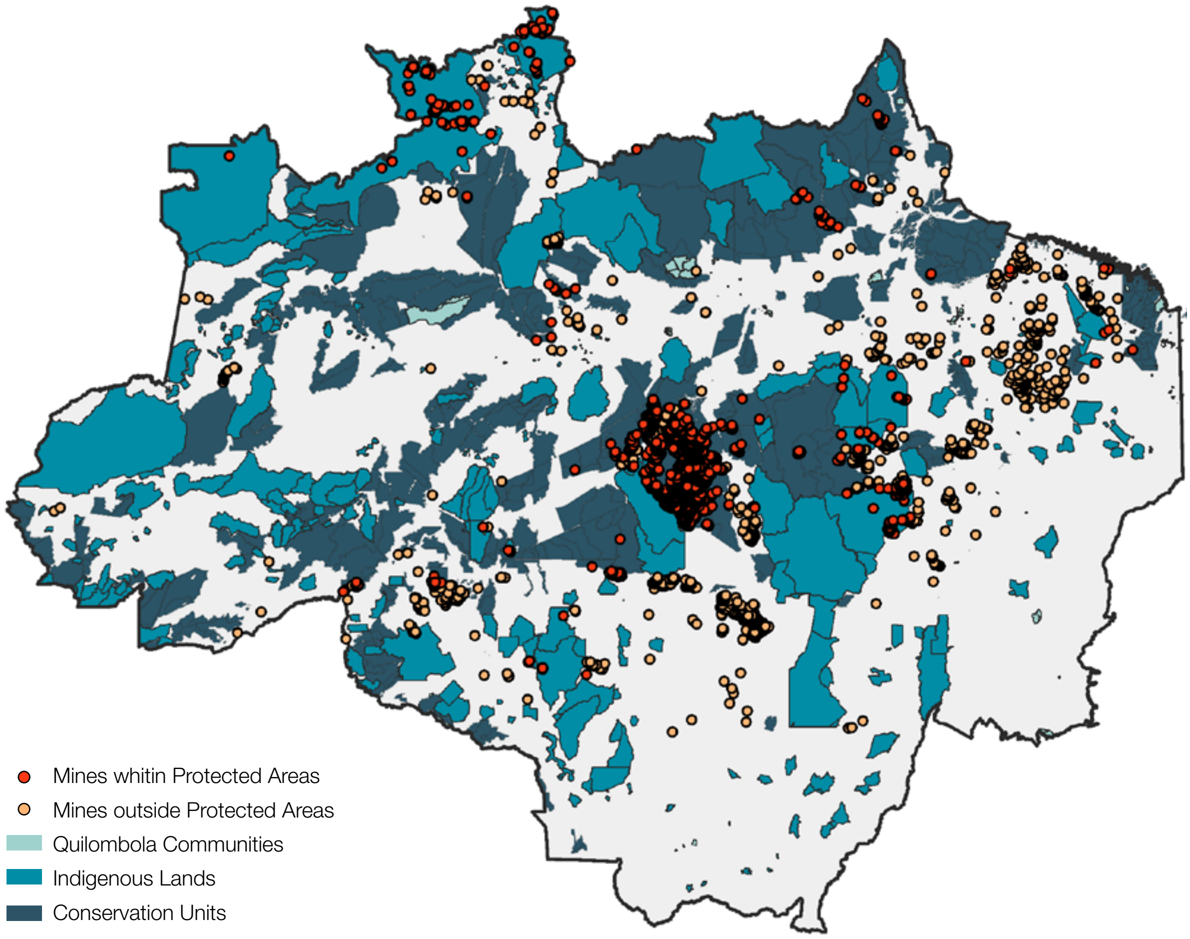
Figure 19. Heat map of CSM Occurrences and Open-pit Mining Detected in 2021



Sources: SGB (2023) Mineral resources; Rainforest Investigations Network & Earthrise Media (2023). Amazon Mining Watch.

Open-pit mining activities often encroach on protected lands, and Figure 20 shows the degree of overlap with homologated indigenous lands, quilombola communities (founded by descendants of slaves who escaped to freedom), and conservation units.

Figure 20. Map of Protected Lands and Open-pit Mining Detected in 2021



Sources:

- Rainforest Investigations Network & Earthrise Media (2023). Amazon Mining Watch.
- National Foundation of Indigenous Peoples (2023). Geoprocessing and Maps.
- Ministry of the Environment (2023). Conservation units.
- National Institute of Colonization and Agrarian Reform (2023). Quilombola areas.

Regarding indigenous lands, indigenous communities sometimes resort to armed resistance to defend their territories against such encroachment.[187] While it is often assumed that indigenous communities are generally opposed to mining, the reality is more complex as some of them engage in artisanal mining to generate income.[188] However, indigenous artisanal mining can lead to disputes over mineral rights and autonomy over indigenous territory; in fact, the Brazilian Constitution states that no mining can take place 40 centimeters below the surface without paying royalties to the federal government, even within indigenous lands.

All of this underscores the extreme importance of considering the socio-environmental risks of mining CSMs. Mineral exploration can bring significant economic benefits and enable the technological innovation needed for a green transition, but it can also have negative social and environmental impacts. The expansion of the CSM market in Brazil must responsibly take place, guaranteeing the protection of the rights of local communities, the conservation of natural ecosystems, and the promotion of sustainable development.

Final Considerations: A Critical and Strategic Role for Brazil?

The global search for critical and strategic minerals has the potential to trigger a cascade of tipping points and instabilities. The risks are particularly acute when mining protocols for these minerals can circumvent regulatory frameworks in the name of supposedly higher goals, such as national interest or the green transition.

There is much more at stake than just scarcity as nearly one-third of CSM reserves are located within Brazil's legal Amazon. The Brazilian government must not only restore and strengthen environmental protections but also build a broader and more stable consensus on energy policy mineral extraction and development goals to ensure a sustainable and responsible path both at home and abroad.

At least four key areas for further policy consideration emerge from this strategic paper.

1. Strategic positioning

With its geological setting, custodianship of the Amazon biome, mineral diversity, and non-aligned foreign policy, Brazil has the opportunity to position itself as a global leader and responsible partner in the minerals industry. The National Mining Plan 2050 should serve as a framework for integrating mining into energy, growth, defense, and climate strategies.

2. Downstream investments, midstream processing

Diversifying Brazil's production with industrial and service sectors and incorporating knowledge-based and technology-intensive products into the economy, will help Brazil overcome its dependence on mineral commodity exports. The government should coordinate the business and academic sectors in developing downstream and midstream processing capabilities for CSMs. Leveraging regional supply chain partnerships, especially in lithium or rare earths, will enhance competitiveness.

3. Inclusive engagement

To ensure fair representation of the market, social, and environmental interests in decision-making, Brazil should consider restructuring and diversifying regulatory frameworks, compliance guidelines, and committees. This could include the Ministry of Indigenous Affairs and the Ministry of the Environment in the CTAPME or reviewing models for redistributing mining royalties to prioritize ecological resilience, among other measures.

4. Communicate the importance of responsible action in the green transition

To promote a cautious and conscious approach to CSM consumption, Brazil should use its leverage to lead a comprehensive evidence-based strategic communication campaign that emphasizes the importance of socioenvironmental responsibility in order to guarantee the efficacy of a green transition to solve the climate emergency. In doing so, Brazil can help governments around the world avoid undue influence from vested interests and facilitate more balanced negotiations on the terms of mineral rights.

Responsible governance of global CSM markets requires policymakers to address both the long-term opportunities and risks associated with the mining of critical and strategic minerals in Brazil. While this strategic paper represents a first step, additional empirical research and policy development is needed to fill gaps and delve deeper into relevant issues. By following this agenda, policymakers can ensure a balanced approach that considers social and environmental interdependencies as well as supply and demand dynamics in CSM supply chains.

Achieving these goals will require building a global consensus. Given its extensive mining expertise, active civil society engagement, delicate diplomatic relations, and untapped natural resources, Brazil is uniquely positioned to provide strategic leadership in shaping this new social, environmental, and economic pact.

Annex 1:
Production of Strategic Minerals (Brazil x Rest of the World [ROW])

	C1	C2	C3	PRODUCTION OF MINES IN BRAZIL (TONNES)	TOTAL MINE PRODUCTION (RDM) (TONNES)	BRAZILIAN PRODUCTION SHARE %
Aluminum (inc. Alumina and Bauxite)			✓	44,000,000	520,000,000	8.46%
Cobalt		✓		n/a	0.190	n/a
Copper		✓	✓	348,000	21,000,000	1.65%
Gold			✓	60	3,100	1.94%
Graphite		✓	✓	87.000	1,300,000	6.69%
Iron (usable ore)			✓	410,000,000	2,600,000,000	15.77%
Lithium		✓		2,200	130,000	1.69%
Manganese			✓	400,000	20,000,000	2.00%
Molybdenum	✓			n/a	250,000	n/a
Nickel		✓		83,000	3,300,000	2.51%
Niobium		✓	✓	71,000	79,000	89.87%
Phosphate	✓			5,500,000	220,000,000	2.50%
Platinum group (including platinum and palladium)		✓		n/a	310	n/a
Potassium (potash)	✓			270,000	40,000,000	0.68%
Rare Lands		✓		80	300,000	0.03%
Silicon		✓		400,000	8,800,000	4.55%
Sulfur	✓			n/a	82,000,000	n/a
Tantalum		✓		370	2,000	18.5
Tin		✓		18,000	310,000	5.81%
Titanium		✓		32.000	8,900,000	0.36%
Thallium		✓		n/a	n/a	n/a
Tungsten		✓		n/a	84,000	n/a
Uranium		✓	✓	29	48,332	0.06%
Vanadium		✓		6,200	100,000	6.20%

Sources:

- OECD (2022), Regulatory Governance in the Mining Sector in Brazil, OECD Publishing, Paris.
- USGS (2023). Mineral commodity summaries 2023.
- World Nuclear Association (2023). World Uranium Mining Production.

Annex 2: Lists of Strategic and Critical Minerals

MINERAL	BRAZIL			USA	EU		CHINA		
	G1	G2	G3	ALL	CRITICAL	STRATEGIC	ENERGY	METALLIC	NON-METALLIC
Aluminum (inc. Bauxite)			✓	✓	✓			✓	
Antimony				✓	✓			✓	
Arsenic				✓	✓				
Baryte				✓	✓				
Beryllium				✓	✓				
Bismuth				✓		✓			
Boron/borate						✓			
Cesium				✓					
Chromium				✓				✓	
Cobalt		✓		✓		✓		✓	
Coking coal					✓				
Copper		✓	✓						
Dysprosium				✓					
Erbium				✓					
Europium				✓					
Feldspar					✓				
Fluorspar					✓				✓
Gallium				✓		✓			
Germanium				✓		✓			
Gold			✓					✓	
Graphite		✓	✓	✓		✓			✓
Hafnium				✓	✓				
Helium					✓				
Holmium				✓					
Indium				✓					
Iridium				✓					
Iron			✓					✓	
Lithium		✓		✓		✓		✓	
Lutetium				✓					

continuation

MINERAL	BRAZIL			USA	EU		CHINA		
	G1	G2	G3	ALL	CRITI-CAL	STRATE-GIC	ENER-GY	ME-TALLIC	NON-METALLIC
Magnesium				✓		✓			
Manganese			✓	✓		✓			
Molybdenum	✓							✓	
Nickel		✓		✓		✓		✓	
Niobium		✓	✓	✓	✓				
Palladium				✓	✓				
Phosphate	✓				✓				✓
Platinum group		✓		✓		✓			
Potassium (potash)	✓								✓
Rare earth minerals		✓		✓		✓		✓	
Rhodium				✓					
Rubidium				✓					
Ruthenium				✓					
Scandium				✓	✓				
Silicon		✓				✓			
Strontium					✓				
Sulphur	✓								
Tantalum		✓		✓	✓				
Tellurium				✓					
Terbium				✓					
Thallium		✓							
Thulium				✓					
Tin		✓		✓				✓	
Titanium		✓		✓		✓			
Tungsten		✓		✓		✓		✓	
Uranium		✓	✓				✓		
Vanadium		✓		✓	✓	✓			
Ytterbium				✓					
Yttrium				✓					
Zinc				✓					
Zirconium				✓				✓	

Annex 3: Recent Government Actions as of 2021

The Brazilian government has undertaken several initiatives to strengthen its mining and minerals sector, particularly in the area of critical minerals. These initiatives include these three main plans and programs:

NATIONAL MINING PLAN 2030	The National Mining Plan 2030[189] aims to guide medium and long-term policy strategies for the mineral sector, based on competitiveness, sustainable development, and innovation. The plan highlights three axes for managing strategic minerals, which include minerals on which the country depends, minerals on which global demand is expected to grow, and minerals on which Brazil has a competitive advantage. The plan focuses on effective public governance, adding value to semi-finished and finished mineral products, and expanding scientific knowledge related to sustainability. Among the key actions proposed in the document is the creation of working groups to monitor strategic mineral resources and inter-ministerial articulation with the productive sector for the elaboration of long-term programs aimed at minerals with a future.
MINING AND DEVELOPMENT PROGRAM	The Mining and Development Program[190], provided for by Order No. 354 of the MME, of September 28, 2020, aims to define the policy for minerals of strategic interest to the country. The program aims to strengthen geological, regulatory, and technological development actions and apply them in metal and mineral production chains for technological innovation. It also aims to promote the adoption of new industry 4.0 technologies in the mineral sector, stimulate the creation of new products and markets, add value to mineral products produced in the country, and stimulate the installation of plants for high-tech products that use mineral resources.
THE SCIENCE, TECHNOLOGY, AND INNOVATION ACTION PLAN	The Science, Technology, and Innovation Action Plan for Strategic Minerals[191] prepared by the MCTIC's Secretariat for Technological Development and Innovation in 2018, outlined the challenges and proposed goals and actions for the minerals identified in the PNM 2030 plan. The plan highlighted the importance of international cooperation, proposing the expansion of existing partnerships with Germany and the European Union to other countries. It also included concrete actions to promote research, development, and innovation, such as the Inova Mineral program, which allocated funds of approximately R$ 1.2 billion to business plans involving research and educational institutions in the Brazilian mineral sector. The program identified minerals containing cobalt, graphite, lithium, rare earth metals, nickel, and titanium.

Annex 4: Relevant Laws, Legislation, Bills and Decrees

CPPI Resolution 126, June 10, 2020	Advocates for the creation and improvement of the Environmental Licensing Support Policy for Strategic Mineral Investment Projects — 'Pro-Strategic Minerals,' within the scope of the Investment Partnerships Program (PPI).
Decree 10657, March 24, 2021	Establishes the Policy to Support Environmental Licensing of Investment Projects for the Production of Strategic Minerals. Establishes the Interministerial Committee for the Analysis of Strategic Minerals Projects.
Resolution 1, June 18, 2021	Defines the functioning and role of the Interministerial Committee for the Analysis of Strategic Minerals Projects (CTAPME) and for the qualification of investment projects in the Strategic Pro-Minerals Policy.
Resolution 2, June 18, 2021	Defines the list of strategic minerals for the country, in accordance with the criteria referred to in Article 2 of Decree No. 10657, of March 24, 2021.
Bill 571/2022	Creates special conditions for the exercise of mining activities in cases of interest to national sovereignty, as declared by the President of the Republic.
Decree 11120, July 5, 2022	Allows foreign trade of lithium minerals and ores and their derivatives.
Decree 11.369, January 1, 2023	Revokes Decree No. 10,966, of February 11, 2022, which established the Support Program for the Development of Artisanal and Small-Scale Mining and the Interministerial Commission for the Development of Artisanal and Small-Scale Mining.

Annex 5: Methodological Notes for Key Analyzes

LOCATION OF KNOWN MINERAL RESERVES	Using a shapefile of known mineral reserves from the GeoSGB Portal, we performed the following steps to pre-process the data and generate maps: 1. We exported the shapefile to CSV format to facilitate data manipulation and analysis. 2. We created four fields in the CSV file based on the mineral's names: "Strategic", "Category 1", "Category 2" and "Category 3." 3. We merged the updated CSV and the original shapefile to incorporate these new fields into the geospatial dataset. 4. Finally, we generate the maps used in the report by selectively displaying only mineral reserves belonging to a particular category.
ACTIVE MINING PROCESSES	We use microdata from the Mining Registry to identify active mining operations involving strategic minerals. Based on the mineral names, we created four variables: "Strategic," "Category 1", "Category 2" and "Category 3." These new variables allowed us to create the graphs included in this strategic paper.
PRODUCTION OF RAW AND PROCESSED MINERALS	We use data from the Brazilian Mineral Yearbook to calculate the value of raw and processed mineral production for strategic minerals. Based on the mineral names, we created four variables: "Strategic," "Category 1," "Category 2" and "Category 3." These new variables allowed us to generate the graphs included in this strategic paper.
FOREIGN INVESTMENT IN BRAZILIAN MINING COMPANIES	To identify foreign investment in the Brazilian mining sector related to strategic minerals, we followed a three-step process: 1. We obtained a list of all companies with active mining processes related to strategic minerals in the Mining Registry database. 2. We cross-referenced the business taxpayer numbers (CNPJs) of these companies with the Brazil Central Bank's direct foreign investment database to determine which of these companies received foreign direct investment. 3. We merged records from the Central Bank database with data from the Mining Registry and calculated the number of companies in each country that invested in Brazilian companies with active mining processes related to strategic minerals.
STRATEGIC MINERALS OPEN-PIT MINING	1. We have shapefiles for: • Homologated Indigenous Lands (FUNAI) • Conservation units (MMA) • Quilombola communities (INCRA) • Mines in the Brazilian legal Amazon (Amazon Mining Watch) 2. Next, we analyze open-pit mining activities concerning strategic mineral reserves and protected areas.

Endnotes

1 Friendshoring: The term, a cousin of "reshoring" and "onshoring" and a sibling to "nearshoring," is shorthand for the practice of relocating supply chains to countries where the risk of disruption from political chaos is low.

2 Downstream processing refers to the activities involved in refining and preparing extracted raw materials or minerals for their end use or marketable form. It includes the steps that follow the extraction of minerals from the earth. Midstream processing refers to processes such as sorting, grading, and storing the extracted materials, as well as their transportation to processing facilities or distribution centers. It also includes ensuring quality control and proper handling of minerals during storage and transportation.

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26 Most major silicon-producing countries have sufficient reserves to meet demand. However, specific estimates regarding these reserves are not available.

27 The world has sufficiently identified tantalum resources to meet future demand – mainly in Australia, Brazil, Canada, and China.

28 Thallium, while abundant in the Earth's crust at around 0.7 parts per million, is mostly found in potassium minerals where extraction is not commercially viable. Nevertheless, the trace amounts of thallium in sulfide ores of copper, lead, zinc, and other metals are sufficient to satisfy global demand.

29 The USGS data only contains estimates for ilmenite in Brazil and not rutile.

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