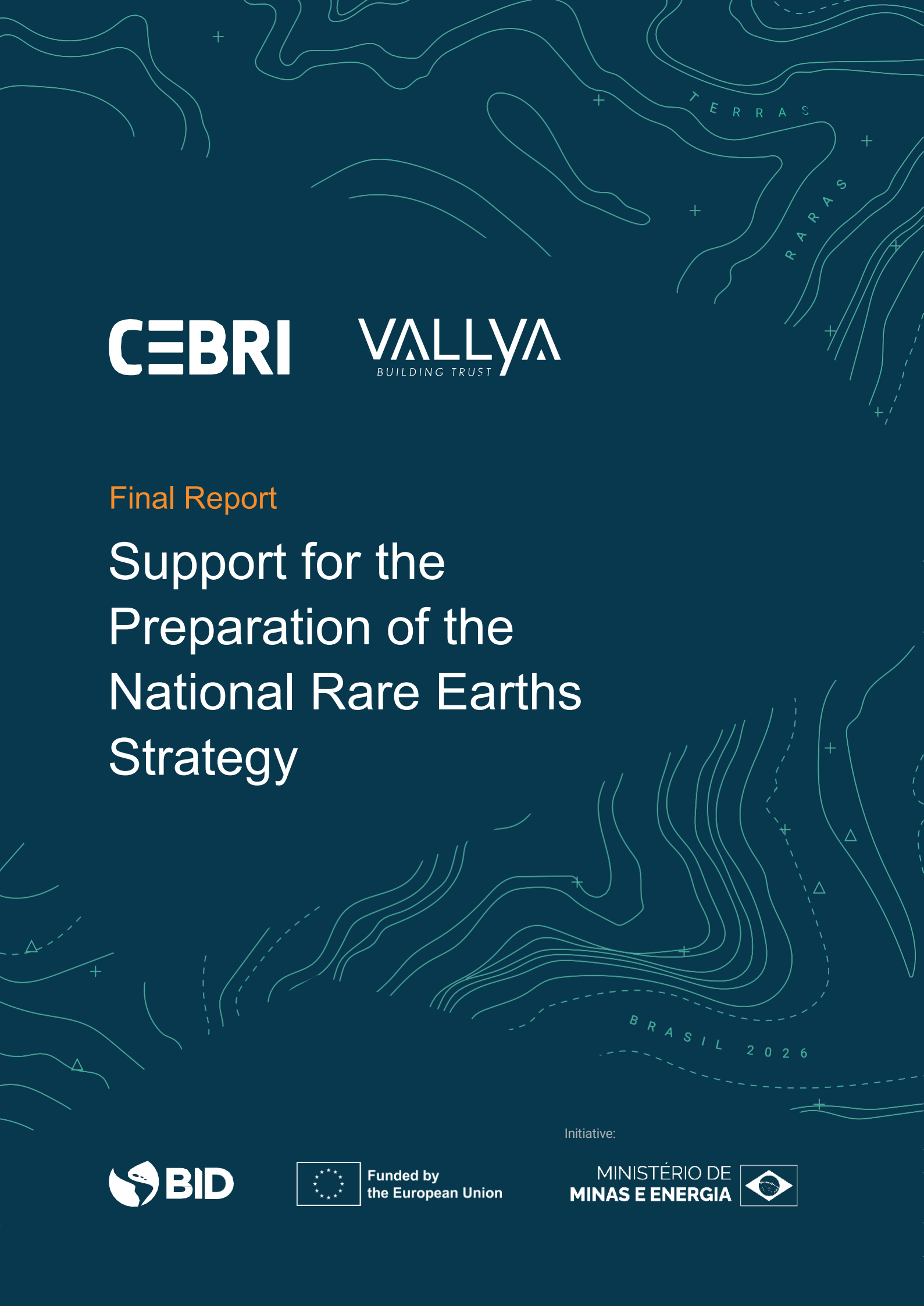




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Final Report

Support for the Preparation of the National Rare Earths Strategy



Funded by
the European Union

Initiative:

MINISTÉRIO DE
MINAS E ENERGIA



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Final Report

Support for the Preparation of the National Rare Earths Strategy

August 2026

Initiative:



Institutional Support
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List of Acronyms

ANM: National Mining Agency

ANSN: National Nuclear Safety Authority

BNDES: National Bank for Economic and Social Development

CAPEX: Capital Expenditure (Capital Investment/Required Capital Expenditure)

CEBRI: Brazilian Center for International Relations

CFEM: Financial Compensation for the Exploitation of Mineral Resources

CNEN: National Nuclear Energy Commission

CNPM: National Council for Mineral Policy

CPLI: Free, Prior and Informed Consent

CPRM: Mineral Resources Research Company (Geological Survey of Brazil)

Dy: Dysprosium

DyTb: Dysprosium-Terbium

EIA/RIMA: Environmental Impact Assessment and Environmental Impact Report

EPE: Energy Research Company

ESG: Environmental, Social, and Governance

FAB: Brazilian Air Force

FINEP: Studies and Projects Financing Agency

GSI: Institutional Security Office

HREE: Heavy Rare Earths

IBAMA: Brazilian Institute of Environment and Renewable Natural Resources

IBRAM: Brazilian Mining Institute

IEA: International Energy Agency

LDO: Budget Guidelines Law

LOA: Annual Budget Law

LREE: Light Rare Earths

LSO: Social License to Operate

MCE: Critical and Strategic Minerals

MCTI: Ministry of Science, Technology and Innovation

MDIC: Ministry of Development, Industry, Trade and Services

MMA: Ministry of Environment and Climate Change

MME: Ministry of Mines and Energy

MREC: Mixed Rare Earth Carbonate

MREO: Magnetic Rare Earth Oxide

Nd: Neodymium

NdFeB: Neodymium-iron-boron (a type of high-performance permanent magnet)

NdPr: Neodymium-Praseodymium

NORM: Naturally Occurring Radioactive Material

NRES: National Rare Earths Strategy

OECD: Organisation for Economic Co-operation and Development

OPEX: Operational Expenditure (Operating Expenses/Operating Costs)

PPA: Multi-Year Plan

PPB: Basic Production Process

Pr: Praseodymium

R&D: Research and Development

R&D&I: Research, Development and Innovation

REE: Rare Earth Elements

REO: Rare Earth Oxide

ROM: Run of Mine (Raw ore as extracted from the mine)

SGB: Geological Survey of Brazil

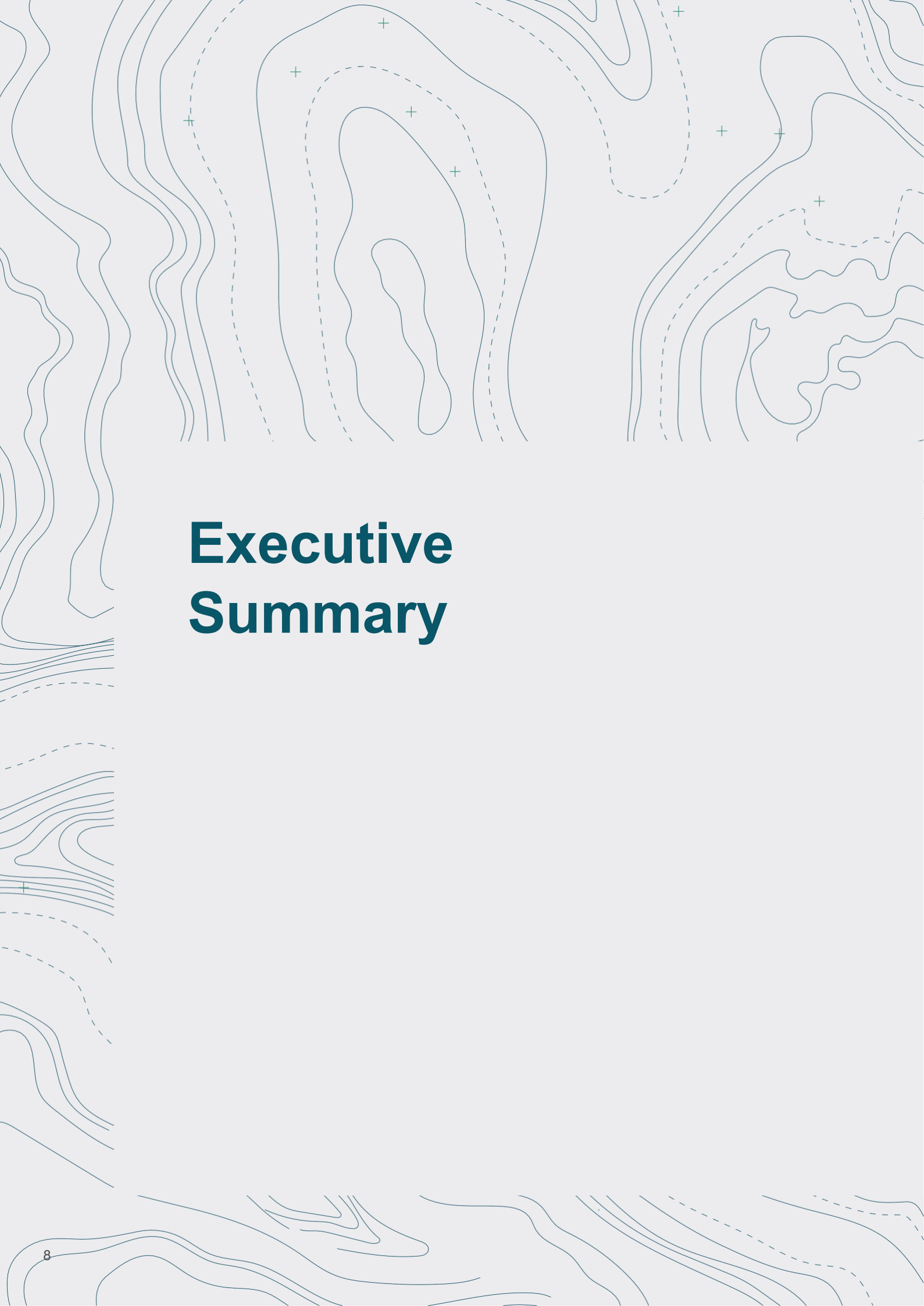
Tb: Terbium

TREO: Total Rare Earth Oxide

TRL: Technology Readiness Level

USGS: United States Geological Survey

WEEE: Waste Electrical and Electronic Equipment



Executive Summary

The current geopolitical context, characterized by the pursuit of economic, energy, technological, and industrial security, has turned critical minerals—especially rare earths—into strategic assets. The growing competition among major powers for control of supply chains linked to the energy transition, the defense industry, and digital technologies has heightened the importance of countries capable of supplying critical minerals in a stable, sustainable, and geopolitically reliable manner. In this context, Brazil emerges as one of the countries with the greatest strategic potential in the world, attracting strong international interest from governments, companies, and investors seeking diversification and resilience in their supply chains. This trend is reflected in the increase in partnership proposals and investment projects, as well as in the strengthening of the national agenda, including ongoing initiatives such as the legislative process for Bill 2780/2024, which establishes the National Policy on Critical and Strategic Minerals (PNMCE), in addition to the incorporation of this issue into industrial, energy, climate, and ecological transformation policies. To transform this potential into concrete results and convert its competitive advantages into real strategic capabilities, Brazil needs public policy instruments capable of defining priorities, coordinating the actions of the various actors in the ecosystem, and guiding investments and efforts toward a common vision of sustainable socioeconomic development, the generation of added value, and a broader sharing of the wealth produced in the country. This report contributes to this objective by presenting an assessment and the rationale for a National Strategy. The report includes an analysis of existing instruments and policies — whether already in effect or still under consideration — and moves forward with a proposal for an integrated, coordinated, and ambitious approach to the development of the rare earths supply chain in Brazil.

This study, conducted to support the preparation of the National Rare Earths Strategy (NRES), concludes that Brazil is exceptionally well-positioned to expand its role in global supply chains for critical minerals. Based on already mapped resources and reserves, the country holds approximately 23.1% of global rare earths resources and possesses the world's second-largest reserve, in addition to a growing portfolio of competitive projects and a robust technical and scientific foundation. However, the report emphasizes that geological advantage alone does not guarantee a strategic position. Brazil's central challenge lies not only in identifying deposits with potential for rare earths exploration, extracting the mineral resources, and developing mineral production capabilities in a sustainable and inclusive manner, but also in developing national capacity for processing, industrial transformation, innovation, and entry into higher-value-added segments.

In this regard, the rare earths value chain can be organized into three main segments: **upstream** (mining, concentration, and mineral processing), **midstream** (separation of individual elements, purification, refining, and conversion into oxides, metals, and alloys), and **downstream** (production of permanent magnets, components, and industrial applications with higher value added). Given China's dominance of the more sophisticated segments of the chain—especially the midstream (separation and refining)—the reorganization of global supply chains to overcome this strategic global bottleneck creates a favorable window of opportunity for Brazil. Countries have been developing industrial policies, financial instruments,

and “friendshoring”¹ agreements to diversify suppliers and reduce geopolitical vulnerabilities. The report highlights that Brazil can position itself as a reliable partner in this process, provided it moves quickly to build domestic industrial and regulatory capabilities.

The analysis of international experiences (international benchmarking) conducted by this study in the main countries involved in the Rare Earth Elements (REE) supply chains shows that the most successful countries have combined public financing instruments, institutional coordination, industrial policies, support for innovation, regulatory predictability, and risk mitigation mechanisms. The main international lesson identified is that competitiveness in critical minerals depends on the integration of mining, processing, technology, and industrial policy. The report recommends that Brazil avoid both a purely extractive strategy and any attempt to internalize the entire supply chain simultaneously. The recommendation is to adopt a gradual, selective, and coordinated path toward productive intensification.

The national assessment indicates that Brazil already has a competitive upstream sector and promising projects, particularly in ion-adsorption clay deposits in Goiás and Minas Gerais, with potential for the discovery of new deposits. The estimated additional potential is approximately 38,700 metric tons of Rare Earth Oxides (TREO), equivalent to about 10% of estimated global production for 2025. Investments of approximately R\$13.2 billion are also projected for the most advanced projects.

Despite this, the main national bottlenecks concentrate on the higher-value-added links of the value chain. Brazil still faces significant limitations in processing capacity and industrial transformation, low technological density, and dependence on foreign sources for critical stages such as separation, refining, and the production of advanced materials. In addition, regulatory, environmental, institutional, and financial challenges persist, hindering the scaling up of projects, increasing the perceived risk of investments, and reducing the capacity for coordination among mining, industry, innovation, and regional development.

Given this scenario, the study argues for the need for a structured national strategy capable of setting priorities, coordinating public policy instruments, and reducing uncertainty for investors. The NRES is conceived as a government strategy aimed at transforming geological advantages into productive and technological capacity.

The proposed structure for NRES is organized into three complementary time horizons.

1. Friendshoring is a political-economic strategy for transferring critical stages of production to allied countries with similar values and institutional commitments, thereby strengthening networks of “reliable” and politically predictable suppliers (Müller, 2023).

In **the short term**, the central objective is to unblock and organize the supply chain. Priorities include:

- consolidating a competitive upstream sector;
- deepening geological intelligence;
- creating instruments to reduce risks in the supply chain (de-risking);
- tax and financial instruments aimed at gradual vertical integration;
- regulatory coordination for radioactivity and Naturally Occurring Radioactive Material (NORM);
- harmonization among federal and state agencies;
- institutional strengthening;
- initial support for selective separation and refining;
- launch of recycling programs.

In **the medium term**, the strategy aims to scale up and consolidate the production chain. Actions include:

- expansion of national separation and refining capacity;
- advances in metals, alloys, and magnets;
- creation of regional processing and innovation hubs;
- integration with strategic consumer sectors such as defense, electric mobility, and renewable energy;
- long-term contracts and measures to stimulate domestic demand.

In **the long term**, the goal is to integrate and reposition Brazil within global value chains with higher value added. The study forecasts:

- consolidation of an integrated supply chain encompassing mining, refining, metallurgy, and magnets;
- strengthening of circularity and recycling;
- expansion of the production of advanced components;
- international integration into strategic supply chains;
- the development of domestic content and public procurement policies.

One of the central pillars of the proposal is the development of a regulatory and institutional framework capable of reducing uncertainty, increasing predictability, and more efficiently coordinating the various agencies involved in the development of the rare earths supply chain. The report highlights that the fragmentation among mineral, environmental, and radiological licensing creates legal uncertainty, increases project risks, and hinders their financeability. To address this challenge, the strategy proposes strengthening coordination between the federal government and the states, improving coordination among regulatory authorities, creating specific solutions for sensitive issues such as the handling of radioactivity, expediting the processing of strategic projects, and expanding mechanisms for territorial governance, public participation, and interministerial coordination.

Another key pillar is the tax and financial agenda, designed to facilitate the gradual vertical integration of the value chain and stimulate investment in the segments with the highest value added. The report proposes a combination of instruments aimed at reducing the cost of capital, mitigating risks, and supporting technological and industrial scaling, including tax incentives, long-term credit, support for innovation, financing for pilot plants, mechanisms for technology internalization, and instruments capable of increasing the economic competitiveness of the processing, refining, metallization, and magnet manufacturing stages within the country. This agenda aligns with and complements the measures outlined in Bill 2780/2024 and Bill 4443/2025, which propose mechanisms to strengthen the supply chain for critical and strategic minerals, including incentives for value addition, institutional coordination, financing, and the promotion of industrialization within the country.

Finally, the study also emphasizes that the success of this strategy will depend on the ability to align economic competitiveness, socio-environmental sustainability, and territorial legitimacy, ensuring the effective involvement of local communities and the generation of shared benefits in the regions where the projects will be developed. The expansion of the rare earths supply chain in Brazil must be anchored in robust governance, socio-environmental sustainability, and territorial development, as these elements are structural—rather than incidental—conditions for the national strategy. Given the complexity and risks associated with the sector, advancing this activity requires institutional coordination, the adoption of high ESG standards, the strengthening of social participation, and mechanisms such as Free, Prior and Informed Consent where applicable. Local development does not occur automatically; it depends on active policies to maximize benefits (employment, income, public revenues) and mitigate adverse effects (pressure on services, territorial conflicts, and displacement). The report presents guidelines, actions, and indicators in this regard, complemented by a handbook of best practices.

The key conclusion is that Brazil has a historic opportunity to become a strategic player in global supply chains for critical minerals, but this will not happen automatically. Success will depend on the country's ability to coordinate public policies, mobilize investments, reduce regulatory uncertainties, develop industrial capabilities, and ensure territorial and socio-environmental legitimacy for these projects.

NRES proposes precisely this path: transforming mineral abundance into sustainable industrial, technological, and geopolitical development. In an international context marked by competition over supply security, Brazil is well-positioned to establish itself as a strategic partner in global value chains with higher value added and greater geopolitical significance. Without a strategy that provides the capacity to negotiate with international partners on an equal footing, the country risks missing the opportunity to position itself within global supply chains for critical minerals, thereby maintaining its historically low capture of economic value, limited industrial integration, and high dependence on foreign technology. On the other hand, the implementation of the NRES could create the conditions to establish an integrated and competitive national supply chain, including the expansion of mineral production, the development of intermediate processing, and the creation of industrial value. The cost of inaction is not limited to the loss of economic opportunities but also extends to limiting the country's ability to occupy a strategic position in the global market for advanced technologies and to expand its geopolitical bargaining power.

1

Introduction

1.1. Global Geopolitical Context

Critical minerals occupy a central position in contemporary geopolitics because they are essential inputs for the energy transition, the digital transformation, the defense industry, and industrial competitiveness. Materials such as copper, lithium, nickel, graphite, and rare earths are increasingly treated as strategic assets due to their role in national security and technological autonomy. In this context, the competition over these resources is no longer limited to geological access but now involves control over the stages of processing, refining, manufacturing, and technological innovation, as well as the pursuit of supply chain resilience.

Among critical minerals, Rare Earth Elements (REEs) are of particular importance due to their magnetic, luminescent, catalytic, and electrochemical properties, which make them essential for a wide range of strategic applications in today's economy. These elements are used in the manufacture of high-performance permanent magnets, which are fundamental to renewable energy and electric mobility technologies, as well as in automation and digital infrastructure. They are also used in optoelectronic devices, lasers, sensors, and catalysts, as well as in aeronautical and defense systems, contributing to increased efficiency and precision in these technologies (CEBRI, 2025).

Four elements (Neodymium, Praseodymium, Dysprosium, and Terbium) have gained particular attention for their role in the production of permanent magnets used in electric vehicles, wind turbines, and advanced industrial systems. Studies indicate that demand for these elements could triple over the next decade, albeit in relatively limited volumes.²

The growing importance of rare earths stems both from expanding demand and from vulnerabilities associated with their supply. On the demand side, three structural trends contribute to their growing importance. First, the electrification of the economy and the expansion of renewable energy have increased demand for wind turbines, electric motors, energy storage solutions, and energy-efficient equipment that are intensive in rare earths, making REEs a pillar of the energy transition. Second, the accelerated digitization of the economy and advances in artificial intelligence, connectivity, and automation require high-performance inputs such as REE to power critical devices and infrastructure.³ Finally, increased geopolitical competition and the modernization of defense systems underscore the importance of these inputs for radars, sensors, drones, satellites, guided systems, and other sensitive technologies.

However, the criticality of REEs does not stem from absolute geological scarcity. These elements exist in various regions of the world, although generally in low concentrations and with high separation and refining complexity. The main risk factor lies in the high geographic and technological concentration of the value chain, especially in the

2. The [International Energy Agency \(2025\)](#) estimates that demand for magnetic rare earths will nearly double between 2021 and 2040, from 78 kilotonnes (kt) to 140 kt. Other, more ambitious studies, such as the one by McKinsey (2025), indicate that demand for magnetic rare earths could triple between 2022 and 2035, from 59 kt to 176 kt. <https://www.mckinsey.com/industries/metals-and-mining/our-insights/powering-the-energy-transitions-motor-circular-rare-earth-elements>

3. According to the International Energy Agency report *"The Role of Critical Minerals in Clean Energy Transitions."* <https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions>

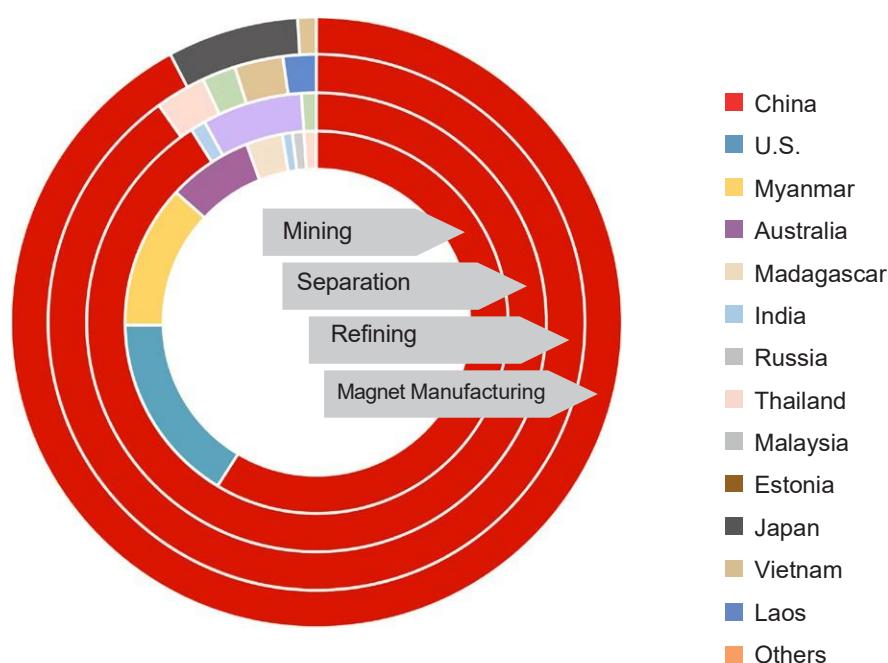
intermediate and final stages. In recent decades, China has consolidated its dominant position in the processing, refining, and manufacturing of higher-value-added products—particularly permanent magnets—in addition to mining.

This pattern of concentration resulted from a combination of favorable geological endowment, long-term industrial policy, investments in production capacity, technological expertise, and competitive costs. China holds about half of the world's REE resources, accounting for 70% of production and virtually the entire processing chain (CEBRI, 2025). In the downstream sector, it accounts for 94% of magnet production, a near-monopoly situation.⁴ Production outside China began to decline at the end of the last century, when companies shifted their operations to China, driven by lower costs and growing Chinese industrial capacity, as well as environmental restrictions and difficulty competing with Chinese prices.

The concentration of the global supply chain in the hands of a small number of players began to raise more acute concerns starting in the 2010s, when export restrictions, trade tensions, and logistical disruptions highlighted the vulnerability of supply chains. Since then, REEs have come to be regarded as critical from the perspective of economic security, technological sovereignty, and industrial resilience.

FIGURE 1

Geographic Concentration of the Stages in the Neodymium-Iron-Boron Magnet Supply Chain



Source: U.S. Department of Energy (2022).

4. <https://oglobo.globo.com/economia/noticia/2025/08/15/china-faz-alerta-a-empresas-estrangeiras-nao-acumulem-estoques-de-terras-raras.ghml>

To reduce their vulnerabilities, countries and economic blocs have begun to adopt strategies aimed at diversifying supply sources, resuming domestic mining, strengthening processing and refining capacities, recycling, and building strategic reserves. This trend reveals a significant shift in how rare earth elements (REEs) are viewed, moving beyond mere access to mineral resources to encompass, more broadly, the competition for productive, technological, and institutional capabilities throughout the entire value chain. The strategic importance of rare earths today is also linked to the ability to transform geological resources into production, processing, manufacturing, innovation, and competitive integration into global value chains with higher value added.

In this scenario, countries with reserves and the potential for expanded production have begun to attract attention. Brazil fits into this context as a key player, given the size of its reserves, its potential to contribute to the geographic diversification of supply, and, progressively, to the development of industrial and technological capabilities related to rare earths. The country's strategic importance, however, will depend on its ability to convert this mineral endowment into a competitive position throughout the value chain, balancing investment attractiveness, value addition, sustainability, and the national interest.

Without a coordinated strategy, the country is likely to concentrate on segments with lower value added, with limited industrial integration and high dependence on foreign technology. In contrast, the implementation of the NRES can create the conditions to increase economic value capture, strengthen industrial and technological capabilities, and position Brazil more prominently in global supply chains for Critical and Strategic Minerals.

1.2. Brazil's Role

Brazil occupies a strategic position in global rare earth production, possessing the second-largest reserves, behind only China. Considering the country's vast exploration potential—which concentrates nearly a quarter (23.1%) of global rare earth resources, totaling 4,058 megatons (Mt) in resources and 21 Mt in reserves (Brazilian Institute of Mining—Ibram, 2025; CEBRI, 2025), Brazil stands out as a key partner in the global effort to diversify sources of REE. Other comparative advantages contribute to growing international interest, including the availability of water and low-cost energy, existing mining capacity, and political stability. Furthermore, the country stands out for having a predominantly renewable electricity mix, which enhances its appeal to investors seeking to reduce the carbon footprint of their operations.

This interest translates, in practical terms, into a significant increase in geological surveys and investment decisions. Between 2023 and 2024, the number of new exploration permits jumped by +291%, according to the National Mining Agency (ANM) (2025), with 1,370 new exploration permits (REE and monazite). Mineração Serra Verde, the only producer currently operating in Brazil, announced in April 2026 its merger with USA Rare Earth, accompanied by a 15-year supply agreement and

\$565 million in financing from the U.S. International Development Finance Corporation (DFC), consolidating a de-risking arrangement and the creation of an integrated rare earths supply chain outside of Asia. Other companies in the pilot phase, such as Meteoric and Viridis, have also made progress in raising funds and negotiating with international partners, including support from ORE Investments, Régia Capital, and Ucore Rare Metals Inc., as well as negotiations with export credit agencies from countries such as Australia, Canada, France, and the United States. In total, projects related to rare earths in Brazil have already attracted approximately R\$ 13.2 billion in announced investments.⁵

These developments should make it possible to increase production in the coming years, given that mining is still in its early stages, with only one mine in operation (Serra Verde). Although the current focus is on the upstream phase (from extraction to mixed REE concentrate), Brazil also has the potential to contribute to various stages of the production chain, with pilot initiatives in the midstream (separation and refining) and downstream (magnet production).

Realizing Brazil's potential and expanding productive capacity at different stages require a public policy framework that balances competitiveness and attractiveness for investors with social and environmental safeguards and benefits for society.

1.3. General Objectives for the NRES and Target Audience

The primary objective of formulating a National Rare Earths Strategy (NRES) is to establish strategic priorities and formulate public policies that ensure Brazil's mineral resources are transformed into assets for development, sovereignty, and the strengthening of the country's industrial, technological, and geopolitical competitiveness within global supply chains for critical minerals.

In particular, the NRES should contribute to:

- Enhancing **Brazil's strategic relevance as a competitive supplier** and building domestic capacity to ensure **supply security** and reduce external dependence at critical stages;
- Ensuring the **orderly and responsible development of the REE production chain** and increasing the sector's attractiveness for the investments necessary for this development, by reducing risks and enhancing regulatory predictability;
- To consolidate a **competitive industry and develop technological capacity** to raise the maturity level and the value added of domestic production, thereby promoting **sustainable development**;
- **Train, develop, and retain qualified human resources** and build skills aligned with the needs of the production chain, generating jobs and income for local communities;

5. <https://valorinternational.globo.com/business/news/2026/02/18/rare-earth-projects-in-brazil-total-r132bn-in-investments.ghtml>

- Strengthen capabilities in **Research, Development and Innovation** to ensure the competitiveness of Brazilian production and expand domestic technological capabilities, thereby reducing dependencies;
- Ensure that industries adopt the principles of **social and environmental responsibility** while maximizing socioeconomic benefits for the affected regions;
- Prioritize the use of rare earths **in energy applications**, driving the transition to clean energy and decarbonization technologies, in line with Brazil's international climate commitments.

The Strategy is primarily aimed at public policymakers at the federal and state levels, seeking to guide decision-making and the legislative process related to rare earth elements based on a strategic vision of the country's priorities and needs.

Other stakeholders include companies, investors, civil society, and international partners, who will gain greater clarity on how the country intends to position itself on this issue and the short-, medium-, and long-term actions that will be implemented to achieve these objectives, thereby strengthening predictability and transparency in decision-making.

1.4. Methodology

The project uses a combination of different methodologies to ensure consistent analyses and recommendations. To gain a better understanding of the problems, challenges, and assessments facing the rare earths sector, a review of the specialized literature was conducted.

This stage was conducted through consultations with primary sources and public databases from the United States Geological Survey (USGS), the National Mining Agency (ANM), the Geological Survey of Brazil (SGB), the International Energy Agency (IEA), and the United Nations Commodity Trade Statistics Database (UN Comtrade, COMTRADE), the Organisation for Economic Co-operation and Development (OECD), as well as information available on government websites, regulatory frameworks, and national legislation.

Academic sources, scientific articles, and publications relevant to the topic—such as those from the Brazilian Mining Institute (IBRAM), the Brazilian Center for International Relations (CEBRI), and the Geological Survey of Brazil (SGB)—were also considered, as were the Scopus and Google Scholar databases. At the same time, a bibliometric analysis was conducted to map scientific output related to REE.

The international benchmarking phase aimed to analyze international experiences in order to identify best practices, highlight gaps, and draw lessons that could inform the design of policies aligned with the institutional and productive specificities of the Brazilian context. The countries selected for analysis were those that stand out for adopting best practices or for consolidating internationally recognized models,

with a comparative analysis of key aspects for structuring the value chains of critical minerals and REE (for more information, see the international benchmarking section).

Next, the stakeholder consultation—conducted through interviews and technical visits—allowed us to validate the findings identified in the literature. The purpose of this process was to validate the challenges, problems, objectives, and strategic axes that should be considered within the scope of NRES. This stage helped to elucidate the perceptions and reasoning that guide the stakeholders analyzed⁶—aspects that are generally more difficult to capture through other data collection methods. This stage was divided into different modalities: individual interviews, field visits, and multisectoral workshops, as detailed below.

1. **Virtual interviews** with representatives from government or regulatory agencies, the private sector—including both mining and processing companies as well as end-user industries—academia and technology centers, associations, and civil society institutions (for more information, see the appendix).
2. **Field visits** to the following municipalities: Minaçu (Goiás), Belo Horizonte (Minas Gerais), and Poços de Caldas (Minas Gerais), including visits to the following organizations: Serra Verde, InvestMinas, Meteoric, the Minaçu City Hall (Goiás), the Poços de Caldas Department of Economic Development (Minas Gerais), and others (for more details, see the appendix). In-person meetings were also held in Brasília with the World Bank, the office of Congressman Arnaldo Jardim, and the Ministry of Foreign Affairs.
3. **An online workshop** serving as a public consultation to gather feedback from the third sector and ensure that its concerns are taken into account.
4. **A virtual multisectoral workshop**, organized with all identified stakeholders in Brazil. The event presented the assessment, the hypotheses raised for the solutions tree, the key recommendations, and the preliminary structure of the NRES. The goal was to gather feedback in an organized and collaborative manner.

To guide the definition of objectives and strategic axes for NRES, the problem-and-solution tree method was used. This tool provides an overview of the challenges faced by the rare earths sector, their implications, and the most relevant solutions⁷ (for more information, see the appendix). Thus, the study combines documentary analysis, international benchmarking, primary data collection, and strategic formulation guided by public policy.

6. <https://www.scielo.br/j/er/a/QPr8CLhy4XhdJsChj7YW7jh/?format=pdf&lang=pt>

7. <https://media.odi.org/documents/192.pdf>



2

Global Overview of the Rare Earths Sector

2.1. Overview of Rare Earths: What They Are and What They're Used For

Rare earth elements (REE) comprise a set of 17 chemical elements, consisting of the lanthanides, as well as Scandium and yttrium. Although they are often treated as a single group, these elements have distinct uses, levels of criticality, and market dynamics. What they have in common are magnetic, luminescent, catalytic, optical, and electrochemical properties that give them high technological significance.⁸

From a geological standpoint, REEs are not particularly rare in the Earth's crust. Their criticality stems less from absolute physical scarcity and more from their low concentration in economically viable deposits, the complexity of separating chemically similar elements, and the geographic concentration of the industrial stages with the highest value added. In general, REEs occur in low concentrations and are often associated with one another or with radioactive elements, such as thorium and uranium, which increases the technical, environmental, and regulatory complexity of their extraction and processing.⁹

REEs are usually classified into two major groups: light rare earths (LREE) and heavy rare earths (HREE). Among the light rare earths, neodymium (Nd) and praseodymium (Pr) stand out, while among the heavy rare earths, dysprosium (Dy) and terbium (Tb) are particularly significant. These four elements are particularly strategic because they form the basis of high-performance permanent magnets, especially Neodymium-iron-boron (NdFeB) magnets, which are widely used in electric vehicles, wind turbines, industrial automation, and defense systems.

REEs have applications in a wide variety of industrial sectors. In addition to permanent magnets, they are used in catalysts, phosphors, special alloys, lasers, sensors, specialty glass, screens, LEDs, optical components, advanced electronics, and semiconductor materials. Their importance stems from the fact that, even in small quantities, these elements can enhance the performance, miniaturization, precision, durability, and energy efficiency of products and systems. In this sense, rare earth elements act as technological multipliers in key sectors of the contemporary economy.

The rare earths value chain can be organized into three main links. The first is the **upstream**, which includes mining, concentration, and mineral processing. The second is the **midstream**, or processing, which includes the individual separation of elements, purification, refining, and transformation into oxides, metals, and alloys. The third is the **downstream**, which encompasses the production of permanent magnets, components, and industrial applications with higher added value. From a broader perspective, the chain also includes value recovery through recycling, waste reuse, and the recovery of secondary materials.

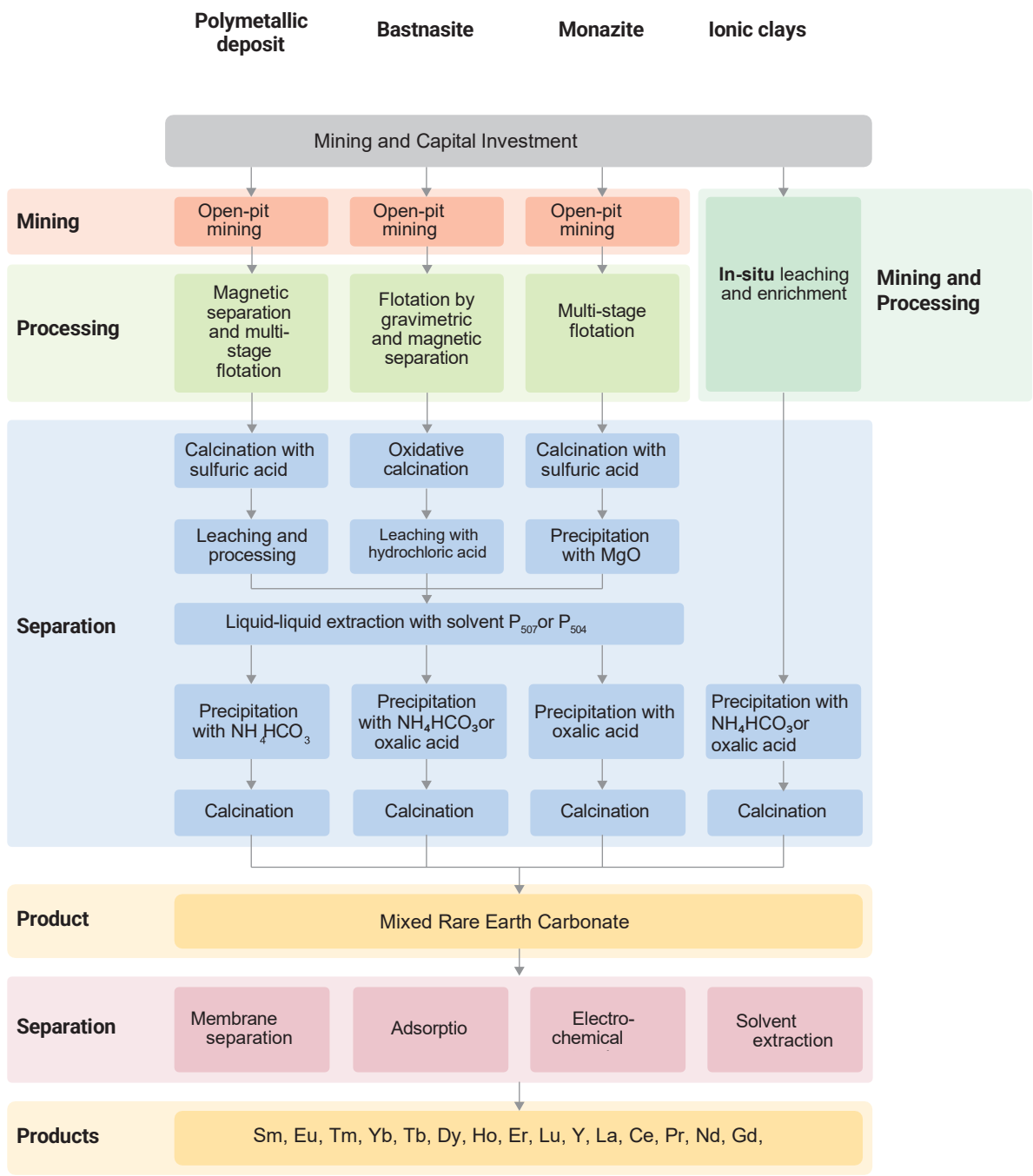
The processing stage deserves special mention because it constitutes the main technological bottleneck in the chain. Since REEs have very similar chemical properties

8. <https://rareearths.com/>

9. <https://www.sgb.gov.br/w/servico-geologico-do-brasil-esclarece-duvidas-sobre-potencial-do-pais-para-terras-raras-e-minerais-estrategicos>

and typically occur in association with one another, their individual separation requires complex processes, generally based on multistage solvent extraction and, in some cases, complementary techniques such as ion exchange (Figure 2). After separation and purification, the oxides can be converted into metals or alloys, which then supply the manufacturing of end products (Dutta et al., 2026; Wei et al., 2026). This combination of low concentration, high chemical similarity, and processing intensity helps explain why rare earths are of such geoeconomic importance.

FIGURE 2
Technological Processing Routes for REE



Source: Prepared by the authors based on Wei et al. (2026) and Wang et al. (2026).

2.2. Evolution of Criticality and Geopolitical Reconfiguration of Rare Earths

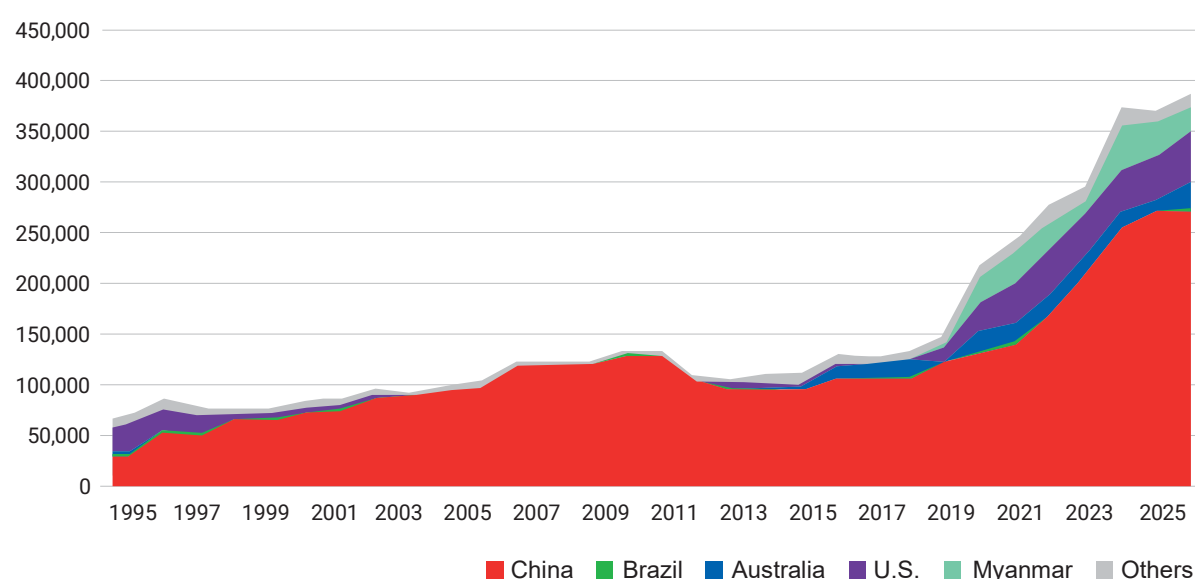
The critical importance of rare earths has not always been understood in the same way. Until the 1990s, these elements were valued primarily for their industrial and technological applications, but they did not yet occupy a central position in the geopolitical debate. The notion of criticality was relatively narrow and more closely associated with the functional utility of these materials than with the perception of systemic risk in supply chains.

This situation began to change with the growing concentration of production and, primarily, processing in China. China's leadership in the sector resulted from a combination of favorable geological endowment, relatively low costs, expansion of industrial capacity, investments in Research and Development, and public policies aimed at vertical integration of the production chain (Liu et al., 2023). Over the past few decades, China has consolidated its position as the leading mineral producer and has also dominated the separation, refining, and manufacturing stages, especially in the permanent magnets segment.

A major turning point occurred in 2010–2011, when Chinese restrictions on exports of rare earths more explicitly exposed the vulnerability of global supply chains. The concept of criticality is no longer limited to geological scarcity or productive importance but now incorporates dimensions such as supply concentration, external dependence, low substitutability, supply response time, and geopolitical exposure.

FIGURE 3

History of Rare Earth Oxide production from 1994 to 2024



Source: Prepared by the authors based on USGS data.

In the years that followed, this perception was reinforced by broader structural changes. On the one hand, permanent magnets made from rare earths have become increasingly important in technologies related to the energy transition—such as electric vehicles and wind turbines—as well as in defense, advanced electronics, automation, and healthcare applications. On the other hand, the pandemic, trade tensions, and intensifying geopolitical competition highlighted the fragility of global supply chains that are overly concentrated in just a few countries and a few suppliers.

As a result, several countries have begun to review their lists of critical minerals and adopt specific strategies for rare earths. In many cases, the response has gone beyond simply searching for new mines and now includes measures aimed at strengthening domestic capabilities in separation, refining, manufacturing, innovation, and recycling (Wei et al., 2026).

2.3. Global reserves, production, and processing worldwide

The global structure of the rare earths supply chain is characterized by significant asymmetry between reserves, mineral production, and processing capacity. Although reserves are distributed across different countries, production—and, above all, refining—remain much more concentrated. This distinction is central to the strategic analysis of the sector: geological endowment does not automatically translate into productive potential, nor does mineral production guarantee control over the links with the highest value added.

According to the United States Geological Survey (USGS, 2026), global rare earth reserves exceed 85 million metric tons in Rare Earth Oxide equivalent. China holds the largest share of these reserves, followed by Brazil, which ranks second globally, as well as countries such as Australia, Russia, Vietnam, and the United States. However, the distribution of reserves does not directly correspond to production share or dominance in the industrial chain. Brazil, for example, has significant reserves but still has limited production and low industrial density. The United States, on the other hand, with a relatively smaller share of reserves, maintains higher production than Brazil.

In the upstream sector, China remains the leading producer, supported by large deposits such as Bayan Obo and the ion-adsorption clays in the south of the country.

Outside of China, assets such as Mount Weld in Australia and Mountain Pass in the United States stand out (Table 1). These projects help diversify global mining, but do not, on their own, alter the strategic configuration of the supply chain, since most of the economic and geopolitical power is concentrated in the intermediate and final stages.

TABLE 1

History of Rare Earths Production from 1994 to 2025

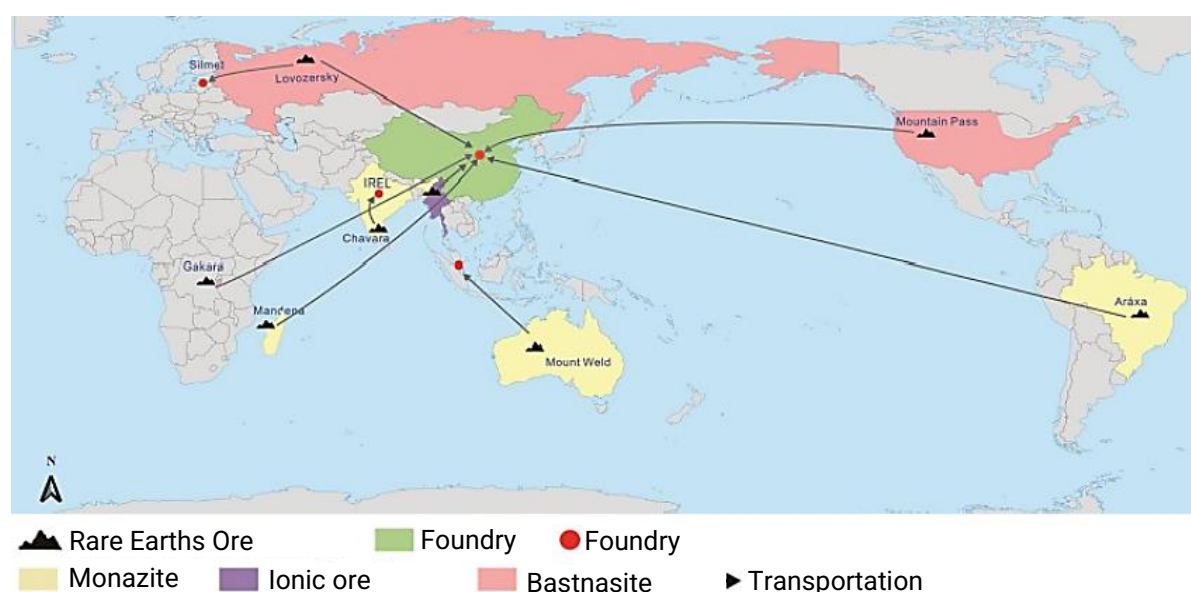
Mine Production	1994	2004	2014	2024	2025
China	22,000	95,000	95,000	270,000	270,000
USA	20,000		7,000	45,000	51,000
Australia	5,000		2,500	13,000	29,000
Myanmar				27,000	22,000
Thailand	50	2,000	1,100	2,100	4,800
India	2,500	2,700	3,000	2,900	2,900
Madagascar				2,000	2,700
Russia	8,000		2,500	2,600	2,600
Brazil	800			20	2,000
Nigeria				1,500	1,500
Vietnam			200	300	150
Malaysia	200	250	200	130	110
South Africa	700				

Source: USGS

It is in the midstream that concentration becomes most critical. The separation and refining of rare earths remain largely dominated by China,¹⁰ which combines scale, industrial experience, technological expertise, and vertical integration. Although there are significant initiatives outside the country—such as the operations of Lynas in Australia and Malaysia, MP Materials in the United States, Indian Rare Earths Limited (IREL) in India, and Silmet in Estonia—most international supply chains still depend, to a greater or lesser extent, on shipping concentrates or intermediates to China for critical separation and refining stages (Figure 4).

FIGURE 4

Main cross-border routes in the REO supply chains



Source: Wei et al. (2026).

10. <https://www.iea.org/reports/global-critical-minerals-outlook-2025>

In the downstream sector, this concentration is even more evident in the permanent magnet segment, where China maintains a largely dominant position. This means that global dependence on rare earths is not merely a dependence on ore or concentrate, but a dependence on an integrated industrial architecture—built up over decades—that connects mining, separation chemistry, metallurgy, alloys, magnets, and final manufacturing.

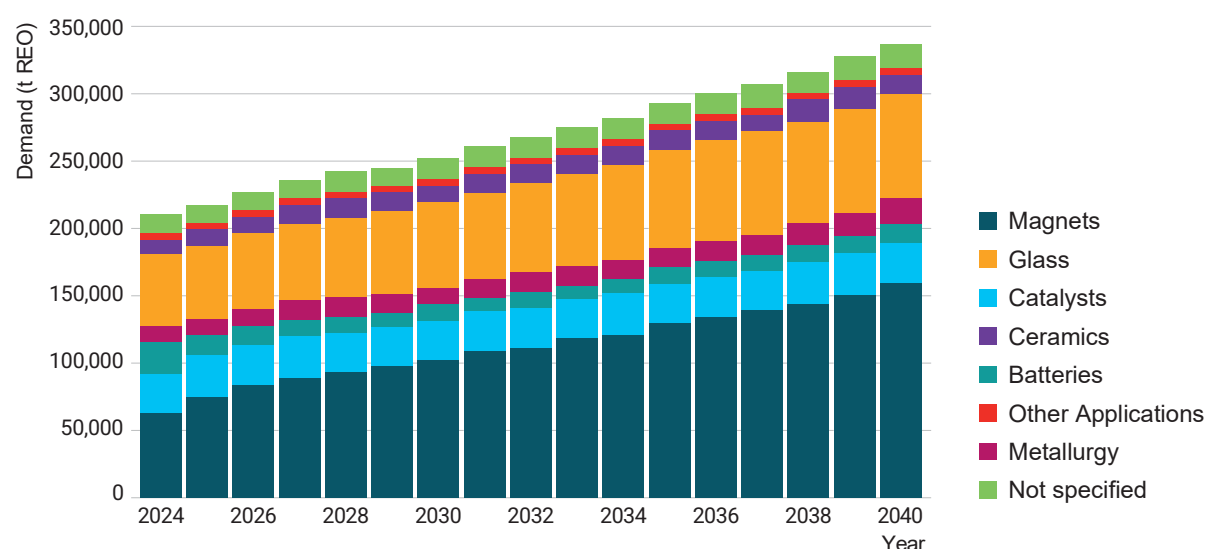
This value chain structure has direct strategic implications. First, it highlights that large reserves are a necessary but insufficient condition for competitive participation. Second, it shows that the decisive link for adding value and reducing vulnerability is the midstream. Third, it reinforces that countries interested in expanding their relevance in the sector need to view the supply chain in an integrated manner, combining mining, processing, innovation, industrialization, and, progressively, recycling.

2.4. Trends in Global Demand for Rare Earths

Global demand for rare earths is expected to grow in the coming decades, driven primarily by technologies related to the energy transition, digitalization, automation, and defense.¹¹ Although total volumes are relatively modest compared to base metals—with annual production in the range of about one billion metric tons for iron ore, millions of metric tons for copper and nickel, and only thousands of metric tons for REE—these elements hold strategic importance due to their ability to enhance the performance, efficiency, and technological density of products and systems.

FIGURE 5

Projected Demand for Rare Earth Oxides (REO) by Application—2024–2040



Source: Argus Media, 2025

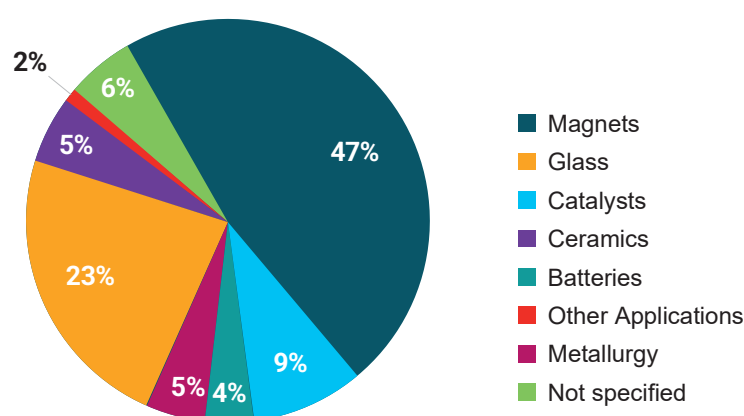
11. IEA (2025), *Global Critical Minerals Outlook 2025*, IEA, Paris. <https://www.iea.org/reports/global-critical-minerals-outlook-2025>

As illustrated in Figure 5, recent projections indicate continued growth in demand for REEs, particularly magnetic REEs—especially Neodymium, praseodymium, dysprosium, and Terbium. These elements are at the heart of the expected growth because they are essential for permanent magnets. Thus, although the REE family is broad, future market dynamics are likely to be increasingly driven by a subset of elements of greater strategic importance. According to data from Argus Media, demand for permanent magnets is expected to grow by 8.5% per year (p.a.) between 2024 and 2030, 4.5% p.a. between 2030 and 2035, and 4.0% p.a. between 2035 and 2040, exceeding 150,000 metric tons of TREO in 2040.

Also according to Argus Media's 2025 data, demand for heavy REE (HREE) and magnetic REE is expected to grow at a faster rate than demand for light REE (LREE). By 2040, 47% of REE demand will come from magnet production, while 23% will come from glass and refractory production, followed by 9% from battery production.

FIGURE 6

Projected Demand for Rare Earth Oxides (REO) by Application, 2024–2040



Source: Aclara, 2026

In response to this growing demand, mining and processing projects have been announced in various regions around the world. Studies do not indicate, at present, an immediate risk of geological scarcity. The main risk remains the high geographic concentration of processing and manufacturing, especially in China. Thus, the challenge for the coming decade lies in reducing the concentration of the intermediate and final links in the supply chain, in addition to expanding mineral supply.

For Brazil, this trend has significant implications. On the one hand, the projected increase in global demand boosts the attractiveness of domestic mining and processing projects. If all major projects move forward, a potential increase of 38,700 metric tons of TREO is expected within Brazil alone, which corresponds to about 10% of global production. On the other hand, the expansion of domestic demand—especially in segments associated with the energy transition—and the distribution of value throughout the supply chain suggest that the discussion on rare earths should not be limited to the export of raw materials, as demonstrated in section 2.5. National energy projections, coupled with the

growth of wind energy, electric mobility, and the electrification of the economy, indicate that the country could significantly increase its domestic demand for materials and components based on rare earth elements (REEs).¹²

The expected growth in global demand reinforces two strategic conclusions: the first is that Brazil has a window of opportunity to expand its share of the global rare earths supply. The second is that this opportunity will be greater if the country manages to move beyond mineral extraction and progressively develop capabilities in processing, refining, and industrial applications associated with the segments experiencing the most dynamic growth in demand.

2.5. Brazilian Demand for Magnetic Rare Earth Elements

In Brazil's case, the main drivers of demand are:

1. **Electric mobility:** Permanent magnets are one of the main applications for NdPr, Dy, and Tb, and the expansion of electric vehicles is already one of the major global drivers of demand. Additionally, there is the issue of domestic demand and the automotive manufacturing industries already established in Brazil and Latin America.
2. **Renewable energy, especially wind power:** higher-performance wind turbines use permanent magnets, particularly those containing Nd, Pr, Dy, and Tb.
3. **Robotics and automation:** According to Adamas (2026), the robotics industry is expected to become the largest global driver of demand for NdFeB by 2040, surpassing EVs in the medium and long term. This issue is important because it links rare earths to Brazil's agenda for reindustrialization and advanced automation.
4. **Healthcare and medical equipment:** elements such as Gadolinium, Lutetium, Ytterbium, Terbium, Yttrium, and Samarium are used in magnetic resonance imaging (MRI), lasers, X-rays, tumor treatment, and other medical applications. This sector has a smaller volume than the automotive/wind turbine magnet sector, but it is high-value and well-suited to technological niches. Furthermore, Brazil concentrates a wide range of specialists at various centers for health-related applied technology (hospitals specializing in tertiary care) and universities across the country.
5. **Defense:** The defense market generates a significant amount of revenue globally, according to data from Adamas (2026), which shows that the defense sector generated US\$2.72 trillion in 2024. Furthermore, Brazil controls the entire uranium processing chain, for example, and has specialists already trained in the defense industry. Furthermore, in 2026, the country

12. Energy Research Company (EPE). (2025). *Report: Critical and Strategic Minerals for the Energy Transition*. Brasília: EPE. Available at: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-877/Caderno_Minerais_Final.pdf

has made progress on yet another industry-related issue with the recent delivery of the F-39 Gripen fighter jets to the Brazilian Air Force (FAB).

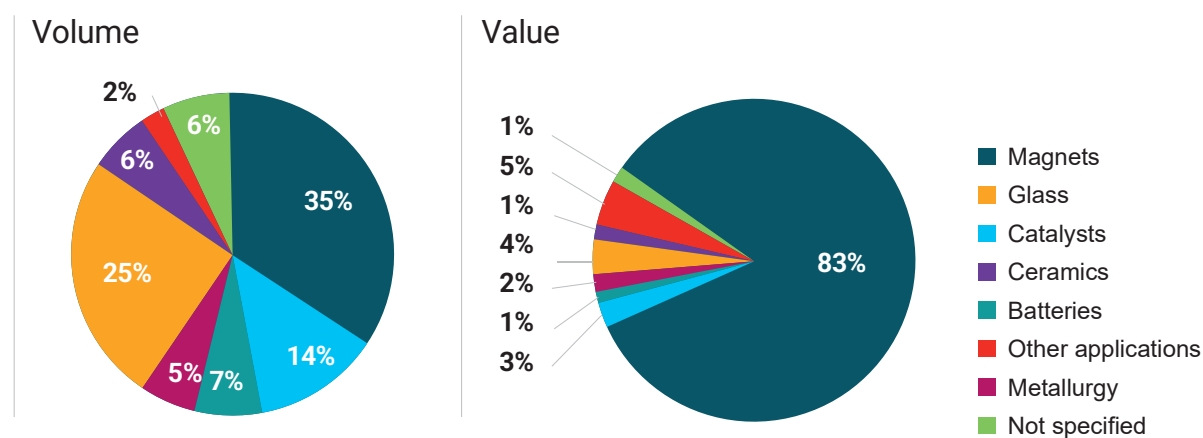
6. **Semiconductors and advanced electronics:** a complementary and selective opportunity, but one in which the applications of lanthanum, cerium, Terbium, yttrium, and others in microchips, optics, polishing, and encapsulation hold potential for specific products, provided there is a selective identification of specific inputs and functional materials—such as those related to data centers, cell phones, and other applications.
7. **Oil industry**—the demand for rare earths in the oil industry is concentrated in two areas: refining (catalytic cracking to convert crude oil into fuels) and exploration technologies, particularly high-power permanent magnets used in drilling and sensors for mapping deep wells.

Estimates of Brazilian demand for magnetic rare earth elements — Neodymium (Nd), praseodymium (Pr), dysprosium (Dy), and Terbium (Tb) — serves a dual analytical purpose: it establishes the basis for the Brazilian economy's embedded consumption of these products and enables the use of this existing demand as a foundation for developing new, more competitive industries and identifying offtake opportunities. Even in the absence of a consolidated domestic industrial chain for permanent magnets, the embedded consumption in the final products demanded by the Brazilian economy is the most natural link for anchoring downstream development.

The choice to focus on magnetic REEs is not arbitrary. According to data from Argus Media (2025), although magnetic applications account for only 35% of the total volume of REEs demanded worldwide, in monetary terms they represent 83% of the market (Figure below).

FIGURE 7

Demand for Rare Earth Elements by Application in 2025

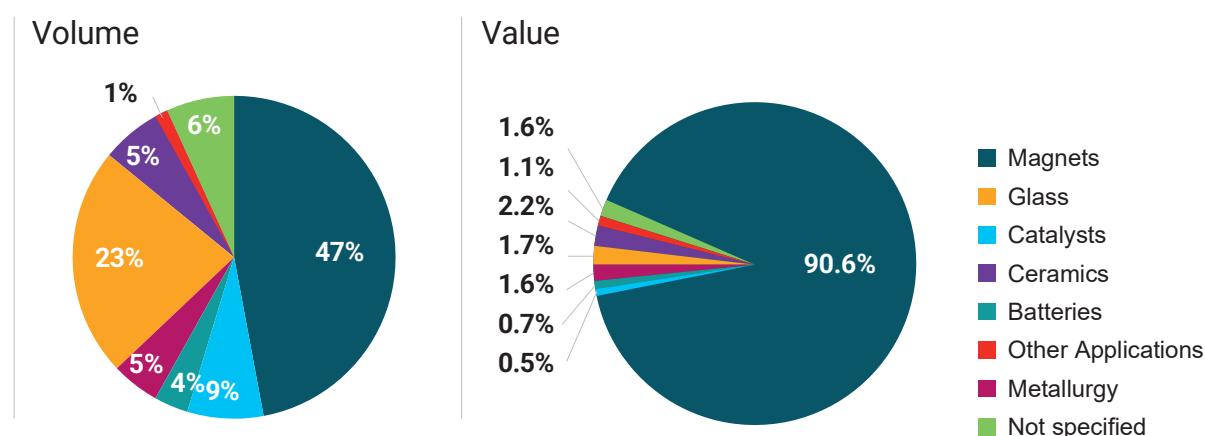


Source: Reproduced from Argus Media (2025).

Argus’s projection for 2040 reinforces this concentration of value: magnetic REEs would account for 47% of the volume and 90.6% of the total value (Figure below). Independent estimates from the IEA (2026) and Adamas Intelligence (2026) converge on similar figures, lending credibility to the analysis.

FIGURE 8

Demand for Rare Earth Elements by Application in 2040



Source: Reproduced from Argus Media (2025).

The conclusion is clear: despite the myriad industrial uses of REE—catalysts, polishing, glass and ceramics, phosphors, metal alloys, and batteries—its application in permanent magnets accounts for nearly the entire value of the value chain and is likely to further concentrate this value in the coming decades. For this reason, it occupies a central position in this study.

2.5.1. Existing Demand in Brazil and the Prioritization of Magnetic Rare Earths

Brazil currently has a demand—small on a global scale, but significant as a starting point—that is concentrated on LREE, particularly cerium (Ce) and Lanthanum (La), which are used in the catalyst and refractory industries. Our own estimates, derived from a study by the Center for Management and Strategic Studies (CGEE)—which is currently being updated by the entity itself—indicate an annual consumption of approximately 1.2 kt of LREE, driven primarily by Petrobras’ contracted demand for catalysts—a supply contract renewed for another 10 years (FCC, 2026). An updated and comprehensive survey of consumption in the Brazilian refractory industry—which also uses LREE—remains on the agenda as a complementary initiative.

Despite this existing demand for light rare earths, the analytical priority lies with HREE and magnetic REE due to their greater value capture in the value chain and the prospects for structural growth associated with the energy transition. It is on this front that the following estimate concentrates its efforts.

2.5.2. Methodology and Parameterization

To estimate Brazil's industrial demand for magnetic REEs (Nd, Pr, Dy, and Tb), the main categories were identified based on the study conducted by the IEA (2026), taking into account the actual sectoral data and the quantitative recovery parameters for each product.

Based on the available information, the projected needs for the year 2025 were estimated for the following categories: wind energy, electric and hybrid vehicle motors, other modes of transportation, and electronic equipment. The limitations of this study are acknowledged, as it does not take into account various types of products derived from industrial automation, process improvements in the manufacturing industry, the defense industry, as well as other industrial uses for magnets and other applications of magnetic REEs.

The first step was to obtain parameters for the grams of magnetic REE per product. For the wind turbine category, the estimate was based on the study by Pavel et al. (2017), which maps the main existing turbines and the materials used, relating weight to the megawatts generated. To account for more conservative estimates, we opted for an average wind turbine estimate that uses 160 kg of magnetic REE to produce 1 megawatt (MW). Regarding data on installed capacity growth, the source was the industry association ABEEólica, which reported an increase in installed capacity of 2,147 MW between 2024 and 2025.¹³

For electric and hybrid vehicles, the recovery value for magnetic REEs was based on a document prepared by the U.S. Department of Energy (2021), which estimates usage of 1 to 2 kg per vehicle. To validate this source, other sector-specific parameters were considered (Huang, 2026), which assess not only the motor and transmission system but also other uses within the vehicle—such as speakers, electric motors for windows, mirrors, seats, etc.—as well as vehicle size: in the case of SUVs, the figure can reach more than 3 kg of magnetic REE per vehicle. Thus, the value of 2.5 kg per vehicle was considered the appropriate parameter as a weighted average. Production data came from the Brazilian Electric Vehicle Association (ABVE)¹⁴—approximately 224,000 vehicles in 2025—supplemented by an official government source on vehicle purchases for public transportation under the New Growth Acceleration Program (PAC) in 2024 (8,250 buses).

For electronic devices, four types of products with significant production volumes in the country and similar parameterization characteristics were considered: cell phones/smartphones, tablets, notebooks/laptops, and air conditioning components.

For cell phones/smartphones, the product life cycle study conducted by Gómez et al. (2023) found that each metric ton of recycled devices contains, on average, 3.3 kg of total REE. Considering an average device weight of 150 grams (g), the total REE is approximately 0.5 g per device; since the largest percentage of the elements present is Nd and Pr, and the

13. Available at: <https://abeeolica.org.br/>

14. Available at: <https://abve.org.br/>

objective is precisely to estimate the magnetic REEs, 0.25 g of these elements per unit was considered a conservative estimate. For tablets and notebooks/laptops, multiples of this value were established, taking into account the total weight of the devices. For components of split-type air conditioners, which have higher concentrations of magnetic REEs, the assumption of 12 g of these elements per unit was adopted—a value that reflects a conservative extraction rate of 10% of these elements from permanent magnets, as well as the conservative weight estimate for split air conditioners (Wang et al., 2024; Huang, 2026).¹⁵

To estimate demand for cell phones/smartphones, tablets, and notebooks/laptops, production data were extracted from compilations by the Telecommunications Intelligence Consulting Firm—Teleco.¹⁶ For information on televisions and air conditioners, production data from the industry association Eletros were used.¹⁷

2.5.3. Breakdown of the Projections

Demand projections were developed using a conservative approach based on a gradual convergence toward the economy's long-term growth rate. For the segments associated with wind energy and hybrid/electric vehicles, it was assumed that recent expansion, while significant, tends to slow progressively as these markets mature, expand their installed base, and begin to grow at a pace more consistent with long-term macroeconomic fundamentals.

In the case of wind energy specifically, in order to avoid overestimates, we chose to apply a demand deceleration curve. While the International Energy Agency (IEA) (2021) projects that installed wind power capacity will grow by 17% per year through the 2030s and by 9.6% per year from 2030 through 2050, Brazil, having already experienced rapid growth in the previous decade, tends to show a slowing growth trajectory. Thus, in order to project conservative figures, we opted to conduct a growth projection divided into four parts: i) for the next five years, this reflects the transition from a cycle of accelerated expansion to a more stable pattern, starting with 10% growth in 2025 and converging to 2% in 2030; ii) after this convergence period, demand is projected to grow at a real rate of 2.0% per year through 2035;¹⁸ iii) 1% per year through 2040; and iv) 0.5% per year through 2050.

For hybrid/electric vehicles, whose adoption curve is still in a phase of more intense growth, a higher initial trajectory was assumed, though one that also declines over the projection horizon. This assumption reflects the expectation that, following a period of technological diffusion and accelerated fleet expansion, the segment's growth will gradually converge toward a long-term structural level, set at 2.0% per year through 2050.

15. A study by Wang et al. (2024) estimates that 30% of Nd and Pr derived from permanent magnets is recovered in a process described in their study.

16. Available at: <https://teleco.com.br/>

17. Available at: <https://eletros.org.br>

18. Used as a proxy for the economy's potential long-term growth, in line with long-term market projections, such as those in the Focus Bulletin.

For the other sectors, given that they are more mature markets with lower expectations of significant structural disruption, a growth rate of 2.0% per year was directly applied from 2025 through 2050. This assumption aims to represent a real, moderate, and sustained evolution in demand, without incorporating extraordinary positive shocks or unsustainable accelerations. It is recognized, however, that long-term macroeconomic projections are subject to high uncertainty; even so, assuming an annual real growth rate of 2.0% over a horizon of more than two decades constitutes a reasonable, prudent, and technically defensible assumption for the purposes of prospective modeling.

The data for the year 2025 is summarized below:

TABLE 2

Magnetic REE Requirements—by Type of Final Product

Estimated data	Grams per REE magnetic	REE products - Units	REE requirement magnetic, in grams (2025)	REE Demand for Magnetic, in Kt (2025)	Magnetic REE demand, in kt (2030)	Magnetic REE requirement, in Kt (2040)	Magnetic REE demand, in Kt (2050)
Wind Turbine	160,000	2,147	343,520,000	0.344	0.411	0.476	0.501
Electric vehicles	2,500	80,184	200,460,000	0.200	0.459	0.583	0.710
Hybrid vehicles	2,500	143,712	359,280,000	0.359	0.498	0.607	0.740
Other modes of transportation	2,500	8,250	20,625,000	0.021	0.047	0.060	0.073
Cell phones/smartphones	0.25	32,433,000	8,108,250	0.008	0.009	0.011	0.013
Tablets	0.75	3,099,000	2,324,250	0.002	0.003	0.003	0.004
Laptops	2.00	7,661,000	15,322,000	0.015	0.017	0.021	0.025
Televisions	6.00	13,643,410	81,860,460	0.082	0.090	0.110	0.134
Air conditioning	12.00	6,280,224	75,362,688	0.075	0.083	0.101	0.124
Total	-	-	1,106,862,648	1,107	1,616	1,972	2,324

Source: Eletros (2025); Huang (2026); International Energy Agency (2026); Pavel et al. (2017); Teleco (2026a, 2026b); U.S. Department of Energy (2022); Wang et al. (2024)¹⁹.

19. Eletros – National Association of Manufacturers of Electrical and Electronic Products. (2025). *Production and Output Indicators for the Manaus Free Trade Zone: Split-System Air Conditioners – 2025 Update*. Eletros. <https://www.eletros.org.br>

Huang, I. (2026). *A comprehensive guide to rare earth magnets*. TOPMAG. <https://www.topmag.in/rare-earth-magnets-guide-2026/> International Energy Agency. (2026). *Rare earth elements: Pathways to secure and diversified supply chains*. IEA. <https://www.iea.org/reports/rare-earth-elements>

Pavel, C. C., Lacal-Arántegui, R., Marmier, A., Schüller, D., Tzimas, E., Buchert, M., Jenseit, W., & Blagoeva, D. (2017). *Substitution strategies for reducing the use of rare earths in wind turbines*. *Resources Policy*, 52, 349–357. <https://doi.org/10.1016/j.resourpol.2017.03.003>

Teleco. (2026a). *Smartphones in Brazil*. Retrieved May 29, 2026, from <https://teleco.com.br/smartphone.asp> Teleco. (2026b). *IT in Brazil*. Retrieved May 29, 2026, from https://teleco.com.br/Ti_Brasil.asp

U.S. Department of Energy. (2022). *Rare Earth Permanent Magnets: Supply Chain Deep Dive Assessment*. <https://www.energy.gov/sites/default/files/2024-12/Neodymium%2520Magnets%2520Supply%2520Chain%2520Report%2520-%2520Final%5B1%5D.pdf>

Wang, Z., Zhang, Z., Meng, L., Li, C., & Guo, Z. (2024). Extraction and recovery of rare earth elements from NdFeB waste using bismuth reinforced by supergravity. *Journal of Cleaner Production*, 485, 144390. <https://doi.org/10.1016/j.jclepro.2024.144390>

The results of these projections are consistent with recent estimates prepared by national institutions, which reinforce the expectation of significant growth in demand for Rare Earth Elements (REE) in the context of the energy transition.

The Ten-Year Energy Expansion Plan (PDE) projected a significant expansion of wind and solar power in Brazil's energy mix, as well as growth in the fleet of hybrid and battery-electric vehicles. Based on these projections, the Energy Research Company (EPE) estimated Brazil's demand for REE and other critical and strategic minerals for the energy transition. According to this study, demand for REE in the country is expected to grow approximately sixfold between 2024 and 2034 (EPE, 2025).

Another study, conducted by CEBRI with the participation of COPPE, CETEM, and SGB, assessed the projected supply and demand for critical and strategic minerals (CSMs) between 2025 and 2050, in the context of Brazil's energy transition. The demand analysis conducted by COPPE took into account the country's Nationally Determined Contribution (NDC) targets and identified Neodymium as the primary driver of demand growth, accounting for approximately 80% of the cumulative total, due to its use in wind turbines and electric motors. In the short term, the demand projection is low (about 70 metric tons), but it could reach approximately 4,300 metric tons by 2045, with a cumulative total of about 12,800 metric tons of Neodymium between 2025 and 2050 (CEBRI, 2025).

2.6. International Comparative Analysis

As governments seek to develop public policies for critical minerals, international benchmarking plays a central role as a tool for institutional learning, strategic comparison, and decision-making support. In the case of rare earths, this exercise is particularly relevant because competitiveness depends not only on the existence of mineral reserves but also on the ability to convert geological resources into production, processing, manufacturing, innovation, and strategic integration into global value chains. In the current context of strong geographic and technological concentration within the supply chain, various countries and economic blocs have adopted industrial policies, regulatory instruments, financing mechanisms, and international cooperation strategies aimed at reducing vulnerabilities and strengthening domestic capabilities, including critical technologies and industrial expertise.

Given this scenario, this section provides a comparative analysis of the experiences of China, the United States (U.S.), the European Union (EU), the United Kingdom, Australia, Canada, India, Indonesia, and Malaysia, with the aim of identifying practices, instruments, and institutional arrangements relevant to the formulation of the NRES. The benchmarking seeks to answer a central question for Brazil: **which countries or blocs are best prepared to compete at each stage of the rare earths value chain, for what reasons, and what lessons does this trajectory offer for the Brazilian context?**

For analytical purposes, the comparison considers the three main links in the chain. The upstream segment comprises exploration, mining, and mineral processing. The midstream segment includes separation,

refining, the production of oxides, metals, and alloys—which account for the greatest technological, chemical, and environmental bottlenecks in the value chain. The downstream sector encompasses the manufacture of permanent magnets, components, and industrial applications with higher value added. The analysis also incorporates key cross-cutting dimensions, such as circularity, regulation and incentives, Research, Development and Innovation capabilities, and strategic partnerships.

The main contribution of this section is to inform public policy. The analysis seeks to draw implications for Brazil, taking into account its specific geological, productive, institutional, and territorial characteristics. The aim is to assess the extent to which international experiences can guide a national strategy capable of increasing value addition, reducing structural bottlenecks, and positioning the country more competitively and strategically within the global rare earths supply chain. Table 3 presents a comparative overview of the countries and blocs analyzed, considering the degree of consolidation or progress in the rare earths value chain. The objective is not to rank the countries but to offer a structured analysis of where each experience shows greater relative maturity and which lessons may be most useful to Brazil.

The international comparison suggests four key conclusions. First, China remains the only actor fully integrated across all links in the chain, simultaneously possessing reserves, production scale, separation and refining capacity, manufacturing capabilities, and strategic coordination. Second, we observe the emergence of a group of countries and blocs that, although they do not yet fully rival China, are already competing in key segments of the value chain, particularly in mining, selective refining, magnets, recycling, and industrial policy instruments. Third, international experience shows that the midstream is the most critical link for capturing value and reducing strategic vulnerabilities. Finally, it is evident that building competitiveness in rare earths depends on coordination among mining, technology, industry, financing, regulation, and international partnerships—and not merely on the availability of reserves.

For Brazil, this comparison underscores a key implication: the country possesses significant upstream assets and a real window of opportunity to move up the value chain, but its competitive position will depend on its ability to use its mineral base as a platform to selectively develop capabilities in processing, refining, innovation, magnets, and circularity. International experience suggests that the most promising path is not to attempt to fully replicate the Chinese model in the short term, but rather to build a gradual and coordinated trajectory of industrial consolidation, focused on the segments most closely aligned with the mineral base and the national production structure.

TABLE 3
Comparative summary of the countries and blocs analyzed in the study

Country / bloc	Upstream	Midstream	Downstream	Circularity	Regulation / Incentives	Government Action	R&D	Strategic partnerships	Key Lessons for Brazil
China	Very strong	Very strong	Very strong	Average, consolidating	Very strong	Strong	Very strong	Very strong	Leadership stems from a long-term national strategy, industrial coordination, vertical integration, continuous R&D, and mastery of the entire value chain, particularly the downstream segment. Reserves alone do not generate leadership; the key differentiator lies in the integration of industrial policy, technology, and scale.
United States	Strong	Moderate and expanding	Moderate, in the process of rebuilding	Medium and expanding	Very strong	Strong	Strong	Very strong	The main lesson is the aggressive use of de-risking tools, strategic acquisitions, financing, and industrial policy to rebuild missing links in the supply chain, especially in the midstream and magnet sectors.
European Union	Weak at present / emerging potential	Strong	Strong	Strong	Very strong	Medium	Strong	Very strong	The EU demonstrates that, even with limited mineral resources, it is possible to build competitiveness through refining, recycling, industrial policy, regulatory targets, and the integration of sustainability and supply security.
United Kingdom	Weak	Moderate in niche markets	Moderate in niche markets	Moderate in areas of progress	Medium	Low	Strong in technology	Strong	The British experience is particularly relevant in recycling, innovation, and the development of technological niches, rather than on a broad mineral or industrial scale.
Australia	Very strong	Moderate and expanding	Initial medium	Medium	Strong	Medium	Strong	Very strong	The main lesson is that a robust mineral base, combined with public policy tools, long-term contracts, and policies supporting refining, can support gradual progress toward vertical integration.
Canada	Medium	Initial medium	Low to medium	Medium	Strong	Low	Strong	Strong	Canada offers useful lessons in institutional coordination, enabling infrastructure, financing, and ecosystem building for critical minerals, even though its REE supply chain is still in the process of consolidation.
India	Medium	Initial medium	Initial medium	Low to medium in terms of development	Strong	Medium	Medium	Strong	India demonstrates the importance of combining industrial policy, protection of domestic supply, stimulation of manufacturing, and strategic use of international agreements.
Indonesia	Medium with potential	Low	Low	Low	Medium to strong	High	Initial medium	Medium	The key lesson lies in the use of value-added instruments and a focus on enabling domestic industrialization, but also in the risks of poor regulatory coordination and insufficient technological capacity.
Malaysia	Low domestic upstream	Strong as a processing hub	Low to medium	Medium	Medium	High	Medium	Strong	The main lesson is the possibility of building a processing hub anchored in logistics, specific regulations, and integration with external supply chains, even without a large domestic mineral base.

Source: Prepared by the authors.



International benchmark: dominant country in the rare earths supply chain

China

Summary of Position in the Value Chain

China's value chain for rare earths is currently the most consolidated in the world. Competitive factors, such as a regulatory environment that has historically been more lenient regarding environmental standards, robust strategic planning, lower labor costs, and easier access to public credit, have enabled rapid expansion of production capacity. Other moves, related to the expansion of geopolitical ties, were carried out through investments in overseas mining assets, thereby expanding China's dominance over strategic deposits. Additionally, sustained large-scale investments in Research and Development have consolidated technical expertise in complex chemical separation—a critical stage in the supply chain and the primary global technological bottleneck in the midstream phase. Furthermore, the perception of REEs as an important raw material for Chinese industry has strengthened the value of these natural resources, linking this supply to industrial demand.

TABLE 4

Consolidation Phase of the REE Value Chain in China

Stages of the Value Chain	Upstream			Midstream					Downstream		
	Relevant Deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
China	X	X	X	X	X	X	X	X	X	X	X

Source: Prepared by the authors.

Upstream

In the upstream sector, the extraction of geological deposits—such as Bayan Obo and ion-adsorption clays in the south of the country—stands out. After consolidating its leadership in the primary segment, China's policy evolved to stimulate downstream processing and manufacturing activities—that is, products with higher value added. In parallel with this strategy, another set of structural advantages also enables China's rise and dominance beyond the extractive industry.

Midstream

In the midstream sector, China is a global leader in chemical separation and refining—a technologically sophisticated and environmentally sensitive stage.

Downstream

The country dominates the production of Neodymium-iron-boron permanent magnets, special alloys, and strategic industrial components. Finally, in the downstream segment, it integrates these inputs into the manufacturing of capital goods, electronics, electric vehicles, and renewable energy systems. This segmentation, however, is not a recent development; it has evolved over the past three decades. China's leadership is not limited to production volume but is also evident in its technological and industrial dominance across all stages of the production chain; it is the only country with the installed capacity to process all types of rare earth elements and transform them into oxides, metals, alloys, and high-value-added end products.

Circular Economy

The rare earths magnet recycling industry, still on a limited scale, is already in operation, with estimated production of approximately 25 kt in China, primarily from industrial waste such as swarf (metal shavings) generated during the machining of NdFeB magnets. At the same time, there is a growing number of business initiatives and technological projects focused on the recovery and reprocessing of rare earths, signaling the gradual consolidation of secondary supply routes within the context of the circular economy.

Regulation and Incentives

In China, the implementation of public policies, such as the Rare Earth Management Regulations, establishes a framework for the protection and use of the country's rare earth resources. These regulations govern activities such as mining, smelting, separation, metallurgy, and the circulation of products, including the import and export of Rare Earth Elements. In addition to strengthening state control over mineral resources, this policy also implements guidelines for sustainable mining and maintains a unified plan for the development of the rare earths industry in conjunction with other relevant sectors related to industry and technology (IEA, 2025). To ensure the coordinated development of the rare earths industry, the State-owned Assets Supervision and Administration Commission of the State Council (SASAC) announced the establishment of the China Rare Earth Group

(China, 2021)²⁰ – strengthening the central government’s direct control over these resources. In addition to these measures, the 14th Five-Year Plan for the Development of the Raw Materials Industry (14th Five-Year Plan for Raw Materials Industry Development) was also published in 2021 (IEA, 2022).²¹ According to this policy, China plans to establish, standardize, and promote rare earths industry clusters and optimize the sector’s industrial structure, forming an even larger and stronger rare earths cluster (Sohee, 2023).²²

Environmental Licensing

Since 2006, the Chinese government has sought to regulate the rare earths industry,²³ by introducing systems and policies that establish industrial and energy emission standards, environmental licensing systems, Environmental Impact Assessments (EIA), and accountability mechanisms for the rehabilitation and restoration of regions hosting such activities (China Water Risk, 2016, 2016).²⁴ Initiatives such as the Comprehensive Directory on Environmental Protection, launched by the Ministry of Environmental Protection, define rare earths and ion-adsorbed rare earth oxides as “products with high pollution and high environmental risk,” requiring stricter regulations for rare earth mining and leaching operations, particularly in the most affected regions such as Hong Kong, Shenzhen, and Guangzhou. In addition, incentive and penalty strategies, green taxes, green financing, and government “green procurement” policies aim to encourage companies to upgrade their mining technologies and adopt mining and extraction processes that are less harmful to the environment (China Water Risk, 2016).²⁵ This includes consolidating operations related to the processing of rare earths and locating them in designated industrial parks with wastewater treatment plants to prevent polluted water from reaching neighboring provinces. Furthermore, measures should be adopted to reduce erosion and dust (Standaert, 2019).²⁶

Strategic Partnerships

China has developed a coordinated international strategy to secure access to and influence over global supply chains for critical minerals and rare earths, combining economic diplomacy, state financing, and trade agreements to ensure a stable supply and leadership in the stages with the highest value added. At the multilateral level, initiatives such as the Belt and Road Initiative (BRI), China’s involvement in BRICS, and the Regional Comprehensive Economic Partnership (RCEP) are expanding investments in mining, infrastructure, and mineral processing, while bilateral agreements with countries holding strategic reserves strengthen technological and financial cooperation.

20. <http://www.sasac.gov.cn/n2588030/n2588924/c22341074/content.html>

21. <https://www.iea.org/policies/14702-14th-fyp-for-raw-material-industry-development>

22. The Gold of Industry and the Core of the Military: China’s Rare Earths Strategy and Its Implications for Korea: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4561555

23. Chinese Government’s Official Web Portal, Situation and Policies of China’s Rare Earth Industry, 2012 http://www.gov.cn/english/2012-06/20/content_2165802_6.htm and <https://e360.yale.edu/features/china-wrestles-with-the-toxic-aftermath-of-rare-earth-mining>

24. <https://www.chinawatererrisk.org/wp-content/uploads/2016/07/CWR-Rare-Earths-Shades-Of-Grey-2016-ENG.pdf>

25. <https://www.chinawatererrisk.org/wp-content/uploads/2016/07/CWR-Rare-Earths-Shades-Of-Grey-2016-ENG.pdf>

26. <https://e360.yale.edu/features/china-wrestles-with-the-toxic-aftermath-of-rare-earth-mining>

In the case of rare earths, the combination of domestic consolidation and regulatory instruments strengthens China's position in supply management and the international governance of these supply chains. In this context, relations between Brazil and China have deepened, notably through joint action within BRICS, the possibility of issuing Panda Bonds, and the implementation of the 2025–2026 Action Plan for Sustainable Mining (2025–2026 Action Plan for Sustainable Mining), which signals a cooperation agenda focused on innovation, value addition, and sustainability. Added to this are various bilateral agreements and memorandums of understanding (MoUs) involving public and private actors, which consolidate China's position as Brazil's key partner in the expansion and modernization of the mineral and industrial sectors, with the potential for the joint development of more sophisticated production chains.

Relevant projects and assets

TABLE 5

REE's Key Projects and Assets in China

Project/Asset	Link in the chain	Type of Initiative	Strategic Relevance
China Northern Rare Earth Group	Upstream / Midstream	Mining, concentration, and processing of light rare earths	Relevant: Located in Baotou, Inner Mongolia, in the northeast. State-owned. Bastnasite deposit.
China Rare Earth Group	Upstream / Midstream	Mining, concentration, and processing of medium and heavy rare earth elements	Relevant: China's largest producer, formed through the merger of other companies, concentrating 70% of the country's remaining production. State-owned. Monazite and bastnasite deposits.
China Minmetals Rare Earth	Upstream / Midstream	Mining and processing of non-ferrous metals—byproduct	Relevant: Subsidiary of China Minmetals; part of the China Rare Earth Group. State-owned. Monazite and bastnasite deposits.
Shenghe Resources Holding	Upstream / Midstream	Mining, concentration, and processing of light rare earth elements	Relevant: Focus on separation technologies. Jointly owned.
Guangdong Rare Earth Group	Upstream / Midstream / Downstream	Mining, concentration, processing, and rare earths products; R&D	Relevant: Subsidiary of China Rare Earth Group, operating in southern China (Guangdong–Jiangxi). State-owned. Bastnasite and ionic clay deposits.
Xiamen Tungsten	Upstream / Midstream / Downstream	Mining and processing of tungsten metals—byproduct. Metallurgy	Relevant: Focus on rare earths, high-performance materials, and strategic metals. Privately held.
JL MAG Rare-Earth	Downstream	Metallurgy and production of permanent magnets	Highly relevant: global leader in rare earths-based NdFeB permanent magnets, relevant to the automotive and wind energy sectors. Privately held.

Ningbo Yunsheng	Downstream	Metallurgy and production of permanent magnets	Relevant: Specializes in magnets made from rare earths and magnetic materials for the automotive, home appliance, and renewable energy sectors. Privately held.
Yongxing Special Materials	Downstream	Metallurgy and Alloy Production	Relevant: Specializes in specialty alloys based on rare earths, magnetic materials, and high-tech components. Privately held.
Rare Earth Materials Chemistry and Applications	All	R&D	Relevant: leading state-run laboratory, affiliated with Peking University.
Rare Earth Resource Utilization	All	R&D	Relevant: state-run laboratory in the Changchun region, Jilin.

Source: Prepared by the authors.



Near-systemic competitors (countries or blocs that already compete with China in more than one link): the U.S., the European Union, Australia

United States

Summary of positioning in the value chain

The United States is rapidly rebuilding its rare earth value chain. The country already has significant upstream assets and is making progress in the reindustrialization of the midstream and downstream segments, but it has not yet achieved full self-sufficiency. Its main strength lies less in the current maturity of the chain and more in its ability to mobilize financial, regulatory, and strategic tools to accelerate this process.

TABLE 6

Stages of Consolidation in the U.S. Rare Earth Elements (REE) Value Chain

Stages of the value chain	Upstream			Midstream					Downstream		
	Relevant Deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
U.S.	X	X	X						X	X	

Source: Prepared by the authors.

Upstream

The United States has significant resources for rare earths, with mineral reserves estimated by the USGS at approximately 13 million metric tons. The main asset is Mountain Pass, in California, which remains the country's most important deposit. Following the decline in domestic production in the late 1990s, the U.S. began to resume investments in the upstream sector as part of a broader strategy for supply security.

Midstream

The midstream sector represents one of the main bottlenecks in the North American supply chain. Although the country has made progress in resuming mineral production, it is still seeking to consolidate domestic capabilities in separation, refining, and chemical processing—stages that have historically been concentrated in China. In recent years, U.S. industrial policy has begun to explicitly direct resources toward these links, recognizing that mineral security depends not only on mining but also on mastery of the intermediate stages.

Downstream

In the downstream sector, the main challenge is the revitalization of the NdFeB permanent magnet industry, which has not operated on a large scale in the country since the mid-1990s. In response, the U.S. government has been supporting the creation of industrial facilities focused on domestic magnet production and integration into strategic supply chains, particularly in the defense, electric vehicle, and energy sectors.

Regulation and Incentives

The United States' strategy for critical minerals and materials combines cross-cutting instruments and specific measures aimed at reducing foreign dependence—particularly on China. In this context, Executive Order 14017 stands out, as it spurred a comprehensive review of strategic supply chains, including rare earths. The

country has mobilized significant amounts of resources for domestic infrastructure, mine rehabilitation, mineral processing, technological innovation, and the strengthening of manufacturing, with the goal of enhancing economic security, stimulating innovation, and consolidating its industrial base. Among these initiatives, Project Vault stands out as an innovative tool that seeks to reduce investment risks by allowing the government to temporarily act as a buyer or interim holder of strategic materials, thereby enabling extraction and processing projects and increasing their attractiveness to private financing.

In addition, the Inflation Reduction Act (IRA) introduced tax incentives equivalent to 10% of the production costs of critical and strategic minerals (CSMs) in the U.S., as well as credits of up to 30% of capital costs for new processing, refining, and recycling facilities.²⁷ In the area of direct investment, the Bipartisan Infrastructure Law of 2021 allocated \$6.3 billion for the processing, recycling, and manufacturing of batteries—whose main components are MCEs— while additional loans, including transactions totaling approximately \$2.5 billion, have been granted to companies focused on the production of these materials and the development of related technologies, particularly in the battery sector.²⁸ The U.S. has also established a 10-year minimum price for neodymium-praseodymium oxide (NdPr), set at \$110 per kilogram (kg).²⁹ This mechanism aims to ensure that MP Materials receives predictable revenue even if global prices fall due to an increase in global production—a strategy learned, in part, from the nickel sector, which is also heavily controlled by a single country and is capable of exerting downward pressure on global commodity prices.³⁰

In the regulatory sphere, there is a trend toward accelerating and coordinating licensing processes. On March 30, 2025, President Donald Trump signed an executive order aimed at increasing domestic production of MCEs, with an emphasis on improving coordination among federal agencies and revising the mining framework.³¹ Additionally, some projects have been included in the FAST-41 program, which seeks greater harmonization among authorities and a reduction in review times. Finally, another executive order, signed on April 24, 2025, aims to expand access to and utilization of mineral resources in the United States' Exclusive Economic Zone.³²

Circular economy

The United States has also been incorporating the circular economy into its rare earths strategy. Public investments include recycling and recovering materials from secondary sources, such as tailings, industrial waste, ash, and electronic scrap.

27. <https://www.congress.gov/bill/117th-congress/house-bill/5376>

28. <https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2024/09/20/fact-sheet-biden-harris-administration-takes-further-action-to-strengthen-and-secure-critical-mineral-supply-chains/#:~:text=,processing%2C%20and%20battery%20component%20manufacturing>

29. The current market price of NdPr in China is less than \$60/kg; therefore, the minimum price acts as a subsidy and market stabilizer.

30. https://wwwenergypolicy-columbia-edu.translate.goog/?_x_tr_sl=en&_x_tr_tl=pt&_x_tr_hl=pt&_x_tr_pto=tc&_x_tr_hist=true

31. <https://www.whitehouse.gov/presidential-actions/2025/03/immediate-measures-to-increase-american-mineral-production>

32. <https://www.whitehouse.gov/presidential-actions/2025/04/unleashing-americas-offshore-critical-minerals-and-resources>

Environmental Licensing

The United States pioneered the adoption of structured environmental licensing mechanisms based on the National Environmental Policy Act (NEPA). The system operates under a cooperative management framework among federal, state, territorial, and tribal levels, with institutional coordination for projects subject to environmental impact assessments. The model combines electronic procedures, public participation, technical guidelines, and multiple sector-specific permits. In general, the system seeks to balance regulatory predictability and environmental rigor, although the federal structure's complexity can lead to overlapping jurisdictions and varying timelines among states. To increase predictability and expedite federal permitting for large projects, Title 41 of the Fixing America's Surface Transportation Act (FAST-41), which provides for interagency coordination, the establishment of binding timelines, transparency through the Permitting Dashboard, and oversight by the Federal Permitting Improvement Steering Council.³³

Strategic Partnerships

On the international stage, the United States has sought to diversify its supply sources and strengthen alliances with countries considered reliable. This strategy includes agreements, memorandums of understanding, and coordination with partners such as Australia, Japan, Malaysia, Thailand, Canada, Saudi Arabia, Brazil, Mexico, and Angola. These partnerships aim to strengthen the exploration, processing, refining, recycling, investment, and trade of critical minerals, forming part of a geoeconomic strategy focused on creating supply chains that are more resilient, transparent, and less dependent on adversarial suppliers. The U.S. government is also seeking to expand its operations in Brazil, particularly in the state of Goiás, culminating in the signing of a memorandum of understanding (MoU).

Relevant Projects and Assets

TABLE 7

Relevant REE Projects and Assets in the U.S.

Project/Asset	Link in the chain	Type of Initiative	Strategic Relevance
Mountain Pass	Upstream	Mining	The U.S.'s primary mineral asset
MP Materials + industrial expansion	Upstream / Midstream	Mining and Processing	Foundation for rebuilding the domestic supply chain
MP Materials + Apple	Circularity / Midstream	Recycling	Recovery of REE from electronic components
MP Materials + General Motors	Downstream	Magnets and Industrial Integration	Connecting with the automotive supply chain and strengthening domestic manufacturing

33. <https://www.permitting.gov/projects/title-41-fixing-americas-surface-transportation-act-fast-41>

ReElement Technologies	Midstream / Circularity	Recycling and Sorting	Strengthening the secondary supply and developing alternative routes
Noveon	Downstream	Magnet production via a short loop	Value recovery in manufacturing and strengthening circularity
Hypromag	Downstream / Circularity	Magnet recycling through hydrogen processing	Development of a technological pathway for recovering magnets from electronic waste
Project Vault	Cross-cutting	Public policy instrument	Risk reduction, support for bankability, and simultaneous stimulation of the upstream and midstream sectors

Source: Prepared by the authors.

European Union and United Kingdom

Summary of positioning in the value chain

The European Union (EU) is characterized by its significant technological capabilities in the midstream and downstream sectors and its high external dependence in the upstream sectors. To reduce this dependence, a robust framework of industrial, regulatory, and innovation policies has been developed, notably the European Critical Raw Materials Act (CRMA) (Regulation EU 2024/1252). This initiative sets ambitious targets for 2030 (10% domestic extraction, 40% processing, and 25% recycling), as well as for initiatives such as the European Raw Materials Alliance (ERMA), with the circular economy as its central pillar, focusing on expanding recycling and the recovery of secondary raw materials through investments in Research and Development (R&D), stringent environmental policies, and international partnerships, including the Minerals Security Partnership and the EU Strategic Partnership on Sustainable Raw Materials Value Chains. Together, these measures aim to reduce geopolitical vulnerabilities and build a more resilient, sustainable, and technologically advanced value chain, highlighting refining and recycling projects by Silmet in Estonia and by Solvay and Carester in France. Throughout the value chain, sustainable mining and remediation practices are incorporated, along with synergies in research and training, seeking, in practice, to convert the Nordic mineral advantage into strategic “EU-ready” products with a smaller carbon footprint and greater security of supply.

The United Kingdom, for its part, is characterized by low domestic mineral production capacity—meeting about 6% of its demand for critical minerals—and high external dependence, especially in the early stages of the supply chain (upstream). In response, the country has developed a strategy focused on supply security, the resilience of global supply chains, and the reduction of geopolitical vulnerabilities, with a particular emphasis on the UK Critical Minerals Strategy 2025. This approach

sets ambitious targets to expand domestic capacity to up to 30% of demand by 2035, combining an increase in domestic production (10%) with robust investments in recycling and the circular economy (20%). Unlike other actors, the United Kingdom is placing less emphasis on expanding large-scale mineral extraction and more on strengthening capabilities in the midstream and downstream segments of the value chain, with a focus on technological innovation, refining, recycling, and financing. At the same time, the country prioritizes international partnerships with resource-rich countries—such as Brazil—and the use of financial instruments and technical cooperation to facilitate projects, seeking to position itself—as an integrator of more resilient, sustainable, and technologically advanced value chains.

TABLE 8

Consolidation Stage of the REE Value Chain in the EU and the UK

Stages of the value chain	Upstream			Midstream					Downstream		
	Relevant occurrences/deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
European Union/ United Kingdom	X			X	X	X	X	X	X	X	X

Source: Prepared by the authors.

Upstream

The European Union (EU) and the United Kingdom do not have any operational mines for rare earths and rely entirely on imports, primarily from China. The constraints in the upstream sector stem from three main factors: regulatory restrictions on the import of minerals containing radioactive elements; difficulties and costs associated with exporting minimally processed concentrates from China; and, finally, the price competitiveness of separated products in Asia, which make primary separation on European soil economically challenging. In response, European companies have developed business models based on the acquisition of pre-separated products, adding value through further purification, cost-optimized formulation, and the development of specific applications.

It is worth noting that recent discoveries point to significant potential in large deposits in Sweden (the Kiruna region) and Norway, a close partner of the EU (the Fen Complex), with projects aimed at beginning production around 2030–2031. In addition, recycling and secondary recovery of REE serve as complementary strategies to offset the current lack of upstream production and strengthen the resilience of the REE supply chain.

Another complementary source of REE currently being studied in Europe is the occurrence of these elements in karst bauxite deposits and in residues from alumina processing, such as red mud. Karstic bauxite is a type of aluminum ore associated with limestone terrain, accumulated in cavities and depressions of karst topography, with significant occurrences in southern Europe, the Balkans, Turkey, Iran, and China (Yalçın & Altunbey, 2026). Unlike bauxites formed by in situ residual alteration, these deposits result from the transport, deposition, and subsequent geochemical enrichment of aluminum-rich materials (Deady et al., 2014).

Although karst bauxites have historically been mined as a source of aluminum, these deposits have recently begun to attract interest as potential secondary sources of critical and strategic minerals, including REEs and other associated trace elements (Kovačević Galović et al., 2025). In addition, the red mud generated during bauxite processing represents a potential source of REEs, as these elements tend to concentrate during alumina production (Deady et al., 2014). Although the concentrations are typically lower than those found in primary deposits, the utilization of these wastes offers significant environmental benefits, such as the reduction of historical mining liabilities, a reduced need to open new mines, and the possibility of recovering value from materials already in stock. Studies of Mediterranean deposits, including those in Croatia, indicate that technological advances can enhance the economic viability of reusing former bauxite mining areas for both aluminum and REE (Kovačević Galović et al., 2025).

Midstream

The value chain focuses on the chemical separation of imported concentrates and the formulation of oxides, metals, and alloys. In the rare earths sector, the main strategic bottleneck in Europe lies in the separation and refining stage, which has historically been dominated by non-European players. In this context, France has been establishing itself as an industrial hub to address this gap. The Solvay plant in La Rochelle, Europe's largest facility for separating rare earths, began commercial deliveries of NdPr in 2025. In addition, it is adding capacity for dysprosium and terbium (Heavy Rare Earths) in 2026, with the goal of meeting 30% of European demand for magnets by 2030, while also reducing its water and carbon intensity. At the same time, Carester is building a €216 million recycling and refining hub in the Lacq basin, scheduled to begin operations by the end of 2026, to process recycled magnets and mineral concentrates, with the goal of meeting 15% of global demand for Heavy Rare Earths.

Downstream

In the downstream segment, the European Union has made progress in consolidating the production of permanent magnets. In 2025, Neo Performance Materials opened Europe's largest factory for producing rare earth-based permanent magnets in Narva, Estonia. At the same time, strategic initiatives funded by the bloc, such as PERMANET, aim to expand production capacity and fully internalize the value chain for producing permanent magnets, bringing together

dozens of industrial and technology partners. Research and Development efforts include the MagREEsources project, which aims to develop 100% recycled magnets—with production set to begin by 2028—and projects such as PASSENGER, which are researching alternative materials, such as manganese-aluminum-carbon (MnAlC) alloys and strontium ferrites, to reduce dependence on REE.

Regulation and Incentives

Within the European Union, notable initiatives include the European Raw Materials Alliance (ERMA), which brings together industry, academia, policymakers, and investors to identify investment opportunities and map regulatory barriers to the sector's development. At the same time, the Raw Materials Initiative establishes a strategic approach to ensure access to the raw materials used by European industry, with an emphasis on supply sustainability, recyclability, and resource efficiency. This set of policies has been reinforced by more recent instruments, such as the CRMA and the Action Plan on Critical Raw Materials, which seek to reduce the EU's dependence on third countries, diversify supply—from both primary and secondary sources—mitigate geopolitical risks and price volatility, and foster partnerships with like-minded countries (European Commission, 2020; Regulation (EU) 2024/1252; Boruta, 2025).

In the area of incentives, on June 24, 2025, the European Union approved a new framework for state subsidies aimed at green industries, as part of the Clean Industrial Deal,³⁴ which is expected to increase investments in sectors dependent on critical raw materials in the coming years, including tax incentives for projects to process these minerals, to be implemented by Member States in accordance with their national policies. In terms of direct financing, the CRMA established the European Critical Raw Materials Board, tasked with supporting projects in securing funding, while the European Investment Bank (EIB) announced that it would make €2 billion available as early as 2025 to strengthen the supply chain for these critical minerals in the region, complementing national initiatives.

In the regulatory sphere, the CRMA introduces mechanisms to enhance coordination and predictability in the licensing process. Projects deemed strategic will now be monitored by European bodies, with priority given to their review and support for coordination among national authorities. The initiative also provides for the creation of single points of contact for environmental licensing, simplifying the process of obtaining environmental and land-use permits, and establishing maximum time limits for decision-making. Finally, the EU is strengthening the monitoring of supply chains, requiring member states to conduct stress tests and report information on inventories, thereby contributing to greater transparency and supply security.

34. https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_pt

Circular Economy

The European Union has positioned itself as a global leader in the transition to a circular economy, based on two successive plans: the “Closing the Loop” Action Plan (2015) and the New Action Plan for the Circular Economy (2020). Initially grounded in a combination of environmental regulations, voluntary commitments, and waste management targets, these initiatives were deemed insufficient. In this context, the future Circular Economy Act (CEA), scheduled for the third quarter of 2026, is expected to become a central pillar of the Clean Industrial Deal and the Competitiveness Compass (2024–2029 term). These initiatives aim to revise the main waste directives, as well as to adopt measures such as environmental tax harmonization and rules for extractive waste. The goal, therefore, is to increase the rate of circular use of materials to 24% by 2030, consolidate a single market for secondary raw materials, expand recycling, and reduce waste generation, while also positioning this as a policy for competitiveness and strategic autonomy. In this context, France is establishing itself as the European leader in rare earths magnet recycling, with initiatives such as Orano’s pilot line with CEA-Liten and Carester’s €216 million plant in Lacq (Caremag), in addition to the MagREEsources project. In Estonia, Neo Performance Materials stands out, and in the United Kingdom, Ionic Rare Earths (in partnership with Ford Motor Company and Less Common Metals), reinforcing the integration between recycling and the rare earths magnet production chain in Europe.

Environmental Licensing

Within the European Union, legislation such as the Environmental Impact Assessment (EIA) Directive and the Mining Waste Directive (2006/21/EC) plays a significant role in the process of obtaining environmental permits for mining activities.³⁵ These measures establish, for example, efficient waste management to minimize the environmental impacts of mining activities, as well as an emergency plan developed by the competent authorities to be implemented in the event of accidents, and monitoring of the affected area for as long as necessary (EU, 2026; OECD, 2025).^{36,37} In this regard, France has implemented measures for compensation and remediation for damages caused by mining—including environmental and public health damages—in order to establish responsible mining practices, ensuring that mining projects are environmentally compatible, particularly with regard to the protection of biodiversity and primary forests (IEA). Spain has also established the Roadmap for the Sustainable Management of Mineral Raw Materials, comprising medium- and long-term actions to drive innovation and other measures aimed at strengthening Spain’s Action Plan for the Circular Economy. The main pillars

35. https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/06/enhancing-regional-mining-ecosystems-in-the-european-union_f4ea9924/97ba1224-en.pdf (p. 126)

36. [https://www.europarl.europa.eu/RegData/etudes/STUD/2017/593788/EPRS_STU\(2017\)593788_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2017/593788/EPRS_STU(2017)593788_EN.pdf)

37. https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/06/enhancing-regional-mining-ecosystems-in-the-european-union_f4ea9924/97ba1224-en.pdf (p. 126)

concentrate on promoting sustainable practices in extractive activities by implementing the best available techniques and reducing raw material consumption through the efficient use of resources.

Strategic partnerships

Cooperation between France and the Nordic countries is emerging as a strategic driver by combining Nordic mineral resources and upstream capabilities with France's infrastructure for separation, refining, and recycling. This complementarity tends to reduce implementation timelines, logistics costs, and supply chain risks, while also promoting the sharing of knowledge about geological resources and the development of joint projects. At the EU level, agreements such as the Minerals Security Partnership (MSP)³⁸ and a series of initiatives known as the "EU Strategic Partnerships on Sustainable Raw Materials Value Chains" aim to boost government and private-sector investment across the entire value chain for critical minerals such as rare earths³⁹ (EU, 2025; IEA, 2022).

Relevant Projects and Assets

TABLE 9

REE's Relevant Projects and Assets in Europe

Project/Asset	Link in the chain	Type of initiative	Strategic Relevance
Fensfeltet Field (Norway)	Upstream	Mining	Largest REE deposit in Europe (still in the licensing phase).
Neo Performance Materials, Silmet (Estonia)	Midstream/Downstream	Separation, oxide processing, and metallization	Essential for reducing the region's dependence on foreign sources. Integration of separation, metals, and magnets. Privately held company.
Neo Performance Materials, Narva Plant (Estonia)	Midstream	Processing and recycling of rare earths	Essential for reducing the region's dependence on foreign sources. Integration of separation, metals, and magnets. Privately held company.
Solvay (France)	Midstream/Downstream	Separation of oxides and production of permanent magnets	Major European refining and separation platform.
Carester/Caremag (France)	Midstream	Processing and recycling of rare earths	Recycling and production of heavy rare earths; processing of neodymium, Praseodymium, dysprosium, and Terbium oxides. Public-private partnership. Essential for reducing the bloc's dependence on foreign sources.

38. The MSP includes participation from the U.S., Australia, Canada, Finland, France, Germany, Italy, Japan, Norway, the Republic of Korea, Sweden, the United Kingdom, and the European Commission.

39. https://ec.europa.eu/commission/presscorner/detail/en/ip_26_862

Leading Edge Materials, Jönköping (Sweden)	Upstream	Norra Kärr Heavy Rare Earths Project	Significant because it is one of the few European deposits currently undergoing a feasibility study.
REETec, Herøya (Norway)	Midstream	Industrial separation and refining plant	Significant for complementing intermediate stages of the rare earths supply chain.
Mkango Resources, Pulawy (Poland)	Midstream / Downstream	Pulawy Separation Project	Downstream project linked to Songwe Hill in Malawi.
VAC - Vacuumschmelze (Germany)	Downstream	Production of permanent magnets	One of the world's largest producers of permanent magnets, and the largest in Europe. Integrated operations in Germany, Slovakia, Finland, and the United States.
Neorem Magnets (Finland)	Downstream	Production of permanent magnets	Part of the VAC Group.
Orano/CEA-Liten (France)	R&D / Circularity	R&D initiatives in hydrometallurgical technologies and recycling	Relevant to technological innovation and reducing recovery costs in a short cycle.
European Raw Materials Act	Cross-cutting	Public policy instrument	Regulatory framework covering the entire supply chain (extraction, processing, recycling).

Source: Prepared by the authors.

Relevant projects and assets in the United Kingdom

Although the United Kingdom (UK) has identified geological reserves, it remains structurally dependent on foreign sources for the basic raw materials needed for mining of rare earths. In this regard, the UK has recently been focusing on developing intermediate links, leveraging its strategic position between Europe and the United States, by investing in companies such as Pensana and Ionic Rare Earths—which are still in the feasibility and industrial consolidation stages—as well as Less Common Metals, which represents an already operational asset in the metallization segment. More recently, in 2025 and 2026, significant progress was made on the proposal to establish a commercial plant in Belfast operated by Ionic Rare Earths, dedicated to recycling rare-earth permanent magnets, with a projected capacity to produce high-purity separated oxides such as Neodymium, Praseodymium, Dysprosium, and Terbium. It is worth noting that, despite the different uses and demands for rare earth elements (REEs), the UK government prioritizes their use to advance the energy transition agenda.

TABLE 10

REE's Key Projects and Assets in the United Kingdom

Project/Asset	Link in the chain	Type of Initiative	Strategic Relevance
Saltend	Midstream	Pensana: processing/separation	Relevant
Belfast	Circularity/ Midstream	Ionic Rare Earths: processing and recycling	Recovery of REEs from electronic components
Birchington, Kent	Midstream	Less Common Metals: Metallization	Production of rare earth metals and alloys
Vision 2035: UK's Critical Minerals Strategy	Cross-cutting	Public Policy Instrument	A combination of domestic production and international partnerships to strengthen the country's industrial resilience. Regionally, there are significant capabilities in England, Scotland, Wales, and Northern Ireland, particularly in the recycling of permanent magnets, the circular economy, and the manufacturing of nickel and titanium

Source: Prepared by the authors.

Australia

Summary of Positioning in the Value Chain

Australia is recognized for its strong mining sector, supported by a rich and diverse geological endowment and a regulatory framework, combined with public policies that attract investment and give the sector a competitive advantage. The mining infrastructure is well-established, and in the rare earths sector, the country is home to Lynas Rare Earths' upstream operation, with an annual production capacity of approximately 22,000 metric tons (Aziman et al., 2023). Australian companies invest in mining projects and in processing and recycling facilities in various countries, indicating the adoption of an internationally integrated value chain model for rare earth elements (REEs). To accelerate the development of value chains for critical minerals (including REEs), the Australian Critical Minerals Research and Development Hub was established, bringing together CSIRO, ANSTO, and Geoscience Australia as part of a national strategy to accelerate the discovery, processing, and commercialization of critical minerals.

TABLE 11

Stages of Consolidation in the REE Value Chain in Australia

Stages of the value chain	Upstream			Midstream					Downstream		
	Relevant Deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide Metal	Metal Alloy	Alloy Magnet	Manufactured Products	Recycling
Australia	X	X	X	X	X	X	X	X			

Source: Prepared by the authors.

Upstream

Australia has one of the highest-grade rare earth deposits outside of China: the Mount Weld project, operated by Lynas Rare Earths. Other significant projects under development include Browns Range, Dubbo, and Nolans. In addition, Australian companies have been expanding their international operations, with investments in REE mining projects in Brazil. In 2024, the Australian government confirmed that it will invest AU\$566.1 million over 10 years in geological research to reduce risks associated with new projects.⁴⁰

Midstream

The concentrate produced at Mount Weld is shipped to Lynas Malaysia for processing. However, Australia has been making progress in bringing these steps in-house. In this context, ANSTO is building a government-run pilot plant to process REE from ionic clay deposits. The facility will be a shared-use facility for companies in the sector, focused on conducting tests and validating processing routes, with the goal of reducing costs and accelerating project development.⁴¹

Downstream

Australian Strategic Materials (ASM) owns the Dubbo mining project in Australia, but the processing takes place in South Korea. The ASM Korean Metals Plant produces Neodymium-Praseodymium (NdPr) metals and Neodymium-iron-boron (NdFeB) magnets.⁴²

Regulation and Incentives

Australia has been promoting a strategic shift in its policy on critical minerals, moving away from acting primarily as an exporter of run of mine ore to

40. <https://investingnews.com/australia-critical-metals-exploration/>

41. <https://research.csiro.au/critical-minerals-hub/research-projects/rare-earth-elements-ree/>

42. <https://asm-au.com/metals/korean-metals-plant/>

prioritize domestic processing and value addition. Policies such as the Critical Minerals Strategy 2023–2030 establish as a central guideline the strengthening of processing, separation, and refining stages, with the aim of reducing vulnerabilities in supply chains and enhancing industrial competitiveness. To make this strategy feasible, the country has implemented specific economic and financial instruments, such as the Critical Minerals Production Tax Incentive—a 10% tax incentive for refining activities applicable to 31 minerals—and the Critical Minerals Facility—US\$4 billion. In addition, a Strategic Reserve of Critical Minerals (US\$1.2 billion) was established in 2026, which aims to secure rights to minerals produced in Australia—such as antimony, gallium, and rare earths—and reorganize these rights to meet demand. Furthermore, the Australian government has adopted price floor mechanisms that compensate for the difference between the market price and a reference price (strike price). Together, these measures seek to internalize higher-value-added stages, stimulate investment in industrial capacity, and increase the economic predictability of projects.

It should be noted that Australian mining rights are regulated primarily at the state level. In this context, two initiatives stand out: i. Western Australia has adopted a single-agency model for environmental licensing and regulatory licensing of mining, namely the Department of Mines, Petroleum, and Exploration (DMPE); ii. Queensland has designated certain MCE projects as priority projects, meaning they must be reviewed before other projects.

The Australian government has announced several tax incentives. In 2024, a refundable tax credit equivalent to 10% of eligible costs for projects involving the processing of certain MCEs in Australia was established, in a clear attempt to stimulate downstream sectors.⁴³ Furthermore, through the Junior Minerals Exploration Incentive,⁴⁴ tax credits may be issued for exploration expenses related to greenfield projects. Furthermore, at the state level, New South Wales has implemented a royalty payment deferral program for projects focused on MCEs to reduce initial costs,⁴⁵ while Queensland has waived license maintenance fees through 2028⁴⁶ and now offers discounts on receivables in cases where the minerals are processed.⁴⁷

Direct investments: In 2021, the Critical Minerals Facility was announced, allocating AU\$2 billion to finance the mining and processing of critical minerals, with that amount doubling two years later.⁴⁸

43. <https://www.ato.gov.au/businesses-and-organisations/income-deductions-and-concessions/incentives-and-concessions/production-tax-incentives/critical-minerals-production-tax-incentive>

44. <https://www.ato.gov.au/businesses-and-organisations/income-deductions-and-concessions/incentives-and-concessions/junior-minerals-exploration-incentive>

45. <https://www.resources.nsw.gov.au/invest-nsw/nsw-mineral-resources/critical-minerals-and-high-tech-metals/critical-minerals-royalty>

46. <https://www.nrmrdd.qld.gov.au/mining-exploration/initiatives/zero-rent>

47. <https://qro.qld.gov.au/royalty/calculate-mineral/discount/>

48. <https://www.iea.org/policies/15865-critical-minerals-facility>

One initiative worth highlighting is the Critical Minerals Development Program, which offered between AU\$1 million and AU\$30 million for early-stage MCE projects.⁴⁹ In addition, portions of the National Reconstruction Fund, which manages AU\$15 billion, can be used to add value to the supply chain for these minerals.

There are also other state-level initiatives specifically targeting MCEs, such as the construction of a state-owned vanadium processing plant in Queensland⁵⁰ and financing programs that will directly impact this market, such as the credit line for infrastructure development in Australia's Northern Territory.⁵¹ In addition, the government itself plans to enter into contracts for the supply of MCEs and keep them in reserve.⁵²

Circular economy

In December 2024, Australia launched the Circular Economy Framework, which sets a goal of doubling the national level of circularity by 2035, promoting the transition from a linear economic model to a regenerative system, with a focus on reducing waste, increasing resource efficiency, and strengthening economic growth in key sectors. In this context, Ionic Rare Earths, through its subsidiary Ionic Technologies, has developed patented hydrometallurgical processes for recycling Neodymium-iron-boron (NdFeB) permanent magnets, enabling the recovery of high-purity Rare Earth Oxides—particularly Neodymium, Praseodymium, Terbium, and Dysprosium—from scrap and end-of-life magnets. The initiative aims to establish a circular value chain, reduce dependence on primary raw materials, and strengthen supply security outside of China, with a focus on the recycling facility in Belfast and plans for international expansion.

Environmental Licensing

In Australia, environmental governance follows a federal model, in which states and territories concentrate most of the authority over land use and environmental protection, while the federal government acts on matters of national significance and in marine areas, with the primary legal framework being the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), supplemented by regulations such as the Water Act 2007. The EPBC Act regulates the protection of issues of national environmental importance—such as threatened species, World Heritage sites, and marine areas—and has been undergoing revisions to improve the assessment of cumulative impacts, environmental restoration, the integration of Indigenous knowledge, and the adoption of national standards, although regulatory overlaps persist. In the mining sector, regulation involves various agencies, such as the Department of Mining and Energy, which is responsible for mineral titles (Mineral Titles Act 2010), and the Department of

49. <https://www.industry.gov.au/node/92221>

50. <https://www.statedevelopment.qld.gov.au/coordinator-general/queensland-resources-common-user-facility#:~:text=The%20state%20Downed%20mineral%20processing,cobalt%20and%20rare%20earth%20elements>

51. <https://www.infrastructure.gov.au/territories-regions-cities/regional-australia/northern-australia-investment-and-projects>. Accessed August 4, 2025.

52. <https://investingnews.com/australia-critical-minerals-strategy/>. Accessed August 4, 2025.

Land, Planning, and Environment, through the evaluation of environmental permits (Environment Protection Act 2019). Applications for environmental permits for mining must be evaluated within the timeframes established in current environmental legislation.

Strategic Partnerships

Australia has been stepping up its international cooperation efforts by establishing strategic partnerships with countries such as the United Kingdom and Canada, with the aim of attracting foreign direct investment; jointly developing industrial capabilities; and strengthening global supply chains for critical minerals guided by environmental, social, and governance (ESG) criteria. Partnerships such as the Joint Declarations of Intent aim to strengthen and promote cooperation, with a focus on integrating production, mineral processing, refining, and recycling—as well as encouraging commercial partnerships, as well as research collaborations between Canadian and Australian companies, financial institutions, research organizations, and Indigenous partners. These efforts to diversify partnerships position the country as a reliable supplier in strategic value chains, meeting the growing international demand for supply security and sustainability.

Relevant Projects and Assets

TABLE 12

REE's Relevant Projects and Assets in Australia

Project/Asset	Link in the chain	Type of Initiative	Strategic Relevance
Lynas Rare Earths, Western Australia	Upstream	Mining	Largest rare earth mine outside of China
ANSTO Rare Earth Processing Facility	Midstream	Processing	State-owned pilot plant
Iluka Resources, Western Australia	Midstream	Eneabba Refinery and Mineral Sands/Rare Earths Platform	Strategic refinery project with government support
Energy Fuels	Upstream	Mining	Supply pipeline serving multiple countries. Integration with global supply chains
Australian Critical Minerals R&D Hub	Cross-cutting	Public policy instrument	Hub bringing together CSIRO, ANSTO, and Geoscience Australia
ANSTO	Cross-cutting	R&D	In addition to the pilot plant, it is the world's leading research and technology center for rare earths, including radionuclide testing

Source: Prepared by the authors.



Partial or specialized platforms: Canada in geological potential and institutional coordination; Malaysia in processing

Canada

Summary of positioning in the value chain

Canada has significant REE resources, but has prioritized strengthening midstream stages—such as refining and metallurgy—with the goal of gradually integrating domestic mineral production as projects advance to production phases and gain scale. In this process, the main challenge has been the transition from a resource- and project-centered approach to a more integrated production structure capable of capturing greater value both in the upstream sector and, above all, in the processing, separation, and refining stages (Natural Resources Canada, 2022; 2024). To address this challenge, national policy has emphasized enabling investments in infrastructure and logistics that connect extraction areas to processing facilities—such as support for the Strange Lake project—while also promoting the integration of supply chains for critical minerals, with a focus on strengthening capacities at strategic points. In this context, the country is also seeking to establish a domestic supply chain geared toward serving allied markets, such as the United States, Japan, and South Korea, positioning itself as an alternative supplier to China in the global REE and permanent magnets supply chain.

TABLE 13

Stages of Consolidation in the REE Value Chain in Canada

Stages of the value chain	Upstream		Midstream						Downstream		
	Relevant Deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
Canada	X	X	X	X	X	X	X	X			

Source: Prepared by the authors.

Upstream

Canada has world-class deposits of rare earths, a stable regulatory environment, and strong government support. The main mine, the Nechalacho Mine, began producing and exporting mixed rare earth oxide concentrate in 2021 but halted production due to financial challenges. The project remains active in the research and development phase and is seeking economic viability to scale up production. At the same time, other advanced projects are under development, such as Strange Lake in Quebec. According to the 2022 budget, C\$79.2 million was earmarked to expand public geological knowledge of the country's rare earth deposits.⁵³

Midstream

Canada has concentrated its efforts on the midstream segment, adopting a strategy of strengthening the processing stages as a foundation for consolidating the domestic REE supply chain. The main processing facility is operated by the Saskatchewan Research Council (SRC) in Saskatoon, designed to process REE ores and produce oxides, metals, and alloys. In Ontario, Ucore Rare Metals operates a demonstration plant, RapidSX, focused on the separation of individual oxides. Other technological routes are being developed with a focus on recycling, such as the Geomega Resources project in Quebec.

Downstream

Canada is home to electric motor manufacturers such as TECO-Westinghouse Motors (Canada) Inc., Techtop, and Lafert North America. However, the country has no domestic production of permanent magnets made from rare earths and relies entirely on imports to supply this critical stage of the supply chain.

Regulation and Incentives

Mining in Canada operates under a complex regulatory framework consisting of federal, provincial, and territorial regulations. Although primary jurisdiction lies with the provinces and territories, various stages of projects—from proposal to mine closure—require federal authorizations and compliance with specific environmental and sector-specific legislation, such as the Canadian Environmental Protection Act, the Impact Assessment Act, the Fisheries Act, the Navigation Protection Act, the Species at Risk Act, the Migratory Birds Convention Act, 1994 (Migratory Birds Convention Act, 1994), and the Transportation of Dangerous Goods Act, 1992, which establish parameters for environmental impact assessment, ecosystem protection, water management, and the transportation of hazardous substances.

Canadian public documents on MCEs underscore the country's goal of reducing red tape and the processing time for mining rights. Thus, the 2024 budget

53. <https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html>. Accessed: August 4, 2025.

established guidelines for defining clear responsibilities among federal departments, provides for the conduct of simultaneous—rather than sequential—reviews whenever possible, and designates a mining approvals coordinator to reduce duplication, following the “one project, one review” approach.⁵⁴

At the same time, the consolidation of the critical minerals supply chain has been driven by an active industrial policy, structured around the Canadian Critical Minerals Strategy, with approximately C\$4 billion mobilized since 2022 for geological mapping, exploration, processing, manufacturing, and initial recycling initiatives. This support includes investments in infrastructure, R&D, and international cooperation through instruments such as the Strategic Innovation Fund and the Critical Minerals Infrastructure Fund, as well as tax incentives. The 2026 budget proposal calls for new instruments, such as the First and Last Mile Fund (up to C\$1.5 billion) and the Critical Minerals Sovereign Fund (C\$2 billion), aimed at the strategic financing of projects. Governance involves multiple federal agencies, in coordination with provinces and Indigenous peoples, and seeks greater regulatory predictability through the Major Projects Management Office, which coordinates projects under the “one project, one assessment” approach, with a target of completing the analysis within two years. In addition, another C\$1.5 billion is to be allocated to infrastructure construction specifically for projects involving these minerals. The 2024 budget also included a commitment to allocate C\$5 billion to Indigenous communities to support them in acquiring mining rights and taking equity stakes in mining companies.⁵⁵

It should be noted that Canada already offered a 15% tax credit system for flow-through shares for companies focused on exploration and greenfield projects. Nevertheless, a 30% credit was established for companies conducting research on 15 substances, all of which are classified as critical minerals by the country. In addition, there is a tax credit for the manufacturing of green technology, as well as for the extraction and processing of critical minerals.⁵⁶

Circular economy

Canada’s circular economy strategy is outlined in the 2025 Circular Economy Action Plan for Canada 2.0, which consolidates the national framework for accelerating the transition from a linear model to a regenerative economic system, expanding upon the guidelines of the 2023 edition, structured around five pillars (information, collaboration, public policy, innovation, and investment), into a set of 36 priority actions and 16 strategic outcomes, incorporating contributions from the Canadian Circular Economy Summit 2025. The plan serves as a coordination tool among the private sector, governments, academia, and investors, with the goal of reducing risks, scaling up innovations, and promoting

54. <https://budget.canada.ca/2024/report-rapport/chap4-en.html>

55. <https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html> and <https://www.canada.ca/en/natural-resources-canada/news/2025/02/government-of-canada-celebrates-launch-of-the-5-billion-indigenous-loan-guarantee-program.html>

56. <https://natural-resources.canada.ca/minerals-mining/mining-policy-taxation-industry/mining-taxation/mining-specific-tax-provisions>. Accessed on: August 4, 2025.

systemic change, and it is integrated into agendas related to climate, biodiversity, and competitiveness. At the operational level, initiatives focused on the circularity of critical minerals stand out, such as the projects by Cyclic Materials—supported by automakers like BMW and Jaguar Land Rover—which employ hydrometallurgical processes for recycling magnets and have a pilot-scale capacity of approximately 100 metric tons per year, in partnership with Solvay and Geomega Resources, with a capacity of approximately 1.5 metric tons per day, reinforcing the integration of the circular economy into Canada’s mineral strategy.

Environmental Licensing

Federal environmental licensing in Canada is regulated by the Impact Assessment Act (IAA). The IAA defines the stages, deadlines, and mandatory factors for analysis, incorporating environmental, social, health, and economic dimensions, as well as the assessment of cumulative effects. The process is structured into five phases—Planning, Impact Study, Assessment, Decision-Making, and Post-Decision—and emphasizes sustainability, transparency, public participation, and meaningful engagement with Indigenous peoples. Decisions are based on scientific evidence, Indigenous knowledge, and other technical factors.

It should be noted, however, that environmental licensing in Canada is shared between the federal and provincial/territorial levels. Provinces and territories play a predominant role in authorizing most potentially polluting projects and activities, using their own regulatory framework and conducting the assessment and licensing processes within their territory. The federal government acts in a complementary capacity in cases involving federal jurisdiction, often through coordination mechanisms designed to avoid duplicate assessments.

In addition, some Canadian provinces have been adopting measures to expedite the review of projects considered strategic, through administrative prioritization and streamlining of procedures, without eliminating core environmental requirements. In the case of Indigenous communities, prior, free, and informed consultation must be conducted in accordance with ILO Convention No. 169.

Finally, authorization for mining projects is typically contingent upon the provision of financial guarantees aimed at the closure of operations and the environmental restoration of affected areas.

Strategic partnerships

Canada has established several bilateral and multilateral partnerships in line with the Canadian Critical Minerals Strategy. Among the key partnerships are: the Canada–European Union Strategic Partnership on Raw Materials; the G7 Critical Minerals Action Plan; as well as agreements with countries such as Germany, Argentina, Australia, Chile, South Korea, France, India, and Japan, focusing on project financing, innovation, value addition, and supply security. Among the multilateral initiatives, Canada

participates in forums such as the G7, the G20, the IEA, and the MSP. Brazil and Canada do not currently have a bilateral trade agreement in effect. However, a Free Trade Agreement between Mercosur and Canada is currently under negotiation. At the same time, the Ministry of Mines and Energy (MME) and Natural Resources Canada are negotiating a Memorandum of Understanding focused on technical and institutional cooperation regarding critical minerals, with the aim of exchanging geological information, best regulatory practices, sustainability, technological innovation, and investment opportunities.

Relevant Projects and Assets

TABLE 14

REE's Relevant Projects and Assets in Canada

Project/Asset	Link in the chain	Type of initiative	Strategic Relevance
Nechalacho Mine (Vital Metals)	Upstream	Mining	Main upstream asset, under development
SRC's Rare Earth Processing Facility	Midstream Downstream	Public R&D entity / state-affiliated	Rare Earths Processing Facility. Metallization plant in Saskatoon.
RapidSX (Ucore Rare Metals)	Midstream	Processing	Demonstration plant.
Torngat Metals	Upstream / Midstream	Strange Lake Project and associated separation plant	Strategic light and heavy rare earths project in northern Quebec; privately held company.
Energy Fuels	Midstream	White Mesa rare earths feedstock and processing platform	Supply pipeline serving multiple countries. Integration with global supply chains; privately held company.
Geomega Resources	Circularity	Recycling	Pilot plant for recovering rare earth elements (REEs) from electronic components; privately held company.

Source: Prepared by the authors.

Malaysia

Summary of Position in the Value Chain

Starting in 2024, Malaysia has banned the export of unprocessed rare earth ores and concentrates, requiring that rare earths be mined within the country before export. This policy supports the growth of downstream sectors of the production chain, aligning with Malaysia's more ambitious goals of establishing

higher value-added industries (see the section below on the country's regulations and incentives) (USGS, 2025).⁵⁷ However, the restriction on the export of rare earth elements faces challenges related to Malaysia's institutional framework. The Federal Constitution grants the states primary control over land and mineral resources, while national policies and export regulations fall under the jurisdiction of the federal government. This division results in fragmented governance, with inconsistent policy implementation and limited national coordination.

TABLE 15**Stage of consolidation of the REE value chain in Malaysia**

Stages of the Value Chain	Upstream			Midstream					Downstream		
	Relevant occurrences/deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
Malaysia	X			X	X	X	X	X			

Source: Prepared by the authors.

Upstream

MCRE operates an REE mine in the state of Perak, Malaysia, using the in-situ leaching method. In November 2025, the government suspended mining activities following indications of possible environmental contamination. It is also worth noting the occurrence of illegal REE mining and export in the country. Documented cases include operations in Negeri Sembilan using ammonium sulfate-based in situ chemical leaching and illegal activities in a forest reserve area in Perak, highlighting challenges and gaps in governance and enforcement in the sector.

Midstream

Malaysia is home to one of the leading rare earth processing facilities outside of China. The plant is operated by Lynas Malaysia; it receives concentrates primarily from Australia and refines and separates them into high-purity Rare Earth Oxides, which are exported to Asia, Europe, and the United States.

Downstream

Malaysia does not yet have a well-established industry for manufacturing magnets made from rare earths (NdFeB).

57. <https://www.trade.gov/market-intelligence/malaysia-critical-minerals-cooperation#:~:text=Since%20January%202024%2C%20the%20federal,be%20processed%20domestically%20before%20export>

Regulation and Incentives

Malaysia has been developing a government plan to tap into the potential of rare-earth elements in ion-adsorption clay (IAC-REE), with the aim of driving the country's technological progress, covering the upstream, midstream, and downstream stages. To this end, programs such as the Academy of Sciences Malaysia (ASM) have been launched, with the goal of formulating a business model for the development of the local IAC-REE, with the aim of becoming a regional player (NRES, 2024). The focus of this initiative lies in the mining, processing, and separation of HREE to stimulate economic growth. As part of this strategy, in 2023, Prime Minister YAB Dato Seri Anwar Bin Ibrahim presented the proposal for Malaysia's Twelfth Plan for 2021–2025. Among the key initiatives addressing rare earths are the High-Value, High-Volume Rare Earths Industry (Big Bold Rare Earths HGHV Industry) and Fiscal Sustainability and Financial System (Big Bold), which involve expanding R&D&I projects, strengthening value chains, and enhancing financial support instruments to drive sustainable growth (Malaysia, 2023). In addition, the government announced a policy restricting the export of rare earths, with the aim of protecting the domestic value chain, encouraging local processing, and increasing the capture of economic value. Overall, the country seeks to advance resource mapping, guide the development of the mineral industry, and strengthen R&D&I and commercialization to promote local production and products for rare earths.

Circular Economy

Malaysia identifies REE and advanced recycling as strategic sectors with long-term structural impact, aligned with its circular economy agenda. The country already has initiatives focused on the recycling of municipal solid waste (MSW), including its conversion into refuse-derived fuel (RDF), and seeks to expand this foundation to develop recycling industries for other high-value materials. Among the priorities is building capacity for the recycling of permanent magnets and rare earths, as well as other strategic raw materials. To this end, the government emphasizes the need for robust regulatory frameworks, partnerships with technology providers, the promotion of technology transfer, and the encouragement of foreign direct investment (FDI), with the goal of reducing dependence on imported raw materials and strengthening industrial self-sufficiency.⁵⁸

Environmental Licensing

Malaysia's environmental legislation is based on the Environmental Quality Act 1974 (Act 127, EQA), which applies to all states and is administered by the Department of Environment Malaysia (DOE), an agency under the Ministry of Natural Resources and Environment. The EQA establishes the Environmental Impact Assessment (EIA) as a legal requirement for activities defined and

58. <https://www.mosti.gov.my/wp-content/uploads/2022/08/Pelan-Hala-Tuju-Teknologi-Bahan-Termaju-Negara-2021-2030-versi-BI.pdf>

listed in Section 34A. In addition to federal legislation, the states of Sabah and Sarawak have their own regulatory frameworks: the Environment Protection Enactment 2002, administered by the Sabah Environmental Protection Department (EPD), and the Natural Resources and Environment Ordinance 1993, under the responsibility of the Sarawak Natural Resources and Environment Board (NREB). These instruments require an Environmental Impact Assessment (EIA) for activities under state jurisdiction, particularly those related to the exploitation and use of land and natural resources, such as water, soil, mineral resources, and forests.⁵⁹

Strategic Partnerships

The country forms strategic partnerships through agreements, for example, with the U.S. government. The Agreement on Reciprocal Trade (ART) and the Memoranda of Understanding on Critical Minerals Cooperation (MoU) strengthen collaboration on best regulatory practices, export-import banks, the implementation of “high-standard markets,” and the exchange of information. In addition, Malaysia has a long-standing history of cooperation with Australia, establishing long-term partnerships with complementary capabilities in the rare earths value chain. In this context, the Lynas Malaysia Sdn. Bhd. processing plant in Gebeng, Pahang, stands out as one of the largest processing and refining facilities, serving as a critical link in the processing of lanthanum concentrates imported from Australia, with an annual capacity of 22,000 metric tons of Rare Earth Oxides (Aziman et al. 2023).

Relevant Projects and Assets

TABLE 16

Relevant REE Projects and Assets in Malaysia

Project/Asset	Link in the chain	Type of initiative	Strategic Relevance
MCRE Resources Sdn. Bhd.	Upstream	Mining	Operations suspended
Lynas Advanced Materials Plant (LAMP) refinery	Midstream	Processing	Strategic for the global market; largest rare earths refining capacity outside of China.

Source: Prepared by the authors.

59. <https://www.doe.gov.my/wp-content/uploads/2021/08/FA-EIA-GUIDELINE-IN-MALAYSIA-1.pdf>



Emerging countries with ambitions to capture value: India, Indonesia, Brazil

India

Summary of Position in the Value Chain

REEs are considered critical minerals by India, which seeks to establish an integrated value chain with strong state control in the upstream sector—led by Indian Rare Earths Limited—and gradual progress in the midstream sector, which is still limited by technological challenges in separation and refining. In the downstream sector, the country has adopted policies to incentivize domestic production of permanent magnets, with the aim of reducing foreign dependence and capturing greater value added. India’s strategy for rare earth elements (REEs) seeks to ensure supply security, create domestic value added, and strengthen the national industry.

TABLE 17

Consolidation Phase of the REE Value Chain in India

Stages of the Value Chain	Upstream			Midstream					Downstream		
	Relevant Deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
India	X	X	X	X	X	X	X				

Source: Prepared by the authors.

Upstream

India has approximately 6.9 million metric tons of proven reserves for rare earths, concentrated primarily in monazite sands in the coastal regions of Odisha, Kerala, Andhra Pradesh, and Tamil Nadu. Mining is strictly controlled by the state-owned Indian Rare Earths Limited (IREL), which is affiliated with the Department of Atomic Energy, due to the presence of thorium associated with the ores. At the same time, the government is moving forward with the creation of “rare earth corridors”

to expand mining and processing capacity, a phase that accounts for a significant portion of the planned investments.

Midstream

In the midstream segment, IREL operates extraction plants in Odisha and refining facilities in Kerala, with the goal of increasing its production capacity for Rare Earth Oxides (TREO) to 5,000 to 6,000 metric tons per year. Despite these advances, the country still faces technological challenges in the individual separation of elements, relying on the domestic development of processes such as chlorination and electrolysis. In June 2025, the government ordered a suspension of exports of certain raw materials, such as Neodymium, with the aim of prioritizing domestic supply and increasing domestic value addition.

Downstream

In the downstream sector, the strategic focus is on the production of neodymium-iron-boron (NdFeB) permanent magnets. To this end, the “Scheme to Promote the Manufacturing of Sintered Rare Earth Permanent Magnets” was approved, combining capital subsidies and sales-linked incentives to enable an annual production capacity of 6,000 metric tons. The strategy calls for public-private partnerships in which the private sector will lead the final manufacturing process, with the goal of beginning full-scale production by the end of 2026, thereby consolidating an integrated value chain with higher value added in the country.

Regulation and Incentives

India has been making progress on its strategy for self-sufficiency in critical materials by prioritizing the creation of a domestic ecosystem for rare earth permanent magnets. In November 2025, the government approved a program to develop an integrated production capacity of 6,000 metric tons per year, covering the entire value chain—from Rare Earth Oxides to the manufacture of finished magnets. The initiative aligns with national strategic guidelines, such as Atmanirbhar Bharat, the Net Zero 2070 climate goal, and the Viksit Bharat @2047 vision, strengthening the country’s position in global advanced materials supply chains. The 2026–27 Union Budget provides for the creation of dedicated rare earths corridors in Odisha, Kerala, Andhra Pradesh, and Tamil Nadu, with a focus on mining, processing, research, and manufacturing. The measure aims to integrate the country’s abundant mineral base—which includes approximately 13.15 million metric tons of monazite, equivalent to roughly 7.23 million metric tons of Rare Earth Oxides—into higher-value-added industrial stages. Despite this potential, domestic magnet production is still in its infancy, and India relies heavily on imports, primarily from China, which accounted for 60–80% of the value and 85–90% of the volume imported between 2022 and 2025. With demand for rare earths-based permanent magnets expected to double by 2030, driven by electric mobility and renewable energy, strengthening domestic capacity has become a strategic priority to reduce vulnerabilities and enhance industrial competitiveness.

Circular economy

India has adopted the circular economy as a strategic tool to reduce its high dependence on imports of critical minerals, which are essential for sectors such as defense, electronics, and clean energy. Following the inclusion of 24 strategic minerals in the 2023 Amendment to the Mines and Minerals Act – Development and Regulation, the country launched the National Critical Mineral Mission, which encompasses domestic exploration, the acquisition of overseas assets, innovation, and recycling. As part of its strategy to strengthen recycling, on September 8, 2025, India's Ministry of Mines announced the publication of the Guidelines for the Incentive Scheme for the Promotion of Recycling of Critical Minerals, with a deadline for submitting applications set for April 1, 2026. The program provides for the granting of subsidies both for the expansion of existing facilities and for the establishment of new facilities dedicated to the recycling of 27 previously defined critical minerals.

Environmental Licensing

The Environmental Protection Act of 1986 is the cornerstone of India's environmental legislation, serving as the basis for sector-specific regulations and for the environmental licensing and enforcement system governing industrial activities, including mining and infrastructure. The EIA Notification of 1994 established the first comprehensive EIA framework, making environmental licensing mandatory for projects with significant potential for impact, while the EIA Notification 2006 overhauled the system by introducing a classification of projects based on their level of impact, with larger projects (Category A) subject to national approval and smaller projects (Category B) assessed by state authorities (SEIAA). The 2006 notification also made public hearings mandatory, strengthening public participation, and established maximum time limits for the various stages of the environmental licensing process, combining administrative decentralization with national oversight in order to increase regulatory efficiency and predictability without compromising environmental rigor.

Strategic Partnerships

In February 2026, Brazil and India signed an agreement involving critical minerals and rare earths. The Memorandum of Understanding between the Ministry of Mines of the Government of the Republic of India and the Brazilian Ministry of Mines and Energy on Cooperation in the Field of Rare Earth Elements and Critical Minerals establishes areas of cooperation, such as technologies and recycling; artificial intelligence for the analysis of geoscientific data; reciprocal investments in exploration, mining, and infrastructure; and support for best practices in the rare earth elements (REE) sector.⁶⁰ Other cooperation initiatives, such as the India-Australia Critical Minerals Investment Partnership, represent an important milestone for investing in critical minerals projects. The partnership seeks to jointly finance the identification of projects and support potential

60. <https://www.gov.br/mme/pt-br/atos-internacionais/atos-internacionais-2025/india/2026-memorando-de-entendimento-brasil-india-sobre-cooperacao-no-campo-de-elementos-e-terras-raras-e-minerais-criticos-portugues.pdf>

India's investments in Australian critical minerals projects, contributing to mutually beneficial critical minerals supply chains (IEA, 2022; India, 2023).⁶¹ India has also become a member of the MSP.

Relevant Projects and Assets

TABLE 18

Relevant REE Projects and Assets in India

Project/Asset	Link in the chain	Type of initiative	Strategic Relevance
IREL OSCOM (Odisha)	Upstream	Heavy mineral extraction and monazite processing	A key upstream asset supplying the entire Indian rare earths value chain; state-owned company.
IREL Chavara Mineral Division (Kerala)	Upstream / Midstream	Mining and heavy mineral separation facility in coastal sands rich in ilmenite, rutile, zircon, etc.	Source of mineral feedstock for downstream processing; strategic refining as an alternative to China; state-owned company.
IREL Rare Earths Division (RED), Udyogamandal, Aluva	Midstream	Refining and Separation	Production of high-purity Rare Earth Oxides. A key midstream link relevant to India's national strategy; state-owned company.
Partnership between BatX and Rocklink, IREL (Bhopal), and Attero (WEEE reverse logistics)	Circularity/Midstream	Reverse logistics and magnet recycling	MOU for the development of a magnet recycling ecosystem and the recovery of REE from electronic components.
IREL (REPM) Vishakhapatnam	Downstream	Project under construction for magnet manufacturing and industrial integration.	Connection to the automotive supply chain and strengthening of domestic manufacturing; state-owned company.

Source: Prepared by the authors.

Indonesia

Summary of positioning in the value chain

Indonesia has mineral reserves in REE, with operations still in their early stages and concentrated in the upstream sector, while its processing and manufacturing sectors remain underdeveloped. The country seeks to expand its participation in the global supply chain by adding value to mineral byproducts and advancing its technological capabilities. The country has established a state-owned enterprise to explore strategic minerals, with a focus on REE: PT Perusahaan Mineral Nasional (Perminas).

61. <https://mines.gov.in/admin/download/642e795463fa91680767316.pdf>

TABLE 19

Consolidation Phase of the REE Value Chain in Indonesia

Stages of the Value Chain	Upstream			Midstream					Downstream		
	Relevant Deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide Metal	Metal Alloy	Alloy Magnet	Manufactured Products	Recycling
Indonesia	X	X	X								

Source: Prepared by the authors.

Upstream

Rare earth elements occur primarily as byproducts of tin, bauxite, and lateritic nickel mining, as well as in deposits associated with granites and ion-adsorption formations. Minerals such as monazite and xenotime contain rare earths, including significant fractions of Heavy Rare Earths. According to a statement by officials from the mining sector, eight mining blocks with high potential for the extraction of Rare Earth Elements and other strategic minerals have recently been identified. These areas are located primarily in regions such as Kalimantan, Sulawesi, and the Bangka-Belitung Islands, which are known for their history of significant mineral production, particularly tin and nickel. Although no reserve estimates have been released, officials have indicated that the identified potential is sufficient to allow the country to compete with other international producers (Reuters, 2026).⁶² Exploration is expected to be conducted by a new state-owned mining company, PT Perusahaan Mineral Nasional (Perminas), created with the aim of strengthening national capacity in the development of critical minerals and reducing dependence on foreign sources (Reuters, 2026).

Midstream

Due to technological, regulatory, and environmental challenges—particularly those related to the presence of radioactivity—the processing, separation, and refining stages remain underdeveloped in Indonesia. In this context, the government announced the launch of two research projects aimed at developing technology for processing rare earths, which are expected to proceed in parallel with mineral exploration activities, with an initial focus on the Mamuju region in West Sulawesi. The initiative is part of Indonesia's strategy to expand its participation in the global supply chain for critical minerals, leveraging its already established position as a major producer of nickel and an important exporter of tin, while also responding to the growing global demand for materials used in electric vehicles, electronics, defense systems, and clean energy technologies (Reuters, 2026).

62. <https://www.reuters.com/world/asia-pacific/indonesia-identifies-eight-blocks-with-large-rare-earth-reserve-potential-2026-02-09/>

Downstream

Indonesia does not produce metals, alloys, or permanent magnets, and the downstream sector is still in its infancy.

Regulation and Incentives

In 2025, Indonesia enacted Law No. 2/2025 (Fourth Amendment to the Mineral and Coal Mining Law—UU Minerba), representing a comprehensive reform of the mineral sector's governance, with greater state control and a focus on strengthening the domestic industry. The measures include a mandatory requirement for domestic processing and refining (downstream mandate), with a ban on the export of run of mine; the strengthening of the Domestic Market Obligation (DMO), prioritizing the domestic market; the requirement to deposit 100% of export revenues in domestic banks for at least 12 months; the restructuring of royalties with progressive mechanisms linked to international prices; and the adoption of an annual system for approving work plans, expanding control over supply. The concession regime was also adjusted to prioritize cooperatives, small and medium-sized enterprises, and entities affiliated with religious or educational organizations—in some cases without competitive bidding—with the participation of state-owned enterprises and large corporate groups in partnerships. In addition, the New Mineral Industry Agency was created to manage strategic minerals, including rare earths, with a focus on extraction, protection, and industrial development.

Circular Economy

In 2024, Indonesia launched its national strategy for the circular economy, the Circular Economy Roadmap and National Action Plan 2025–2045. The plan establishes long-term guidelines to guide public and private stakeholders in the transition to a circular economy, with an emphasis on resource efficiency, reducing waste generation, and mitigating environmental impacts.

Environmental licensing

Indonesia's environmental legal framework is established by Law No. 32/2009 on Environmental Protection and Management, subsequently amended by Law No. 6/2023 (UU 6/2023), which introduced significant changes regarding liability for environmental violations (Firmansyah et al., 2025). The legislation requires that potentially polluting activities obtain, in advance, documents such as an AMDAL (environmental impact assessment), UKL-UPL (environmental management and monitoring), and permits for waste management and disposal; originally, failure to comply with these obligations constituted an automatic crime; with the 2023 reform, this classification now depends on proof of actual environmental damage, reducing the preventive nature of environmental licensing and requiring technical evidence for accountability (Ramdan, 2025; Firmansyah et al., 2025). Mining in Indonesia, particularly nickel mining, is associated with high socio-environmental costs, including significant deforestation,

water contamination, loss of livelihoods, and social conflicts, with particularly severe impacts in regions such as Sulawesi and Halmahera (Nasution et al., 2024). Within the context of a decentralized unitary state, in which the central government sets general standards and subnational entities are responsible for implementation, the country has also made progress on specific instruments, such as the 2022 regulation on the treatment of mining wastewater using constructed wetlands (Constructed Wetland Technology for Mining Wastewater), which establishes technical requirements to reduce pollutant loads and promote more sustainable practices in the sector's water management (IEA, 2025).

Strategic Partnerships

Indonesia is expanding its strategic partnerships with countries such as the United States and Brazil. Cooperation on the rare earths agenda reflects a shared commitment to strengthening upstream-downstream integration, creating jobs, generating economic benefits, and building a resilient supply chain in the country. Recently, Indonesia and the U.S. finalized the Agreement on Reciprocal Trade (ART), which facilitates business cooperation between U.S. investors and Indonesian companies overseen by the Danantara sovereign wealth fund.⁶³ In addition, the country is concentrating discussions with partners such as Australia, Canada, and Japan to help build a domestic supply chain for magnets, in an effort to reduce its dependence on Chinese processing technologies (Wealthion, 2026). The MoU signed with the Australian government aims to boost investment in the sector, collaborate on the adoption of sustainable mining practices, and develop technical skills through education and training.⁶⁴ Strengthening ties with the Brazilian government through the Revitalized Action Plan for the Strategic Partnership 2023–2026 may also promote technical cooperation, knowledge exchange, capacity building, technology transfer, and dialogue on cooperation regarding critical minerals.⁶⁵

Relevant Projects and Assets

Indonesia currently has no operational projects or assets for REEs.

63. <https://www.whitehouse.gov/briefings-statements/2025/10/agreement-between-the-united-states-of-america-and-malaysia-on-reciprocal-trade/>

64. <https://www.dfat.gov.au/sites/default/files/iacepa-mou-indonesia-aus-skills-development-exchange-pilot-project.pdf>

65. https://www.gov.br/mre/pt-br/canais_atendimento/imprensa/notas-a-imprensa/comunicado-conjunto-progresso-da-parceria-estrategica-brasil2013indonesia



Conclusions from the international benchmarking

TABLE 20

Comparative Profile of Selected Countries

Country/ Block	Main Strength	Main bottleneck	Most competitive link	Key instrument	Key lesson for Brazil
China	Full integration of the supply chain	Geopolitical and environmental pressure	All	Government coordination and scale	Integration of mining, processing, and manufacturing
U.S.	Industrial policy and financing	Dependence on stages that are not yet complete	Mid-stream/downstream under construction	Government procurement, EO 14017, Project Vault	Use risk mitigation tools
Australia	Mineral resources and government support	Lower downstream density	Upstream	Tax incentives and funding facilities	Moving away from the “raw material exporter” model
EU	Industrial capacity and recycling	Low domestic mineral base	Midstream/downstream	CRMA and industrial policy	Combining regulation, innovation, and recycling
Canada	Governance and coordination	Industrial scale still limited	Upstream/midstream potential	One project, one review	Regulatory coordination and infrastructure
India	Reserves and focus on magnets	Technological bottlenecks	Upstream	Subsidies for magnets	Prioritizing specific industrial niches
Malaysia	Processing and regional positioning	Social and environmental constraints	Midstream	Value retention policy	Leveraging Processing Even Without Controlling the Entire Chain
Indonesia	Aggressive insourcing policy	Limited technological base	Emerging upstream sector	Ban on raw material exports	Industrial policy must be backed by technical capacity
Brazil	Geological potential and institutional framework under development	Low midstream/downstream capacity	Upstream potential	Strategies and financing under development	Focus on separation, refining, and magnets

Source: Prepared by the authors.

The comparative analysis indicates that competition with China in the rare earths supply chain does not occur uniformly across countries or across stages of the production chain. China remains the only player fully integrated from upstream to downstream, combining mineral scale, technological dominance, separation and refining capacity, magnet manufacturing, and industrial coordination. In response, other countries have adopted selective strategies. Australia and Canada seek to strengthen the upstream sector and advance in the midstream; the United States and the European Union concentrate their efforts on reindustrialization, refining, manufacturing, and recycling; India, Malaysia, and Indonesia seek to capture value through industrial policies and greater control over strategic resources.

For Brazil, the main lesson from benchmarking is that a geological advantage, while necessary, is not sufficient. The countries best positioned to compete with Chinese production are precisely those that combine mineral resources with financing instruments, institutional coordination, regulatory predictability, support for processing, incentives for innovation, and links to industrial demand. In this sense, Brazil's opportunity lies not only in expanding mineral extraction but also in building progressive capacity in the areas of separation, refining, recycling, and—selectively—the manufacturing of higher-value-added products.

Thus, benchmarking suggests that Brazil's National Rare Earths Strategy should prioritize:

- i) capacity building in the midstream sector, where the main global bottleneck outside of China is concentrated;
- ii) the use of public risk-reduction instruments to make strategic projects viable;
- iii) coordination among geology, industry, science, and financing;
- iv) the establishment of international partnerships focused not only on the export of concentrates but also on the joint development of technological and industrial capabilities.

Interconnections and complementarities in global value chains

The following table summarizes the preliminary results of the mapping of participation in value chains, comparing the Brazilian case with the other countries selected for the study. China has all stages of the chain integrated, holding a dominant position in the international rare earths market. Australia and Canada are nations with a strong mining tradition, established partnerships, and investments aimed at strengthening their value chains for critical and strategic minerals. Despite this, Canada faces financing and infrastructure challenges that hinder the development of its potential; as a result, it has no industrial-scale projects currently underway. In this context, the government has been developing policies and tools to accelerate progress along the value chain. The United States also possesses reserves of rare earths and has been increasing investments to regain a leading role in both the upstream and downstream stages, with strong government involvement in coordinating the different links in the chain through public investments and strategic

partnerships. Europe and the United Kingdom are seeking to diversify their REE supply to ensure raw material security for downstream stages, moving forward with international partnerships and investments financed by EU and national instruments, in a spirit of complementarity with the U.S. and Canada. It is worth noting the complementary relationship between REE mining in Australia and processing in Malaysia, which has established itself as a major international processing hub, in part due to regulatory restrictions in the upstream sector in other countries.

There is, therefore, complementarity in terms of strengthening value chains for rare earths: on the one hand, countries and/or blocs with major downstream producers are investing efforts in partnerships and financing intermediate activities; on the other hand, there is a group of countries with significant mineral potential, such as Brazil, which are taking their first steps in developing intermediate processing.

This trend points to an increased likelihood of integration into global processing and beneficiation chains for rare earths, driving a strategic transformation in the coming decades. Below is a summary table containing the stages identified in the rare earths value chain for the selected countries.

TABLE 21
Stages of the Value Chain for the Countries Covered

Stages of the value chain	Upstream			Midstream					Downstream		
	Relevant occurrences/deposits	Mining & Extraction	Processing Concentration	Chemical decomposition/Leaching & Dissolution	Purification & Precipitation	Separation & Refining	Oxide/Metal	Metal/Alloy	Alloy/Magnet	Manufactured Products	Recycling
Australia	X	X	X								
Canada	X										
China	X	X	X	X	X	X	X	X	X	X	X
USA	X	X	X						X	X	
India	X	X	X	X	X	X	X				
Indonesia	X										
Malaysia	X			X	X	X	X	X			
EU/United Kingdom	X			X	X	X	X	X	X	X	X
Brazil	X	X	X								

Source: Prepared by the authors.

Concluding Remarks

When evaluating different regulations, strategies, and international agreements aimed at strengthening the rare earths sector, it is evident that each country establishes public policy guidelines and instruments aligned with its national interests. In general, efforts concentrate on diversifying the supply chain; ensuring national sovereignty; promoting industrial development; providing incentives for innovation, Research and Development; as well as enhancing competitiveness and generating economic value.

Although the international landscape is currently marked by geopolitical instability, countries demonstrate strategic interdependence regarding critical minerals such as rare earths, even as they are guided by national interests and motivations. This is because the high concentration of the rare earths value chain in a single country creates a perception of shared risks, such as supply shortages, external dependence, and geopolitical vulnerability. Even so, countries exhibit varying levels of development in terms of value chain maturity, availability of information, progress toward a circular economy, consolidation of environmental and social standards, as well as their capacity to mobilize resources to achieve their strategic and climate goals.

In addition to China, countries such as Australia and the United States have demonstrated consistent and structured performance in developing strategies for the rare earths sector. This performance stems from the fact that they channel significant public and private investments into research and innovation and enter into agreements with reliable suppliers, while at the same time maintaining cooperative relationships with allies who possess complementary expertise at different stages of the supply chain, in order to share information, mutual investments, techniques, technologies, and training.

3

Assessment of the Rare Earths Sector in Brazil

Brazil occupies a promising position in the global rare earths landscape, though it still has untapped opportunities. Despite possessing significant geological assets, having begun primary production, and having projects that can support future expansion, Brazil still concentrates on the early stages of the supply chain, with significant bottlenecks in detailed geological knowledge, separation and refining technology, financing, licensing, infrastructure, and institutional coordination.

The strategic nature of this moment stems from the combination of structural growth in global demand for REE-derived products—driven by the need for geopolitical diversification of supply chains—and the emergence of a domestic production base capable of serving as a platform for vertical integration.

The central question, therefore, is whether Brazil will be able to transform its potential into industrial, technological, and geoeconomic capacity. In this regard, this section seeks to identify opportunities for the development of rare earth value chains in Brazil, from mineral exploration to high-tech industrial applications, based on relevant international experiences and potential strategic partnerships. The analysis highlights the potential for intermediate and advanced processing within the country, the priority industrial sectors (renewable energy, electric mobility, semiconductors, defense, and healthcare), and the key drivers for a national strategy on critical technologies, innovation, and applied research.

3.1. Overview of the rare earths sector in Brazil

Brazil is well-positioned to expand its role in the global rare earths value chain by combining a significant geological base, a growing portfolio of projects, established scientific and technological capabilities, and increased government attention to the issue—all within an international context marked by rising demand for critical inputs for the energy transition, digitalization, defense, and the geopolitical reorganization of supply chains.⁶⁶

Despite these conditions, Brazil's current position in the sector is still in its infancy when viewed from the perspective of the value chain. The country is beginning to reestablish its presence in the mining segment (with production concentrated in just one mine in 2026), but still has

66. CEBRI. (2025). *Technical Report: Brazil's Role in the Global Agenda on Critical and Strategic Minerals: Projected Demand and Brazil's Potential Contribution to the Energy Transition* (1st ed.). Brazilian Center for International Relations—CEBRI.

limited capacity in the intermediate and final stages, particularly in chemical separation, refining, metallurgy, alloy production, and the manufacture of permanent magnets. Generally speaking, the sector remains concentrated in the upstream segment, with promising initiatives in the midstream and downstream segments, but without sufficient industrial density to capture, at scale, the segments with the highest value added.

This mismatch between geological potential and industrial density is the defining feature of Brazil's current situation. On the one hand, the country possesses significant mineral resources, a growing portfolio of projects, and technological assets and competitive advantages that point to its capacity for progress. On the other hand, it still faces structural limitations in converting these assets into industrial production, applied innovation, and strategic integration into more sophisticated global supply chains. Thus, Brazil's challenge lies not only in expanding mineral production but also in creating the conditions to internalize critical stages of the supply chain and bridge the gap between resource endowment and processing capacity.

The recent resumption of commercial production of rare earths represents, in this sense, a significant turning point. It signals that Brazil is no longer merely a country with geological promise and has once again begun to make concrete progress in developing the sector. At the same time, the sector is still in its early stages: domestic production remains limited, the more complex industrial links are still underdeveloped, and Brazil's international presence concentrates on materials with lower value added, while processed and manufactured products continue to come largely from outside the national production base.

Among the country's main assets, the following stand out: first, its geological diversity and the presence of different types of deposits with economic potential (Silva et al., 2024).⁶⁷ Second, there is progress in projects at various stages of maturity, suggesting greater dynamism in the sector and growing business interest. Third, Brazil possesses scientific and technological expertise accumulated at universities, research institutes, and innovation centers, including expertise in geology, chemical separation, metallurgy, and materials prototyping. Finally, there is an evolving institutional environment, with the issue of Critical and Strategic Minerals featuring more prominently on the mineral, industrial, technological, and financing agendas.

These assets, however, coexist with significant bottlenecks. The first is the low industrial density of the value chain, which limits the country's ability to add value domestically. The second is the difficulty in moving from the laboratory and pilot stages to demonstration and industrial production scales, which slows the pace of technological maturation. Challenges also persist in infrastructure and logistics, financing, regulatory predictability, institutional coordination, market development, and the integration of mining, industrial processing, and end demand. Furthermore, the sector's advancement will require careful handling of socio-environmental, territorial, and regulatory issues, especially when radioactive minerals are involved or when operations impact sensitive areas.

Brazil's vulnerability in the separation, refining, and processing stages stems from the technological complexity of these processes, but the lack of

67. Geological Survey of Brazil. (2024). *Overview of Brazil's Potential for Critical and Strategic Minerals*.

an economic and regulatory environment compatible with the capital-intensive nature, technological risk, and prolonged maturation period typical of these activities. In particular, the high tax burden on industrial CAPEX, the costs of importing inputs and equipment, the difficulty of internalizing foreign technology, and the lack of specific risk mitigation instruments limit the viability of midstream projects. This suggests that advancing the supply chain will require not only technical expertise but also an incentive structure geared toward mineral processing.

The current moment is particularly strategic because it combines both an external and an internal window of opportunity. Internationally, the concentration of the global supply chain—especially in processing—has led various countries to seek diversification of supplies and new partners capable of contributing to more resilient supply chains. Domestically, Brazil now enjoys a more favorable set of factors than in the past: projects reaching maturity, resumed production, accumulated technical and scientific expertise, and greater mobilization of public policies and support instruments. Taken together, these elements indicate that the sector is at a turning point.

Thus, the overall assessment is that of a country with strong potential for repositioning, but one that is still in the early stages of building a more comprehensive and competitive value chain. Brazil already has a solid foundation on which to build, but it has not yet consolidated the industrial and technological links necessary to establish a strong position in the segments with the highest value added. **The core of Brazil's challenge in the rare earths sector lies in the transition from geological advantage to industrial competitiveness.**

3.2. Resource base: geological potential, reserves, and projects under development

Brazil's mineral resource base is one of the main pillars underpinning the country's repositioning in this sector. Brazilian territory is home to a diverse range of geological occurrences, distributed across different mineral provinces and associated with multiple types of deposits, which broadens the range of possibilities for the development of exploration and economic exploitation projects. In recent years, there has been a growth in business interest and investment in mineral exploration, reflected both in the expansion of the project portfolio and in the increase in the number of exploration permits and the mobilization of exploration capital. This section presents the main elements of Brazil's geological base, the territorial distribution of mineral resources and mineral reserves, and the current status of the most significant projects under development.

Geological Potential and Types of Deposits

Brazil has a geological foundation that is particularly favorable to the development of the rare earths sector, both because of its vast territory and the diversity of geological environments

capable of concentrating these elements under economically viable conditions. The key issue is not merely the presence of rare earths in the Earth's crust, but rather the existence of deposits with grades, mineralogy, and mining conditions compatible with economic exploitation. In this regard, the country possesses distinctive attributes.

The geological explanation for this potential is linked to two structural characteristics of Brazil's territory. The first is its vast size, which increases the variety of geological contexts and mineralization processes. The second is the geological age of much of the national territory, which consists of ancient cratons and rock blocks; over geological time, this has favored natural processes of mineral alteration, concentration, and redistribution. In practical terms, this has allowed for the formation of deposits with high grades and, in some cases, with easier extraction routes and, therefore, potentially lower costs.

Furthermore, this potential manifests itself through various natural concentration mechanisms. In certain cases, such as in ancient volcanic environments, the combination of geological structure, weathering, leaching, and topographic retention would have favored the formation of concentrated clay deposits. In other contexts, such as in the monazite sand areas of the Northeast, the prolonged action of weathering, gravity, water, and sedimentary processes would have contributed to the concentration of heavy minerals in favorable environments. The same logic of concentration through long-term geological evolution appears, according to the data provided, in different regions of the country, including Goiás, Minas Gerais, and the Northeast.

More specifically, REE occurrences in Brazil are predominantly associated with three major geological contexts. The first corresponds to alkaline-carbonatite complexes, which concentrate a significant portion of the country's potential and include occurrences in areas such as Poços de Caldas (Minas Gerais), Araxá (Minas Gerais), Catalão (Goiás), Tapira (Minas Gerais), and Seis Lagos (Amazonas). The second comprises weathering mantles developed on granitic rocks, notably deposits of the ion-adsorption clay type, such as those identified in Pela Ema (Goiás), Bluebush (Tocantins), Iporá (Goiás), Capão Bonito (São Paulo), and Pitinga (Amazonas). The third category encompasses sedimentary deposits, such as those found in Itapemirim (Espírito Santo) and São Francisco do Itabapoana (Rio de Janeiro).

This diversity of geological contexts is significant for two reasons: first, it indicates that Brazil's potential is not concentrated in a single type of mineralization, which can reduce dependence on a single exploration model. Second, different types of deposits tend to have distinct profiles in terms of mineral composition, grades, economic viability, environmental challenges, and processing technologies, which broadens the possibilities for productive specialization in the medium and long term.

In addition to primary deposits, rare earth elements (REEs) in Brazil are also found in association with other mineral systems. Since these elements rarely occur in isolation, their presence can be observed as a byproduct or co-product in mineral systems that are already being mined commercially, such as those containing niobium, tin, and bauxite. In niobium deposits, such as those in Araxá (MG), there are significant concentrations of light rare earths, especially Cerium, lanthanum,

and neodymium. In tin deposits associated with cassiterite, in turn, REE-bearing minerals such as xenotime and monazite may occur. Bauxite deposits and their processing residues, particularly red mud, are also being considered as potential sources for the recovery of these elements.

This configuration opens the door to two complementary approaches to developing the resource base. The first is primary production from dedicated deposits of rare earths. The second involves advancing strategies for utilizing byproducts and secondary sources, including tailings, mineral waste, and materials already extracted through other mining activities. Although these approaches depend on technical and economic evaluations and specific technological developments, they broaden the scope for resource utilization and can contribute to greater efficiency in the use of the country's mineral resources.

TABLE 22

REE Deposits in Brazil and Their Characteristics

Deposit Type	Examples of occurrences	General characteristics
Alkaline-carbonatite complexes	Poços de Caldas, Araxá, Catalão, Tapira, Seis Lagos	Significant occurrences associated with complex mineral systems
Ion-adsorption clays / weathering mantles	Pela Ema, Bluebush, Iporá, Capão Bonito, Pitinga	Recent highlight in the national pipeline
Sedimentary deposits	Itapemirim, São Francisco do Itabapoana	Specific potential, with a smaller presence in the current pipeline
Secondary sources and byproducts	niobium, tin, bauxite, red mud, tailings	Complementary potential, dependent on technical and economic feasibility

Source: Prepared by the authors.

Resources, reserves, and geographic distribution

The base of rare earths resources and reserves in Brazil must be understood from two complementary perspectives. The first is the existence of a significant set of deposits and projects already identified, distributed across different states and associated with distinct geological types. The second is the need for methodological caution when comparing aggregate figures for reserves or resources reported in broad consolidations with the volumes actually supported by specific projects with a higher degree of technical maturity.

From a territorial perspective, the distribution of assets is widespread and reinforces the nationwide nature of Brazil's potential, as evidenced by existing projects and occurrences in Goiás, Minas Gerais, Bahia, Amazonas, and also in the Northeast, specifically in states such as Paraíba and Rio Grande do Norte. This territorial dispersion is consistent with the geological diversity previously

noted and suggests that the country has different potential development hubs, rather than an absolute concentration in a single mineral province.

In the Midwest and Southeast, deposits associated with ionic clays and specific geological contexts—such as those in Goiás and Poços de Caldas—stand out. In Minas Gerais, in addition to dedicated projects, there are also sites where rare earths may be associated with operations in other mineral chains, as in the case of Araxá. In the North, the Pitinga mine is cited as an example of an asset where rare earths may occur as a secondary component within a broader mineral operation. In the Northeast, meanwhile, monazite sands and other occurrences related to ancient sedimentary processes underscore the breadth of Brazil's territorial base.

In quantitative terms, information sources can be viewed in two ways. The first involves large aggregate figures often attributed to Brazil and derived from international compilations. The second stems from the sum of the resources identified and technically described in the main projects under development. Additionally, the information consolidated in international databases may be derived from data reported to the ANM by the developers themselves, which do not necessarily, in all cases, adhere to the same level of statistical, geological, and economic rigor as more mature technical studies. Thus, any comparison between the national aggregate figure and the data actually supported by more detailed projects should be made with caution.

This observation is important because it prevents two misinterpretations: underestimating Brazil by ignoring the robustness of its geological base; and overestimating the immediate convertibility of the entire theoretical volume into economically viable production. In terms of public policy and sectoral strategy, the most appropriate approach is to recognize that Brazil has a promising and diversified base, but that the quality of geological information, the stage of studies, and the progress of projects remain decisive factors in transforming potential into actual supply.

In addition to the best-known primary deposits, the distribution of mineral resources must also take into account “hidden” assets or those partially captured in other mineral chains. The database highlights the presence of rare earths as secondary components in deposits or tailings associated with aluminum, niobium, phosphate, tin, and polymetallic concentrates, as well as the extraction of monazite sand not currently mapped under this type of activity. This point is particularly relevant because it broadens the concept of the resource base beyond dedicated projects. In other words, part of Brazil's potential may be distributed across existing mineral flows that are still underidentified, underspecified, or economically undervalued.

A recent example illustrating how deposits originally mined for aluminum can take on new strategic importance in light of the growing global demand for critical and strategic minerals involves mining areas in southern Minas Gerais that were previously mined by Companhia Brasileira de Alumínio (CBA). After the bauxite deposits were depleted, the company had requested, in 2022, to relinquish its mining titles. However, subsequent studies identified potential for rare earths in the same areas, leading the company to request that its mining rights be maintained, which was authorized by the

National Mining Agency (ANM) in 2025. Subsequently, in 2026, Votorantim completed the sale of CBA to a joint venture formed by the Chinese state-owned company Chinalco and the Australian company Rio Tinto, a sign of growing international interest in Brazilian mineral assets associated with the rare earths supply chain. It is worth noting that Brazil's main bauxite deposits are of lateritic origin, unlike the karstic bauxite deposits found in regions of Europe, China, and parts of the Mediterranean-Tethys belt.

Brazil is often cited as one of the countries with the largest reserves of rare earths globally, which gives it potential significance in the context of the restructuring of international supply chains. However, transforming this geological advantage into productive capacity depends on the level of available geological knowledge, the conversion of deposits into economically viable reserves, and the maturation of projects over time.

The geographic distribution of REE occurrences and projects in Brazil shows a higher concentration in certain states, notably Goiás, Minas Gerais, Amazonas, Tocantins, São Paulo, Espírito Santo, and Rio de Janeiro. Goiás and Minas Gerais stand out in particular for concentrating projects in more advanced stages of development, as well as for accounting for a significant portion of the occurrences associated with both ion-adsorption clays and alkaline complexes. The Northern region, on the other hand, stands out for its still-underexplored geological potential in some areas, although this is often associated with greater logistical and infrastructure challenges.

Recent progress in exploration activity underscores the growing interest in Brazil's resource base. In 2024, according to data from the Declaration of Investments in Mineral Research (DIPEM-ANM), investments in mineral research related to REE reached R\$ 89.9 million, a 35% increase over the previous year. The distribution of these investments showed a strong concentration in Bahia, followed by Minas Gerais and Goiás, with funds predominantly allocated to drilling, support infrastructure, geology, and chemical analyses. This trend suggests not only an expansion of exploration efforts but also greater sophistication in the stages of deposit evaluation.

In addition, data from the National Mining Agency's Mining Registry System indicated a significant increase in the number of new exploration permits issued in 2024 for REE and monazite, particularly in Bahia, Minas Gerais, and Goiás. Although the increase in permits does not automatically translate into new viable projects, it signals an expansion of the portfolio of areas of interest and a more dynamic environment in the sector. It is worth noting that the substance listed in the Mining Registry may not fully reflect the area's potential, due to possible inconsistencies in the registry or the evolution of geological knowledge throughout the exploration process, which may lead to the identification of new substances, such as REE.

Figure 9, which shows the locations of the main deposits, along with the summary table of occurrences and projects presented below, illustrates the geographical extent of this resource base and the diversity of geological contexts associated with the sector's development in the country.

FIGURE 9

Map showing the locations of the main REE deposits



Source: CEBRI, 2025

Projects under development

The rare earths project portfolio in Brazil is currently expanding, with projects at various stages of development, ranging from mineral exploration to construction and the start of operations. Although the country currently has a limited number of projects in more advanced stages, there has been a significant shift compared to previous years, marked by greater capital mobilization, progress in geological studies, and advancements in business initiatives focused on REE production.

Among the projects in more advanced stages, the Pela Ema Project in Minaçu (Goiás), operated by Serra Verde Mineração, stands out as the first in the country to produce REE from ion-adsorption clays. In its initial phase, the project is projected to have a production capacity of 5,000 metric tons per year of Total Rare Earth Oxides (TREO), with published reserves of approximately 300 million metric tons of clays and an average grade of approximately 0.15% REE plus yttrium. The start of operations for this project represents a significant milestone for the sector in Brazil, as it marks the resumption of commercial production and demonstrates the viability of a model based on ionic clays (DBO Engenharia Ambiental, 2018).⁶⁸

In addition to Serra Verde, other projects are moving forward in different regions and at various stages. Among them are initiatives associated with the Poços de Caldas plateau (Minas Gerais) and

68. DBO Environmental Engineering. (2018). Rare Earths Mining in Minaçu, Goiás (Serra Verde): Environmental Impact Report – RIMA. Available at: [https://www.dfc.gov/sites/default/files/esia/2025/serraverde/Project/05_Local%20Language%20Summary%20of%20ESIA%20\(RIMA\)_508.pdf](https://www.dfc.gov/sites/default/files/esia/2025/serraverde/Project/05_Local%20Language%20Summary%20of%20ESIA%20(RIMA)_508.pdf)

to new exploration fronts in Goiás and Minas Gerais. Companies such as Meteoric, Aclara, Viridis, Appia, and Atlas Critical Minerals, among others, comprise a set of projects in the research, licensing, or structuring phases, expanding the national rare earths pipeline. In some cases, progress already includes pilot-scale processing tests and the production of intermediate materials, indicating an initial convergence between mineral exploration and subsequent stages of the supply chain.

Overall, the Brazilian portfolio currently exhibits three main characteristics:

1. A predominance of projects still in the pre-operational stage, indicating that much of the country's potential still depends on geological verification, licensing, financial structuring, and technical maturation;
2. The growing importance of ion-adsorption clay deposits, which are taking on a central role in the national pipeline;
3. The sector's geographic distribution is relatively concentrated in a few states, particularly Goiás and Minas Gerais, which are emerging as the sector's main hubs.

Taken together, these factors show that Brazil already has a robust geological foundation and a portfolio of projects in the consolidation phase, but is still in the process of building up its production scale. The existing potential is significant; however, its conversion into sustained and competitive production will depend on the progress of projects currently in the maturation phase, as well as other factors such as the institutional, regulatory, technological, and financial environment, which will be discussed in the following sections.

TABLE 23

Summary of the main REE projects under development in Brazil

Project/Company/Pre-dominant capital	Location	Project	Deposit Type	General Stage	Resource (Mt)
Serra Verde (USA)	Minaçu (GO)	Pela Ema	ionic adsorption clays	operation / expansion	911
Meteoric (Australia)	Poços de Caldas (MG)	Caldeira	ionic adsorption clays	permitting / pilot project	1,497
Aclara (Canada)	Goiás	Carina	ionic adsorption clays	permitting / pilot project	298
Viridis (Australia)	Minas Gerais / Goiás	Colossus	ionic adsorption clays	permitting / pilot project	493
Brazilian Critical Minerals (Australia)	Apuí (AM)	Ema	ionic adsorption clays	Research and Development	341

Sources: Prepared by the authors based on interviews and specialized reports.⁶⁹

69. Aclara Resources Inc. (November 2025). *Revitalizing the Supply of Heavy Rare Earths: Corporate Presentation*. / Brazilian Critical Minerals Limited. (2025). *Annual Report – June 30, 2025*. / Meteoric Resources NL. (February 2026). *Caldeira Rare Earth Project: RIU Explorers Conference*. / Denham Capital & Arsago. (August 2016). *Serra Verde Rare Earth Project: Geology*. / Viridis Mining and Minerals Ltd. (February 2026). *Colossus Ionic Clay Project: Investor Pack*. / CEBRI. 2025. *Brazil's Role in the Global Agenda for Critical and Strategic Minerals: Projected Demand and Brazil's Potential Contribution to the Energy Transition*.

TABLE 24

Project Status of Brazilian Companies Focused on Rare Earths

Companies / Stages	Confirmed Deposit	Mineral Resource	Mineral reserve	Preliminary Economic Assessment (PEA/ Scoping Study)	Pre-feasibility study (PFS)	Definitive Feasibility Study (FS or BFS)	Preliminary License / Installation / Operation	Pilot plant	Operation
Serra Verde	X	X	X	X	X	X	X	X	X
Meteoric Resources	X	X	X	X	X		X	X	
Aclara Resources	X	X	X	X	X	X		X	
Viridis Mining	X	X	X	X	X		X		
Brazilian Critical Minerals	X	X		X					
St. George Mining	X	X							
Appia Rare Earth &	X	X							
Brazilian Rare Minerals	X	X							

Source: Prepared by the authors.

3.3. Assessment of the Rare Earths Value Chain in Brazil

An analysis of the rare earths value chain in Brazil points to a sector in transition, with concrete progress in mining, technological development, and institutional coordination. Even so, the chain remains sparsely developed and marked by significant asymmetry among its links. While the upstream sector shows more tangible progress, the midstream and downstream segments still exhibit low industrial maturity, with initiatives concentrated at the laboratory, pilot, or demonstration scale. In the area of circularity, although there are promising signs, development is still in its infancy and depends on the consolidation of technological, regulatory, and market foundations.

This pattern reveals the main characteristic of the Brazilian sector at present: there is a combination of relevant geological, scientific, and institutional assets, but they are not yet sufficiently integrated to sustain a complete national value chain, from extraction to industrial processing. In practical terms, this means that Brazil has made progress in revitalizing the mineral sector and is beginning to build capacity in the subsequent stages. Considering the range of projects at different stages of maturity, it is estimated that the country could add, in the medium term, a significant volume of TREO production in the range of tens

of thousands of metric tons annually, with the potential to position Brazil as a major supplier on the global stage. However, the country has not yet established, on an economically viable scale, the processes for individual separation, refining, metallurgy, and the manufacture of higher-value-added end products, such as permanent magnets.

TABLE 25

Assessment of the Rare Earths Sector in Brazil

Link in the Chain	Current situation	Key players/initiatives	Maturity	Main bottleneck	Key opportunity
Upstream	Production resumed and pipeline expanding	Serra Verde; projects under development in GO and MG; companies in the exploration and licensing phase	Medium	Low production diversification and concentration on a few projects	Consolidate Brazil's position as a reliable supplier and expand production based on viable projects and byproducts
Midstream	Industrial capacity still very limited; progress in pilot and demonstration projects	Initiatives by Meteoric, Viridis, technology centers, laboratories, and pilot plants	Low	Separation and refining not yet established on a commercial scale	Develop selective midstream operations, starting with higher-purity carbonates/oxides and the separation of key elements
Downstream	Emerging industrial base; efforts focused on alloys, prototypes, and magnets	CIT Senai ITR, MagBras, universities, ICTs, and partner companies	Low	Lack of industrial scale, anchor demand, and integration with the midstream	Move forward with alloys, magnetic powders, semi-finished magnets, and, progressively, permanent magnets
Circularity	An emerging field, not yet industrially structured	R&D projects, waste reuse, secondary sources, and recycling initiatives	Low	Scattered supply of waste, small scale, and routes still in the process of consolidation	Structuring the recycling of industrial scrap, mineral waste, and the recovery of REE from byproducts and tailings

Source: Prepared by the authors.

Upstream

The upstream segment is currently the most developed part of the rare earths supply chain in Brazil. The country has a broad and diversified geological base, a growing portfolio of projects, and, since 2024, has resumed commercial production of rare earths with the start of operations at Serra Verde in Minaçu (GO), using ionic clay deposits. This advancement represents an important milestone, as it demonstrates the viability of domestic production on a commercial scale and lends greater credibility to Brazil's potential in the sector.

In addition to Serra Verde, the growing number of exploration permits, investments in mineral exploration, and the progress of other projects at various stages of development indicate that Brazil's upstream sector is expanding. Goiás and Minas Gerais are emerging as the main hubs, combining the availability of mineral resources, projects under development, and greater coordination among companies, subnational governments, and supporting institutions.

This analysis focuses on projects that are already at an advanced stage of development—that is, projects for which the existence of mineral deposits has already been confirmed, but which require further progress in the areas of environmental licensing, engineering studies, and social impact assessment and mitigation.

The economic evaluation of mining projects typically relies on a relatively well-defined set of variables: the capital expenditure required to establish the operation, recurring production costs, potential revenue from product sales, and the expected margin over the asset's lifetime. For many commodities, even though there are significant differences between deposits and processing routes, these indicators provide a reasonably stable starting point for comparing assets, identifying relative competitiveness, and estimating economic attractiveness.

In the case of rare earths, however, this interpretation requires an additional degree of methodological caution. This is because—unlike other mineral products—we are not dealing with a single homogeneous product, but rather with a group of 17 elements with distinct properties, industrial applications, and market values, whose production generally takes the form of a set of elements rather than a uniform commodity. The direct consequence is that the attractiveness of a rare earth elements (REE) project stems not only from the existence of mineralization but also from the ability to convert that mineralization into an effectively marketable product, on an adequate scale, with acceptable specifications and at a cost compatible with the market.

This is why the economics of a rare earths project depend on a greater number of critical variables than in most conventional mineral projects. Grade alone explains very little. The composition of the elements present (the “basket”), the mineralogy of the deposit, the chosen processing route, metallurgical recovery, the presence of impurities, and the stage of the product actually sold to the market all have a decisive influence on the economic outcome. Two projects that, at first glance, appear comparable in terms of volume or grade may yield radically different economic outcomes if one of them contains elements with a higher unit value, employs a simpler metallurgical process, requires fewer purification steps, or is able to capture greater value in more downstream segments of the value chain. In the rare earths sector, therefore, the economic analysis must necessarily integrate geology, engineering, product, and market considerations, as detailed in the table below.

TABLE 26

Competitiveness Indicators

Variable	What it measures	What it consists of / main components	Why it is important	Interpretation Considerations
CAPEX (US\$)	Capital expenditure required to implement the project and bring it online	Mine, processing and beneficiation plant, energy and water infrastructure, logistics access, auxiliary facilities, engineering, contingencies, start-up costs, and, where applicable, environmental requirements and impurity treatment	Indicates the scale of the financial commitment required from the developer and the financier. Helps to gauge the practical feasibility of implementation and the barrier to entry for the asset	The absolute value, on its own, does not reveal relative efficiency. Projects with a broader industrial scope or greater metallurgical complexity naturally tend to require higher CAPEX
CAPEX intensity per unit of processing	Ratio of invested capital to processing capacity	US\$ per metric ton processed	An indicator of a project's competitiveness related to its ability to process efficiently. It pertains to exogenous favorable factors, such as the deposit's geometallurgical characteristics, ease of extraction, energy costs, etc.	It relates more to factors external to the production process
CAPEX Intensity by Product	Ratio of capital invested to unit of capacity or delivered production	US\$ per kg of TREO produced	Project competitiveness indicator related to the efficiency of the processing stage of the deposit. It refers to the ability of the designed metallurgical process to deliver product in economically viable quantities	It relates directly to the metallurgical process route and its capacity to recover the various REEs. However, it does not incorporate the maximization of the basket based on market price or liquidity
OPEX	Recurring costs required to operate the asset over the project's lifetime	Mining operations, processing, reagents, energy, water, maintenance, labor, internal logistics, disposal of tailings and waste, environmental management, and additional operational requirements, such as the separation of radionuclides where applicable	It is central to assessing long-term competitiveness, as it indicates the project's ability to sustain production at a cost consistent with expected revenue.	Low OPEX does not guarantee greater attractiveness if it is associated with lower-quality product, lower metallurgical recovery, or a higher commercial discount

Basket price	A proxy for the potential revenue associated with the mix of elements produced by the project	Reflects the combination of elements present or recovered and their reference prices, weighted by each element's relative share in the basket	This is particularly relevant for rare earths because the economic value depends on the composition of the set of elements, and not just the aggregate volume produced	It should not be confused with realized revenue. Actual recovery, the stage of the product sold, purity, specifications, impurities, commercial discounts, and market liquidity can materially reduce the value captured
Operating Margin	An estimate of the project's operating profitability before considering the capital structure	In analytical terms, it results from the interaction between realized price, metallurgical recovery, product quality, and operating cost	It is one of the indicators that most directly reflects the economic attractiveness of the asset, as it reflects the ability to convert revenue into operating income	High margins may reflect aggressive assumptions regarding price, ramp-up, purity, marketing, or metallurgical efficiency. They should always be interpreted in light of the technical and commercial assumptions that underpin them

Source: Prepared by the authors.

In general terms, as has already been discussed in other sections, Brazil has promising REE mining projects in three distinct categories: (a) ionic clays (IAC), (b) heavy sands (HSM), and (c) hard rock. The existence of behavioral patterns regarding the technical and economic assumptions of such projects is now considered established fact, such that there is a predictable economic performance for each type of project.

TABLE 27

Technical Parameters and Deposit Types

Parameters	Ionic Clays (IAC)	Heavy Sands (HSM)	Hard Rock
Average grade	Low/Medium	Medium/High	High
CAPEX	Low	Low/Medium	High
OPEX	Low	Low/Medium	Medium/High
Operating margin	High	Medium/High	Low/Medium
Probability of radionuclides	Low/Medium	High	High

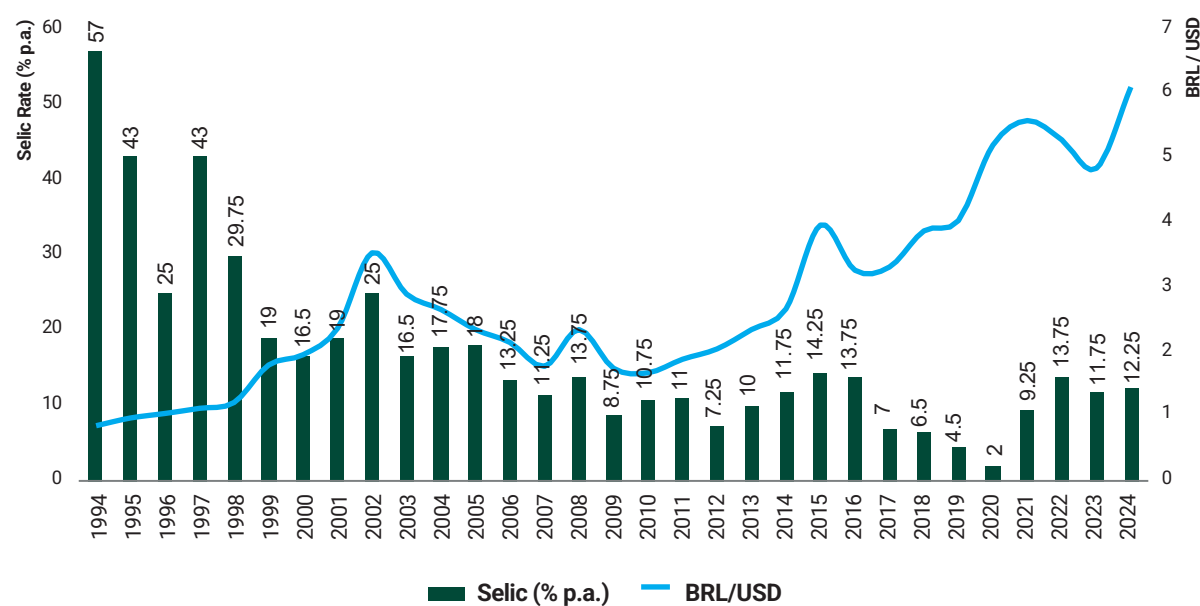
Source: Prepared by the authors.

Today, in Brazil, the projects that are most advanced in terms of technical and operational development are those involving ionic clays, notably represented by Serra Verde, Meteoric, Viridis, Aclara, and Brazilian Critical Minerals. Other heavy sand projects, such as Brazilian Rare Earths, and hard-rock projects, such as St. George Mining, are still in the mineral exploration phase and have not yet tested and proven the technical and economic feasibility of their projects, even though initial results are promising.

In the case of Brazil, the economic analysis must also incorporate an additional structural dimension: the cost of capital. Historically, the country has operated in an unstable macroeconomic environment, with high exchange rate volatility and very high base interest rates, which makes the economic environment less favorable for capital-intensive ventures with high geological risk. This factor weighs particularly heavily during the mineral exploration and initial development phases, when risk is highest and the predictability of returns is still limited. As a result, rates of return that may seem attractive from the perspective of international investors do not always offer the same relative premium to domestic capital. This helps explain the recurring importance of foreign capital in making mineral projects viable in Brazil, particularly in emerging or still-consolidating sectors.

FIGURE 10

Brazilian Exchange Rate and Base Interest Rate



Source: Bacen.

In the case of rare earths, given the growing strategic importance of these minerals and the stated goal of major powers—such as the United States—to diversify their supply sources, foreign capital participation and involvement have reached a new level.

The recent case of Mineração Serra Verde is a concrete example of this dynamic. On April 20, 2026, USA Rare Earths—a company listed on the U.S. Nasdaq stock exchange and whose primary shareholder is the U.S. government—announced the acquisition of the Serra Verde Group. In addition to the acquisition, a 15-year supply agreement was also signed with a Special Purpose Entity (SPE), capitalized by U.S. government agencies and private investors, which will fully absorb the production from Phase I of the Pela Ema project in Minaçu (Goiás), with guaranteed minimum prices for neodymium, praseodymium, dysprosium, and terbium.

The company's stated intention is to create a multinational platform with assets in Brazil, the United States, France, and the United Kingdom, covering the entire value chain—from mining to the manufacture of permanent magnets—and positioning Serra Verde's operations as the upstream hub of one of the first integrated "mine-to-magnet" rare earths chains outside of Asia. This includes USAR's downstream assets, such as the rare earth metals and alloys manufacturer Less Common Metals (LCM) in the United Kingdom; a magnet plant in Stillwater, Oklahoma; and the Round Top deposit in Texas.

The announced package is bolstered by a \$565 million financing facility already secured from the U.S. International Development Finance Corporation (DFC), intended to optimize operations in Brazil, expand production capacity, and improve the product. Together with the merger and the long-term supply contract with minimum prices, this arrangement constitutes a robust de-risking mechanism—still relatively uncommon in the rare earths sector^{70,71}. This mechanism reduces commercial risk and facilitates financing by guaranteeing long-term demand, which should contribute to production expansion. On the other hand, in the short term, this means that, in the absence of an agreement among the countries, all of the carbonate currently produced in Brazil must be exported for processing abroad, delaying the domestic implementation of higher-value-added stages in Brazil.

This complex economic environment can serve as a criterion for selecting projects based on merit, given that the projects that tend to move forward possess unique characteristics compared to their domestic and international counterparts. In the case of REE projects, Brazil possesses geological conditions that, in some cases, appear to favor potentially competitive cost structures, with lower capital intensity and lower operating costs than those observed in more complex projects involving other commodities or in certain international jurisdictions. This potential advantage is associated, in certain deposits, with favorable geology, relatively lower complexity of mineralization, potentially simpler processing routes, a competitive energy base, and a more moderate scale of investment. However, this argument should be treated with caution. These advantages are neither automatic nor universal; they depend on the specific quality of the deposit, the processing route, the intended final product, the available infrastructure, and, above all, the project's execution capacity. In other words, Brazil may have the conditions to produce highly competitive upstream projects, but

70. <https://www.brasilmineral.com.br/noticias/serra-verde-anuncia-fusao-com-a-usa-rare-earth-e-fecha-contrato-de-15-anos-para>

71. <https://investors.usare.com/static-files/51392825-c0d8-41cb-a604-0842d6a5dfa1>

this advantage must be demonstrated on a case-by-case basis and cannot be assumed in advance.

Finally, any economic assessment of Brazilian projects involving rare earths must recognize that their competitiveness will continue—at least for the foreseeable future—to be determined by the structure of the international market and by China’s central role in the global midstream sector. Today, the supply chain remains highly concentrated in the stages of separation, refining, and magnet manufacturing, which means that the price and marketability of upstream products continue to be largely influenced by a buyer and processor market dominated by Chinese actors. This does not eliminate the economic space for competitive projects in Brazil; on the contrary, it can ensure demand for products that are well-positioned in terms of cost and quality. However, it imposes an important limitation on the interpretation of value: upstream competitiveness does not automatically equate to industrial autonomy or the full capture of value throughout the value chain.

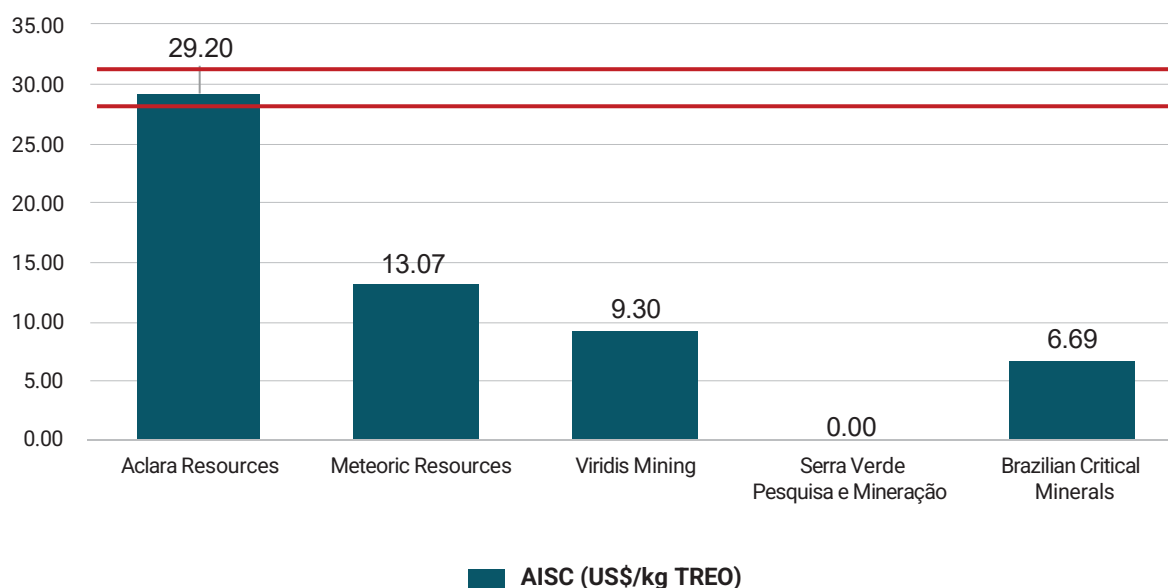
Brazil vs. China Competitiveness Analysis - Upstream

It is particularly complex to compare the production costs of specific projects with today’s most relevant global benchmark: China. China’s rare earths supply chain is integrated and, in practice, vertically integrated. As a result, intermediate prices—such as those for concentrates, mixed carbonates, oxides, etc.—are merely transfer prices within the supply chain as a whole. Depending on corporate or government objectives, these prices may be set higher or lower, generating profits or losses at different points in the chain—which may be absorbed in light of broader strategic interests.

However, this study made a methodological effort to compare the Chinese cost structure with that of other countries. A calculation method used in the market involves determining the cost of production based on a set of the most relevant elements: neodymium (Nd), praseodymium (Pr), dysprosium (Dy), and terbium (Tb)—all of which are magnetic REEs and extremely important for the production of permanent magnets, a product that currently dominates the sector’s economic significance.

Argus Media, a market intelligence firm, estimates the production cost of REE in China at \$75–80/kg NdPr (Argus Media, 2025). Considering that the typical Nd/Pr content in a mining project in China is in the range of 20–25% and that the Nd/Pr share of the “basket price” is in the range of 50–65%, a production cost benchmark of US\$ 75–80/kg NdPr would imply an equivalent cost of approximately US\$ 29–31/kg TREO.

FIGURE 11

All-In Sustaining Cost ⁷²

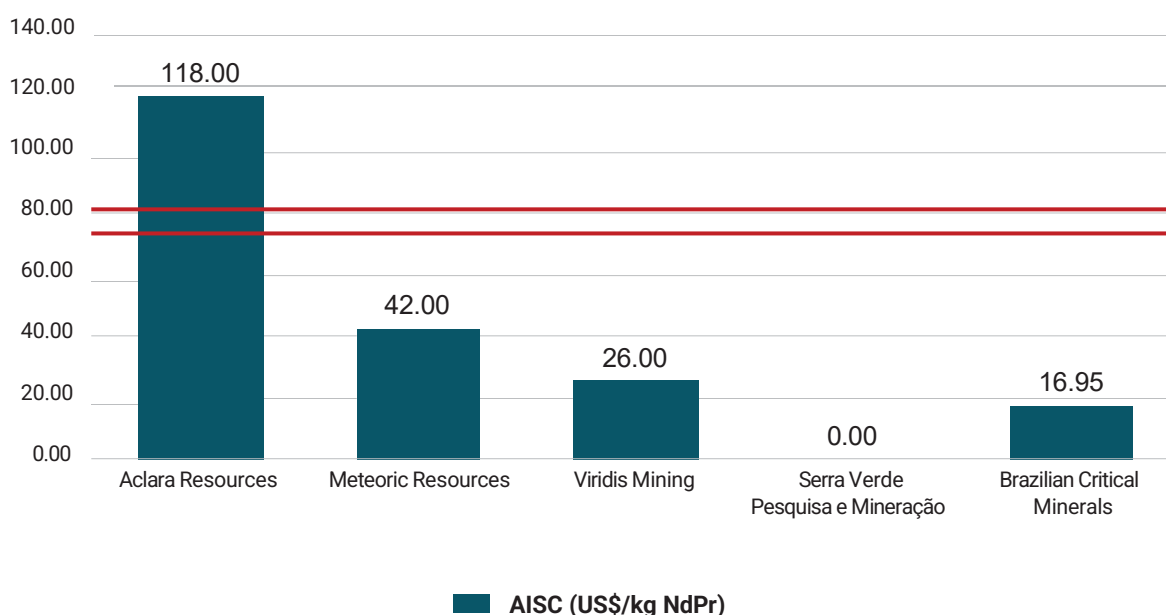
Source: Prepared by the authors, based on information from company reports.

From this perspective, it is possible to assess the significant cost competitiveness of Brazilian projects compared to the Chinese benchmark. However, a caveat is warranted regarding the Aclara and Serra Verde projects. The Carina Project, as extensively documented in its technical reports, employs a distinct value-creation strategy through the integration of the supply chain with oxide separation units and permanent magnet production facilities located alongside the mine. Serra Verde, on the other hand, does not disclose technical data that would allow us to conduct this analysis.

Conversely, from the perspective of the Brazilian projects, it is possible to calculate the operating cost per unit of Nd/Pr produced. In this context, the Carina (Aclara), Caldeira (Meteoric), and Colossus (Viridis) projects would have costs of US\$ 118/kg NdPr, US\$ 42/kg NdPr, and US\$ 26/kg NdPr, respectively.

72. A key indicator of competitiveness in the mining sector, used to measure the cost of producing one ounce (oz) of metal.

FIGURE 12

Operating cost expressed in terms of Nd/Pr production

Source: Prepared by the authors, based on information from company reports.

This chart also demonstrates the competitiveness of Brazilian projects compared to the Chinese benchmark. In this analysis, the Carina project stands out from the others due to its unique characteristics and strategy focused on value capture throughout the value chain, as well as because of the Dy/Tb credits—which are not included in this analysis, as it focuses exclusively on Nd/Pr. In this sense, it should not be considered a sign of a lack of competitiveness, even though there are clear technical differences between the projects.

With regard to the competitiveness of Brazilian projects aimed at selling MREC to China, it can be said that the historical benchmark of competition with China's lower-cost domestic supply has become less favorable than in the past. This change does not stem, strictly speaking, from a general ban on in-situ leaching, but rather from a stricter regulatory framework for the rare earths sector in China. The Regulations on the Administration of Rare Earths (State Council Decree No. 785), promulgated on June 22, 2024, and the issuance of the Interim Measures for the Control of the Total Volume of Rare Earth Mining and Smelting/Separation (Interim Measures for Total Volume Regulation of Rare Earth Mining and Smelting/Separation—MIIT/NDRC/MNR Order No. 71), issued in July 2025, tighten regulations on mining, subject the activity to total volume control, and impose requirements for traceability, environmental compliance, and crackdowns on the circulation of products derived from illegal mining or separation. In economic terms, this regulatory framework reinforces the view that part of the downward pressure historically associated with Chinese domestic production—which has been more disorganized, permissive, and characterized by artificially low marginal costs—tends to lose relative relevance as a benchmark for the current system.

According to Argus' assessment, prices for rare earths are expected to continue rising in 2026, converging toward more sustainable levels above the average cost of production

in China, estimated at around US\$75–80/kg on an NdPr basis. This expectation stems, on the one hand, from the low probability of an expansion in Chinese production quotas and, on the other, from supply constraints outside China, driven by historically low prices and negative margins. In this context, the combination of structural supply constraints and a more tense geopolitical and trade environment tends to sustain upward pressure on Chinese prices for rare earths used in permanent magnets, reinforcing the perception of a market still marked by strong sensitivity to regulatory decisions and imbalances between supply and demand.

In summary, the economic analysis of rare earths projects cannot be conducted by examining isolated indicators. CAPEX, capital intensity, OPEX, basket price, and margin are essential variables, but they only become truly informative when considered together and in light of the technical and commercial context of each asset. The true competitiveness of a rare earth project stems from a combination of geology, engineering, product, market, capital structure, and regulatory environment. It is through this analytical framework—rather than superficial comparisons—that the following section will examine the selected projects and identify, with greater precision, their advantages, limitations, and risks.

CAPEX

In this context, CAPEX remains the primary measure of the capital investment required to bring a project online. For assets such as REE projects, it is particularly sensitive to factors such as:

- project location;
- need for complementary infrastructure;
- access to electricity and water;
- logistical conditions;
- mining method;
- overburden volume; and
- complexity of the beneficiation and chemical processing plant.

Additional requirements related to the treatment of impurities, environmental management, and, in some cases, the need to handle radionuclides can also substantially increase this effort. Absolute CAPEX matters because it reflects the magnitude of the financial commitment required of the developer and, in certain circumstances, of the financier or the government itself. In emerging sectors, it also helps assess the practical feasibility of implementation, especially when the technology, the supply chain, and the buyer market are still in the process of consolidation.

Still, absolute CAPEX, on its own, says little about relative efficiency. For this reason, capital intensity is a particularly useful indicator when comparing projects. Depending on the methodological framework adopted, it can be expressed in metrics such as dollars per metric ton processed, dollars per kilogram of TREO produced, or other equivalent units. This metric allows us to understand how much capital the chosen technological route requires

to produce a given unit of output. However, the usefulness of the comparison depends entirely on the equivalence of the bases under consideration. Projects that involve more advanced chemical processing, a higher degree of product segregation, additional purification steps, or more complex treatment of impurities naturally tend to exhibit higher capital intensity. In other words, high capital intensity may reflect inefficiency, but it may also be the logical consequence of a more sophisticated final product or a more comprehensive industrial process.

OPEX

The same reasoning applies to OPEX. In REE projects, operating costs are not limited to mining and processing; they typically reflect, to a significant degree, reagent consumption, energy intensity, water availability and treatment, tailings and waste management, the metallurgical complexity of the process, and the required purity level of the final product. For certain assets, additional environmental or operational requirements can have a material impact on the cost structure. Therefore, OPEX is central to assessing long-term competitiveness, but it only gains real significance when interpreted in conjunction with product quality, effective recovery rates, and potential revenue. A project with a lower apparent cost may, in practice, capture less value if it sells a simpler product with lower grade, lower purity, or larger commercial discounts.

Basket price

Among the most characteristic indicators of this segment is the basket price, which serves as an estimate of the potential revenue associated with the set of elements contained in or recovered by the project. Its relevance stems from the fact that, in REE, economic value depends not only on the total volume produced but also on the relative composition of that set. Projects with a higher proportion of elements with greater unit value tend, in principle, to have greater potential for value capture. Nevertheless, the basket price should not be confused with actual revenue. There is an important difference between the theoretical basket price and the price actually obtained in the market, and this difference reflects factors such as metallurgical recovery, the stage of the marketed product, material content and specifications, purity, the presence of impurities, commercial discounts, and the liquidity of the buyer's market. An illustrative example, drawn from the scope of this analysis itself, is that Aclara projects a concentrate with a TREO content close to 95%, while Meteoric and Viridis project concentrates with a content below 60%; even though all are rare earths projects, economic equivalence among these products cannot be assumed.

Operating Margin

The expected margin, in turn, is the indicator that most directly links operational profitability to the asset, as it results from the interplay between price, recovery rate, and cost. In theory, it provides a powerful snapshot of the project's economic attractiveness. In practice, however, high margins warrant scrutiny. For REE assets, especially those still in the feasibility study phase, an apparently robust margin may be based on

aggressive assumptions regarding price, metallurgical efficiency, operational ramp-up, marketing, or the ability to place the product in specific markets. It is reliable only when the technical and commercial assumptions underpinning it are equally robust.

This caution is even more important because comparability among rare earths projects is, by nature, limited. Different companies may report their metrics on non-equivalent bases: Run of mine versus ore fed into the plant; contained TREO versus recovered TREO; concentrate versus intermediate product versus separated oxides; mine cost versus cost incorporating more advanced chemical processing. Direct comparisons of CAPEX, OPEX, capital intensity, basket price, and margin can thus lead to erroneous conclusions when there is no prior standardization of concepts and calculation bases. In a sector where small differences in scope can substantially alter the economic assessment, methodological discipline is not merely an academic refinement; it is a prerequisite for serious analysis.

Based on the observations above, which are essential for understanding Brazil's rare earths upstream sector, the table below compiles the key technical and economic variables that highlight the sector's competitiveness within the industry as a whole.

TABLE 28

Competitiveness Analysis: Selection of Technical and Economic Variables for Key players in Brazil

Parameter	Aclara Resources	Meteoric Resources	Viridis Mining	Serra Verde Pesquisa e Mineração	Brazilian Critical Minerals
Project Name	Carina	Caldeira	Colossus	Pela Ema	Ema
Project Stage	FS	PFS	PFS	N/A	Scoping Study
LOM Mineral Resource (Mt)	170.90	129.00	98.50	N/A	341.00
LOM Mineral Resource Grade (ppm)	1,472	3,750	3,380	N/A	746
Processing method	Ion exchange extraction / desorption	Ion exchange extraction / desorption	Ion exchange extraction / desorption	Ion exchange extraction / desorption	In-situ leaching
ROM processing capacity (ktpa)	9,700	6,000	5,000	N/A	N/A
Production of REE Mixed Carbonate (MREC) (metric tons per year)	7,297	25,776	N/A	N/A	8,700
MREC content (% TREO, wet basis)	60%	53%	N/A	N/A	N/A
TREO Production (tpa)	4,378	13,584	9,500	6,500	4,800
TREO Recovery (%)	25.5%	55.0%	57.0%	N/A	48.0%

CAPEX (US\$ MM)	780.90	443.40	358.00	682.00	55.00
Capital intensity (US\$/ktpa ROM)	80.50	73.90	71.60	N/A	N/A
Capital intensity (US\$/kg TREO)	178.37	32.64	37.68	104.92	11.46
OPEX – Cash Cost (US\$/t)	13	21	12	N/A	N/A
OPEX – All-In Sustaining Cost (US\$/kg TREO)	29	13	9	N/A	7
OPEX – All-In Sustaining Cost (US\$/kg NdPr)	118	42	26	N/A	17
Basket Price (US\$/kg TREO)	209.00	33.00	43.00	N/A	30.93
Payability	100%	70%	70%	N/A	70%

Source: Prepared by the authors, based on information from company reports.

Despite this progress, the Brazilian upstream sector still faces limitations. Production remains concentrated in a small number of projects; most projects are still in the exploration or licensing phase; and a significant portion of the sector's efforts continues to focus on verifying resources, technical feasibility, and financial structuring. Thus, although the country already has a solid foundation for consolidating REE mining, the sector is still far from achieving the scale and diversification commensurate with its geological potential.

Midstream

While the rare earths upstream sector in Brazil is already beginning to take on a more concrete shape—with projects of recognized geological merit, potentially competitive cost profiles, and gradual progress in licensing, engineering, and structuring—it is in the midstream sector where the main frontier for value capture in the country's value chain currently lies. Brazil's major strategic leap in rare earths depends not only on bringing mines online, but also on building the industrial capacity to transform domestic mineral production into intermediate products capable of supplying global markets. It is at this stage that it will be determined whether Brazil will remain merely a supplier of raw materials and minimally processed intermediates, or whether it will succeed in retaining a more significant share of the economic, industrial, and strategic value associated with Rare Earth Elements.

This point is particularly important because Brazil already has, at least in principle, a promising upstream base. Projects such as Pela Ema, by Serra Verde; Caldeira, by Meteoric; Colossus, by Viridis; Carina, by Aclara; and Ema, by Brazilian Critical Minerals, indicate that the country can consolidate a significant domestic supply of rare earth concentrates and mixed carbonates, particularly from ionic clay deposits and processing routes already under development. This fundamentally changes the debate on the industrialization of the supply chain: the problem in Brazil is no longer the existence of production but rather

it is increasingly a matter of separating and refining within the country itself what we are already able to produce in an extremely competitive and cost-effective manner.

Today, however, this transition has not yet taken place. Despite the progress observed in applied research, the development of processing routes, and bench-scale and pilot-scale testing, Brazil still lacks a consolidated industrial capacity to process upstream products on a commercial scale. Even with the expected increase in the production of concentrates and MREC, domestically produced materials still lack an industrial base within the country capable of absorbing them and converting them, on a regular and competitive basis, into higher-purity separated oxides, metals, or alloys. In practice, therefore, the country has not yet internalized precisely the link that, internationally, represents one of the greatest bottlenecks in the global rare earths supply chain.

This bottleneck is both industrial and geopolitical. The midstream is currently one of the most sensitive segments of the entire global REE chain, because it is here that the rest of the world's dependence on China becomes most acute. The stage involving the chemical separation of elements—especially the oxides of greatest economic interest, such as Neodymium, praseodymium, dysprosium, and Terbium—remains heavily concentrated in a few jurisdictions, with clear Chinese dominance in terms of scale, operational experience, supplier base, workforce skills, access to ancillary industries supplying reagents and solvents, and integration with subsequent links in the chain. Thus, while the upstream sector can diversify geographically relatively quickly, the midstream sector remains the true bottleneck for global diversification.

From an economic standpoint, this link has an important characteristic: it is, in essence, an industrial stage with low product differentiation. The work of the midstream sector consists primarily of transforming mixed streams from mining and chemical processing into separate, standardized products—primarily individual Rare Earth Oxides and, in subsequent stages, metals and alloys. Once the commercial specifications required by the market are met, an oxide of neodymium, praseodymium, dysprosium, or terbium is, to a large extent, undifferentiated: it is the same product in Brazil, China, or any other country. In this sense, the midstream can be understood as the last major “commoditized” frontier in the rare earths supply chain. Here, the key determining factor tends to be economic competitiveness: whoever can deliver the specified product at a lower cost, with greater operational reliability, and with less execution risk will come out ahead.

This does not mean that the midstream is trivial. On the contrary: it is a technically demanding stage that requires extensive knowledge of processes, chemical control, plant engineering, and operational discipline. However, once the production route has been mastered and industrial capacity established, competition comes to depend primarily on economic variables. Unlike more downstream segments, where relationships with product or component manufacturers (Original Equipment Manufacturers, OEMs), qualification with end buyers, integration with specific industrial chains, and long-term corporate strategies carry greater weight, in the midstream the core of the competition is more straightforward: feedstock costs, energy costs, labor costs and productivity, the regulatory environment, the tax burden, infrastructure, and logistics. In short, it is a segment where competitive advantages are more tangible and measurable—and also a segment where

financial and tax incentives aimed at reducing CAPEX and OPEX are particularly important. From this perspective, Brazil possesses certain attributes that, at least in theory, could make it a significant competitor. The first is potential access to competitive domestic feedstock from projects that have already demonstrated the capacity to produce—or are expected to produce—economically viable streams of Nd, Pr, Dy, and Tb—precisely the elements of greatest value and strategic importance for permanent magnets. The second is the possibility of combining this mineral supply with a favorable energy infrastructure, especially if the country can offer predictable rates and stable access to energy for energy-intensive chemical plants. The third is the existence of technical human capital which, although still insufficient in scale, can be developed at competitive costs, especially if there is coordination among companies, technology centers, and training institutions. Added to this is the importance of a secure legal environment, a tax system compatible with the capital-intensive nature of the activity, and adequate logistics infrastructure for the distribution of inputs and products.

At the same time, it must be acknowledged that there is still a significant gap between technological demonstration and large-scale industrial implementation. The progress made in pilot plants, the experimental production of intermediates, and the activities of companies and technology centers show that the Brazilian midstream sector is beginning to move beyond the laboratory stage. This is significant and should not be underestimated. Furthermore, the country still relies heavily on imports of specialized chemical inputs, such as organic extractants and separation reagents, as well as equipment, services, and technical capabilities, highlighting a gap in domestic capacity to support the refining and separation stages. Even so, there is a considerable industrial leap between proving the process and operating a stable commercial plant with the necessary scale, yield, impurity control, cost discipline, and market penetration. It is precisely in this gap that the greatest challenges in financing, execution, and coordination concentrate.

Therefore, the most concrete opportunity for Brazil does not seem to lie in envisioning, from the outset, a fully vertical and comprehensive supply chain, but rather in pragmatically developing a midstream sector anchored in domestic production that is already contractable or foreseeable from the major projects currently under development. Instead of approaching the issue abstractly, the country can start from a logic grounded in real industrial capacity: building separation and refining capacity based on the volume potentially supplied by projects in more advanced stages, such as those of Serra Verde, Meteoric, Viridis, Aclara, and Brazilian Critical Minerals, which have mineral resources disclosed in accordance with international technical standards and at least one preliminary economic assessment study. This point is central because the viability of the midstream sector depends, first and foremost, on feedstock scale, supply predictability, and competitive raw material acquisition costs. Without these factors, industrialization remains merely an intention; with them, a concrete basis for investment is established.

In this context, the Brazilian midstream sector should be understood as the bridge between the country's geological potential and any more ambitious goal of industrial integration into the global rare earths supply chain. It is through this link that Brazil can capture more value, reduce its dependence on foreign sources, and build greater production autonomy. But it is also here that international competition

is even more blunt: the winner will be whoever offers the best combination of cost, scale, reliability, and business environment. The geopolitical factors currently at play create conditions for countries to override economic logic and strike international agreements backed by offtakes, investment commitments, and the construction of industrial plants to support them. This situation could lead to jurisdictions less competitive than Brazil's—thanks to their governments' strategic planning capabilities—successfully attracting the siting of these facilities. Therefore, even though Brazil enjoys these competitive advantages, it cannot afford to waste time in combining its economic and competitive potential with active engagement on the international stage, in order to solidify the understanding that the country is an excellent partner for establishing an industrial plant in this supply chain—whether for oxide separation or the production of metal alloys.

The midstream—understood here as the stage in which separated oxides, metals, and alloys are produced—is, to a large extent, the final frontier of the undifferentiated stages of the rare earths industry. From this point onward, although cost remains a decisive factor, relationships with end buyers, industrial qualification processes, proximity to consumer sectors, and integration into denser, context-specific production chains—such as those for permanent magnets, motors, defense, electronics, and the energy transition—gain increasing importance. In other words: if the upstream sector is geology and mining, and the midstream sector is pure industrial competitiveness, the downstream sector is, to a greater extent, relational industrial strategy. This is why Brazil's progress in the midstream sector is so crucial: without it, the discussion about capturing more sophisticated stages downstream remains premature.

TABLE 29

Competitiveness Factors for Midstream Development in Brazil

Competitiveness Area	What this means for the midstream
Competitive feedstock (continuity, scale, and prices)	Stable, low-cost access to concentrates and/or MREC from domestic projects.
Competitive and stable energy	Availability of energy at predictable prices and with operational reliability for energy-intensive chemical plants.
Infrastructure and logistics	Transportation of inputs and products, access to water, reagents, equipment, and physical integration with the upstream sector.
Appropriate taxation	A tax structure compatible with capital-intensive, chemical, and export-oriented activities.
Technical Capability and Process Know-How	Mastery of separation routes, purification, impurity control, yield, and continuous operation are not trade secrets. However, they require continuous effort on the part of producers to refine the process route to optimal parameters for their project.
Skilled and available workforce	Process engineering, chemical operations, maintenance, quality control, and industrial management.
Secure legal environment	Legal certainty, regulatory predictability, and institutional stability for long-term investment.
Supplier base and industrial inputs	Access to reagents, solvents, equipment, EPC, and specialized services.

Source: Prepared by the authors.

Downstream

The downstream sector remains the least developed link in the national industrial chain, although it is developing technological and institutional capabilities. The country still lacks consolidated commercial production of rare earths-based permanent magnets on a significant scale, as well as a mature industrial base for special alloys, magnetic components, and advanced applications. Consequently, Brazil remains dependent on imports of higher-value-added products, even though it possesses mineral resources that could, in theory, support part of this production in the future.

On the other hand, the Brazilian downstream sector is not starting from scratch. There are significant initiatives aimed at building technological and industrial capabilities, especially in the field of Neodymium-iron-boron (NdFeB) permanent magnets. The existence of laboratories, pilot plants, and industrial demonstrators associated with the SENAI ecosystem and the MagBras program signals a concrete effort to build a path toward industrialization that goes beyond mineral extraction. This perspective suggests that the main challenge is to transform this promising technological project into a scalable economic activity integrated with domestic industrial demand.

A more realistic path for the country involves moving forward in stages: first with metals, alloys, magnetic powders, and semi-finished magnets; then, progressively, with permanent magnets and more sophisticated components. This approach reduces risk, facilitates industrial learning, and increases the chances of gradually capturing value.

Circularity

Circularity is still in its infancy in Brazil's rare earths supply chain, but it is already emerging as a strategic frontier. The concept manifests itself in two main directions:

1. Utilization of secondary sources derived from mining activities, such as tailings, by-products, and residues from associated supply chains, such as niobium, tin, and bauxite;
2. Recycling of industrial and post-consumer materials, especially permanent magnets and electronic waste (WEEE).

Brazil has a large volume of electronic equipment in circulation that, at the end of its useful life, can be processed to recover these secondary materials. The Brazilian electronics industry has grown strongly in recent years, particularly in the production of air conditioners, which has reached record levels and made Brazil the world's second-largest manufacturer, behind only China,⁷³ in addition to the strong performance of brown and white goods. Despite high production and a high degree of self-sufficiency—with 97% of appliances assembled domestically—the sector remains heavily dependent on imported components, primarily from China. Imports of electronics also increased, with the import penetration rate reaching 26.7% in 2024,

73. <https://agenciabrasil.ebc.com.br/economia/noticia/2025-03/brasil-se-toma-o-segundo-maior-fabricante-mundial-de-ar-condicionado>

the highest rate in the historical series.^{74,75}

Brazil has a well-structured legal framework for the reverse logistics of WEEE, notably the National Solid Waste Policy (PNRS) and Decree No. 10,240/2020, supplemented by GM/MMA Ordinances No. 1,560/26 and No. 1,561/26. In the specific case of medical and hospital equipment, such as magnetic resonance imaging (MRI) machines, disposal must also comply with RDC No. 222/2018 issued by the National Health Surveillance Agency (ANVISA), which regulates Good Practices for the Management of Health Services Waste (RSS). Manufacturers and importers of electronic products and household appliances are required to participate in the reverse logistics system, which currently mandates proof of collection and disposal of 17% by weight of the equipment placed on the market (base year 2018). Currently, 136 companies—including manufacturers and importers—have joined the reverse logistics system (SLR) and, either through managing entities or individually, submit annual reports verifying the mass of WEEE collected and disposed of.⁷⁶ There is still ample room for growth given the total of approximately 4,000 manufacturers, importers, and distributors subject to this legal obligation. The reverse logistics chain is expanding, with approximately 150,000 metric tons collected in 2024. However, higher-value components with a higher content of critical minerals, such as printed circuit boards, are collected in the country but mostly exported for processing abroad, highlighting a strategic opportunity to develop the industry domestically, create more jobs, and increase the value added of these materials in Brazil.

As is the case with printed circuit boards, there is still no industrial capacity in place for recycling rare earths in the country. However, initiatives are underway that aim to incorporate this component into the development of the national supply chain.⁷⁷

In Brazil, there are still no consolidated estimates regarding the potential for recovering REE from WEEE, which indicates a significant knowledge gap for sector planning. In contrast, international estimates indicate that approximately 7,200 metric tons of rare earths are lost annually worldwide due to the disposal of electronic equipment. In the European context, the Critical Raw Materials Act sets a target that 25% of the demand for critical raw materials be met through recycling. To support this objective, European initiatives, such as LIFE INSPIREE, seek to develop technological solutions for recovering rare earths contained in electronic waste, thereby contributing to supply security and reducing external dependence.

In Latin America, electronic waste management has been developed through various complementary initiatives—ranging from data collection and analysis (E-waste LATAM), to coordination among countries (RELAC Platform) and technical training (EWAM), to more structured cooperation programs, such as the Electronic Waste Project

74. <https://noticias.portaldaindustria.com.br/noticias/internacional/consumo-de-importados-por-brasileiros-e-o-maior-em-20-anos/>

75. <https://veja.abril.com.br/economia/vendas-de-eletronicos-saltam-378-de-1994-a-2024-e-atingem-130-milhoes-de-aparelhos/>

76. <https://circularbrain.io/wp-content/uploads/2025/08/Relat%C3%B3rio-de-Sustentabilidade-Circular-Brain-2024.pdf>
<https://greeneletron.org.br/blog/green-eletron-avanca-em-engajamento-dialogo-e-resultados-ambientais/>

77. FIEMG – Federation of Industries of the State of Minas Gerais. (May 22, 2025). *Brazil takes a historic step with the first delivery of recycled Rare Earth Oxides from Viridion*. <https://www.fiemg.com.br/sala-de-imprensa/noticias/brasil-da-passo-historico-com-primeira-entrega-de-oxidos-de-terras-raras-recicladospela-viridion/>

in Latin America (PREAL). Although Brazil participates in some of these initiatives, it is not part of the core group of PREAL countries, which suggests a more limited regional integration, with possible implications for data availability, supply chain integration, and technological development. In this context, strengthening regional cooperation and interaction among countries can contribute to the development of more integrated production chains—including reverse supply chains—with the potential to achieve economies of scale, efficiency, and value addition in the region.

Although there is not yet a structured rare earths recycling supply chain in the country, initiatives are underway that seek to incorporate this component into the development of the national supply chain.⁷⁸

In this context, circularity emerges as a potential tool for ensuring supply security, diversifying sources, and adding value, in addition to contributing to the environmental agenda. Its advancement, however, depends on reaching a minimum industrial scale, the availability of economically viable waste, the establishment of collection and reverse logistics systems, and, above all, the maturation of domestic technological pathways and appropriate institutional arrangements.

Another short-term opportunity is the recovery of industrial waste, tailings, and materials already mobilized by existing mineral and industrial supply chains. In the medium and long term, the trend is for circularity to become an integral part of a broader strategy to strengthen the national supply chain, linking mining, processing, manufacturing, and recycling.

3.4. Regulatory Framework and National Policies

Legislation and Regulation

The legal framework for mining in Brazil is structured in a hierarchical and integrated manner, bringing together constitutional, infra-constitutional, and infra-legal norms, as well as regulatory instruments at different levels of the federal government, as illustrated in the table below. The Federal Constitution of 1988 sets forth the foundations of the sector, stipulating that mineral resources belong to the federal government and establishing the conditions for their exploitation.

At the infra-constitutional level, the Mining Code is the primary regulatory instrument and governs the exploitation of mineral resources, the rights and obligations of licensees, and the procedures for granting exploration and mining permits. The code is supplemented by other laws and decrees, including resolutions and administrative orders, notably those issued by the National Mining Agency—which is responsible for technical regulation and oversight of the sector—and the National Nuclear Safety Authority, with regard to nuclear and radiological safety.

78. FIEMG – Federation of Industries of the State of Minas Gerais. (May 22, 2025). *Brazil takes a historic step with the first delivery of recycled Rare Earth Oxides by Viridion*. <https://www.fiemg.com.br/sala-de-imprensa/noticias/brasil-da-passo-historico-com-primeira-entrega-de-oxidos-de-terras-raras-recicladospela-viridion/>

The management of mining rights is carried out by the ANM, while the Geological Survey of Brazil is responsible for producing geoscientific information.

The various mineral exploitation regimes are set forth in the Mining Code and its Regulations; for NRES, the exploration authorization and mining concession regimes—which are complementary and interconnected—are particularly relevant. The exploration permit grants the holder the right to conduct geological studies and assess the economic potential of the deposit, while the mining concession authorizes the extraction of mineral resources, in accordance with the conditions established by the government.

In addition, mining activities are subject to environmental licensing, which is structured in accordance with the National Environmental Policy and the General Environmental Licensing Law, which establishes general rules at the national level. The legislation defines licensing procedures, types of licenses, and environmental impact assessment tools, including the Environmental Impact Assessment and its corresponding Report (EIA/RIMA). Law No. 15,190/2025 establishes modalities such as the License by Adherence and Commitment (LAC) and provides for the standardization of procedures and the distribution of responsibilities among federal entities.

In the socio-environmental context, it is important to note that Free, Prior and Informed Consultation (CPLI), in accordance with Convention No. 169 of the International Labor Organization (ILO), is mandatory when mining projects may affect indigenous peoples and traditional communities; it must be conducted prior to the licensing stages and throughout the entire process, based on the principle of self-identification of these peoples. In cases where environmental licensing falls under federal jurisdiction, FUNAI and the Palmares Cultural Foundation (FCP) participate in the analysis of impacts on indigenous peoples and quilombo communities, in accordance with Interministerial Ordinance No. 60/2015. FUNAI also supports processes related to the development of Autonomous Consultation Protocols, while the Palmares Cultural Foundation works on initiatives related to self-identification, the recognition of quilombo communities, and the observance of the right to CPLI. Nevertheless, ensuring the right to consultation remains relevant for projects subject to state licensing as well.

The NRES must recognize that processes of prior, free, and informed consultation require ongoing approaches that are contextually tailored to each territory and compatible with the sociocultural specificities of each community, and are not limited to one-time procedures related to environmental licensing. In this context, the Autonomous Consultation Protocols developed by the peoples and communities themselves and recognized by Brazilian case law become important tools for enhancing the predictability, legitimacy, and legal certainty of projects. It is also important to consider that the application of safeguards associated with the CPLI does not necessarily depend on the final conclusion of certification, recognition, or land regularization processes, and may be relevant in contexts where these processes are still ongoing.

Alignment with the international standards already mentioned in this report—such as IRMA and the ICMM guidelines—can help establish more robust mechanisms for territorial governance, transparency, and social engagement, thereby reducing the risks of conflict and litigation throughout the projects' life cycle.

In addition, mining is regulated by rules related to waste management, the protection of cultural heritage, the rights of traditional peoples and communities, land-use planning and land use, as well as by labor laws and occupational health and safety standards. This set of rules is enforced in coordination with state and municipal regulations, in accordance with the respective jurisdictions of each level of government.

States with significant mining activity, such as Minas Gerais, Pará, Goiás, and Bahia, have more developed regulatory frameworks and institutional arrangements for the sector, including specific standards and procedures for environmental licensing, in accordance with federal law.

It is important to note the progress of Bill No. 2780/2024, which establishes the National Policy on Critical and Strategic Minerals (PNMCE) and was approved by the Chamber of Deputies; it is currently awaiting consideration by the Federal Senate. The bill proposes guidelines aimed at strengthening the supply chain for critical and strategic minerals, including incentives for research, mining, processing, mineral transformation, and value addition within the country, as well as mechanisms for institutional coordination and the prioritization of strategic projects. Among the proposed instruments, the following stand out: the creation of the National Council for the Industrialization of Critical and Strategic Minerals (CIMCE), the Mineral Activity Guarantee Fund (FGAM), the Federal Program for the Processing and Transformation of Critical and Strategic Minerals (PFMCE), the Low-Carbon Mineral Certificate (CMBC), the National Registry of Critical and Strategic Mineral Projects (CNPME), as well as the National Network for Research and Development and Professional Training in Critical and Strategic Minerals (RNMCE).

TABLE 30

Key Legal Frameworks in Mining in Brazil

Regulation/Instrument	Year	Key aspects
Federal Constitution	1988	Stipulates that mineral resources belong to the Federal Government; establishes principles of economic order and environmental protection.
Mining Code (Decree-Law No. 227)	1967	Legal framework for mining: rights, duties, mining titles, and procedures for exploration and mining.
Law No. 9,314	1996	Consolidates mineral exploitation regimes and institutional responsibilities.
Decree No. 10,965	2022	Modernizes the Mining Code (simplification, transparency, and efficiency).
Decree No. 9,406	2018	It regulates the Brazilian Mining Code (standardizes procedures, defines the stages of exploration, and establishes the structural and tax obligations of industry operators with respect to the ANM).
Law No. 13,575	2017	Establishes the ANM, which is responsible for regulating and overseeing the sector.
Decree No. 11,108/2022	2022	Establishes the Brazilian Mineral Policy and the National Council for Mineral Policy (CNPM).

Decree No. 11,482	2023	Provides for the National Council for Industrial Development (CNDI).
Law No. 14,066	2020	National Dam Safety Policy (PNSB); reinforces responsibilities and prohibits raising dams upstream.
Decree No. 97,632	1989	Establishes the PRAD (Restoration of Degraded Areas).
Decree No. 10,657/2021	2021	Establishes criteria for strategic minerals.
MME Resolution No. 2/2021	2021	Establishes the list of strategic minerals and creates the Pro-Strategic Minerals Program.
Law No. 14,514/2022	2022	Regulates the mining and commercialization of minerals and nuclear materials.
Law No. 7,990/1989	1989	Establishes the CFEM (mining royalties).
Law No. 13,540/2017	2017	Updates the calculation basis, rates, and distribution of the CFEM.
Law No. 6,938/1981	1981	Basis for environmental licensing (EIA/RIMA).
Complementary Law No. 140/2011	2011	It defines the division of authority among the federal government, states, and municipalities regarding licensing.
Law No. 9,605/1998	1998	Environmental Crimes Act; establishes criminal and administrative penalties for environmental damage.
Law No. 9,985/2000	2000	Regulates protected areas, impacting mining viability.
Law No. 15,190/2025	2025	General Law on Environmental Licensing.
Policies and Strategies for Critical Minerals	2021–present	Guidelines for supply security, innovation, value addition, and global integration.
Resolutions, ordinances, and regulatory instructions (ANM and other agencies)	Ongoing	Detail technical and operational procedures and regulatory standards.
State and municipal legislation	Ongoing	Environmental licensing, land-use planning, and land use.

Source: Prepared by the authors.

National plans and policies

The development of the national rare earths supply chain depends on a dynamic and supportive industrial environment capable of sustaining investment, innovation, and increased productivity. In this context, the National Rare Earths Strategy must be aligned with “New Industry Brazil” and coordinated with complementary agendas, such as the Pro-Strategic Minerals Policy, the Ecological Transformation Plan, the National Energy Transition Plan, the Brazilian Sustainable Taxonomy, and the Circular Economy Policy, in order to facilitate integration among industrial policy, energy transition, sustainability, and financing. Based on this pre-existing framework of federal policies and programs, the strategy must go beyond the

expansion of mineral extraction, prioritizing the consolidation of the production chain within the country, ensuring Brazil's meaningful integration into global supply chains for sustainable mobility, energy transition, and digital technologies.

Implementing this strategy requires an integrated approach across the entire value chain, from mineral exploration to the circularity of materials. In the initial phase, the Climate Plan guides the incorporation of climate risk and vulnerability analyses, aiming to build the resilience of projects. In the upstream segment, key elements include the use of non-reimbursable financial instruments for the development of sustainable technologies (NIB) and the need to reduce emissions intensity by incorporating renewable energy sources into mining operations (Climate Plan).

In the upstream segment, mineral, industrial, environmental, energy, and climate policies converge, combining instruments to foster innovation—such as non-reimbursable financing provided for under the “Nova Indústria Brasil” initiative—with climate mitigation guidelines aimed at reducing emissions and using renewable sources in mining operations, as outlined in the Climate Plan. Added to this set are guidelines regarding supply security for strategic minerals (National Energy Transition Plan), the decarbonization of production chains (Ecological Transformation Plan), and the criteria for sustainable financing (Brazilian Sustainable Taxonomy), as well as the parameters for the sustainable expansion of mineral production established by the draft National Mining Plan 2050. In addition, Bill 2780/2024 provides for the creation of the Low-Carbon Mineral Certificate (CMBC), a voluntary program aimed at promoting lower-carbon research, mining, processing, mineral transformation, and urban mining activities.

In the midstream sector, the strategy should prioritize value addition within the country, avoiding the export of primary goods and encouraging the internalization of intermediate industrial stages. This approach is aligned with the New Industry Brazil initiative, which emphasizes the deepening of production chains, and is reinforced by the Ecological Transformation Plan, which promotes the expansion of activities with greater technological complexity and lower carbon intensity. Additionally, the Pro-Strategic Minerals Policy, currently under revision, contributes by encouraging the development of priority projects with greater industrial integration, while energy and climate policies also impact the sector: the National Energy Transition Plan highlights the need for domestic production of strategic inputs, while the Climate Plan guides efforts to reduce emissions and increase energy efficiency in industrial processes.

In the downstream phase, a key focus is the development of production chains related to magnets made from rare earths, which are essential for electric motors and wind turbines. This direction is aligned with the New Industry Brazil initiative, which prioritizes the strengthening of strategic industrial supply chains and domestic production of equipment related to the energy transition, and is complemented by the Ecological Transformation Plan, which promotes integration into low-carbon supply chains. The Strategic Minerals Policy reinforces this movement by prioritizing projects with greater potential for integration into global supply chains, while the MOVER Program introduces requirements for traceability and the measurement of emissions

throughout the product life cycle, encouraging production with a smaller carbon footprint, in line with the growing demand for technological goods associated with the National Energy Transition Plan.

In addition to the production stages, the consolidation of the rare earths supply chain depends on cross-cutting factors—particularly innovation and circularity—that reshape both production processes and the efficient use of resources throughout the entire life cycle of materials. In this regard, it is essential to strengthen R&D&I, with a focus on advanced materials, low-carbon technologies, and eco-design solutions that facilitate the recycling of products containing Rare Earth Elements. This approach is aligned with the technological priorities of “Nova Indústria Brasil,” the decarbonization guidelines of the Ecological Transformation Plan, and the principles of the National Circular Economy Plan; it is further reinforced by the guidelines of the Climate Plan and made possible by sustainable financing instruments defined in the Brazilian Sustainable Taxonomy. In this context, the Pro-Strategic Minerals Policy contributes to this pillar by stimulating technological development related to critical minerals and by prioritizing structuring projects with innovation potential throughout the value chain. Furthermore, circularity involves the traceability of materials, the promotion of recycling, and the fight against planned obsolescence, in line with PLANEC, and is reinforced by the National Energy Plan through its recognition of urban mining as a strategic secondary source. In line with this, Bill 2780/2024, currently under consideration, incorporates guidelines related to urban mining and the recovery of critical minerals from waste, strengthening strategies for circularity, supply security, and the use of secondary materials in the rare earths supply chain.

In the economic sphere, the Brazilian Sustainable Taxonomy guides the allocation of investments toward activities aligned with ESG criteria, while financing and credit instruments for innovation—such as those operated by institutions like BNDES and FINEP—are essential for strengthening the production chain. In this context, the Pro-Strategic Minerals Policy, currently undergoing reformulation, contributes by identifying national priorities and reducing the perception of risk for investors, thereby enhancing the attractiveness of structuring projects.

Finally, the governance of the strategy requires interministerial coordination and multilevel collaboration, integrating the efforts of the government, the private sector, academia, and civil society in alignment with the guidelines of the NIB and the Climate Plan. In this context, mechanisms for coordinating and prioritizing strategic projects can help strengthen the integration of mineral, industrial, and energy policies, including those already provided for in Bill 2780. The effectiveness of the National Rare Earths Strategy will thus depend on the ability to coherently and continuously coordinate the available regulatory, financial, and institutional instruments, thereby consolidating an innovative, resilient, and sustainable production chain that is effectively integrated into the country’s industrial, energy, and environmental agendas.

TABLE 31

Matrix for the Integration of Public Policies and Pillars of the National Rare Earths Strategy

Pillars / Policies	New Industry Brazil	Pro-Strategic Minerals	MOVER (Green Mobility)	NDC Climate Plan	PNE / PDE	PTE (Ecological Transformation)	Sustainable Taxonomy	Circular Economy (PNRS)	PNM 2050 Draft
Geological Knowledge	Indirect Support	Resource mapping and prioritization	—	Environmental risk assessment	Foundation for energy planning	Basis for transition resources	Improves project classification	—	Foundation for mineral planning
Upstream	—	Prioritization of Strategic Projects	Raw materials for batteries and motors	Raw materials for low-carbon technologies	Supply security	Materials for the transition	Enabling Activities	—	Sustainable expansion of production
Midstream	Industrialization	Promoting value addition	Materials for the automotive supply chain	Reducing emissions in processing	Energy Chains	Production of strategic inputs	Green industrial financing	—	Processing in the country
Innovation	R&D and technology missions	Technological development in MCE	Innovation in electric mobility	Clean Technologies	Indirect Support	Innovation for Decarbonization	Sustainable technologies	Technology Recycling	Technology training
Downstream	Strategic Industrial Chains	Integration into global supply chains	Automotive components (magnets, motors)	Support for the transition	Meeting Energy Demand	Low-carbon products	Sustainable Products	—	Value addition
Circularity	Industrial integration	Complementarity to the primary supply	Battery recycling	Emissions reduction	—	Resource efficiency	Eligible circular economy activities	Regulatory framework	Efficient use of resources
Economic environment	Incentives and funding	Attracting Priority Investments	Incentives for the green automotive supply chain	Climate financing	Indirect Support	Capital mobilization	Green financing	—	Business environment
Governance	Industrial coordination	Interministerial project coordination	Integration with automotive policy	Climate Integration	Energy and Mineral Integration	Coordination of the ecological transition	ESG Guidelines	—	Long-term governance

Source: Prepared by the authors.

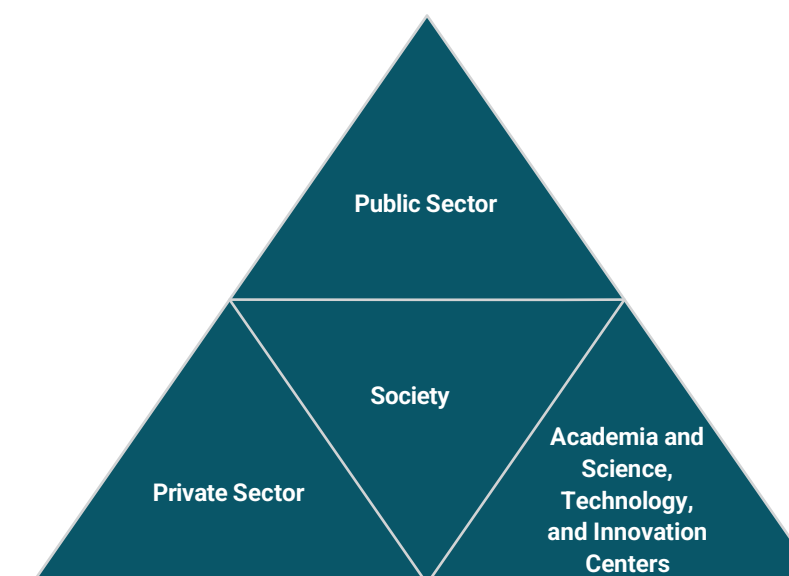
3.5. Institutional Ecosystem and Stakeholder Mapping

Objectives and Analytical Approach to Stakeholder Mapping

The institutional and stakeholder mapping served a dual purpose within the scope of this assessment. First, it sought to identify the main public, private, academic, and social actors that make up the Brazilian rare earths ecosystem, including their respective roles, interests, and capabilities throughout the value chain. Second, it served as the basis for defining the engagement strategy adopted in the field research, guiding the selection of interviewees and institutions visited. Furthermore, the mapping allowed for a preliminary assessment of the degree of coordination among the actors and identified governance gaps relevant to the development of a national strategy for the sector. To develop this mapping, the following were considered as stakeholder groups related to the topic of REEs: the government—comprising the executive and legislative branches at various federal levels—the private sector, science, technology, and innovation centers along with academia, and organized civil society (Figure 13).

FIGURE 13

Rare Earths in Brazil – Stakeholder Groups



Source: Prepared by the authors.

3.5.1 Public Sector

In the government sector, the rare earths agenda involves a broad and diverse set of institutions. In the federal legislative branch, the focus is on the National Congress, particularly the Parliamentary Front for Sustainable Mining, which operates in both the Chamber of Deputies and the Federal Senate. In the Chamber of Deputies, Bill 2780/2024 stands out; authored by Representative Zé Silva and with Representative Arnaldo Jardim serving as rapporteur, it proposes the establishment of the National Policy on Critical and Strategic Minerals with the goal of sustainably promoting the research, mining, and processing of these minerals. The bill, which was recently approved by the Chamber of Deputies and is currently under consideration in the Senate, provides for tax incentives, regulatory flexibility, and the prioritization of projects—among which those focused on REEs could be included. The General Environmental Licensing Law No. 15,190, dated August 8, 2025, aligns with this agenda by expediting environmental licensing procedures, although it has been criticized by segments of civil society for relaxing socio-environmental requirements that are already considered insufficient. Also in the Chamber of Deputies, in 2026, Bill 542 was proposed, which establishes a moratorium on the mining of rare earths throughout the national territory, and Bill 500, which designates the area located in the Southern Volcanic Plateau of Minas Gerais and São Paulo as a national mineral reserve for rare earths.

In the Federal Senate, there has been a backlog of bills since 2013. Notable among them are Bill 8,325/2014 and Bill 529/2013, which propose the establishment of the Program to Support the Technological Development of Rare Earth Elements and the Creation of a Production Chain (PADETR), as well as Bill 2210/2021, which proposes the creation of the Policy to Promote the Technological Development of the Production Chain for Minerals Containing Rare Earth Elements (PADT). These initiatives converge around the idea of structuring a coordinated network of research, technology, and innovation to ensure scientific and technological mastery of the different stages of the value chain and add value to rare earth elements (REEs). In 2025, Bill 2197 was also introduced, which limits exports of unprocessed strategic minerals, such as rare earth elements—a topic that remains the subject of intense debate. This set of proposals reveals that the legislature has become a key arena for shaping and debating the future of the REE supply chain in Brazil.

Within the federal government, the key player is the Ministry of Mines and Energy, through the Secretariat of Geology, Mining, and Mineral Processing. The National Mining Plan (PNM) 2030 established definitions and guidelines for Critical and Strategic Minerals, and the PNM 2050, currently in the process of being published, aims to update this framework with a greater emphasis on mineral processing, systematic geological mapping, and diversification of the production matrix. Based on the PNM 2030, the Geological Survey of Brazil produced, in 2015, the study “Assessment of Rare Earths Potential in Brazil,” which remains one of the main public references on the subject. Also worthy of note is Decree No. 10,657, dated March 24, 2021, which established the Strategic Minerals Policy, qualifying projects under the Investment Partnership Program and creating the Interministerial Committee for the Analysis of Strategic Minerals Projects, with participation from the Office of the Chief of Staff, the Ministry of Science, Technology and Innovation (MCTI), and the Institutional Security Office of the Presidency of the Republic.

(GSI) and the Ministry of Finance. This committee was granted the authority to include or exclude strategic minerals from the official list established by Resolution No. 2.

Within the scope of the Office of the Chief of Staff, Decree No. 11,108 of 2022 established the current Brazilian Mineral Policy and recognized REEs as a priority, in addition to creating the National Council for Mineral Policy (CNPM). In the field of industrial policy, the Ministry of Development, Industry, Trade and Services assumed an increasingly prominent role through the “New Industry Brazil” initiative, the reestablishment of the National Council for Industrial Development, and the implementation of the Green Mobility Program (MOVER), which funded the SENAI project in Lagoa Santa aimed at the pilot-scale production of permanent magnets. These initiatives reveal that the rare earths agenda is not limited to mineral policy but has also become linked to industrial policy, mobility, technological transformation, and neo-industrialization.

In addition to these agencies, there are affiliated institutions that play a decisive role. The National Mining Agency stands out, among other things, for regulating the CFEM calculation basis based on reference prices, although REEs still fall under the residual category of “others,” with a 2% tax rate, creating the perception of very low territorial returns in mining municipalities. The Geological Survey of Brazil has conducted surveys in states such as Rondônia, Roraima, and Amazonas and is part of the National Institute of Science and Technology (INCT), which received an investment of R\$ 10.2 million over five years to drive the development of innovative REE-based materials. The National Nuclear Safety Authority (ANSN) and Indústrias Nucleares do Brasil (INB) also occupy a strategic position, as the presence of natural radionuclides in some deposits and production processes makes the radiological aspect a central component of the supply chain’s governance. At the public-private interface, the BNDES has played a significant role in financing projects involving critical and strategic minerals and in managing funds dedicated to Research and Development and mineral processing.

At the subnational level, the states of Bahia, Goiás, and Minas Gerais stand out, as they are home to projects that are either in operation, under implementation, or in the advanced research phase. Minas Gerais, through the State Secretariat for Economic Development of Minas Gerais (SEDE/MG), launched the State Mining Plan in 2025, presenting ongoing projects and proposing financing instruments aimed at vertical integration of the supply chain. Goiás, in turn, launched the State Plan for Mineral Resources (PERM 2040), proposing the establishment of mineral clusters—particularly for Critical and Strategic Minerals—with active participation from the Technology Park of the Federal University of Goiás (UFG). In the state, governance of this area is divided between the State Secretariat of Industry, Commerce, and Services and the State Authority for Critical Minerals. In Bahia, the Jiquiriçá Valley has been attracting a growing number of companies and projects. This leading role played by the states is an important asset, but it also heightens the need for clearer coordination with federal guidelines.

At the municipal level, Minaçu, in Goiás, holds a unique position as the only municipality with actual REE carbonate production to date. It is also in this municipality that the expectations, tensions, and impacts related to the implementation of these projects—including socioeconomic, environmental, and political effects—are most immediately felt. Other municipalities deserve attention because they are home to projects in the planning or implementation phases,

such as Nova Roma and Aparecida de Goiânia, which are associated with the Aclara Mina Carina project, as well as Araxá and Poços de Caldas in Minas Gerais, which concentrate a significant portion of the state's mineable reserves. Also included are municipalities such as São Francisco de Itabapoana, Conceição do Castelo, and Caraguatatuba, which report receiving CFEM payments from REE, although there is no robust public data on actual production. In this context, the Brazilian Association of Mining Municipalities (AMIG) stands out as the main representative body for mining municipalities, working with government authorities and actively participating in the debate on mineral policy.

3.5.2 Private Sector and Industry Associations

In the business sector, the industry is dominated by foreign companies—primarily Australian and Canadian—operating in the areas of prospecting, exploration, and environmental licensing. Among the most prominent companies are Appia Rare Earths & Uranium, Aclara Resources, Meteoric Resources, Viridis Mining and Minerals, Atlas Critical Minerals, Brazilian Rare Earth, and, at a more advanced stage, Mineração Serra Verde, acquired by US Rare Earth, which is so far the only active producer of REE in the country. The presence of these companies confirms strong foreign interest in Brazil's geological resources, but also highlights that a significant portion of the projects is still in the pre-operational phase and depends on capital, licensing, engineering, and technological partnerships to move forward. The only commercial operation currently underway has its production contractually committed, which reinforces the importance of the Brazilian supply chain's integration into the international market.

Among business organizations, the following stand out: Ibram, the Mining Industry Union of the State of Goiás and the Federal District, the National Movement for Mining and Development, and the newly created Association of Critical Minerals, which seeks to position Brazil as a reliable, sustainable, and geopolitically stable partner. On the side of industries that consume permanent magnets, companies involved in the production of motors for electric vehicles, generators for wind turbines, industrial equipment, electronics, and the medical sector stand out. The MAGBRAS project, approved under a structural call for proposals by Senai and Fundep, represents a particularly significant initiative as it aims to build a full-cycle industrial demonstrator for Brazilian rare earths magnet production—from mining to recycling—bringing together seven science and technology institutions and 28 companies. The project highlights the potential for collaboration between mining, mineral processing, innovation, and industrial demand, even though it is still in its early stages.

3.5.3 Society, Academia, and Technology and Innovation Centers

In the realm of civil society, the Mining Observatory and the Movement for Popular Sovereignty in Mining (MAM) are particularly noteworthy. Both maintain a critical stance toward the expansion of mining in Brazil on the grounds of the energy transition, arguing that the critical minerals agenda could entrench the extractivist model, weaken the state's regulatory capacity, and increase the sacrifice of territories and populations, particularly in the Amazon and in areas inhabited by traditional communities. These organizations play an important role in stimulating public debate by raising concerns

with socio-environmental justice, human rights, consultation, and territorial protection. Although these positions often clash with the perceptions of some in the private sector and among policymakers, their role is central to understanding the conflicts and disputes over legitimacy that underlie the rare earths agenda.

In the science, technology, and innovation ecosystem, the leading role is played by SENAI units in Minas Gerais and Santa Catarina, the INCT–Rare Earths, and institutions such as the Institute for Technological Research (IPT), the Mineral Technology Center (CETEM), and SGB. The CIT Senai ITR in Lagoa Santa houses a laboratory and a pilot plant for the production of rare earth magnets and alloys, making it the first laboratory-factory of its kind in the Southern Hemisphere, with a production capacity of 100 metric tons per year. Senai in Santa Catarina, in turn, features an industrial demonstration facility that covers all stages of the supply chain, including recycling. The INCT - Rare Earths coordinates 15 institutions in a collaborative network focused on expanding knowledge about geological occurrences, advanced materials, and the training of researchers. Within this ecosystem, CETEM also plays a significant role, both due to its tradition in applied research in the mineral sector and its involvement in strategic research networks focused on advanced materials and rare earths. As an agency affiliated with the Ministry of Science, Technology, and Innovation (MCTI), CETEM enhances Brazil's institutional capacity to develop technological pathways, mineral characterization, resource utilization, and solutions applied to the rare earths (REE) supply chain.

3.5.4 The Brazilian rare earths supply chain ecosystem

A comprehensive analysis of this ecosystem reveals that Brazil already has a significant number of actors and initiatives that could potentially be mobilized for the development of the rare earths supply chain. However, field research and documentary analysis indicate that governance of this agenda remains marked by significant institutional fragmentation. Although formal leadership of mineral policy rests with the federal executive branch, multiple ministries and agencies have been adopting parallel initiatives that impact the sector, without, to date, sufficient clarity regarding their practical coordination, common goals, and consistent coordination mechanisms. Even the National Council for Mineral Policy, which brings together different ministries and stakeholders, has not been meeting with a frequency commensurate with the strategic importance of the issue. The result is an institutional environment in which various relevant actions coexist but remain insufficiently integrated around a clear national vision for the development of the REE supply chain.

This issue is particularly relevant because mineral resources belong to the Union, pursuant to Article 20 of the Federal Constitution, which assigns the federal executive branch a central role in shaping mineral policy. In an agenda such as that of the REEs, this would require not only formal leadership but also the effective capacity to align objectives, instruments, regulatory powers, and investment priorities. As noted by the Federal Court of Accounts, good public governance requires clear rules, explicit objectives, transparency, accountability, and public participation. The analysis conducted in this study suggests, however, that these attributes are not yet fully established in the institutional framework governing rare earths in Brazil.

In practice, the REE agenda involves the MME, the Ministry of Finance, and the

Office of the Chief of Staff, the Ministry of Development, Industry, Trade and Services (MDIC), the Ministry of Science, Technology, and Innovation (MCTI), the Ministry of Environment and Climate Change (MMA), as well as regulatory agencies, the National Nuclear Safety Authority (ANSN), public banks, Science and Technology Institutes (ICTs), and state and municipal governments. Although there are several relevant initiatives underway, it remains unclear how these efforts are coordinated with one another, particularly with regard to defining national priorities for the industrialization of the supply chain, the allocation of responsibilities, and the development of metrics and monitoring tools. The gap, therefore, lies not only in the absence of policies but also in the absence of a sufficiently coordinated institutional framework to integrate them.

This assessment becomes even more evident when examining the interface between the executive and legislative branches. The survey conducted shows that there is a profusion of legislative proposals related to critical minerals, strategic minerals, and REE, often proceeding at different paces and in different directions from the agendas being formulated by the executive branch, the concerns of social movements, and the expectations of the productive sector. The Chamber of Deputies and the Senate have become key arenas for competing narratives regarding the strategic significance of rare earths, the role of the state, the desirable degree of regulatory intervention, and the risks associated with the acceleration of mining in the country. For some in the productive sector and among policymakers, the main risk is missing the international window of opportunity; for some social movements and local stakeholders, the main risk is deepening socio-environmental conflicts and reinforcing extractivist patterns without adequate compensation.

The need for greater coordination among different institutional levels is also evident at the federal level. States such as Minas Gerais and Goiás have made rapid progress in formulating their own policies, conducting environmental licensing, and attracting REE projects. It is clear that mechanisms to harmonize state and federal jurisdictions must be strengthened. In this context, initiatives aimed at expanding coordination and institutional alignment can contribute to greater regulatory certainty, predictability, and integration across different areas of action.

This challenge is particularly acute when dealing with naturally occurring radioactive materials (NORM). Since the mining and processing of REE may involve natural radionuclides, governance of the supply chain depends on the interaction between mineral regulation, environmental licensing, and radiological oversight. The research indicates that the lack of sufficient integration among these areas constitutes one of the most sensitive issues in the sector's governance. In particular, the possibility of preliminary radiological classifications based on self-reported data—subject to subsequent review by the competent authority, the ANSN—can create situations in which a project is already being licensed by a state agency when it is later classified into a more sensitive category from a radiological standpoint. This type of institutional misalignment increases the risk of legal uncertainty and litigation and highlights the need for earlier coordination among the agencies involved.

The sociopolitical dimension of governance also deserves attention. The rare earths agenda evokes very different perceptions among companies, regulators, local governments, parliament, academia, social movements, and potentially affected communities. For

some social movements, the expansion of the critical minerals agenda is seen as part of a race for minerals that could put pressure on protected areas or territories in the process of being recognized, including rural settlements, conservation areas, Indigenous lands, and Quilombola territories. For some economic and government actors, however, the greatest risk is that the lack of regulatory predictability will prevent the country from taking advantage of a strategic window of opportunity for international repositioning. The coexistence of these perceptions should not be treated as peripheral noise, but as a constitutive element of the sector's governance.

In summary, the Brazilian rare earths ecosystem already brings together key public, private, scientific, and social actors. However, there is an opportunity to enhance coordination among instruments, policies, and institutions, as well as to promote greater convergence around priorities, risks, and development strategies. In this context, the development of the NRES will require mobilizing existing capacities and strengthening mechanisms for coordination, collaboration, and governance. The primary research presented in the following section delves deeper into this assessment by identifying the main cross-cutting findings and structural gaps perceived by the stakeholders consulted.

3.6. Evidence from the field research, key findings, and gaps

3.6.1 Methodology for interviews, surveys, field visits, and workshops

Based on the institutional and stakeholder mapping presented in the previous section, a primary data collection phase was conducted with the aim of complementing the documentary and bibliographic review and deepening the understanding of the main barriers and opportunities for the development of the rare earths supply chain in Brazil. This phase combined semistructured interviews, an online survey, field visits, and workshops, seeking to capture the perspectives of stakeholders directly involved in policy-making, regulation, investment, research, industrial operations, and social representation.

Conducting primary research proved particularly important because, although there are already several ongoing initiatives in the country related to REEs, these efforts remain fragmented, spread across different government agencies, companies, scientific institutions, and local stakeholders. In this context, structured stakeholder consultations made it possible not only to validate information gathered from the literature but also to identify areas of agreement, tensions, and coordination gaps that would be difficult to detect through secondary sources alone. Among the themes that emerged most strongly in the research are the fragmentation of governance, the lack of a clear definition of national priorities for the industrialization of the supply chain, the overlap of regulatory jurisdictions, and differing perceptions regarding licensing, environmental risk, and territorial development.

The primary data collection phase was structured around three complementary tools: semi-structured interviews, workshops, and field visits. The interviews sought to capture informed perspectives from representatives of the public sector, the private sector, academia, technology centers, associations, and civil society. The field visits provided an opportunity to observe, within a territorial and operational context, the stage of project development, technological capabilities, local perceptions, and concrete challenges associated with the rare earths supply chain. The workshops were designed as forums for validating hypotheses and broadening perspectives, serving as an additional mechanism for consultation and discussion of the proposed solutions.

The selection of interviewees and institutions visited was guided by the stakeholder mapping conducted in the previous section, prioritizing actors with relevant roles in different links of the value chain and in cross-cutting dimensions such as regulation, financing, innovation, licensing, territorial development, and sustainability. The aim was to include, in a balanced manner, representatives from public agencies, companies with projects at different stages, science and technology institutions, sectoral entities, and territorial actors.

Field visits played a particularly important role in complementing institutional consultations with direct observation of ongoing initiatives, existing capacities, and local perceptions regarding opportunities and constraints for the development of the supply chain. Being present in areas directly involved with relevant projects and institutions allowed us to enrich the assessment with insights that would be difficult to obtain solely through virtual interviews or document analysis. At the same time, the diversity of positions identified among public agencies, companies, social movements, municipalities, regulators, and research institutions was treated as an analytical input for the assessment—rather than as methodological noise—since this plurality of perspectives constitutes, in and of itself, a relevant part of the NRES governance challenge.

This subsection provides a brief description of the methodological approach. Additional details—such as interview guides, complete respondent profiles, visit forms, and data collection instruments—can be found in the appendices. The following sections focus on summarizing the main findings and the structural gaps identified throughout the process.

3.6.2 Key Findings from the Primary Research

The primary research revealed a set of recurring findings among the different groups of stakeholders consulted. Although there are differences in emphasis among the government, businesses, academia, funders, and civil society, relative convergence was observed around certain central themes, which help to refine the assessment of the sector in Brazil. Overall, the interviews, field visits, and supplementary analyses confirmed the assessment already identified in the literature: Brazil possesses significant geological, institutional, and technological assets, but still faces challenges in converting this potential into a dense and competitive value chain. At the same time, the stakeholders consulted showed greater agreement regarding the existence of a strategic window of opportunity for the country than regarding the pace, approach, and tools needed to transform this opportunity into a lasting competitive advantage. The following section presents the main cross-cutting findings from the primary research.

Finding 1. The main bottleneck is industrial, not geological

The most common view among interviewees is that Brazil's main challenge lies not in a lack of mineral resources, but in the difficulty of transforming this geological base into industrial capacity. In general, stakeholders recognize that Brazil possesses significant reserves, geological diversity, and a growing portfolio of promising upstream projects, with the potential to produce competitively, even compared to Asian producers. The central issue regarding rare earths is creating the conditions to process, refine, and use them in higher-value-added products within the country.

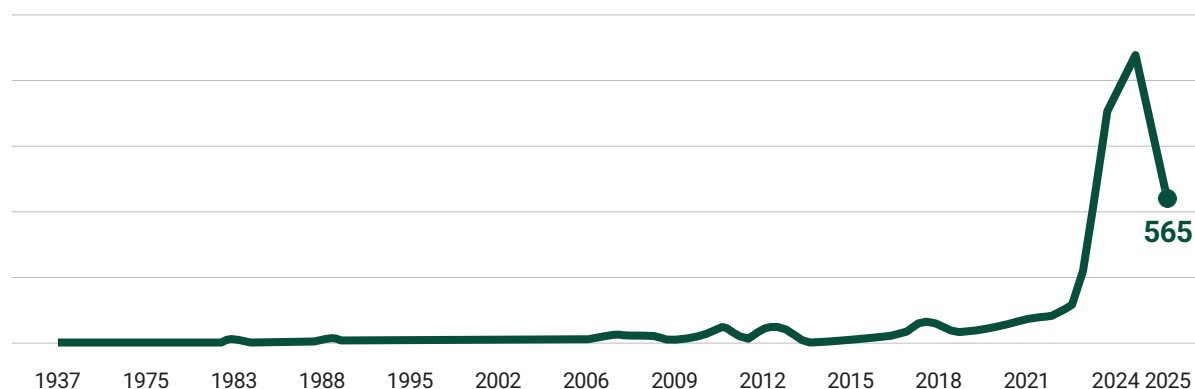
This assessment does not negate the importance of geological knowledge, but it puts its significance as the main bottleneck into perspective. According to the SGB (or Mineral Resources Research Company, CPRM), the percentage of the Brazilian territory that has been mapped is 27% at a scale of 1:100,000 and 50% at a scale of 1:250,000. These percentages reach 44% and 70%, respectively, in the Precambrian shields, which hold the greatest potential for the discovery of deposits. SGB experts point out that, although these percentages may seem low, they are comparable to those observed in other jurisdictions, considering that higher-scale mapping tends to be the responsibility of the private sector, using techniques that vary depending on the substance of interest. It was also noted that the Amazon remains the region with the lowest level of geological knowledge, while more than 50% of Brazilian territory outside the Amazon already has 1:100,000-scale mapping. In 2023, the federal government announced an investment of R\$ 307 million in the SGB, part of which is expected to be allocated to the country's ten-year plan for expanding geological mapping, to be implemented in 2024.

In the specific case of REEs, the SGB conducted a comprehensive study in 2015, in addition to more recent studies, and is currently seeking to update and expand these publications, including through an agreement signed with the Inter-American Development Bank (IDB) to further research in Minas Gerais and Bahia. At the same time, private interest in the sector has surged: from 2018 to 2024, the number of exploration applications for REE rose from 19 to 1,008. In 2025, there was a partial reversal of this trend, with 565 applications filed, but the overall trend still points to a strong increase in private interest in areas with rare earths potential.

A brief analysis of the operating costs projected by the companies themselves in independent technical reports also reinforces this point. In general, major Brazilian projects show positive operating margins, even under conservative pricing scenarios. As noted earlier, the projected costs of Brazilian projects appear to be competitive. This suggests that the central constraint does not, in principle, lie in a lack of resources or the mineral unfeasibility of upstream operations, but rather in the ability to move these projects forward through the licensing process, engineering, stable operation, and, above all, integration with subsequent links in the chain.

FIGURE 14

REE – Active Mining Rights in Brazil, by Year



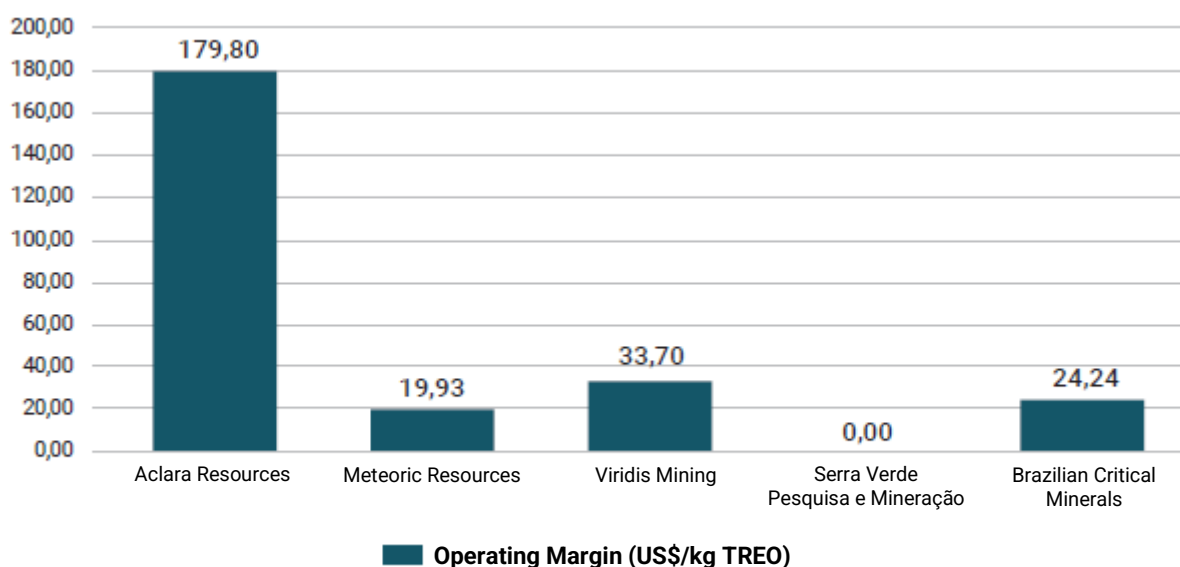
Source: P3M Platform.

The most common perception among interviewees is that the main challenge lies in the difficulty of transforming geological resources into industrial capacity. In general, stakeholders recognize that Brazil possesses significant reserves, geological diversity, and a growing portfolio of promising upstream projects capable of producing competitively, even when compared to Chinese and Asian producers.

The competitiveness analysis presented in section 3.3 of the report corroborates this assertion. The operating costs projected by the companies in their published independent technical reports show that all of them have a positive operating margin for their projects, even when considering conservative price scenarios for their products.

FIGURE 15

Operating margin (US\$/kg TREO)



Source: Prepared by the authors, based on information from the companies' reports.

However, the projects must progress through the licensing and engineering development stages so that the project figures can be confirmed and create the actual economic foundation that will enable advancement to the remaining stages of the chain.

Finding 2. There is consensus on the centrality of the midstream, but uncertainty regarding the most viable path

The midstream segment is almost unanimously identified as the main bottleneck in the Brazilian value chain. Companies, researchers, and policymakers recognize that separation and refining represent the most significant step in value addition and, at the same time, the segment posing the greatest technical, financial, and regulatory challenges. Even so, primary research suggests that there is no full consensus on what the priority path forward should be: some stakeholders advocate starting with higher-purity carbonates and oxides; others emphasize the selective separation of NdPr; and there are also those who highlight the importance of metals, alloys, and magnets as a medium-term goal. The common thread among these views is the understanding that Brazil needs to avoid both remaining exclusively in the upstream sector and the unrealistic ambition of fully replicating a complete industrial chain in the short term.

The research indicates that Brazil is still in the early stages of its learning curve and that consistent progress in the midstream sector will require technical cooperation, mastery of chemical processes, and greater operational maturity. The case of Serra Verde illustrates this challenge well: although the company began pilot production in 2023, studies on technological routes date back to 2015–2016, highlighting a lengthy process of testing, adjustments, and corrections. Adapting a technological route to the specific characteristics of the deposit is a necessary condition for reducing environmental risks and increasing operational stability. Public information released by specialized media outlets and by the company itself suggests an expected total investment of approximately \$682 million, including the latest \$565 million loan from the U.S. International Development Finance Corporation (DFC). Considering the major REE projects under development in Brazil, this level is consistent with the nature of these ventures and underscores the capital intensity required by the industry.

In this context, the Brazilian project pipeline is an important asset, as it shows that the country's rare earths agenda is no longer limited to a single operating project. If all major projects move forward, a potential increase of 38,700 metric tons of TREO is expected within Brazil alone, which corresponds to about 10% of global production recorded in 2025, according to the U.S. Geological Survey. This figure is significant because it shows that the realization of the Brazilian pipeline would have an impact not only domestically but also internationally. Even so, this potential remains contingent on progress in licensing, engineering maturity, fundraising, and the definition of viable technological and commercial pathways.

TABLE 32

Major Rare Earth Projects Under Development in Brazil: CAPEX, Current Status, and Potential for Supply Expansion

Project	Operator	State	Initial CAPEX (US\$ MM)	Product/ Substance	Note
Pela Ema (Phase 1 + Phase 2)	Serra Verde	GO	682	REE	Commercial production since Q1 2024; capacity increase to 6,500 metric tons of TREO
Caldeira	Meteoric Resources	MG	443	REE	Under development; permit obtained in Dec. 2025
Colossus	Viridis Mining & Minerals	MG	358	REE	Under development; permit obtained in Dec. 2025
Carina	Aclara Resources	GO	781	REE	Construction is scheduled to begin in the first half of 2027
Ema	Brazilian Critical Minerals	AM	55	REE	Project in the Scoping Study phase

Source: Prepared by the authors, based on information from company reports.

At the same time, when comparing the level of investment in projects for rare earths under development in Brazil with mining projects for other minerals that are under construction or have recently been completed in the country, it becomes clear that the capital intensity of rare earth projects is significant but not exceptionally high in relative terms. Compared to large-scale iron, copper, nickel, potash, and gold projects, REE projects in Brazil fall into the medium-sized category. This reinforces an important conclusion of the study: the challenging nature of rare earth projects stems less from the absolute volume of capital and more from a combination of technological complexity, regulatory risks, the learning curve, market uncertainty, and dependence on expertise and inputs that are not yet well-established in the country.

TABLE 33

CAPEX Intensity of Selected Mining Projects in Brazil: A Comparison Between Rare Earths and Other Commodities

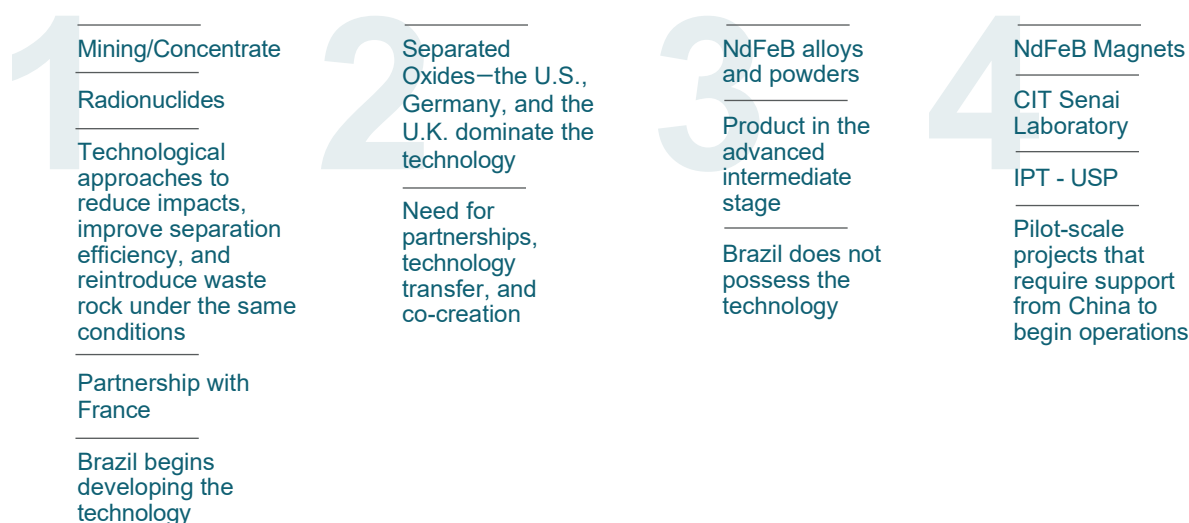
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Carina	Aclara Resources	GO	781	REE	Construction is scheduled to begin in the first half of 2027
Ema	Brazilian Critical Minerals	AM	55	REE	Project in the Scoping Study Phase
S11D / Serra Sul	Vale	PA	14,300	Fe	In operation since Dec. 2016
Serra Sul +20 Mtpy	Vale	PA	1,500	Fe	Construction. Startup scheduled for the second half of 2026
Compact Crusher S11D	Vale	PA	755	Fe	45 Mtpa of additional capacity
CSN P15 / Casa de Pedra (Itabirito)	CSN Mineração	MG	2,900	Fe	Under development (2024–2028); new 16.5 Mtpa processing plant
Minas-Rio	Anglo American	MG	190	Fe	Phase 3: capacity increase to 26.5 Mtpa
Pedra de Ferro + Porto Sul + FIOL I	Bamin	BA	3,700	Fe	Mine development with an integrated logistics solution. 26 Mtpa
LHG Mining / Urucum + Santa Cruz (expansion)	LHG Mining	MS	1,000	Fe/Mn	Capacity expansion to 10 Mtpa
Cedro Mining – Mine development + logistics	Cedro Participações	MG	985	Fe	Capacity increase to 42 Mtpa + development of logistics solutions (ports)
Salobo III (expansion)	Vale Base Metals	PA	1,100	Cu	Capacity expansion from 24 Mtpa to 36 Mtpa
Tucumã	Ero Copper	PA	310	Cu	Commercial production since July 2025; 27 ktpa
Tocantinzinho	G Mining Ventures	PA	458	Au	Commercial production since Sept. 2024; 175 koz per year
Borborema	Aura Minerals	RN	188	Au	Commercial production beginning in Sept. 2025; ~83 koz Au/year; 19 months of construction
Araguaia (FeNi)	Horizonte Minerals	PA	2,704	Ni (FeNi)	Under construction, undergoing review, and capacity expansion
Autazes	Brazil Potash	AM	2,500	K	Pre-construction, permitting

Source: Prepared by the authors, based on information from company reports.

FIGURE 16

Stages of the REE production



Source: Prepared by the authors based on documents and interviews (2026).

The interviews also reinforced that the country's external dependence extends beyond mining to include equipment, inputs, and critical expertise. The Rare Earth Magnet Laboratory-Factory and pilot plants face challenges because some of their equipment depends on Chinese supplies, amid growing resistance to technology transfer.

At the same time, some of the interviewees emphasized that this need can become a strategic opportunity. Removing radioactivity at the extraction site is mandatory, since it is not sustainable to transport radioactive material and worthless waste alongside the concentrates. This implies that processing must take place, to a large extent, at the extraction site itself, with the simultaneous return of tailings to the mined soil. From this perspective, value addition ceases to be merely a discretionary option and becomes an integral part of the value chain's very logic of sustainability, paving the way for technological cooperation and attracting companies with expertise in extraction, separation, and the reintroduction of tailings. In this context, the interviews mentioned the potential for partnerships with countries that have mastered these technologies.

Finding 3. Funding for technology scaling is perceived as a critical challenge

Another frequently cited issue concerns financing. The study confirmed that the main problem is facilitating the transition from the laboratory to the pilot plant, demonstration, and industrial scale. In practical terms, there is a widespread perception that the financial bottleneck is particularly severe in the midstream and downstream sectors, where investment is intensive, returns take longer to materialize, and market and technology risks are higher. Many stakeholders recognize that the country already possesses scientific expertise and a certain level of technological infrastructure, but lacks more appropriate tools to mitigate technological risk, establish intermediate plants, and support the transition to commercial operations.

The study also showed that financing should be understood in a broader sense, as part of a set of market-enabling conditions. For the private sector, the government should play a more active role in providing financial guarantees, promoting Science, Technology, and Innovation (STI), resolving infrastructure bottlenecks, and, in certain cases, even mitigating price risks through specific instruments. Public banks and existing funds have been expanding their operations, but, in the view of some companies—especially junior mining firms—access conditions remain asymmetrical and favor larger, better-capitalized players. In a sector where most projects under development still depend on venture capital, evolving engineering, and technology demonstration, this asymmetry constitutes a critical bottleneck.

Finding 4. The issue of thorium and NORM (Naturally Occurring Radioactive Material) emerges as a bottleneck in a significant part of the chain

The association between certain mineral deposits and naturally occurring radioactive materials (NORM), including thorium and other NORM, emerged as a recurring theme in the interviews and site visits, especially among stakeholders involved in mining, regulation, and project development. The perception is that this issue adds regulatory complexity, costs, operational uncertainties, and obstacles to financing, particularly in projects involving monazite or other associated minerals. More than a strictly technical issue, the research suggests that, for some stakeholders, the institutional handling of NORM acts as a structural bottleneck to the expansion of certain segments of the supply chain. This reinforces the need for a coordinated and specific approach within the framework of NRES.

Finding 5: There is an ambivalent perception regarding licensing: a need for speed, but also for predictability and legitimacy

The issue of licensing came up repeatedly, but with different emphases among the groups consulted. Among companies and some government actors, the prevailing view is that licensing needs to be more predictable, coordinated, and expedited, above all to reduce uncertainty and improve the attractiveness of investments. Among local stakeholders and some members of civil society, however, the focus is less on speed and more on the need to ensure the quality of the assessment, public participation, environmental safety, and respect for rights. In this context, although the CPLI is provided for in the legal framework, there is a recurring perception that public consultation processes are inadequate, which has led to an increase in challenges filed with the Public Prosecutor's Office and the litigation of projects. The common ground between these positions is that institutional predictability matters. Rather than a simple debate between “speeding up” or “tightening,” the research suggests that the main shortcoming lies in the lack of clarity, coordination, and trust in how the processes operate.

Finding 6: Future industrial demand is recognized as an opportunity, but is still not well-structured as an anchor market

The interviews indicate a growing awareness of the potential for connecting the

rare earths supply chain with sectors such as electric mobility, renewable energy, automation, healthcare, and defense. However, it has also become clear that this demand is still more prospective than structured. Many stakeholders recognize that end-use sectors can serve as anchors for the Brazilian downstream sector, but there is still little concrete coordination between mineral projects, industrial processing, and potential domestic buyers or integrators. This suggests that market formation will not occur automatically and will depend on demand-side policies, industrial coordination, and mechanisms to bridge the gap between mineral supply, processing, and end-use sectors.

Finding 7: The need for greater institutional coordination is seen as a cross-cutting issue

The primary research clearly confirmed the perception that Brazil already possesses significant capabilities within the government, the private sector, science and technology institutions (ICTs), and at the local level, but that there is still room to expand coordination mechanisms among these sectors. Respondents also highlighted the importance of greater clarity and alignment in the division of responsibilities among federal entities, especially between the state and federal levels, in order to reduce procedural overlaps, increase regulatory certainty, and mitigate the risk of litigation. In addition, the importance of strengthening integration among mineral policy, industrial policy, science and technology, financing, regulation, and sustainability was frequently mentioned. In summary, the results indicate that progress in the supply chain can be fostered not only by creating new instruments but also by strengthening coordination among existing initiatives and mechanisms.

TABLE 34

Table summarizing the main findings of the primary research

Topic	Summary of Findings	Implications for NRES
Main bottleneck	The main challenge is industrial, not geological	The strategy should prioritize value addition, not just mining expansion
Midstream	Separation and refining are the main critical link	It is necessary to structure a selective and scalable midstream
Financing	The biggest gap lies in financing the transition from pilot to industrial scale	Instruments for de-risking and supporting demonstration projects must be created
NORM (especially thorium)	This issue is perceived as an obstacle for some projects	Requires a specific approach to regulatory and institutional coordination
Licensing	The central debate is about predictability, not just speed	NRES should seek legal certainty, coordination, and legitimacy
Industrial demand	There is potential, but the anchor market is still poorly structured	Mineral supply must be connected to priority user sectors
Coordination	A broad understanding of the importance of greater institutional coordination	NRES must establish a clear mechanism for coordination and governance

Source: Prepared by the authors

Conclusive summary of the findings

Despite the progress made, Brazil's geological potential will only be realized if the gaps—which are primarily industrial, financial, regulatory, institutional, and territorial in nature—are addressed. Mineral production, processing, and intermediate treatment are still in their infancy in the country, although pilot plants and demonstration initiatives are gaining momentum, especially from 2024 onward. The progress of these plants depends on two closely related factors: licensing and investments in research, development, and engineering, both during the extraction phase and in subsequent stages. Given the recent regulatory changes in the environmental licensing framework, their effects on the new procedures are not yet measurable. On the one hand, greater speed is expected; on the other, the effectiveness of the new regulation remains unknown, given its recent implementation. Therefore, attention to these factors in the coming years will be decisive in ensuring the development of the rare earths industry's capabilities in the short and medium term.

3.6.3 The gaps

The findings of the primary research and literature review indicate that the barriers to the development of the rare earths supply chain in Brazil do not stem from a single, isolated factor, but rather from a set of interdependent gaps that cut across different links in the chain and different dimensions of public policy. In summary, these gaps can be organized into six main groups: i) geological and information gaps;

ii) technological and industrial gaps; iii) gaps in human capital, suppliers, and specialized services; iv) regulatory and licensing gaps; v) gaps in financing and market development; and vi) territorial, social, and environmental gaps. The following systematization consolidates these challenges in a structured manner, preserving the data and insights generated throughout the research and guiding the definition of strategic priorities for NRES.

1. Geological and Information Gaps

Brazil does not start from a position of complete ignorance, but it still faces significant gaps in the production, updating, and strategic use of information. The public geological mapping database is substantial but uneven across regions, with a notably lower level of knowledge in the Amazon. There is also a need to deepen the information applied to the different types of rare earth element (REE) deposits, improve the integration of geological data, market intelligence, and strategic investment signals, and expand the capacity for systematically updating public studies on rare earths. The challenge, therefore, beyond mapping, is to transform scattered information into decision-oriented sectoral intelligence.

2. Technological and Industrial Gaps

Technological and industrial gaps lie at the heart of Brazil's problem. Mining and the production of compounds are beginning to gain momentum, but the country still lacks

a consolidated foundation in separation, refining, metallization, alloys, magnets, and components. Uncertainties remain regarding the approaches most aligned with the national mineral base, limited operational experience at an industrial scale, heavy reliance on foreign sources for equipment, reagents, raw materials, and critical expertise, and challenges in transitioning from pilot-scale to commercial operations. The issue of radioactivity associated with some of the deposits further compounds this challenge, requiring specific technological expertise, greater institutional capacity, and heightened attention to sustainability and safety. The pipeline of projects under development is significant, but their transformation into an effective industrial base will depend on licensing, engineering, capital, operational learning, and strategic coordination. It is worth emphasizing the importance of structured traceability systems for mineral supply chains to verify the origin, sustainability, and compliance of products—an aspect that is increasingly relevant for international market entry, particularly in the European market.

3. Shortages of Human Capital, Suppliers, and Specialized Services

The assessment identifies significant gaps in specialized human capital and in the national base of suppliers and support services for the supply chain. There is a shortage of supervisors, operators, and specialists with practical experience in mining and processing of REE, as well as standards and institutions capable of supporting the smooth operation of the projects. The readiness of the supplier base for equipment, reagents, parts, maintenance, metrology, analytical services, and technical assistance is also limited. This issue is exacerbated when projects rely on external technology packages that make little use of the country's existing skill base, which weakens incentives for training and retaining professionals. In other words, the gap is not limited to the industrial plant: it involves the entire ecosystem of goods, services, and people necessary to sustain the supply chain.

4. Regulatory and Licensing Gaps

Significant gaps persist in the coordination between mineral, environmental, and radiological licensing, especially in projects involving NORM. The nascent nature of structured mechanisms for transparency and public participation, coupled with a lack of clarity regarding procedures, jurisdictions, and specific requirements, increases the risk of legal uncertainty, institutional overlap, and litigation.

It is important to note that the presence of naturally occurring radioactive material is not unique to rare earths mining. Sectors such as phosphate, niobium, titanium, zirconium, coal, and oil and gas also operate under specific protocols for radiological control and environmental management. In rare earth elements (REE) mining projects, radioactivity levels vary depending on the type of mineral deposit: minerals such as monazite tend to have higher concentrations of thorium and uranium, requiring stricter radiological controls, while ionic clay deposits generally have lower concentrations of NORM.

Projects involving NORM are subject to strict national and international radiation protection protocols, including continuous radiological monitoring, occupational control,

safe waste management, containment systems, environmental monitoring, as well as decommissioning and environmental restoration plans. These practices follow guidelines from international organizations, such as the International Atomic Energy Agency, and, in Brazil, are overseen by institutions such as the National Nuclear Safety Authority.

Thus, in the mining sector, NORM assessment is a required step in projects, and ANSN classifies the level of radiological activity based on Standard CNEN NN 4.01 of the National Nuclear Energy Commission (CNEN). However, the preliminary classification relies on information provided by the companies themselves, which is self-reported. Depending on this classification, the licensing process may be conducted by Ibama or by state agencies, in accordance with Complementary Law No. 140/2011. The problem highlighted by various stakeholders is that ANSN tends to conduct more detailed analyses only at later stages, after the environmental licensing process has begun, thereby either confirming or rejecting the preliminary classification. If the project is subsequently reclassified into a more sensitive category, this may conflict with a licensing process already underway at another level, creating a significant source of legal uncertainty and encouraging litigation.

TABLE 35

Radiological Classification of Mining and Industrial Facilities According to CNEN Standard NN 4.01 ⁷⁹

Facility Classification	Total activity concentration of radionuclides from the natural uranium and/or thorium series
Category I	greater than 500 Bq/g
Category II	between 500 Bq/g and 100 Bq/g
Category III	less than 100 Bq/g and greater than 10 Bq/g
Exempt from CNEN Standard NN 4.01	Less than 10 Bq/g

Source: Prepared by the authors.

The research also suggests that regulatory fragility is not limited to the management of radioactivity. It is also evident in the coexistence of state and federal initiatives that are not always fully coordinated, even in states that have been making rapid progress in the environmental licensing of REE projects. In contexts where natural radionuclides may be present and where there are intermunicipal or interstate impacts, this fragmentation can raise questions about the appropriate jurisdiction and the adequacy of the procedures adopted. Thus, the main regulatory shortcoming lies not only in the length of the licensing process, but also in the lack of predictability, coordination among agencies, and technical confidence in the process.

79. CNEN Standard NN 4.01 does not apply to (i) mining and industrial facilities where the activity concentration of natural or concentrated solid radioactive substances is below 10 Bq/g; (ii) facilities intended for the extraction of uranium and/or thorium, which are regulated by CNEN Standard NE 1.13; (iii) facilities regulated by CNEN Standard NN 6.02, "Licensing of Radiation Facilities."

A practical implication of this assessment is the need to address critical issues in phases preceding the environmental licensing process itself. Field research suggests that a preliminary assessment of critical issues—including the level of radioactivity in the ore and tailings, potential impact on water resources, delineation of affected watersheds, and identification of local communities, even those still in the process of being identified—could reduce risks to communities, improve the quality of the assessment, and decrease the likelihood of legal challenges. The ANSN itself acknowledges limitations in the current model and is studying improvements to Standard 4.01.

5. Funding and market development gaps

The main financial challenge lies in technological and industrial scaling—particularly between the laboratory, pilot plant, demonstration, and commercial production stages. In addition to the difficulty in accessing capital compatible with this risk profile, there remains a lack of instruments for de-risking, supporting industrial demonstrations, and mitigating market uncertainties. There is also a significant gap in the development of demand and anchor markets for higher-value-added products, particularly in the downstream sector. Without a more concrete link between mineral supply, processing, and priority user sectors, some industrial investments tend to lack sufficient economic viability.

This situation is exacerbated by political and regulatory disagreements over the very model for the international integration of the Brazilian mining sector. The study identified, for example, legislative proposals that advocate restricting raw mineral exports as a way to encourage domestic value addition. Although these proposals stem from a legitimate concern about reprimarization, they also provoke a strong negative reaction from companies and investors, who perceive them as an additional source of uncertainty. This indicates that the development of the market and enabling conditions also requires greater predictability regarding the rules of the game and the public policy outlook.

6. Territorial, social, and environmental gaps

Finally, the assessment shows that the development of the supply chain faces significant territorial, social, and environmental gaps. The case of Minaçu illustrates that, even with expanding production, territorial tax revenue may remain limited if the activity is concentrated on compounds and the export of intermediate materials. In 2025, the value of the REE operation was R\$ 95 million, exports reached US\$ 12 million (equivalent to R\$ 66 million), and CFEM collected amounted to R\$ 1.9 million. Under a full-production scenario, the estimated impact on municipal revenue remains modest, although the activity accounts for a significant share of local formal employment. This reinforces the fact that the main direct benefit tends to be employment and that the expansion of territorial gains will depend on greater value addition, production networks, and the development of local suppliers.

In addition, recurring concerns persist regarding pressure on local infrastructure and public services—such as health care and education—especially in small municipalities, as well as risks associated with the involuntary displacement of populations, environmental contamination (including water resources), and social acceptance of the projects,

free, prior, and informed consultation and impacts on traditional communities and territories in the process of recognition. Thus, the long-term viability of the supply chain will depend not only on its economic competitiveness but also on its ability to build territorial legitimacy and distribute benefits more robustly.

Summary of Gaps

Taken together, these gaps show that Brazil's challenge regarding rare earths is multidimensional. It will not be resolved solely through the expansion of mining, nor through a single instrument of innovation, financing, or regulation. The development of the value chain will require an integrated approach, linking geological information, industrial policy, science, technology, and innovation (STI), financing, regulation, territorial development, sustainability, and international integration. It is from this perspective that the concrete opportunities for value addition and the strategic priorities to be detailed in the following section become clearer.

TABLE 36

Economic Impacts of REE Mining in Minaçu (2025) and Projection of Full Capacity

Variables	2025	Full production
Quantity produced (in metric tons)	100	5,000
Estimated value (R\$/t) (based on ComexStat-MDIC)	97	97
Production value (R\$ thousand, ANM)	94,717	484,250
CFEM Amount (2%) (R\$ thousand, ANM)	1,894	9,685
CFEM Amount Collected by SAMA in 2025 (R\$ thousand, ANM)	11,700	-
Estimated impact on municipal revenue (60% of CFEM* R\$ 225 million)	0.5%	2.6%
Impact on local employment (MSV = 1,000 jobs / total employment 3,800 – CAGED/MTE)	32%	32%
Mineral exports in 2025 (US\$ 12 million = R\$ 66 million, ComexStat-MDIC)	0.05% of the total	-

Source: Prepared by the authors.

Although it is not possible to provide exact figures on the number of suppliers and the value of local purchases that support the operation by category—such as maintenance, logistics, technical services, and other services—it is possible to estimate certain multiples and breakdowns based on the information listed in the Serra Verde Communication Plan released in 2020⁸⁰, as well as by using proxies for the economic impacts derived from the Vale Partilhar Program⁸¹

80. https://www.dfc.gov/sites/default/files/esia/2025/serraverde/Project/06_Stakeholder%20Engagement%20Plan_508.pdf

81. <https://vale.com/documents/d/guest/categorias-de-suprimentos-elegiveis-ivc>

and CBMM's Sustainability Report⁸², both of which are used for large-scale mining projects in Brazil.

Regarding job creation, at the time the communication plan was released, Serra Verde projected that 400 people would be directly employed after operations began, along with approximately 1,200 indirect jobs. In other words, calculating the overall multiplier—as explained below—we have:

$$\frac{400 + 1.200}{400} = 4,0x$$

Thus, to assess the effect that most closely reflects the local reality—taking into account that the number of jobs is based on the net local employment figure reported by CAGED in 2025⁸³ in Minaçu—where the average number of employees in the non-ferrous metal mining industry for the year was 323—we can infer that the total number of indirect jobs is 969, resulting in a total impact of 1,292 jobs in the region stemming from the company's operations. Taking into account the average real starting salary for the year⁸⁴, R\$ 2,295.40, the average monthly payroll for the year was R\$ 2,965,656.80 for all jobs (direct and indirect).

With regard to suppliers, taking into account the information on categories of local suppliers used by Vale's "Vale Partilhar" program and the resulting adjustment to the information disclosed by Serra Verde itself, a sectoral benchmark for operations in Minaçu was established at approximately 42 recurring local suppliers, with a likely range of between 35 and 50 suppliers. The estimate includes suppliers in the areas of industrial maintenance, road transportation, cargo handling, technical services, food services, security, cleaning, building maintenance, site preparation, environmental services, safety, health, and operational support.

Based on an estimate of 42 recurring local suppliers, the 1,200 indirect jobs were distributed in the spreadsheet below according to the labor intensity and operational relevance of each supplier group. The largest estimated concentrations are in facilities and general services/other, with approximately 312 indirect jobs, followed by logistics/transportation and industrial maintenance, with about 216 indirect jobs each.

Finally, to estimate the distribution of the financial impact among suppliers—since access to Serra Verde's financial expenditure data is not possible—we apply an assumption of marginal spending with suppliers, calculated for every R\$1 million spent in the region. Thus, using the CBMM/Araxá case as a benchmark—where approximately 13.3% of the total supplier budget is converted into local purchases—we have the following table:

82. <https://cbmm.com/relatorio-sustentabilidade/assets/files/cbmm-relatorio-completo.pdf>

83. For more information, visit the CAGED Business Intelligence portal at: <https://www.gov.br/trabalho-e-emprego/pt-br/assuntos/estatisticas-trabalho/novo-caged/2026/marco/pagina-inicial>

84. Available only nationwide.

TABLE 37

Estimate of the indirect economic impacts of the REE operation on local suppliers in Minaçu

Supplier sector ⁸⁵	Applied sectoral weight	Estimated number of suppliers	Estimated indirect jobs	Total marginal procurement budget	Estimated local purchases – 13.3%
Industrial and plant maintenance	22%	9	264	R\$ 220,000	R\$ 29,260
Logistics and transportation	18%	8	216	R\$ 180,000	R\$ 23,940
Facilities and general services/other	18%	8	216	R\$ 180,000	R\$ 23,940
Fleet and Mobile Equipment Maintenance	13%	5	156	R\$ 130,000	R\$ 17,290
Civil and electromechanical works	12%	5	144	R\$ 120,000	R\$ 15,960
Mining technical services	10%	4	120	R\$ 100,000	R\$ 13,300
Environmental services, safety, health, and monitoring	7%	3	84	R\$ 70,000	R\$ 9,310
Total	100%	42	1,200	R\$ 1,000,000	R\$ 133,000

Source: Prepared by the authors.

TABLE 38

Perceptions and realities of critical issues in REE activities

Perceptions	Realities
There is a significant lack of geological knowledge in Brazil	According to the SGB, the percentage of the Brazilian territory that has been mapped is equivalent to the international average. 27% at a scale of 1:100,000 / 50% at a scale of 1:250,000 In the case of Precambrian shields, these percentages rise to 44% and 70%, respectively.
Brazil has a high tax burden on the mining industry	65% of the value of Brazilian mineral production is exported; that is, it is not subject to the Tax on the Circulation of Goods and Services (ICMS), the Social Integration Program (PIS), and the Contribution for the Financing of Social Security (Cofins), and, if located in areas under the jurisdiction of the Amazon Development Authority (Sudam) (60% of the national territory), the Midwest Development Authority (Sudeco), and the Northeast Development Authority (Sudene), it is exempt from 75% of the Corporate Income Tax (IRPJ), and the remaining 25% of the tax due may be reinvested in expansion or modernization. It should be noted that more than 40% of Brazil's mineral production comes from Sudam's areas. Thus, the tax burden applies only to 35% of mining output that is not exported, and this portion is indeed subject to a high tax rate.

85. As a validation reference, Serra Verde itself reported the participation of 31 local suppliers in a workshop organized by the Avançar Program, focused on the company's procurement processes and requirements. This number was treated as an observable baseline, to which an adjustment was applied to account for suppliers not participating in the workshop, additional recurring contracts, and the operational expansion planned by the company.

Environmental licensing is a lengthy process	The environmental licensing process for major REE projects in Minas Gerais and Goiás has progressed more quickly than is typically seen for mining projects.
There are serious infrastructure bottlenecks	There are logistical problems, but it should be noted that the volume of REE is small compared to traditional Brazilian mining. For example, in 2025, Brazil exported 680 metric tons of REE compounds (compared to 400 million metric tons of iron).
There are STI challenges	Brazil has a capable STI ecosystem, with research centers, technology hubs, and universities, but it needs to be supported with funding.
There are challenges in determining technological pathways, given that each deposit is unique	That's true. The Serra Verde mining project, which began actual production in 2023, started its studies on processing routes in 2015–2016, undergoing an exhaustive process of route refinement. Tailoring a processing route to the specific deposit to minimize environmental impact has few precedents, so the process is slow.
REE deposits have no radioactivity, or very low levels of it	Ideally, this radioactivity would need to be neutralized near the extraction site. On-site processing is a sine qua non condition for avoiding the transport of radioactive elements.

Source: Prepared by the authors.

TABLE 39

Summary of Structural Gaps in Brazil's Rare Earths Supply Chain and Their Strategic Implications

Dimension	Main Gap	Evidence/manifestation of the gap	Strategic Implication for NRES
Geology and Information	Information base remains uneven and insufficiently geared toward decision-making	Regional asymmetry in mapping, the need to update REE studies, and greater application of mineral intelligence	Strengthen strategic mapping, data updates, and sector-specific intelligence
Technology and industry	Low industrial density in high-value-added sectors	Emerging midstream sector, technology pathways still taking shape, dependence on foreign equipment, inputs, and know-how	Prioritize selective midstream development, pilot projects, demonstrations, and industrial scaling
Human capital, suppliers, and specialized services	Support ecosystem still insufficient for large-scale operations	Shortage of skilled labor, low supplier readiness, limited capacity for maintenance, metrology, and analytical services	Develop specialized training and a national base of critical suppliers and services
Regulation and licensing	Lack of regulatory predictability and coordination, especially regarding radiological issues	Tensions between mining, environmental protection, and nuclear regulation; uncertainties regarding NORM; risk of litigation	Harmonize jurisdictions, proactively address critical issues, and enhance legal certainty

Financing and the market	Difficulty in financing the transition from pilot to commercial scale and underdeveloped market	Unequal access to capital, greater difficulty for junior companies, and a lack of established anchor demand	Create de-risking tools, support for demonstration, and market-making mechanisms
Territory, society, and the environment	Limited territorial benefits and persistent socio-environmental concerns	Low local fiscal impact when concentrated on compounds, water risks, insufficient consultation, and social opposition	Integrate value addition, territorial development, social legitimacy, and environmental safeguards

Source: Prepared by the authors.

3.7. Opportunities for Value Addition and Strategic Implications

An analysis of Brazil's rare earths sector indicates that the country's main strategic opportunity lies in its ability to transform its geological base into a progressive path of value addition throughout the value chain. Brazil is well-positioned to move beyond its role as a supplier of raw or intermediate materials, provided it can build productive, technological, and institutional capacities in the most critical links of the value chain.

This opportunity is particularly significant because rare earths play a strategic role in technology-intensive sectors of growing geopolitical importance, such as electric mobility, wind energy, automation, advanced electronics, healthcare, and defense. In this context, value addition should not be understood merely as mineral processing, but as the development of capabilities in processing, separation, refining, metallurgy, manufacturing, and, progressively, recycling and secondary supply. Brazil's path toward value addition, however, is unlikely to follow a linear course or occur simultaneously across all links in the value chain. International experience suggests that the most consistent progress typically occurs in stages, combining the expansion of mineral supply, the selective strengthening of the midstream, the gradual development of intermediate products, and manufacturing in strategic niches.

TABLE 40

Staged Development Path of the Brazilian Rare Earths Chain

Horizon	Main Focus	Priority Opportunities
Short term	Consolidation of the upstream sector and the start of industrial densification	Competitive upstream; byproducts; secondary mining; initial selective midstream; pilot plants and demonstration facilities; recycling of industrial scrap and mineral waste

Medium term	Advances in mineral processing and intermediate products	metals and alloys; semi-finished magnets; regional processing and innovation hubs; integration with industrial demand
Long term	Consolidation of an integrated supply chain and technological diversification	permanent magnets; components; functional materials; advanced circularity; integrated mine-refining-manufacturing-recycling ecosystem

Source: Prepared by the authors.

3.7.1 Opportunities in the competitive upstream sector

In the short term, the most concrete opportunities for Brazil lie in consolidating a competitive upstream sector and using that foundation as a platform for the gradual deepening of the supply chain. The first of these opportunities is to establish the country as an alternative and reliable supplier of rare earths outside the most concentrated global markets. The growing portfolio of projects, the resumption of commercial production, and the existence of a significant geological base provide Brazil with real opportunities to expand its presence in the mineral sector, especially in a scenario where buyers and governments are seeking not only greater volume but also geographic diversification of supply.

The interviews and technical documentation analyzed indicate that a significant portion of Brazilian projects show promising signs of competitiveness in the upstream sector. Since Brazil currently has only one operational project and several others remain in the licensing, engineering, and maturation phases, the transformation of this projected competitiveness into a real economic foundation will depend on concrete progress in these projects.

A second concrete opportunity lies in specialization in ion-adsorption clay deposits, which are taking on a central role in the national pipeline. This type of deposit is particularly relevant because it may be associated with the production of more critical magnetic elements, such as Dysprosium and Terbium, which are essential for high-performance magnets.

Another important avenue for adding value in the upstream sector is the utilization of co-products and by-products in existing mineral supply chains. Rather than relying exclusively on dedicated mines, the country can capture value through synergies with supply chains such as niobium, phosphate, tin, and bauxite, as well as through existing logistics, processing, and geological knowledge infrastructure. This approach reduces entry costs, accelerates the learning curve, and can expand the future feedstock base for separation and refining plants. Also part of this strategy are secondary mining and the reuse of tailings and mineral residues, which can simultaneously contribute to supply security, liability reduction, and technological innovation.

From a strategic perspective, the Brazilian upstream sector should not be viewed merely as an export link, but as the foundation for the progressive development of the other segments of the chain. The opportunity, therefore, lies in using the expansion of the upstream sector as a lever to enable subsequent stages.

3.7.2 Opportunities in the selective midstream sector

The midstream sector concentrates both the main bottleneck and the main strategic opportunity in the Brazilian supply chain. It is at this stage that the most significant leap in value addition occurs between mining and more technology-intensive products. Brazil's opportunity lies in structuring a selective midstream sector, anchored in viable routes, aligned with the available mineral resources, and compatible with the country's current scale and maturity.

In the short term, this means advancing the production of mixed carbonates—a concentrate with superior characteristics—as well as establishing selective separation capabilities for the most critical elements, particularly NdPr and, on specific production routes, Dy/Tb. In the medium term, this opens the door to the production of selected metals and alloys, with greater control over the specifications and quality of raw materials. This approach allows for risk reduction, the concentration of resources, and the incremental development of industrial expertise.

Another important opportunity in the medium term is the consolidation of regional processing and innovation hubs, especially in areas where mineral resources, infrastructure, companies, technology centers, and financing instruments are closely located. This territorial strategy is more promising than the geographic dispersion of isolated initiatives, as it promotes economies of scale, workforce development, infrastructure sharing, and greater integration among mining, processing, and applied research. The consolidation of these hubs may be particularly relevant in Goiás and Minas Gerais, where a relatively higher density of projects, institutions, and installed capacity is already evident.

The selective midstream sector is, therefore, the most critical link for Brazil to move beyond being merely a potential supplier of mineral resources and assume a more robust position in global supply chains. It represents the point where geology, chemistry, engineering, industrial policy, regulation, and financing intersect most intensely.

To test this hypothesis and shed more light on the premises developed, the following economic exercise was conducted.

3.7.2.1 Oxide Separation in Brazil: A Comprehensive Exercise

This report has already demonstrated that the midstream sector is the decisive link for Brazil to move beyond being merely a major holder of mineral resources and take a more robust position in the global rare earths supply chain. The separation and refining stage—especially the production of separated oxides—constitutes the industrial backbone of the midstream and serves as a bridge between the mineral competitiveness of the upstream sector and any subsequent ambitions for the production of metals, alloys, magnets, or components. For this reason, this subsection does not revisit the general geopolitical rationale for the NRES, which has already been discussed. Its objective is more specific: to assess under what conditions the establishment of oxide separation capacity in Brazil can be competitive, financeable, and strategically justifiable.

This assessment, however, cannot be reduced to a conventional financial analysis. International experience shows that the current structure of the rare earths supply chain did not result solely from private decisions driven by financial returns. On the contrary, the global imbalance in favor of certain

jurisdictions was built on a combination of scale, industrial policy, financing, technological coordination, tolerance for strategic risks, and the ability to set aside strictly financial criteria in favor of long-term industrial and geopolitical objectives. In other words, the decision to invest in midstream is not merely a project decision; it is also a strategic positioning decision.

This does not mean, however, that economic rationality should be ignored—quite the contrary. Brazil will only be able to transform its mineral advantage into industrial capacity if oxide separation is competitive in terms of cost, risk, and market access. Brazil’s opportunity stems from a promising foundation: domestic REE projects often exhibit favorable characteristics associated with the significant presence of heavy and magnetic elements, notably Nd, Pr, Dy, and Tb. This composition tends to increase the value of the mineral mix and can enhance the economic attractiveness of domestic processing, especially when combined with low-OPEX upstream production routes, competitive energy availability, proximity between the mine and the plant, and adequate infrastructure conditions.

The central question, therefore, is not merely whether Brazil should move forward in the midstream sector, but rather what economic, industrial, and institutional framework would allow it to do so with less risk and greater value capture. To this end, the analysis must assess the availability and quality of domestic feedstock, the appropriate scale of plants, CAPEX requirements, key OPEX components, international prices excluding China, the commercial risk associated with Chinese competition, the cost of capital, and public policy instruments capable of reducing uncertainty.

The Brazilian midstream sector should therefore be viewed as a frontier that is simultaneously economic, industrial, and strategic. Its viability will depend on the ability to combine the country’s intrinsic advantages—such as its mineral resources, energy, and geographic location—with instruments designed to foster competitiveness, such as financing, tax exemptions for critical inputs, demand guarantees, offtakes, price floors, and regulatory solutions for sensitive issues. The litmus test will be to demonstrate whether these conditions, when coherently coordinated, enable Brazil to produce separated rare earth oxides at a competitive cost, with manageable risk, and reliable market access outside of China.

The analysis presented in this subsection is preliminary in nature and should be understood as an initial assessment of the potential competitiveness of Brazil’s rare earth midstream sector. Its purpose is not to provide an exhaustive economic model or a definitive conclusion regarding the feasibility of establishing oxide separation plants in the country, but rather to organize the key variables that should guide future studies. The assumptions discussed here—particularly regarding the availability and composition of feedstock, CAPEX, OPEX, international prices, offtake conditions, cost of capital, public incentives, and regulatory risks—should be validated through further rounds of technical-economic analysis, financial modeling, consultation with industry stakeholders, and international comparisons.

Industrial Scale and Domestic Feedstock as the Basis for Competitiveness

The first step in assessing the competitiveness of a Rare Earth Oxide separation industry in Brazil is to precisely define what its feedstock base will be. Before discussing plant scale, CAPEX, OPEX, selling price, or public policy instruments,

it is necessary to verify whether there is sufficient domestic feedstock that is predictable, contractable, and of suitable composition to sustain an industrial operation.

For this preliminary exercise, the feedstock projected for the five Brazilian REE projects in the most advanced stages of development is used as the basis for analysis. This is a simplifying assumption, but a useful starting point: if the exercise indicates feasibility, optimized scenarios can be developed later, incorporating adjustments resulting from commercial, technical, industrial, or regulatory constraints.

Based on this analysis, potential production in the upstream sector is projected to exceed 40,000 metric tons of TREO per year. This volume alone would already indicate a critical mass significant enough to evaluate domestic processing alternatives. However, the most important factor is not just the aggregate scale, but the composition of the Brazilian feedstock basket. The projects under consideration exhibit a significant concentration of elements of greater economic and strategic value, especially Heavy Rare Earths and magnetic rare earths.

This composition substantially alters the discussion on competitiveness. Nd, Pr, Dy, Tb, and Y account for just over 46% of the projected volume but represent 96.7% of the revenue generated.

For the purposes of this analysis, it is proposed that the composition of the “Brazilian feedstock basket” be the composition considered for the separation plant. It is worth emphasizing that this is a simplifying assumption, but one that is appropriate for an initial competitiveness assessment, as it allows for an evaluation of the economic attractiveness of the midstream sector based on a representative domestic framework and leaves room for future optimizations of commercial, technical, and industrial arrangements.

TABLE 41

Projection of the Brazilian feedstock basket for the midstream competitiveness exercise (2027–2036)

Upstream production of REO equivalent (t)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
La ₂ O ₃	1,786	10,015	14,998	16,126	16,436	16,876	18,013	18,240	18,011	17,755
CeO ₂	288	661	1,003	1,047	1,144	1,243	1,068	1,106	1,086	1,062
Pr ₆ O ₁₁	403	1,749	2,638	2,823	2,881	2,977	3,144	3,188	3,145	3,098
Nd ₂ O ₃	1,498	6,093	9,215	9,832	10,091	10,469	10,754	10,883	10,754	10,605
Sm ₂ O ₃	173	763	1,201	1,310	1,352	1,422	1,454	1,468	1,450	1,433
Eu ₂ O ₃	29	165	246	259	269	276	275	275	275	273
Gd ₂ O ₃	173	548	866	957	979	1,005	1,014	1,019	1,013	1,005
Tb ₄ O ₇	29	72	114	124	129	134	127	127	127	126
Dy ₂ O ₃	173	360	554	613	631	645	652	651	650	650
Ho ₂ O ₃	29	68	108	121	126	129	132	131	131	132
Er ₂ O ₃	86	179	277	310	325	336	332	330	330	332
Tm ₂ O ₃	12	30	46	51	54	56	57	57	56	57

Yb₂O₃	58	119	189	214	226	242	246	242	239	242
Lu₂O₃	6	8	15	17	20	22	22	22	21	22
Y₂O₃	1,020	2,350	3,707	4,161	4,344	4,371	4,470	4,467	4,489	4,518
TREO	5,760	23,180	35,178	37,965	39,006	40,204	41,760	42,204	41,776	41,308

Source: Prepared by the authors.

TABLE 42

Projected Brazilian Production of Strategic Rare Earth Elements (2027–2036)

Strategic subtotals	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
NdPr	1,901	7,841	11,854	12,655	12,972	13,446	13,898	14,071	13,899	13,703
DyTb	202	432	668	737	760	779	779	778	777	775
MREO	2,102	8,274	12,521	13,392	13,732	14,225	14,677	14,849	14,675	14,478
HREE	1,786	4,663	7,323	8,137	8,454	8,638	8,780	8,787	8,781	8,789
LREE	3,974	18,517	27,855	29,828	30,552	31,566	32,979	33,417	32,995	32,520

Source: Prepared by the authors.

Size and scale

Determining the plant size is one of the central premises of this exercise, as it influences the level of CAPEX, the OPEX structure, feedstock requirements, the degree of commercial risk, and the operational complexity of the project. In the case of rare earth oxide separation, there are various possible industrial architectures. Some plants are designed to process and separate a broad range of rare earth elements (REEs), producing multiple refined oxides. Others adopt a more selective scope, focusing on NdPr, heavy elements such as Dy/Tb, or specific product streams better aligned with the composition of the available feedstock and buyer demand.

For this preliminary study, we chose to model a multipurpose plant with a production capacity of 25,000 metric tons of TREO per year (25 ktpa). This choice is not based on the assumption that this will necessarily be the optimal configuration for Brazil. On the contrary, it is recognized that there may be industrial arrangements that are more economically efficient, especially plants that are more selective, modular, or integrated into specific projects. A plant designed for a specific mineral mix, with a higher concentration of magnetic or heavy elements, may offer more favorable CAPEX, OPEX, recovery rates, learning curves, and commercial strategies than a multipurpose facility designed to process a more diverse feedstock base.

Nevertheless, the decision to conduct a comprehensive study is justified by the very diversity of the Brazilian projects under consideration. Each project has its own compositional characteristics: some have a higher relative abundance of Dy/Tb; others, a higher proportion of Nd/Pr; still others, a higher concentration of Y, La, Ce, or other light elements. Given this heterogeneity,

a multipurpose plant allows for testing the competitiveness of a broader configuration, one better able to reflect the variety of the “Brazilian basket” of feedstock. It is, therefore, a deliberately non-optimized scenario, but one that is useful as a conservative feasibility test.

The logic behind this exercise is as follows: if a comprehensive configuration—one that is less tailored to the specific characteristics of each project—demonstrates economic and industrial competitiveness, then there is reason to believe that more optimized versions, designed around specific feedstocks, dedicated contracts, selective routes, or modular arrangements, could deliver even better performance. In other words, the 25 ktpa multipurpose plant serves as a baseline test. It is not intended to conclude the discussion on the optimal design of the Brazilian midstream sector, but rather to establish a reference point from which more refined alternatives can be evaluated.

The decision to set the capacity at 25 ktpa also aims to strike a balance between industrial ambition and prudent implementation. The estimated potential production of the Brazilian projects analyzed exceeds 40,000 metric tons of TREO per year, which would, in theory, indicate room for a higher-capacity plant. However, this production stems from projects that are not yet operational and that may face delays, schedule revisions, regulatory restrictions, financing difficulties, changes in commercial strategy, or even project cancellations. Designing a plant sized to absorb all potential production from the outset would increase the risk of idle capacity and a mismatch between the ramp-up curve of mining projects and the plant’s ongoing feed requirements.

In this context, 25 ktpa represents an intermediate and more prudent scale. It is large enough to test a significant industrial plant and is comparable to units of similar size, including in terms of operational assumptions, but not so large as to depend entirely on the simultaneous implementation of all Brazilian upstream projects. Furthermore, since the implementation of a separation plant requires advance planning, engineering, permitting, technology licensing, financing, and commercial structuring, the decision regarding capacity must be made before there is complete certainty about the future production of all projects.

Thus, the decision to build a 25 ktpa multipurpose plant aims to reconcile three objectives: to reflect the diversity of Brazilian feedstock, to avoid an overly optimistic projection regarding the future availability of raw materials, and to create a conservative basis for testing the competitiveness of the domestic midstream sector. If this scenario proves viable, the most relevant conclusion will not be that the 25 ktpa plant is necessarily the final solution, but that Brazil has the initial conditions to move forward with more specific, selective, and potentially more competitive industrial alternatives.

CAPEX

CAPEX is one of the main barriers to establishing Rare Earth Oxide separation capacity outside of China. It is a capital-intensive process that requires specialized separation equipment, chemical infrastructure, utility systems, process engineering, effluent treatment, environmental and radiological control, and

storage facilities, automation, quality control laboratories, and, in many cases, the importation of technology or the adaptation of processes developed in other jurisdictions. For this reason, the estimated initial investment is a critical factor in assessing the competitiveness of the Brazilian midstream sector.

The main methodological challenge is the scarcity of reliable public data from China, where there is little transparency regarding implementation costs, capital intensity, and the economic structure of the plants. Furthermore, the structure of the Chinese industry itself makes comparisons difficult: because it is a highly integrated and vertically integrated supply chain, many companies do not separately analyze, report, or price the mining, concentration, separation, refining, metallization, and manufacturing stages. As a result, the data available for international benchmarking is limited and requires careful interpretation.

Given this limitation, the analysis used as a reference the few recent projects for new separation or refining facilities currently under development outside of China. Although these projects differ significantly in terms of technological route, feedstock type, jurisdiction, product scope, and commercial strategy, they provide useful benchmarks for estimating the order of magnitude of the CAPEX required for an REE separation plant.

The first benchmark considered is the Iluka project in Western Australia. Although the plant was designed to process monazite concentrate, rather than MREC, its processing capacity is comparable to the scale analyzed in this study. The estimated capital intensity for this project is approximately US\$64/kg TREO. This benchmark should be interpreted with caution, as monazite processing tends to be more complex than MREC processing, particularly due to challenges associated with mineralogical composition, impurities, and radiological management. Furthermore, Australia is a jurisdiction with potentially higher implementation costs than Brazil. For these reasons, this benchmark may be overestimating the CAPEX applicable to a Brazilian plant based on MREC.

The second benchmark is Energy Fuels' White Mesa plant. According to information released by the company itself, the new facility is expected to produce approximately 6.3 ktpa of REO, with an estimated CAPEX of US\$410 million. This implies a capital intensity of approximately US\$65/kg TREO. In this case, the comparison also requires some caveats, as the plant has a more selective profile, focusing on NdPr, Dy, and Tb. Selective plants geared toward higher-value elements may have higher capital intensity, whether due to greater technical complexity or stricter requirements for separation, purity, process control, and product qualification.

The third benchmark considered is the plant that Aclara plans to build in Louisiana, intended for processing associated with the Carina Project. Although there are significant gaps in the information, the materials submitted by the company to the regulatory authority indicate an approximate CAPEX of US\$ 277 million. Considering an average annual production of approximately 4.246 ktpa of TREO from the Carina Project, the capital intensity is estimated to be close to US\$ 66/kg TREO. This benchmark is particularly relevant because it is associated with a Brazilian ionic clay project and because it is similar to the type of feedstock considered in this analysis.

TABLE 43

Comparative Analysis of the Capital Intensity of New Facilities Under Development Outside China

Project	Country	Scope/feedstock	Projected capacity	CAPEX Indicated	Capital intensity
Iluka	Western Australia	Monazite concentrate	17.5 ktpa REO	US\$ 1.2 billion	US\$ 64/kg TREO
White Mesa / Energy Fuels	USA	Selective plant, focusing on NdPr, Dy, and Tb	6.3 ktpa REO	US\$ 410 million	US\$ 65/kg TREO
Aclara / Louisiana	USA	Plant associated with the Carina Project	4.3 ktpa TREO	US\$ 277 million	US\$ 66/kg TREO

Source: Prepared by the authors based on data published by the companies.

The convergence among very different benchmarks is noteworthy. Despite differences across jurisdictions, routes, and products, the three projects indicate a similar level of capital intensity. This figure should not be interpreted as a definitive estimate, but rather as a reasonable reference for preliminary CAPEX modeling, especially given the scarcity of public data on separation plants outside of China.

Accordingly, for this analysis, we adopt the assumption of US\$ 66/kg TREO as a benchmark for capital intensity. Applied to a 25 ktpa multipurpose plant, this assumption results in an estimated CAPEX of approximately US\$ 1.65 billion. This is a preliminary and conservative estimate, with a clear tendency to overestimate, subject to validation through engineering studies, the definition of the technological route, plant location, the degree of equipment localization, waste treatment, radiological requirements, the scope of utilities, and the final project design.

Nevertheless, this figure provides a consistent basis for testing the economic competitiveness of the proposed scenario and for comparing, in later stages, the impact of alternatives that are more selective, modular, or integrated with specific projects.

OPEX

The operating cost of a Rare Earth Oxide separation plant is determined primarily by a set of recurring industrial cost drivers: energy, labor, reagents and solvents, maintenance, industrial services, waste management, quality control, and costs associated with environmental and radiological requirements. In the specific case of rare earth oxide separation, reagents play a particularly important role, including sulfuric acid, hydrochloric acid, ammonium carbonate, oxalic acid, sodium hydroxide, organic extractants, diluents, and other chemical inputs used in the leaching, separation, precipitation, purification, and finishing stages of the oxides.

An accurate estimate of the consumption of these inputs, however, depends heavily on the process route, the composition of the feedstock, the level of impurities, the desired selectivity, the recovery factors, and the commercial specifications of the final products. In other

words, it is not possible at this preliminary stage to determine the exact consumption of reagents and utilities without specific process engineering for the Brazilian plant. For this reason, the analysis adopts a comparative approach, using parameters from similar projects as a reference and qualitatively adjusting the main factors in which Brazil tends to have a relative advantage or disadvantage.

TABLE 44

Total Cost Benchmark for Rare Earth Oxide Separation

Project	Aclara USA	Lynas Malaysia	Solvay France	China (benchmark)
Total Cost (US\$/kg REO)	22–24	13 (integrated)	22–28	10–17 (subsidized)

Source: Prepared by the authors.

As a starting point, the price parameter for oxide separation in US\$/kg REO associated with Aclara’s oxide separation project—planned for installation in the state of Louisiana, in the United States—was used. This reference is useful because it involves a recent project outside of China, associated with a supply chain originating outside of China, and linked to a feedstock of ionic clays—a profile more closely aligned with some of the Brazilian projects analyzed.

TABLE 45

Estimated Breakdown of Operating Costs for the Aclara USA Plant

Component	USD/kg	Note
Total Aclara fee	46.3	Oxide separation fee in accordance with BFS 2026
Amortized Capex Aclara	(6.5)	Capex of \$280 million as reported
Less: Tax + Aclara margin	(15.8)	Estimated U.S. tax burden + 15% profit margin
Operating cost	24.0	—

Source: Prepared by the authors.

Based on this benchmark, the price was broken down into operating costs, depreciation, taxes, and margin. This procedure made it possible to isolate an operating benchmark of approximately US\$ 24/kg TREO. This figure was adopted as a conservative anchor for this exercise because it does not take into account other competitiveness factors in which Brazil performs better, such as energy and labor.

In short, the cost used for the purposes of this exercise does not reflect Brazil’s competitive capacity, as it is based on a unit to be installed in the U.S.

However, cost drivers have been identified that, in the specific Brazilian context, may offer more competitive options than the benchmark used.

TABLE 46

Operating Cost Drivers and Brazil's Competitive Advantages

Cost driver	Brazil's competitive advantage	Points to Consider
Feedstock	Favorable, due to proximity to domestic projects and a composition rich in magnetic elements and HREE	Acquisition cost, long-term supply contracts, project timelines, and MREC quality
Energy	Potentially favorable, provided it is procured via long-term PPAs/ACLs	Effective price in US\$/MWh, contract term, exposure to volatility, and surcharges
Commodity reagents	Competitive or neutral compared to peers	Evaluate domestic supply versus foreign dependence, specific consumption by route, CIF/DDP prices, taxation, and domestic logistics.
Specialized reagents	Neutral or potentially unfavorable, due to reliance on imports	Suppliers, purchase volume, import taxes, lead time, and supply security
Labor*	Favorable compared to most Western economies in the case of general operational labor	Productivity, need for expatriates, and need for training and qualified professionals to develop a specialized technical workforce
Maintenance and sustaining	Moderately favorable	Maintenance plan, ability to source domestically produced replacement parts, service contracts, and localization of suppliers
G&A, quality control, and technical services	Favorable compared to other Western economies, but dependent on local maturity	Laboratories, certifications, specialized services, and compliance costs must be available domestically

Source: Prepared by the authors.

* Supplementary analysis on labor:

Given that labor costs are not uniform, an analysis was conducted to estimate general operational labor—an area in which Brazil has a real and immediate cost advantage—as well as specialized technical labor related to hydrometallurgy, separation chemistry, radiological control, instrumentation, analytical laboratories, process engineering, and senior geology, areas in which Brazil still faces significant bottlenecks.

Four sources of information were used to prepare the estimates. These are: i) Aclara's technical note NI 43-101⁸⁶, which provides the number of workers by job function in three separate categories (Aclara mine, mining contractor, and hydrometallurgical plant); ii) 2022 statistical data from the Census Bureau for the mining, extraction, oil, and

86. https://cdn.prod.website-files.com/67b9c5dc15db73b34fcf2bce/690dfe2a4ac3bfeec08486e6__NI43-101_Technical-Report_ACLARA_Carina-Project_251105.pdf

gas, the report—EEOC NAICS 21 (Mining)⁸⁷ ; iii) employment and wage data from the U.S. Bureau of Labor Statistics⁸⁸ for the metallic minerals sector—BLS Benchmark for Metal Ore Mining (NAICS 212200) from 2022; and iv) MiHR Canada—10-year projection for Ontario (metallic and nonmetallic mining and coal).

According to information from Aclara, the Carina project in Goiás is the only primary source providing detailed staffing figures for an integrated REE operation in Brazil. Therefore, to determine the number of workers, the workforce was divided by function into three separate categories (Aclara mine, mining contractor, and hydrometallurgical plant):

TABLE 47

Workforce Breakdown for the Carina Project by Operational Block

Mine segment – Aclara direct team (Table 16-8): 33 workers	Managers, engineers, and geologists (long-, medium-, and short-term; grade control; drainage; geotechnical; monitoring, etc.): approximately 15 positions Specialized technicians (environmental, safety, geotechnical, grade control): approximately 10 positions Administrative staff and assistants: approximately 8 positions
Mine Block – Contractor (Table 16-10): 391 workers on average	Mining operations: 336 Equipment maintenance: 54
Hydrometallurgical plant block (Table 21-9): 130 positions	Management and senior engineering: 12 Supervision and instrumentation: 12 Qualified process operators (control room, leaching, filtration, samplers): 52 Trades and general operations (electricians, mechanics, mobile equipment operators, warehouse): 54
Total for the Carina project: 554 positions	Highly skilled workforce (engineering, management, technical geology): 27 positions - 5% Specialized technical workforce (environmental technicians, safety, instrumentation, supervision): 22 positions - 4% Qualified process operators: 52 positions - 9% General operational/trades personnel (mining contractors, basic plant operations, maintenance): 440 positions - 80% Administrative and logistical support: 13 positions - 2%

Source: Prepared by the authors.

Taking into account the nature of the Aclara project, which focuses on ionic clays, the approximate distribution of personnel is 5–7% highly specialized labor, 13% technical and supervisory professionals, and 80% operational workers and tradespeople.

87. <https://www.census.gov/data/tables/2022/econ/economic-census/naics-sector-21.html>

88. https://www.bls.gov/oes/2023/may/naics4_212200.htm

With regard to the EEOC's aggregate industry benchmark for NAICS 21 (Mining), the statistical data reported for 2,005 companies, with 305,327 employees, show that approximately 10% of professionals are skilled, 73% are unskilled labor, and 17% are in management/administrative roles, which is close to the structure reported by Aclara.

As for the 2022 BLS Metal Ore Mining data (NAICS 212200), official figures show that of the 42,300 total jobs, the workforce is predominantly operational, accounting for about three-quarters of total employment ($\approx 76\%$), while skilled professionals account for approximately 9% and management and administrative roles for about 15% of the total.

In addition to the occupational distribution, the statistics show the sector's average total salary of \$72,600 per year, with \$155,000 for specialized professionals and approximately \$50,000–\$70,000 for unskilled workers. These figures indicate a 3:1 ratio between specialized and unskilled professionals.

When comparing the situation in the Brazilian labor market to that of other markets, it is clear that the domestic market is highly competitive relative to the international market.

The annual direct cost of domestic operational labor is competitive, ranging from approximately \$5,500 to \$9,900 per worker per year. Specialized technical labor, on the other hand, is at a higher level, ranging from \$12,100 to \$20,900 per year, which is about 2.1 times the average cost of operational staff. In the case of specialized engineering, the estimated annual cost ranges from US\$25,300 to US\$43,900, or approximately 4.5 times the average cost of operators. A summary table is provided below.

TABLE 48

Estimated Labor Costs by Category

Category	CBO - CAGED/MTE 2026	Base monthly pay range – R\$	Estimated annual cost – R\$	Estimated annual cost – US\$ ⁸⁹	Profile
Mineral processing operator	7121-10	2,069 – 3,566	27,600 – 47,500	5,500 – 9,500	Non-specialized / operational
Mill operator – processing	7121-05	2,137 – 3,706	28,500 – 49,400	5,700 – 9,900	Non-specialized / operational
Mining machinery operator	7111-30	2,354 – 3,336	31,400 – 44,500	6,300 – 8,900	Non-specialized / operational
Mining technician – thorium, zirconium, and rare earth minerals	3163-05	5,020 – 6,860	66,900 – 91,500	13,400 – 18,300	Specialized technical
Mining Technician – General	3163-05	4,511 – 7,812	60,100 – 104,200	12,100 – 20,900	Specialized technical

89. PTAX sale price as of April 30, 2026 = R\$ 4.9886/US\$

Chemical Engineer – Mining/Metallurgy	2145-15	9,477 – 16,429	126,400 – 219,100	25,300 – 43,900	Specialized higher education
Mining Engineer	2147-05	Equivalent range	126,400 – 219,100	25,300 – 43,900	Specialized higher education

Source: Prepared by the authors.

MiHR Canada’s 10-year projection for Ontario, covering metal mining, coal mining, and nonmetallic mining, confirms the finding that most of the mineral sector’s hiring needs concentrate in operational and technical trades roles: unspecified trades and operational roles account for 62% of hiring needs, while supervisors, coordinators, and foremen account for 11%, physical science professionals and specialists 10%, technical occupations 6%, support workers 6%, and managers and financial professionals 4%.

Thus, by cross-referencing the four sources, it is possible to categorize the data according to specialization levels, as shown in the summary table below:

TABLE 49

Estimated occupational structure for projects involving rare earths in Brazil by level of specialization

Category	Typical Range	Application to the Brazilian context
Highly specialized (chemical engineers, metallurgists, senior geologists, technical managers, radiation protection specialists)	5–10%	Where Brazil has a structural bottleneck and where the advantage is contingent on Axis 4
Technical and supervisory roles (chemical technicians, instrumentation, quality control, shift supervisors, geotechnical engineers, safety)	8–15%	Brazil can train personnel through SENAI/IFs, but a specific plan is required; partial training advantage
Qualified operational staff (plant operators, control room operators, mining equipment operators)	15–25%	Most immediate training benefit – 6–18-month sector-specific training supports
Trades and general operations (mechanics, electricians, drivers, tradespeople, laborers, mobile equipment operators)	45–65%	Clear and immediate training advantage in Brazil. Since these positions do not require a high level of specialization, they can be adapted to a specialized rare earths mining market.
Administrative and support	5–10%	Clear and immediate training advantage in Brazil

Source: Prepared by the authors.

Finally, to assess the demand for positions in the domestic rare earths industry’s labor market, it is necessary to conduct an analysis consistent with the ktpa projection of equivalent TREO.

First, taking into account the TREO production in ktpa of companies currently in production or about to begin production, the range varies from 100 to 250 direct jobs per ktpa of TREO, with these figures varying depending on the technological route used. Thus, using the average of the ranges for the categories detailed in the previous table and multiplying by the number of possible jobs in three ranges (100 jobs/ktpa; 175 jobs/ktpa; 250 jobs/ktpa), the following scenarios were developed:

TABLE 50

Labor Demand Projection for Scenario 1 – 100 jobs per ktpa produced

Year / est.	TREO (ktpa)	Jobs – Scenario 1 (100 jobs/ktpa)	Highly specialized (a)	Technical and supervisory (b)	Skilled operational (c)	Trades and general operations (d)	Administration and support (e)
2026	3.2	320	24	35	64	176	24
2027	5.8	576	43	63	115	317	43
2028	23.2	2,318	174	255	464	1,275	174
2029	35.2	3,518	264	387	704	1,935	264
2030	38.0	3,797	285	418	759	2,088	285
2031	39.0	3,901	293	429	780	2,145	293
2032	40.2	4,020	302	442	804	2,211	302
2033	41.8	4,176	313	459	835	2,297	313
2034	42.2	4,220	317	464	844	2,321	317
2035	41.8	4,178	313	460	836	2,298	313
2036	41.3	4,131	310	454	826	2,272	310
2037	41.1	4,110	308	452	822	2,261	308
2038	38.5	3,853	289	424	771	2,119	289
2039	39.1	3,907	293	430	781	2,149	293
2040	38.8	3,883	291	427	777	2,136	291

Source: Prepared by the authors.

TABLE 51

Labor demand projection for Scenario 2 – 175 jobs per ktpa produced

Year / est.	TREO (ktpa)	Jobs – Scenario 2 (175 jobs/ktpa)	Highly specialized (a)	Technical and supervisory (b)	Skilled operational staff (c)	Trades and general operations (d)	Administration and support (e)
2026	3.2	560	42	62	112	308	42
2027	5.8	1,008	76	111	202	554	76
2028	23.2	4,056	304	446	811	2,231	304
2029	35.2	6,156	462	677	1,231	3,386	462
2030	38.0	6,644	498	731	1,329	3,654	498

2031	39.0	6,826	512	751	1,365	3,754	512
2032	40.2	7,036	528	774	1,407	3,870	528
2033	41.8	7,308	548	804	1,462	4,019	548
2034	42.2	7,386	554	812	1,477	4,062	554
2035	41.8	7,311	548	804	1,462	4,021	548
2036	41.3	7,229	542	795	1,446	3,976	542
2037	41.1	7,193	539	791	1,439	3,956	539
2038	38.5	6,742	506	742	1,348	3,708	506
2039	39.1	6,838	513	752	1,368	3,761	513
2040	38.8	6,795	510	747	1,359	3,737	510

Source: Prepared by the authors.

TABLE 52

Labor demand projection for Scenario 3 – 250 jobs per ktpa produced

Year / est.	TREO (ktpa)	Jobs – Scenario 3 (250 jobs/ktpa)	Highly specialized (a)	Technical and supervisory (b)	Skilled operational staff (c)	Trades and general operations (d)	Administration and support (e)
2026	3.2	800	60	88	160	440	60
2027	5.8	1,440	108	158	288	792	108
2028	23.2	5,795	435	637	1,159	3,187	435
2029	35.2	8,795	660	967	1,759	4,837	660
2030	38.0	9,491	712	1,044	1,898	5,220	712
2031	39.0	9,751	731	1,073	1,950	5,363	731
2032	40.2	10,051	754	1,106	2,010	5,528	754
2033	41.8	10,440	783	1,148	2,088	5,742	783
2034	42.2	10,551	791	1,161	2,110	5,803	791
2035	41.8	10,444	783	1,149	2,089	5,744	783
2036	41.3	10,327	775	1,136	2,065	5,680	775
2037	41.1	10,275	771	1,130	2,055	5,651	771
2038	38.5	9,632	722	1,059	1,926	5,297	722
2039	39.1	9,768	733	1,075	1,954	5,373	733
2040	38.8	9,708	728	1,068	1,942	5,339	728

Source: Prepared by the authors.

Regardless of the scenario, it is clear that considerable amounts of human capital are required, with varying training needs for more or less specialized roles. It is worth noting that the scenarios in question do not include potential more significant increases in production, the entry of new operators, or other factors.

International prices ex-China, revenue, and commercial risk

Defining price assumptions is a central step in the competitiveness analysis of an oxide separation plant, especially given the complexity of the sector as a whole. After all, there are 17 elements with different applications, prices, and technological, commercial, and production dynamics. For this reason, price floors and off-take agreements are essential for establishing the viability of a given product.

Today, two distinct benchmarks coexist with increasing clarity: on the one hand, prices set within the Chinese industrial sector (which concentrates more than 90% of refining and production of permanent magnets); on the other hand, prices and contractual mechanisms outside of China, structured by buyers, governments, and financial institutions to facilitate new production capacity in alternative jurisdictions.

The so-called China spot price is the price benchmark observed in the Chinese market or in transactions linked to the Chinese supply chain. Although it is widely used as an international benchmark, it should not be interpreted as a pure reflection of a free and fully competitive market. The primary source for this data is the Shanghai Metals Market, and it is updated daily.

This benchmark is established in an industrial environment characterized by large scale, strong vertical integration, technological dominance, the presence of local suppliers, lower relative costs at various stages of the supply chain, and the direct or indirect influence of industrial policies. For this reason, the Chinese price reflects not so much a market price as it does a cost structure and production organization that is unlikely to be replicated in the short term by new entrants from outside China.

At the same time, countries and buyers outside China have been adopting price guarantee mechanisms, long-term contracts, and price floor structures to encourage production of rare earths in alternative supply chains. These instruments should not be viewed as general subsidies, but rather as mechanisms for reducing commercial risk and enhancing bankability. Their purpose is to facilitate investments in mining, separation, refining, and magnets in jurisdictions where initial costs are higher, scale is still smaller, and the industrial learning curve has not yet been established.

The difference between these two trends is significant, especially for higher-value oxides. The data analyzed indicate that, for NdPr, the China FOB spot price in mid-2026 ranged between US\$160 and US\$184/kg, even exceeding some long-term ex-China price benchmarks (although in the past this figure had been considerably lower). For Dy, Tb, and Y, however, the difference between Chinese benchmarks and ex-China prices is much more pronounced. As shown in the table below, there are significant spreads between Chinese prices and Argus CIF Europe 2030 prices (which represent prices in the Western market, supported by these pricing mechanisms and guaranteed demand), with premiums exceeding three times for Dy and Tb and even higher for Y.

Nevertheless, to assess the competitiveness of potential Brazilian production, the value of the Chinese basket—based on the 2026 China spot price—was adopted as a conservative estimate.

This choice is methodologically important. By using a price benchmark that more closely reflects the Chinese market, the analysis avoids relying, in its first round, on fully capturing the ex-China premium. In other words, it tests whether the Brazilian plant could remain competitive even in a scenario of lower prices, associated with a global environment of lower prices and greater competitive pressure. If the project proves viable under this benchmark, its attractiveness tends to increase in scenarios where part of the ex-China premium is captured through long-term contracts, price floors, strategic offtakes, or demand guarantee mechanisms.

To project price trends, we assume a real growth trajectory of 2.5% per year starting from the 2026 China spot price. This assumption is also conservative given the recent trends observed by our team, which estimated growth of over 10% per year in Chinese prices over the past ten years, based on a consolidation of various indicative sources. The choice of 2.5% per year aims to avoid excessive extrapolation from a period of strong appreciation while, at the same time, acknowledging that demand for magnetic REEs is likely to continue growing, driven by electric mobility, wind energy, automation, defense, and digitization. It is, therefore, a middle-of-the-road assumption: it does not assume full price stabilization, but nor does it incorporate an aggressive upward trajectory.

This pricing structure has two implications for the analysis. The first is that the Brazilian plant should be evaluated under a conservative monetization scenario, in which competitiveness stems primarily from feedstock, OPEX, scale, CAPEX, and the cost of capital—rather than from the automatic capture of price premiums. The second is that mechanisms outside of China should be treated as upside potential or as risk-mitigation tools, especially during the financing phase and the final investment decision (FID). Offtake contracts with Japanese, Korean, European, or North American buyers, as well as price floors associated with industrial policies and strategic programs, can substantially improve a project’s bankability, but should not be assumed without commercial validation.

In this regard, the Brazilian plant’s revenue should be analyzed in layers. The first layer is the conservative scenario, based on the 2026 China spot basket with real growth of 2.5% per year. The second layer is the “ex-China” scenario, in which part of the production is sold under long-term contracts with a diversification premium and price floors. This price projection is represented by the Argus Media indicator.

TABLE 53

Price Benchmarks for Rare Earth Oxides

Oxide	China spot price	Ex-China benchmark	Implications for the model
NdPr	US\$ 160–184/kg FOB China	Contractual floors ex-China of US\$ 110/kg; Argus 2030 CIF Europe of US\$ 130/kg	China spot prices are already above some long-term benchmarks; using the 2026 spot price with moderate real growth is defensible
Dy	US\$ 317/kg FOB China	Argus 2030 CIF Europe at US\$ 1,055/kg	Strong ex-China premium; capturing this premium depends on offtakes and market penetration outside China

Tb	US\$ 1,182/kg FOB China	Argus 2030 CIF Europe at US\$ 3,781/kg	Strong premium ex-China; a critical factor for the financial viability of the Brazilian basket
Y	US\$ 30–50/kg FOB Estimated China	Argus 2030 CIF Europe at US\$ 251/kg	Significant difference between the Chinese price and the ex-China benchmark; requires specific commercial validation
Other oxides	Varies by basket	No equivalent public price floor	Should be treated conservatively

Source: Prepared by the authors.

Thus, the pricing approach adopted in this analysis seeks to balance prudence and realism. The non-Chinese market shows concrete signs of a willingness to pay for supply security, particularly through long-term contracts and price floors associated with NdPr and strategic magnet supply chains. Nevertheless, the baseline model uses the Chinese benchmark as a conservative test of competitiveness. This approach allows us to assess whether the Brazilian midstream sector has its own economic fundamentals while, at the same time, preserving the potential for upside should domestic production succeed in securing contracts outside of China, capturing diversification premiums, and structuring commercial mechanisms capable of reducing revenue risk.

Assumptions Considered

The modeling was structured based on conservative international benchmarking assumptions, with the aim of testing whether the Brazilian midstream sector could achieve sufficient attractiveness to justify moving forward with more detailed technical, commercial, and financial studies.

TABLE 54

Assumptions considered for the economic and financial modeling scenarios

Assumption	Scenario 1: China Spot + Brazil Base	Scenario 2: China Spot + Brazil with Incentives	Scenario 3: Argus 2030 + Brazil Base
Plant capacity	25 ktpa TREO	25 ktpa TREO	25 ktpa TREO
Operational period	2031–2050, 20 years	2031–2050, 20 years	2031–2050, 20 years
Price	China spot price + 2.5% per year	China spot price + 2.5% per year	Argus 2030, with an ex-China premium
Brazilian regulatory framework	Base, current legislation	Brazilian incentives	Base, current legislation
Feedstock	“Brazilian Basket”	“Brazilian Basket”	“Brazilian Basket”
Payability to the upstream sector	70% of realized revenue	70% of realized revenue	70% of realized revenue
Unit OPEX	US\$ 21/kg TREO	US\$ 21/kg TREO	US\$ 21/kg TREO
OPEX	US\$ 525 million/year	US\$ 525 million/year	US\$ 525 million/year

Unit CAPEX	US\$ 66/kg TREO	US\$ 66/kg TREO	US\$ 66/kg TREO
Initial CAPEX	US\$ 1.65 billion	US\$ 1.485 billion net (10% subsidy)	US\$ 1.65 billion
Capital structure	70% debt / 30% equity	70% debt / 30% equity	70% debt / 30% equity
Equity invested	US\$ 495 million	US\$ 445.5 million	US\$ 495 million
Debt	US\$ 1.155 billion	US\$ 1.0395 billion	US\$ 1.155 billion
Nominal interest rate (% per annum)	8% p.a.	8% p.a.	8% p.a.
Taxation	34% IRPJ + CSLL	15.25% effective (75% IRPJ discount)	34% IRPJ + CSLL
Depreciation	20 years, straight-line	Five years (accelerated depreciation)	20 years, straight-line
Subsidy (CAPEX discount)	Not considered	\$165 million	Not considered

Source: Prepared by the authors.

The first key assumption is the scale of 25 ktpa. This capacity was chosen because it represents a significant industrial facility, without assuming that the full potential output of the Brazilian projects will be available simultaneously. Since the upstream portion still depends on licensing, financing, construction, and ramp-up, the choice of 25 ktpa serves as a conservative estimate. In addition to Iluka Resources' Eneabba project, currently under construction in Western Australia (with a production capacity of 17.5 ktpa), Lynas operates a plant in Malaysia with a processing capacity of approximately 20 ktpa. The French company Solvay has also stated that it intends to expand its La Rochelle plant to a capacity of 20 ktpa by 2030.

The second premise is the use of the weighted Brazilian basket as a feedstock reference. The modeling takes into account the estimated composition of the five most advanced Brazilian projects, consistent with the premise that Brazil has a basket with a significant proportion of magnetic and heavy elements, which increases the potential economic value of the plant's feedstock. As noted earlier, the use of the aggregate Brazilian basket may not be the most efficient combination; there may be combinations that prioritize HREE, MREE, or only a portion of the existing projects in Brazil. Any other combinations, however, will result in a more efficient—and profitable—solution than the one currently being tested.

The third premise is the "payability" of 70% of revenue generated by mining projects. This means that the separation plant retains 30% of revenue as gross margin before OPEX, CAPEX, taxes, and financing. Two additional points are worth noting here. The first is that this assumption applies to the supply of MREC, which is already a high-quality concentrate. In the case of monazite sand concentrates, for example, this discount is considerably higher and can reach levels exceeding 60%. The second point is that payability may increase to

up to 85% during periods when supply is tighter. In such cases, final prices rise considerably, offsetting this trend.

The fourth assumption is an OPEX of \$525 million per year, equivalent to approximately \$21/kg of TREO. This figure reflects an adjusted version of the assumption presented by Aclara in its latest technical report regarding the oxide separation plant it intends to build in the U.S. state of Louisiana. Thus, it is important to note that this OPEX reference does not yet reflect the reality of costs in Brazil, which, as presented, offers significant advantages that have not yet been taken into account.

The fifth assumption is CAPEX of \$1.65 billion, based on a capital intensity of \$66/kg TREO. In Scenario 2, this figure is reduced to an effective \$1.485 billion, assuming that 10% of the initial investment is covered by an economic subsidy program for the definition of process routes.

The sixth assumption is a capital structure of 70% debt and 30% equity. This configuration is consistent with a capital-intensive project but depends on long-term financing and risk-mitigation instruments.

The seventh assumption is the cost of capital. The cost of equity was set at 15% in real USD across all three scenarios, serving as the minimum rate of return required to attract investors. The cost of debt considered was 8% per annum, a nominal rate, based on a line of credit denominated in U.S. dollars. We believe that, given the international interest in the sector, it is reasonable to assume that a project like this would be able to secure rates at this level.

The eighth assumption relates to taxation. In Scenarios 1 and 3, a 34% IRPJ + CSLL tax burden applies. In Scenario 2, an incentive regime with an effective tax rate of 15.25% is considered, associated with a specific program for the midstream sector of critical minerals.

The ninth assumption is depreciation. In the Base scenarios, CAPEX is depreciated on a straight-line basis over 20 years. In the Incentivized Brazil scenario, accelerated depreciation over 5 years is assumed, which improves the cash flow profile in the early years and increases the tax benefit of the investment.

Finally, the tenth assumption is price. Scenarios 1 and 2 use the China spot price with real growth of 2.5% per year, a conservative benchmark. Scenario 3 uses Argus 2030, incorporating the premium for non-China markets. This comparison allows us to distinguish between two effects: the effect of Brazilian public policy and the effect of access to non-China off-take prices and demand.

Results found

The modeling evaluated three scenarios. Scenario 1 represents the conservative case: China spot prices growing at 2.5% per year and the current Brazilian regulatory framework. Scenario 2 maintains the same conservative price but incorporates an industrial policy package focused on the midstream sector. Scenario 3 maintains the current Brazilian regulatory framework but replaces the price benchmark with Argus 2030, reflecting greater capture of the ex-China premium.

TABLE 55

Economic and Financial Results of the Modeled Scenarios

Variable	Scenario 1: Spot + Base	Scenario 2: Spot + Incentivized Brazil	Scenario 3: Argus + Base
Average annual gross revenue	US\$ 2.7 billion/year	US\$ 2.7 billion/year	US\$ 3.2 billion/year
Average annual EBITDA	US\$ 274 million/year	US\$ 274 million/year	US\$ 442 million/year
Average annual net income	US\$ 86 million/year	US\$ 114 million/year	US\$ 196 million/year
Average annual FCE	US\$ 110 million/year	US\$ 144 million/year	US\$ 221 million/year
Equity invested	US\$ 495 million	US\$ 445.5 million	US\$ 495 million
Project IRR (p.a.)	9.0%	11.5%	16.0%
Equity IRR (p.a.)	11.8%	16.5%	31.0%
Project NPV	US\$ 370 million	US\$ 540 million	US\$ 1.5 billion
Equity payback period	10.4 years	8.9 years	Four years
Average EBITDA margin	10.3%	10.3%	13.7%

Source: Prepared by the authors.

The first finding is that the project is operationally viable but not necessarily attractive to private capital under the most conservative assumptions. In Scenario 1, the project's internal rate of return (IRR) and the equity internal rate of return (IRR Equity) are 9.0% and 11.8%, respectively. The project's net present value (NPV) is \$370 million, and the payback period is approximately 10.4 years. This indicates that, although the plant generates cash flow over the 20-year period and has a positive NPV, the risk-return profile is still very close to the investment decision-making threshold of a typical private investor, especially if the investment alternatives are in jurisdictions considered less risky.

The second finding is that an industrial policy package focused on the midstream significantly improves the project's attractiveness. In Scenario 2, with a 10% CAPEX subsidy, a reduced effective tax rate, and accelerated depreciation, the project's IRR is 11.5% and the shareholder's IRR is 16.5%. The project's NPV rises to \$540 million, and the payback period falls to eight to nine years. In this scenario, the project exceeds a threshold considered adequate for this type of project—a return on investment of more than 15% per annum—even though the margin for achieving this may be considered “tight.”

The third scenario shows that, in an institutional environment where international prices excluding China are enforced through price floors and demand guarantees, the results move beyond the investment decision threshold and reach a highly attractive level of profitability. The adoption of Argus 2030 prices raises average annual gross revenue to approximately \$3.2 billion, average annual EBITDA to approximately \$442 million, and the project and shareholder IRR to 16.0% and 31.0%, respectively, even without additional Brazilian incentives.

The project's NPV reaches approximately \$1.5 billion, and the payback period drops to about four years.

There are three main conclusions from the modeling regarding the implementation of an oxide separation project in Brazil:

- Brazil has conditions that make investment viable (though not necessarily attractive from a purely financial standpoint), even given the current dynamics of the global rare earths market. However, it should be noted that, given the *modus operandi* of the dominant countries, this “natural competitiveness” does not shield the country from anti-competitive practices, such as dumping. The attractiveness of investments based exclusively on private capital remains subject to a high degree of uncertainty.
- Brazil can, through tax incentives, de-risking, and reductions in the cost of capital, greatly improve the conditions for positive investment decisions. In the scenario presented, measures such as tax incentives and accelerated depreciation play a decisive role in making an investment like this viable, even in a scenario with Chinese prices.
- Linking a project like this to an international mechanism that sets price floors, guarantees demand, and provides capital appears to be highly effective in steering the decision toward a favorable investment in Brazil.

It is also important to note that the results were obtained using conservative assumptions. The modeling does not incorporate optimization of the feedstock mix, potential CAPEX reductions through Brazilian engineering, more favorable OPEX due to domestic competitiveness, scale expansion beyond 25 ktpa, or a simultaneous combination of ex-China prices and domestic incentives. Therefore, the results should be interpreted as a methodological baseline, not as a maximum estimate of attractiveness.

As a future step, it is recommended that specific technical-economic studies be conducted for representative projects in the rare earths separation sector in Brazil, including sensitivity analyses of critical variables—such as NdPr prices, CAPEX, OPEX, exchange rates, and financing terms—with the aim of assessing the economic robustness of the investments under different market conditions.

Implications for NRES

The results appear to reinforce a central understanding around which this study revolves: alongside realizing the potential of the upstream sector—which is already under development—the midstream sector should be treated as a focus for NRES. On the other hand, its implementation will not occur automatically simply because mineral resources exist. Brazil has favorable fundamentals, especially domestic feedstock with a significant composition of magnetic and heavy elements, potentially competitive OPEX, and sufficient critical mass to sustain an industrial-scale plant. However, these fundamentals

must be converted into an investment environment capable of attracting private capital, even with the support of national entities.

The first implication for NRES is that public policy should target the variables that most affect investment decisions: actual CAPEX, taxation, depreciation, cost of capital, price risk, and demand risk. Scenario 2 shows that a midstream program—combining partial CAPEX subsidies, accelerated depreciation, and tax reductions—can raise the IRR from an insufficient level to an attractive one. This result justifies the creation of specific instruments for mineral separation, refining, and processing, rather than treating the midstream merely as an extension of conventional mining.

The second implication is that NRES must engage with buyers and governments from the project development phase onward. Scenario 3 demonstrates that capturing the premium ex-China through off-take agreements, price floors, or price guarantee structures decisively alters economic attractiveness. Therefore, NRES must support the formation of commercial arrangements with international buyers, particularly in supply chains related to permanent magnets, defense, electric mobility, wind energy, and automation.

The third implication is that the decision to invest in a separation plant in Brazil must occur concurrently with the full maturation of all upstream projects. This requires coordination among mining, processing, financing, and the market. If the country waits for the full consolidation of mineral production before structuring the midstream sector, it runs the risk of missing the strategic window to other jurisdictions that are already combining public financing, offtakes, and industrial policy.

It is therefore recommended that, starting in 2027, a coordinated program for commercial relations with strategic buyers be established, involving the Ministry of Mines and Energy (MME), which will coordinate mineral and industrial policy; the Ministry of Foreign Affairs (MRE), through economic diplomacy and the network of Trade and Investment Promotion Sectors; Apex-Brasil, for trade promotion, investment attraction, and connections with international buyers; and the interministerial executive coordination mechanism for NRES proposed in the National Strategy in Chapter 4 of the report, as the technical body for sectoral coordination. This agenda should be aligned with the future National Policy on Critical and Strategic Minerals, seeking to integrate Brazil in a meaningful way into global value chains, promote mineral processing, and attract investments toward stages with higher value added.

This program may include a set of due diligence information for Brazilian rare earths projects, containing geological data, reserves and resources, technology roadmap, mass balance, chemical specifications, licensing plan, ESG matrix, traceability, implementation timeline, CAPEX/OPEX, corporate structure, land tenure status, logistics, energy availability, certifications, and adherence to international standards. Thus, this information package could serve to reduce transaction costs, allowing buyers, lenders, and multilateral insurers to evaluate projects with greater predictability.

In addition, multilateral institutions could play a significant role in reducing the risks perceived by buyers and financiers. Eco Invest Brasil, for example, has already been designed to

attract foreign capital for long-term sustainable projects, using foreign exchange risk mitigation tools and financial mechanisms geared toward ecological transformation. Although the program is not, in itself, a guarantee of a sales contract, its approach to risk reduction and the mobilization of foreign capital could be adapted or supplemented to support critical minerals projects and midstream operations.

Other multilateral institutions, such as the Inter-American Development Bank (IDB / IDB Invest), the World Bank, the French Development Agency (AFD), the German Agency for International Cooperation (GIZ), the New Development Bank (NDB), among others, could also play a role through guarantees, risk-sharing structures, credit enhancement, working capital financing for the supply chain, and instruments associated with project finance or structured trade finance. In this context, the recommendation would not necessarily be for these multilateral banks to guarantee the “commercial contract” in the broad sense, but rather to mitigate specific risks associated with credit, performance, exchange rates, political risk, compliance with public obligations, critical infrastructure, and the bankability of projects. The Multilateral Investment Guarantee Agency (MIGA), part of the World Bank Group, could also be considered for covering political risks in eligible investments, especially when foreign investors or buyers are involved in long-term structures.

Fourth, the NRES must distinguish between intrinsic competitiveness and induced competitiveness. Intrinsic competitiveness stems from feedstock, energy, labor, logistics, and the quality of the mineral mix. Induced competitiveness stems from public policy instruments, contracts, price floors, financing, and risk mitigation. The modeling shows that Brazil has its own fundamentals, but that investment attractiveness depends on the combination of these two dimensions.

Finally, the results indicate that NRES should treat the midstream sector as an economic implementation agenda, not merely as a strategic guideline. This means defining concrete instruments, capacity targets, criteria for eligible projects, coordination mechanisms among BNDES, Finep, MME, MDIC, and the Ministry of Finance, as well as an active international strategy for securing offtakes. The practical conclusion is clear: Brazil is well-positioned to host an REE oxide separation industry, but turning this potential into investment will depend on a targeted industrial policy and market access outside of China prior to the final investment decision.

3.7.3 Opportunities in the gradual downstream sector

In the downstream sector, opportunities do exist in Brazil, but they must be approached gradually and selectively. In the medium term, the country can make progress in intermediate and semi-finished products, such as metals, alloys, magnetic powders, and semi-finished magnets, thereby building an industrial base and acquiring technological know-how without immediately requiring the full internalization of the more complex final stages. This path is more realistic than directly pursuing a fully integrated, large-scale industry for magnets and final components.

Also relevant in the medium term is the connection between rare earths and priority industrial sectors.

Opportunities become more robust when linked to specific or potential markets, particularly electric mobility, wind energy, robotics and automation, healthcare, and defense. In this context, value addition depends on the ability to bring together mining projects, industrial processing, technology developers, and end-user sectors. This integration is crucial for generating anchor demand, guiding investments, and reducing uncertainties regarding the economic fate of more sophisticated production.

In the long term, Brazil's strategic opportunity lies in consolidating an integrated ecosystem of mining, processing, manufacturing, and recycling—one capable of bridging the gap between the country's geological resources and the higher-value-added segments of the global value chain. This vision includes advances in the production of permanent magnets, magnetic components, functional materials, and more sophisticated technological applications. Domestic production of permanent magnets represents the most emblematic downstream opportunity, both for its economic value and for its role in linking to more dynamic industrial chains, such as electric mobility, renewable energy, industrial automation, defense, and medical equipment. However, this stage requires technological maturity, industrial capacity, anchor demand, and a stable supply of processed materials, which positions it as a longer-term objective within a gradual path toward industrial consolidation.

3.7.4 Opportunities in Circular Economy and Secondary Supply

Circularity offers Brazil a complementary—yet strategically significant—avenue for adding value. In the short term, the most viable opportunities concentrate on the recycling of industrial scrap, process losses, and mineral waste, which tend to be more easily traceable and processable than dispersed end-of-life products. At this stage, recycling should be viewed not as a substitute for primary mining, but as an important complement to supply security, innovation, and material efficiency.

In the medium term, the integration of recycling, tailings reuse, and secondary supply could become a more structured part of the industrial strategy. This includes the recovery of REE from tailings, red mud, and other mineral waste, as well as the development of capabilities to reuse industrial byproducts from processing routes. This agenda is particularly promising because it combines liability reduction, technological development, and greater supply chain resilience.

In the long term, advanced circularity should cease to be a complementary front and instead become a structural component of the national strategy. This includes recycling permanent magnets, reusing industrial and urban waste, integrating manufacturing with reverse logistics, and increasing the use of secondary sources as part of the country's supply security. To achieve this, it will be necessary not only to master technological pathways but also to build an appropriate regulatory, logistical, and institutional environment so that the circular economy can operate at scale.

3.7.5 Enabling Conditions for Value Addition

The opportunities for value addition described in the previous subsections do not materialize automatically simply because reserves exist or mining operations are underway. Their

feasibility depends on a set of enabling conditions that span the entire chain and which, in the Brazilian case, are just as important as the existing geological, technological, and institutional assets. The transformation of the mineral base into productive and industrial capacity will depend on the ability to create an economic, regulatory, and technological environment compatible with the high-value-added links in the value chain.

The first of these conditions is the **definition of a selective and phased strategy**. Brazil is unlikely to be able to simultaneously and competitively integrate all links in the rare earths supply chain in the short term. Therefore, the most rational approach is to prioritize segments in which the country already possesses some combination of mineral resources, technological expertise, market potential, and feasibility of implementation—especially in the selective midstream sector and, progressively, in downstream niches.

The second condition is the **strengthening of financing and risk mitigation instruments**. Projects involving processing, refining, metals, alloys, magnets, and recycling require significant capital, a long technological maturation period, and greater demand predictability than conventional mining. Thus, instruments aimed at risk reduction, financing for pilot plants and demonstration plants, support for mineral processing, strategic orders, and market guarantees will be decisive in enabling the supply chain to advance beyond mineral extraction.

The third condition is the **expansion of technological scaling capacity**. The country already possesses significant scientific and laboratory expertise, but it still needs to convert its accumulated knowledge into robust pilot plants, demonstration facilities, and industrial assets. The transition from technologies at an intermediate level of maturity to industrial application remains one of the main bottlenecks for value addition, especially in the separation, refining, metallization, and recycling sectors.

The fourth condition is the **creation of a regulatory, tax, and institutional environment compatible with vertical integration**. This involves greater coordination among mineral policy, industrial policy, science and technology, financing, licensing, and territorial development. In certain segments, it also involves specific measures for issues such as natural radioactivity, waste, and environmental licensing, as well as economic instruments designed to reduce the cost of capital, mitigate risks, and encourage the internalization of stages with higher value added. Without this enabling environment, the country is likely to advance in mining without being able to consolidate industrial capacity in the subsequent stages.

The fifth condition is **market development and integration with end-user sectors**. The downstream sector cannot sustain itself without demand. Therefore, it will be essential to align the development of the rare earths supply chain with industrial sectors that can serve as anchors, such as electric mobility, renewable energy, automation, healthcare, defense, and specialized equipment. This connection is necessary both to economically justify the advancement of the supply chain and to guide investments, reduce uncertainties, and accelerate industrial learning.

The sixth condition is the **link between value addition and territorial and socio-environmental sustainability**. Building a competitive national value chain will require social legitimacy, territorial governance, environmental predictability, and the ability to effectively manage the risks and impacts inherent to the sector. Value addition will only be sustainable if

it is accompanied by adequate governance and mechanisms that reinforce its economic, institutional, environmental, and social legitimacy.

3.7.6 Strategic Implications of the Analysis

The analysis presented in the previous sections suggests that Brazil has concrete opportunities across all links in the rare earths value chain, though not to the same degree, with the same urgency, or with the same level of risk. The greatest immediate potential lies in consolidating and expanding the upstream sector, using this foundation to anchor a selective midstream sector, and, from there, developing a downstream sector focused on strategic niches, as well as recycling and reusing secondary sources.

The main strategic implication of this analysis is that the NRES should be guided neither by a maximalist ambition to internalize the entire chain in the short term nor by a passive vision that reduces the country to exporting raw or intermediate materials. The most promising path lies in a gradual, selective, and coordinated strategy capable of using the country's geological advantage as a foundation to develop productive, technological, and institutional capacities in stages of increasing sophistication. This involves prioritizing the midstream as a critical link, strengthening instruments for technological scaling, resolving regulatory and financing bottlenecks, and linking the supply chain with industrial and regional sectors capable of sustaining its expansion.

This interpretation also suggests that Brazil's strategic position will depend less on the volume of reserves considered in isolation and more on the ability to combine mining, processing, innovation, territorial development, and international integration into a coherent public policy framework. It is this transition that defines the meaning of the national strategy.

3.8. Brazil's Position in Global Value Chains and Strategic Partnerships

Brazil's position in global rare earths value chains must be understood in light of a central tension between its geological advantage and low industrial density. The country possesses significant mineral resources, a growing pipeline of projects, and substantial assets in research, institutions, and mineral production capacity. At the same time, it still has limited involvement in the higher-value-added segments of the value chain, particularly in the separation, refining, metallurgy, and advanced manufacturing stages. Although it is a major player in terms of supply potential, Brazil has not yet established itself as a key player in controlling the most strategic industrial and technological segments.

This intermediate position is important because, in the current context, a country's strategic relevance in the rare earths sector does not stem solely from the existence of reserves or even from its mining capacity. What defines a more robust integration into global supply chains is the ability to convert geological resources into reliable production, selective processing,

industrial transformation, technological innovation, and international relations capable of reducing excessive dependence on a single center of industrial power. It is from this perspective that we can more accurately assess where Brazil stands, where it can move forward, and which partnerships can contribute to this repositioning.

3.8.1 Brazil's Current Position

Currently, Brazil holds a significant position in the upstream segment of the supply chain, but remains in its infancy in the midstream and downstream segments. The analysis presented in this report shows that the country has made the most progress in the upstream sector, with expanded mineral exploration, a growing pipeline of projects, and a commercial operation already in place, while the midstream and downstream sectors remain in their early stages, relying primarily on pilot and demonstration initiatives, as well as laboratory or pre-industrial capabilities. Brazil's position, therefore, is that of a country with supply potential and the attributes to become a strategic partner in value chains undergoing restructuring, but one that still relies heavily on technologies, processes, and, in part, foreign markets to move toward greater value addition.

This position should be viewed in contrast to the global supply chain landscape. The international backdrop is marked by growing demand for magnetic rare earths in electric vehicles, wind energy, defense, semiconductors, advanced electronics, and healthcare, while a high degree of concentration in refining and strong dominance in permanent magnets persist. In this context, Brazil emerges as a potential alternative supplier and a possible base for production expansion outside Asia, but not yet as a systemic competitor in the higher-value segments of the value chain. The country possesses significant assets, but its integration remains asymmetrical: strong in mineral resources, yet still weak in terms of industrial control over the value chain.

At the same time, Brazil's current position should not be underestimated. The country possesses attributes that make it particularly attractive in the context of global diversification: a significant geological base, an institutional environment still taking shape, relatively clean energy, water availability in key regions, accumulated technical and scientific expertise, and the presence of industrial sectors that can serve as anchors for demand. These factors reinforce the potential for more sophisticated integration into global supply chains, even though the country still needs to determine under what conditions it will be able to do so and with what degree of relative autonomy.

Brazil is well-positioned to become a regional supplier of processed rare earths products, capitalizing on its geographic proximity, trade integration, and potential economies of scale. In this regard, aggregating regional demand can enhance the economic viability of investments in the midstream and downstream segments, particularly in separation, refining, and the manufacture of permanent magnets.

Countries such as Argentina, Uruguay, and Chile have plans and investments in renewable energy and electric mobility, which is likely to increase regional demand for inputs such as permanent magnets and other rare earth products. However, there remains a significant gap in consolidated and publicly available data on this demand, which limits

a more accurate assessment of this market potential. Progress on this agenda requires the development of regional studies and the systematization of data capable of informing investment planning and the formulation of public policies.

South American countries exhibit significant complementarity in their natural resource bases, particularly with regard to lithium, copper, REE, and graphite. Furthermore, deepening regional cooperation on Critical and Strategic Minerals can facilitate more integrated production chains, increasing value addition and the internalization of industrial processes. In this context, the resumption of the work of Working Subgroup No. 15 (SGT-15)—Mercosur Geology and Mining—is noteworthy. This subgroup is responsible for promoting technical cooperation and the harmonization of public policies among member countries, with an emphasis on strategic minerals for the energy transition and regional regulatory integration.

3.8.2 Trends in repositioning

Recent trends suggest that Brazil has a concrete window of opportunity for repositioning. This shift stems from a combination of international and domestic factors. Internationally, the reorganization of supply chains and the effort to reduce excessive dependence on a small number of suppliers have been driving increased interest in new production and processing hubs. Domestically, there has been progress in the project pipeline, greater mobilization of financing instruments, the emergence of pilot projects and industrial demonstrators, closer coordination between mining, technology, and industrial policy, as well as growing interest from international partners in different links of the chain.

This repositioning, however, is unlikely to occur uniformly across all segments. The greatest immediate potential remains in strengthening the upstream sector, especially in competitive deposits and materials with magnetic properties. From there, the most realistic trend is a move toward a selective midstream focus, rather than an attempt to fully internalize the entire chain in the short term. This assessment is consistent with the report's analysis, which identifies the separation/refining of NdPr, the production of metals and alloys for the magnet supply chain, permanent magnets and semi-finished magnets, the recycling of REE, and—at the appropriate time—the separation of Dy/Tb as priority areas of strategic and economic rationality.

This repositioning also depends on the ability to connect the rare earths supply chain to more dynamic end-use sectors. The report already identifies electric mobility, renewable energy, robotics and automation, healthcare and medical equipment, and defense as particularly promising fields. These sectors are significant not only because of their potential demand but also because they serve as a bridge between mineral resources and industrial policy. Brazil's repositioning will be more robust if it occurs through integration into denser productive and technological ecosystems.

Even so, this movement should not be romanticized. The analysis indicates that the main obstacles perceived by the stakeholders consulted are economic, regulatory, and industrial in nature: price volatility, cost of capital, unequal access to financing, low

maturity of the midstream sector, the absence of an anchor market, concerns regarding radioactivity, and fragmented governance. This means that Brazil's repositioning will not occur automatically as a result of increased international interest. It will depend on public coordination, financing, technological scaling, regulatory predictability, and the gradual development of an industrial base.

3.8.3 Strategic Partnerships and Implications for NRES

In the Brazilian context, strategic partnerships should be understood as the development of a functional portfolio of cooperation aimed at overcoming the weak links in the chain. The findings from the interviews clearly indicate that the rare earths agenda must also be an agenda for cooperation. In this regard, NRES should seek partnerships aligned with the concrete needs of the Brazilian supply chain, and not merely with the expansion of mineral exports—without necessarily ruling them out, as has already been discussed on other occasions. This includes: i) partners for financing and risk mitigation; ii) partners for processing and refining; iii) partners for technological innovation; iv) partners in end-user markets and manufacturing; v) circularity partners; and vi) governance and supply security partners.

The most important implication of this interpretation is that partnerships should not be treated as a peripheral aspect of the strategy, but as one of its central tools. In the short term, they are especially important for facilitating financing, engineering, equipment procurement, operational learning, and market access. In the medium term, they become crucial for sustaining selective separation/refining, the production of metals and alloys, and integration with manufacturing. In the long term, they can support the development of more sophisticated capabilities in permanent magnets, components, circularity, and critical technologies. In all these cases, the primary criterion should be the partnership's alignment with NRES's industrial and technological priorities.

In practice, this means that Brazil's partnership policy must combine pragmatism with selectivity. The country neither needs nor should it aim to replicate the entire global supply chain on its own. On the other hand, it should not limit itself to being merely a source of mineral raw materials for externally controlled supply chains. The best strategy lies in combining its own mineral base, the selective strengthening of domestic capabilities, and international cooperation aimed at overcoming specific bottlenecks. In this way, partnerships come to fulfill a dual function: reducing excessive dependencies in the short and medium term while simultaneously supporting the development of greater relative autonomy in priority sectors.

In terms of implications for NRES, this suggests that the national strategy should establish clear criteria for selecting partners, aligning international cooperation with priorities related to technology, markets, processing, circularity, and governance. It also suggests that Brazil should avoid partnerships that reinforce a purely extractive approach without the transfer of capabilities, knowledge, or the creation of domestic production capacity. In other words, NRES's international agenda should be subordinate to the national project of strengthening the supply chain, and not the other way around.

3.9. Summary of the Assessment

The analysis presented in this chapter shows that Brazil possesses significant assets that could enable it to occupy a stronger position in global rare earth value chains, but it still faces structural barriers that limit the conversion of this potential into effective national capacity. The key point is that Brazil's main advantage today lies in its geological base and progress in the upstream sector, while its main weakness lies in the low industrial, technological, and institutional density in the links with the highest value added. This asymmetry defines the core of Brazil's strategic challenge.

Among the key assets identified by the study, the following stand out: i) a significant geological base and a growing portfolio of projects; ii) an initial, albeit limited, presence of commercial operations and pilot projects in processing and manufacturing; iii) technical and scientific expertise accumulated at universities, institutes, and technology centers; iv) the existence of industrial and technological sectors that can serve as anchors for demand; v) growing interest from international partners; and vi) an emerging institutional environment, with public instruments already mobilized in mining, innovation, and mineral processing. These assets indicate that the country is not starting from scratch and already has a solid foundation for a strategy of gradually strengthening the value chain.

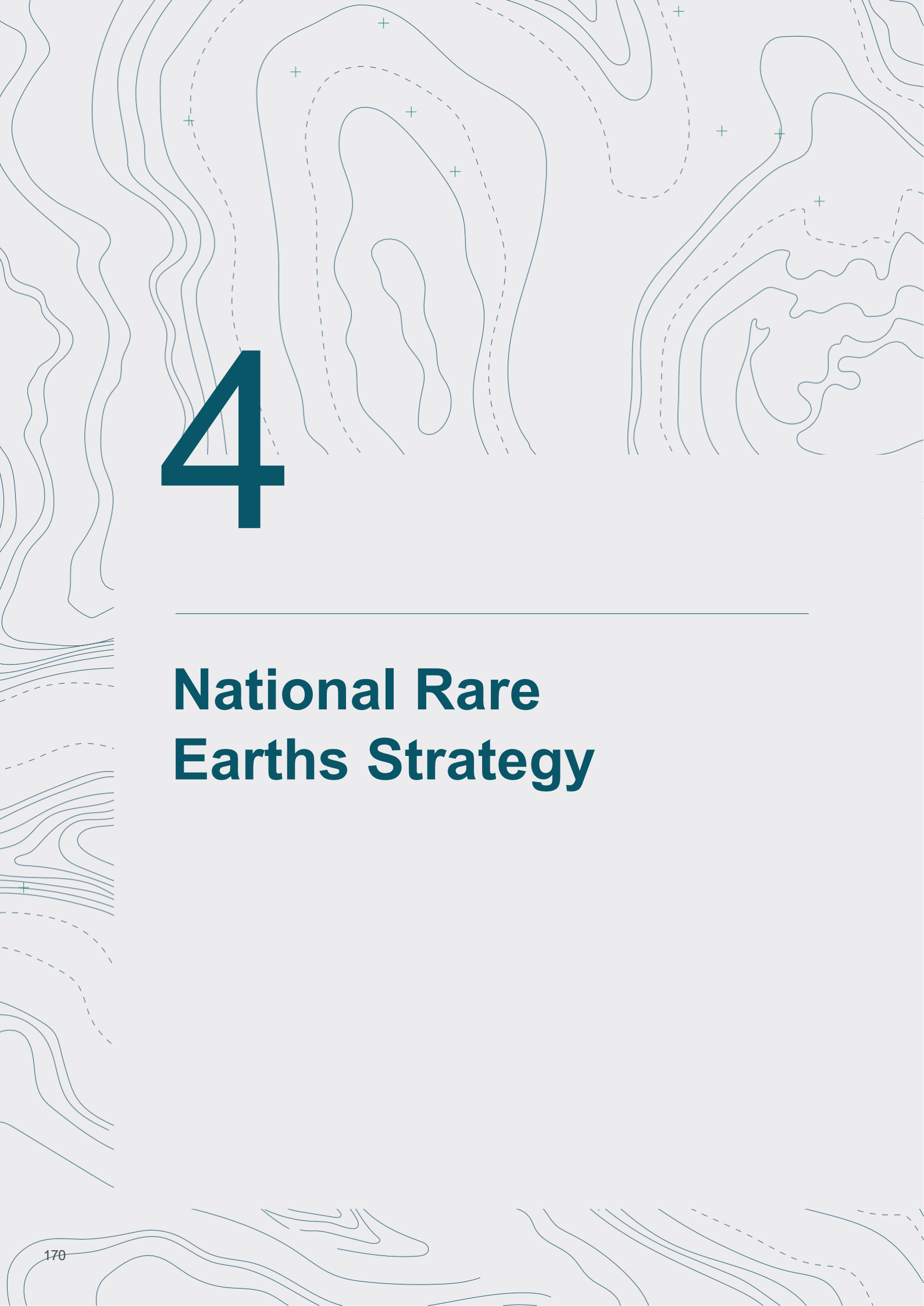
The critical gaps, in turn, concentrate on areas that have been repeatedly highlighted in the interviews, field visits, and document analysis: i) low industrial maturity of the midstream sector; ii) financing bottlenecks, especially in the transition from pilot to commercial scale; iii) external dependence on equipment, inputs, know-how, and critical technological pathways; iv) regulatory and institutional uncertainty regarding issues such as licensing, radioactivity, and NORM; v) the absence of a more structured anchor market to support the downstream sector; vi) fragmented governance; and vii) territorial and socio-environmental vulnerabilities that may compromise the legitimacy and predictability of projects. These gaps demonstrate that the main constraint on Brazil's progress is the difficulty in coordinating, financing, regulating, and scaling up the supply chain.

The analysis reveals concrete opportunities at different points in the chain, albeit to varying degrees and over different time horizons. In the short term, the most robust opportunities lie in the consolidation of the upstream sector and in using that foundation to anchor a selective midstream. In the medium term, opportunities arise in the separation and refining of NdPr, metals, and alloys associated with the magnetic chain, semi-finished magnets, and integration with end-user sectors. In the long term, more sophisticated opportunities emerge in permanent magnets, components, functional materials, advanced circularity, and secondary supply. NRES's strategic rationale stems precisely from recognizing that these opportunities exist, but that they should not be pursued simultaneously and indiscriminately.

The strategic agenda that emerges from this assessment is, therefore, clear. First, the NRES should be developed as a gradual, selective, and mission-driven strategy, avoiding both a continued reliance on an exclusively extractive model and the unrealistic ambition of internalizing the entire supply chain in the short term. Second, it should prioritize the midstream as a

critical link for value addition. Third, it must combine financing, technological scaling, a compatible regulatory environment, market development, and territorial sustainability as enabling conditions for the advancement of the value chain. Fourth, international cooperation must be organized as a functional tool to overcome specific bottlenecks and support domestic capacity building. Finally, it must be recognized that institutional coordination and governance are strategic prerequisites—not merely ancillary elements—for transforming scattered assets into effective national policy.

Brazil already meets the conditions to move beyond being merely a country with great geological potential and begin to position itself as a more significant player in global value chains. The success of this transition will depend on its ability to use its mineral advantage as a foundation for building productive, technological, institutional, and territorial capacity. It is from this transition—from geological endowment to a national value chain strategy—that the need for NRES arises, along with the rationale for the strategic guidelines developed in the following chapter.



4

National Rare Earths Strategy

4.1. Vision, Principles, and Objectives

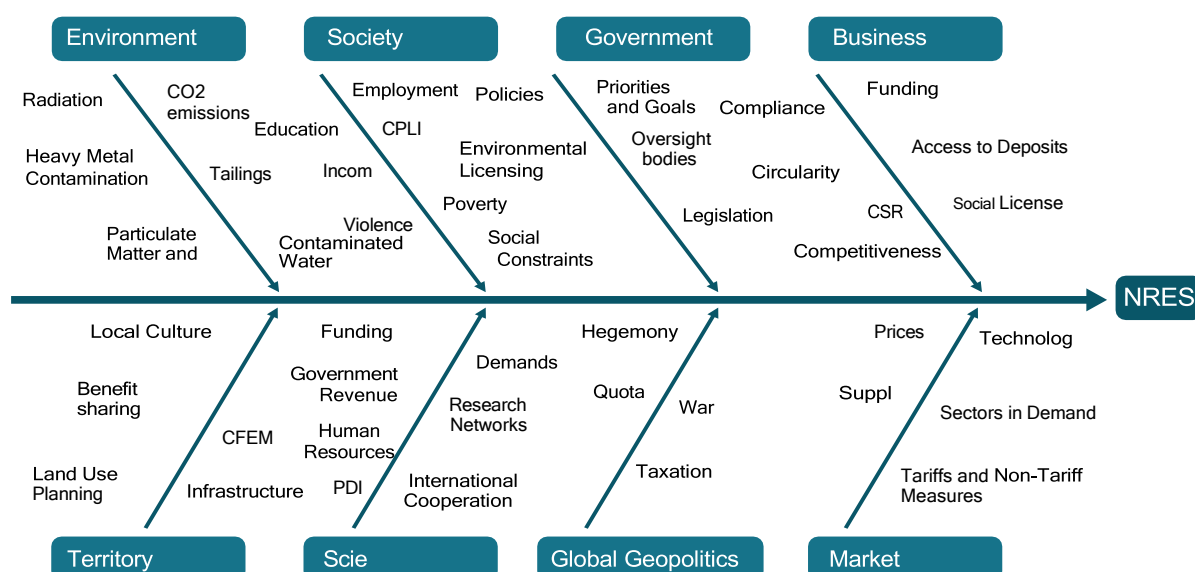
The National Rare Earths Strategy should guide Brazil in its transition from a predominantly mineral-based position to a more intensive, selective, and strategic role in the global value chain. The central objective of the National Rare Earths Strategy (NRES) is to transform the country's geological resources and ongoing projects into productive, technological, institutional, and territorial capabilities, in a manner consistent with national interests, sustainability, and the gradual creation of greater value within the country. This strategy is based on the recognition that the country is unlikely to internalize all links in the chain in the short term, but can move forward progressively by combining pragmatism and ambition.

NRES's national vision must be underpinned by several guiding principles: supply security and strategic relevance; progressive value addition; technological and industrial selectivity; socio-environmental sustainability; territorial development and social legitimacy; inter-institutional coordination; and international cooperation aimed at strengthening domestic capacities. These principles reflect the premise that Brazil's strategy should not be limited to the expansion of mining, yet it cannot do without it either. The challenge is to use the country's mineral advantage as a foundation for developing capabilities in processing, refining, metallurgy, magnets, recycling, innovation, and industrial integration.

The NRES should pursue, in particular, the following objectives: consolidate Brazil's position as a competitive and reliable supplier; develop selective capabilities in mineral processing and transformation; convert science and technology into industrial capacity; establish a regulatory, tax, financial, and institutional environment compatible with vertical integration; promote territorial legitimacy and sustainability; and expand the country's international integration into higher-value-added value chains.

FIGURE 17

Determining Factors of a National Rare Earths Strategy for Brazil



Source: Prepared by the authors based on Kamenopoulos and Agioutantis (2013) regarding the dimensions and variables addressed in this study.

4.2. Strategic Axes

The assessment presented in this report indicates that developing a national base of critical technologies for rare earths requires more than general support for scientific research or isolated incentives for mining. It requires a coordinated, mission-driven strategy capable of linking geological knowledge, applied research, technological scaling, intellectual property protection, industrial demand, financing, regulation, territorial sustainability, and international cooperation. It is based on this logic that the strategic axes of NRES are proposed.

Axis 1. Geological Knowledge, Information, and Sectoral Intelligence

Objective: To expand the knowledge base and transform information into decision-making capacity. Guidelines:

- to deepen geological mapping in priority areas;
- systematize data on resources, reserves, projects, infrastructure, and the market;
- ensure greater dissemination and reuse of geological knowledge after the expiration of permits, where applicable;
- create a continuous system for market intelligence and demand monitoring.

Axis 2. A Competitive, Reliable, and Sustainable Upstream Sector

Objective: To consolidate Brazil's mineral base as the initial platform for NRES, combining economic competitiveness, reliability of supply, operational safety, regulatory predictability, and socio-environmental standards compatible with Brazil's integration into global value chains with higher added value.

The upstream sector constitutes the material foundation of the National Rare Earths Strategy. In Brazil's case, it represents the segment with the greatest relative maturity in the short term, due to the country's significant geological base, the progress of the project pipeline, and the concrete possibility of expanding domestic supply in an international context marked by a search for geographic diversification of supply. The consolidation of this segment is, therefore, a necessary condition for any subsequent path toward value addition. At the same time, this consolidation should not be understood as a simple expansion of mining operations, but rather as the building of a mineral base capable of providing a reliable, predictable, and sustainable supply for subsequent stages of the value chain.

In this regard, the Brazilian upstream sector should be guided by four complementary fronts: i) support for viable projects with greater strategic alignment, especially those capable of combining mineral competitiveness, operational safety, regulatory predictability, and the potential to connect with later stages of the supply chain; ii) utilization of co-products, by-products, tailings, and secondary sources, reducing entry costs and expanding the supply base without relying exclusively on the opening of new dedicated mines; iii) strengthening

traceability, risk management, social and environmental standards, and the territorial legitimacy of projects; iv) coordination between mineral expansion, territorial planning (including strategies for local jobs, the use of local suppliers, and local content), efficient energy use, and emissions reduction, in order to transform Brazil's mineral base into a competitive advantage from a socioeconomic, climate, and environmental perspective as well.

The energy aspect deserves special attention. The rare earths (REE) value chain is characterized by high energy intensity and a significant carbon footprint, particularly in the chemical processing, separation, and metallurgy stages. Processes such as the electrolytic production of rare earth metals and alloys is particularly electricity-intensive, requiring specific policies to mitigate costs and emissions. Estimates indicate that REE production requires approximately 40.0 gigajoules (GJ) per metric ton of final energy, and can reach approximately 200.0 GJ per metric ton of primary energy when a conversion efficiency of 20% is considered. This data underscores that the future competitiveness of the supply chain will depend not only on the quality of the deposit or the cost of mining, but also on the energy profile and decarbonization capacity of the projects.

From this perspective, Brazil has a significant potential advantage. The combination of a predominantly renewable electricity mix, the potential for expanding renewable sources, and the availability of mineral resources creates favorable conditions for the development of a more efficient and lower-carbon supply chain. In particular, the possibility of integrating mining and processing with renewable electricity, existing infrastructure, and the complementary use of biofuels could become a strategic advantage for positioning the country as a reliable and sustainable supplier. The Serra Verde project already points in this direction by highlighting, among its sustainability credentials, access to renewable electricity, the use of biofuels, low-impact operations, and good infrastructure and labor conditions.

International experience reinforces this point. In Europe, it is recommended to create industrial zones with access to low-cost electricity from renewable sources, reduce charges on electricity consumption, and expand the use of renewable energy in mining and processing activities—precisely to make energy-intensive processes viable and reduce emissions. These guidelines have been incorporated into the European Critical Raw Materials Act (CRMA) and aligned with recycling and circularity goals. For Brazil, this suggests that the consolidation of the upstream sector should not be separated from energy planning and the pursuit of greater efficiency in resource use.

Furthermore, circular economy practices and urban mining should be viewed as complementary to the upstream strategy, rather than as an exclusive alternative. The recovery of secondary REEs through the recycling of electronic waste, end-of-life permanent magnets, and mineral waste can significantly reduce the need for primary mining, which is more energy- and resource-intensive. Although circularity is addressed in greater detail in another section, its integration with the upstream sector is important from the outset, as it helps reduce losses, improve material efficiency, and position Brazil's mineral base more closely aligned with the sustainability requirements of global supply chains.

In the international context, transparency and governance initiatives in the extractive sector, such as the Extractive Industries Transparency Initiative (EITI), have been adopted by several countries that produce critical minerals, including 11 Latin American countries. Although Brazil is not currently a member of the EITI, the country has its own transparency and traceability mechanisms related to the mineral sector, including public systems administered by the ANM, CFEM collection and distribution mechanisms, regulatory reporting obligations, and environmental and fiscal control mechanisms. In this sense, Brazil's non-membership in the EITI (Extractive Industries Transparency Initiative) does not imply a lack of transparency mechanisms, but rather indicates a distinct institutional trajectory compared to other countries in the region. The advancement of NRES may, therefore, contribute to strengthening mechanisms for monitoring, the disclosure of strategic information, and social and environmental accountability, in line with international governance practices and growing market demand for traceability, transparency, and robust mechanisms for social and environmental accountability in supply chains for critical minerals.

Waste and tailings management also requires a specific approach due to the possible presence of NORM, chemical reagents, and large volumes of material handled in connection with mining and mineral processing activities. The types of waste vary depending on the mineral deposit and the processing route adopted, and may include mineral tailings with varying concentrations of thorium and uranium, waste rock, liquid effluents, and chemical waste from hydrometallurgical processes. In the case of ionic clay deposits, the low content of rare earths results in high material handling volumes and the generation of large volumes of waste rock, underscoring the need for adequate planning for the management, disposal, and environmental restoration of mined areas. At the same time, some of the projects under development in Brazil have sought to incorporate technological solutions that are novel or still not widely adopted internationally, such as closed-loop leaching systems combined with the recovery and recirculation of water and reagents in a closed circuit. In this context, NRES should encourage the adoption of robust standards for tailings management, radiological monitoring, and environmental control throughout the entire life cycle of mining projects, including safe storage, traceability, monitoring of water, soil, and air, emergency plans, mine closure, and environmental restoration, in compliance with applicable requirements for radiological safety, environmental protection, and occupational health.

The consolidation of the upstream sector also depends on institutional predictability. Mining expansion must be aligned with land-use planning, regulatory coordination, operational safety, and sound management of issues such as radioactivity, tailings, and water resource use. Without this, the country runs the risk of expanding its project portfolio without building the trust necessary to attract capital, structure long-term contracts, and link mineral production to a broader industrial strategy. In other words, the Brazilian upstream sector will only become a strategic platform for NRES if it is simultaneously competitive, reliable, and sustainable.

Guidelines

- support viable projects with greater strategic alignment, especially those capable of combining mineral competitiveness, operational safety, and the potential for

connectivity with downstream stages of the supply chain, through a project evaluation and prioritization matrix and periodic interministerial evaluation meetings;

- encourage the use of co-products, by-products, tailings, and secondary sources, thereby expanding the supply base and reducing entry costs;
- strengthen traceability, socio-environmental standards, risk management, and operational safety throughout the mineral cycle;
- monitor regional outcomes linked to production, including job creation as well as the existence and mobilization of qualified local suppliers, the use of local content in procurement, and the availability of services for producing regions;
- align mining expansion with regulatory predictability, territorial planning, and coordination among the various licensing and oversight bodies, with a view to simplifying procedures and reducing inefficiencies;
- promote efficient energy use and emissions reduction in mining, processing, and initial processing activities, leveraging the comparative advantage of Brazil's electricity mix;
- encourage the use of renewable electricity, biofuels, energy-efficiency solutions, and lower-carbon infrastructure in the sector's projects;
- align the consolidation of the upstream sector with the circular economy agenda, in order to reduce losses, increase material efficiency, and strengthen the sustainability of the supply chain;
- establish specific guidelines for the management of tailings and waste rock in REE mining, considering the potential presence of NORM, the large volumes of material moved in ionic clay deposits, and the adoption of innovative technologies still in the process of consolidation and operational maturation at an industrial scale.

Axis 3. Selective midstream as the core of the strategy

Objective: To develop domestic capabilities in mineral separation, refining, and processing, making the midstream the core of Brazil's value-added strategy for rare earths.

The midstream sector plays a central role in the National Rare Earths Strategy because it is where both the main bottleneck in the Brazilian supply chain and the primary opportunity for value capture are concentrated. The analysis presented in the report and the findings from stakeholder consultations converge in pointing out that the greatest leap in value addition lies in the country's ability to move beyond exporting concentrates or mixed carbonates and advance toward higher-purity intermediate products, selective separation, metals, and alloys. It is in the midstream sector that Brazil can begin to bridge the gap between its geological advantage and a more robust presence in the strategic industrial and technological segments of the global supply chain.

At the same time, international experience and the national assessment indicate that this transition should not be viewed as a complete replication, in the short term, of the entire industrial chain currently concentrated in China. The most realistic strategy for Brazil is to build a selective midstream sector, guided by clear technological priorities, alignment with available mineral resources, economic rationality, and the capacity for progressive industrial learning. It is unlikely that the country will be able to simultaneously and competitively internalize all stages of separation, refining, metallization, and the processing routes associated with all rare earth elements. The strategic response, therefore, must be selectivity rather than dispersion.

In this context, the initial priority should be the separation and refining of NdPr and higher-purity intermediate products, in line with what the report itself already defines as a strategic direction. This choice makes sense because Neodymium and Praseodymium are at the heart of the magnetic supply chain and global demand for permanent magnets, especially in electric mobility, wind energy, automation, and advanced industrial applications. By prioritizing these routes, Brazil increases the likelihood of building industrial critical mass in a segment that is more closely aligned with its project portfolio and international demand dynamics.

Building on this first step, progress in metals and alloys should be viewed as a natural and progressive evolution of the midstream. The report already explicitly points in this direction by recommending gradual progress in metals and alloys and by identifying metals and alloys associated with the magnetic chain as among the priorities with the greatest strategic and economic rationale. This segment is particularly relevant because it serves as a bridge between refining and the more sophisticated downstream sector, allowing for greater value capture without immediately requiring full mastery of the final manufacturing of permanent magnets. In terms of public policy, this is an area where Brazil can combine technological scaling, financial support, and coordination with end-user sectors in a more viable manner than through a premature attempt at complete vertical integration.

Specific routes for Dy/Tb should be approached with strategic caution. The report recommends supporting them only in eligible projects and at the appropriate time, which is consistent with the greater complexity, relatively smaller scale, and greater regulatory and economic sensitivity of these elements. This does not mean excluding them from the strategy, but rather subjecting them to a more rigorous prioritization framework, linked to the mineralogy of the deposits, economic viability, technological maturity, and the existence of markets or partnerships capable of sustaining their industrial transformation. The practical implication is that the country should avoid committing scarce resources to paths with greater uncertainty before consolidating a more robust foundation in segments with greater immediate viability.

Another central component of this pillar is the establishment of regional processing and innovation hubs. The report explicitly identifies this guideline and highlights, in the sections on opportunities, that the formation of regional hubs is particularly promising in Goiás and Minas Gerais, where there is greater proximity between mineral resources, infrastructure, companies, technology centers, and financing instruments. This territorial strategy is superior to the scattering of isolated initiatives because it promotes economies of scale, infrastructure sharing, the training of a skilled workforce, coordination between mining and processing, and greater integration with applied research. Instead of attempting to distribute scarce capacities

across various regions lacking critical mass, NRES should support the formation of hubs with sufficient institutional and industrial density to sustain learning and scaling.

A more in-depth analysis at the municipal level—considering locations such as Minaçu, Araxá, Poços de Caldas, Catalão, and Mariana—could be the subject of future studies focused on the NRES implementation roadmap, including comparative assessments of the availability of feedstock, energy, water, logistics, labor, industrial infrastructure, technological capacity, and the socio-environmental context.

In this context, consideration could also be given to establishing a national program of rare earths hubs, with pilot initiatives focused on processing, separation, and shared industrial services. Models of this type can help reduce technological and scale risks, expand infrastructure sharing, and facilitate cooperative arrangements among different mining and industrial projects, including through shared solutions for processing, tailings management, financing, and technological development.

The centrality of the midstream sector also stems from its systemic role in the value chain. Without separation, refining, and mineral processing, the country tends to remain dependent on external stages to convert its mineral production into relevant industrial inputs. This limits value capture, reduces the attractiveness of more sophisticated activities within the country, and weakens the connection between mining, innovation, and industry. Therefore, strengthening this sector must be viewed as a structural decision to reposition Brazil within global rare earth value chains. It is at this link that chemistry, engineering, regulation, financing, scale, and industrial policy intersect most intensely.

Finally, progress in selective midstream development depends heavily on enabling conditions already identified in the report: public financing and de-risking instruments, support for pilot plants and demonstrators, strengthening the innovation ecosystem, and greater alignment between the regulatory environment and the industrial logic of the supply chain. The document notes that the central role of public financing and risk mitigation instruments will be decisive in making this leap feasible. Axis 3 cannot be implemented based solely on technological guidelines; it requires close coordination with the axes of financing, innovation, regulation, and territorial development. Without this, the country runs the risk of continuing to expand mineral production without being able to transform this expansion into domestic capacity for mineral separation, refining, and processing.

Guidelines

- Prioritize the separation/refining of NdPr and higher-purity intermediate products as the primary focus for greater strategic and economic rationality;
- progressively advance in metals and alloys associated with the magnetic chain, creating a bridge between refining and more sophisticated manufacturing;
- support specific routes for Dy/Tb only in eligible projects and at the appropriate time, avoiding premature dispersion of efforts;

- establish regional processing and innovation hubs, prioritizing regions that already concentrate mineral resources, infrastructure, companies, technology centers, and financing instruments;
- coordinate midstream development through pilot plants, demonstrators, de-risking tools, and public financing, thereby reducing the gap between proof of concept and industrial scale;
- link the midstream strategy to the national innovation ecosystem, in order to transform scientific knowledge and laboratory capabilities into large-scale mineral separation, refining, and processing;
- use the midstream as a structural link in the value-added strategy, reducing external dependence and increasing the attractiveness of subsequent segments of the value chain within the country.

Axis 4. National Development of Critical Technologies, Innovation, and Applied Research

Objective: To convert accumulated knowledge into productive and industrial capacity, establishing a national base of critical technologies in rare earths and bridging the gap between research, demonstration, and economic application.

The development of a national base of critical rare earths technologies requires more than just general support for scientific research. It demands a coordinated, mission-driven strategy capable of linking geological knowledge, applied research, technological scaling, intellectual property protection, industrial demand, and international cooperation. In a sector characterized by high technological complexity, a strong global concentration of capabilities, and growing geoeconomic significance, public policy must seek to expand the production of knowledge and transform that knowledge into processes, products, intellectual property assets, and industrial capabilities established within the country.

The report already identifies that Brazil's main challenge is to convert scientific and laboratory expertise into scalable technological pathways and productive assets. In this context, the critical technologies and innovation pillar should serve as a bridge between the selective focus defined by the strategy and the development of a viable industrial base. Rather than a diffuse and fragmented approach, it is recommended that the national technological effort be organized around clear priorities and results-oriented instruments, enabling the country to move from research to demonstration and, progressively, to industrial production.

To this end, the strategy should support the formation of a **national network for applied R&D and innovation with an industrial mission**, bringing together universities, ICTs, and companies in consortia focused on technological and industrial outcomes. A network involving federal universities, USP, Unicamp, Unesp, the Technological Institute of Aeronautics (ITA), IPT, CETEM, the Institute of Energy and Nuclear Research (IPEN/CNEN), Senai, national science and technology institutes, and other institutions with relevant expertise in geology, separation chemistry, extractive metallurgy, alloy production, magnets, recycling,

characterization, and testing. Rather than duplicating efforts, the strategy should aim for a functional division of responsibilities, leveraging each institution's expertise in specific links or technological challenges.

This arrangement will only be effective if the support mechanisms require the formation of consortia between ICTs and companies, with explicit technological goals, interim deliverables, progress on TRLs, and an industrial absorption plan. The goal is to prevent technological efforts from remaining confined to the production of knowledge disconnected from the needs of the supply chain. Public policy should prioritize results-oriented projects focused on separation, refining, metallization, alloys, magnets, recycling, and radiological management, with a clear understanding of where each path is intended to lead and which industrial or technological assets are to be developed.

We must directly address Brazil's main bottleneck in the rare earths supply chain: the difficulty of transitioning from the laboratory environment to industrial implementation. The country already possesses significant scientific and technological expertise at various stages of the supply chain, but it still lacks the tools and infrastructure capable of converting validated technological routes into pilot plants, demonstration facilities, and industrial operations. In this regard, the strategy should be organized according to stages of technological maturity: support for applied research and proof of concept; robust support for pilot plants and integrated process validation; support for industrial demonstration units, pre-commercial batches, and user qualification testing; and, finally, support for the commercial deployment of technologies that have reached adequate maturity.

The creation and consolidation of a **national infrastructure for testing, certification, and demonstration** must be an integral part of this pillar. In the field of rare earths, it is not enough to master a process in the laboratory; it is necessary to demonstrate repeatability, quality, performance, and industrial compliance in controlled and certified environments. To this end, the report proposes a national platform bringing together IPT, Senai, Cetem, IPEN/CNEN, universities, and technology centers, featuring laboratories for chemical and mineralogical characterization, pilot plants, demonstration plants, facilities for the experimental production of alloys and magnets, and capabilities for testing, reliability assessment, and certification. This foundation is essential for reducing technological risk, attracting private partners, qualifying products for demanding sectors, and enabling the advancement of intermediate TRLs to levels close to commercial scale.

Another important component is the protection and retention of value through intellectual property. It is necessary to provide guidance to projects regarding the choice between patenting and trade secrets, especially in cases involving process routes and sensitive parameters. In an industry where a significant portion of competitive advantage lies in process knowledge, chemical expertise, and engineering, public policy should encourage not only the generation of knowledge but also its protection and retention within the country. This is particularly important to avoid excessive dependence on foreign technology packages and to expand the nation's capacity to capture value from its own solutions.

Finally, this area must be closely linked to human resources development. It is recommended that programs be promoted to train and retain specialized human resources. Such training should not be treated merely as an educational issue, but as

a component of industrial policy. In a sector that relies heavily on chemistry, metallurgy, characterization, radiation safety, automation, and process engineering, without a base of qualified personnel, the transition between science and industry tends to remain stalled. Public policy, therefore, must combine academic education, technical training, and experience in pilot and industrial settings.

Guidelines

- support pilot plants, demonstrators, and technology scaling, creating a bridge between laboratory research, validation, and production implementation;
- establish a national network for applied R&D and innovation with an industrial mission, bringing together universities, ICTs, and companies in results-oriented consortia;
- strengthen the innovation ecosystem involving Senai, IPT, Cetem, Ipen/CNEN, universities, and companies, with a functional division of responsibilities and a focus on priority pathways;
- promote technologies for separation, metallization, alloys, magnets, recycling, and radiological management;
- create a national platform for testing, certification, metrology, and technological demonstration in the field of rare earths;
- promote training programs for specialized personnel, integrating academic education, technical training, and hands-on experience in pilot plants and industrial settings;
- provide guidance on projects regarding the protection of intellectual property, thereby enhancing value retention and the nation's capacity for technology capture.

Axis 5. Gradual Downstream Development, Anchor Sectors, and Circularity

Objective: To build a progressive presence in the segments with the highest value added, linking industrial development, anchor demand, and circularity as parts of the same path toward densification.

The Brazilian downstream sector may offer opportunities in the medium to long term and should be aligned with actual industrial demand. It is believed that, in the medium term, the country can make progress in intermediate and semi-finished products, such as metals, alloys, magnetic powders, and semi-finished magnets, thereby creating an industrial base and fostering technological learning without immediately requiring the full internalization of the more complex final stages. This path is more realistic than directly pursuing a large integrated industry for magnets and final components.

The downstream sector must combine two complementary strategies. The first is progressive expansion into industrial segments with higher value added, starting with metals, alloys, magnetic powders, and semi-finished magnets, and, in the long term, paving the way for permanent magnets, specialized components, and functional materials. The second is the intentional linking of this advancement with anchor sectors—that is, markets and production chains

capable of absorbing, testing, and driving the development of the products created. Without this connection, there is a risk of moving forward with prototypes and scattered capabilities without building a sufficient economic foundation to consolidate the supply chain.

The main anchor sectors to be considered are in the following segments: renewable energy, electric mobility, robotics and automation, healthcare and medical equipment, defense, semiconductors, and advanced electronics. In the case of electric mobility, permanent magnets are one of the main applications for NdPr, Dy, and Tb, and the expansion of electric vehicles is already one of the major global drivers of demand. In wind energy, high-performance turbines use permanent magnets primarily based on Nd, Pr, Dy, and Tb. Robotics is poised to become one of the largest drivers of demand for NdFeB by 2040, linking rare earths to the agenda of reindustrialization and advanced automation. Healthcare, defense, and advanced electronics, in turn, offer markets with lower volume but higher value and greater alignment with Brazilian technological niches.

In this context, downstream development must be linked to specific technological challenges, such as the domestic production of separated NdPr oxides, the manufacture of magnetic alloys, the development of permanent magnets, and recycling pathways for magnets and industrial waste. Business participation should begin as early as the applied research phase, with the involvement of companies that are potential users, integrators, or purchasers of the products being developed. Whenever possible, public policy should incorporate anchor-demand mechanisms, including technology-based public procurement, institutional orders, and instruments that promote competitive import substitution in strategic sectors. The goal is to transform technological efforts into an industrial base and a market.

The rare earth elements (REE) value chain is characterized by high energy intensity and a significant carbon footprint, especially in the chemical processing, separation, and metallurgy stages. Processes such as the electrolytic production of rare earth metals and alloys is particularly electricity-intensive, requiring specific policies to mitigate costs and emissions (Roland et al., 2021). This context underscores the importance of strategies focused on energy efficiency and decarbonization throughout the entire production chain.

Circular economy practices and urban mining are effective alternatives for reducing the sector's energy consumption (Ibaram, 2025). The recovery of secondary rare earth elements through the recycling of electronic waste and end-of-life permanent magnets significantly reduces the need for primary mining, which is more energy- and resource-intensive. At the same time, redesigning products with a focus on circularity—facilitating repair, disassembly, and reuse—helps extend the life cycle of materials and reduce losses throughout the supply chain.

The European Union is a leader in this area and can serve as a source of inspiration. The report *"Rare Earth Magnets and Motors: A European Call for Action"* (Gauß et al., 2021) underscores the need for industrial policies aimed at ensuring the sector's sustainability. Among the key recommendations are the creation of industrial zones with access to low-cost electricity from renewable sources, as well as the reduction of charges on

electricity, in order to make energy-intensive processes economically viable. The report also recommends expanding the use of renewable energy in mining and processing activities to reduce emissions. These guidelines were subsequently incorporated and expanded upon in the CRMA, which includes targets for strengthening recycling and establishes the circular economy as a strategic pillar for the energy transition and the security of critical materials. The recycling of REEs is considered strategic for supply security and sustainability, with less than 1% of these elements currently recycled in the European Union, despite the high potential represented by discarded permanent magnets (a secondary source). Some of the proposals include establishing a market for recycled materials; retaining waste containing REEs (preventing the export of such waste); and requiring manufacturers to adopt minimum recycled content targets.

At the same time, Europe is investing in R&D&I to enable more efficient technological pathways. Some of the key initiatives are supported by the Horizon Europe program and ERMA and include the development of urban mining and technologies for extracting REE from secondary sources (such as industrial waste and mining tailings), as well as the training of a skilled workforce and the incorporation of this topic into academic curricula.

In Brazil, the combination of a predominantly renewable electricity mix, the potential for expanding renewable energy sources, and the availability of mineral resources creates favorable conditions for the development of a more efficient and lower-carbon supply chain. In this regard, the integration of energy efficiency, the circular economy, and technological innovation will be crucial for positioning the country competitively and sustainably in the global rare earths market.

Circularity should be treated as an integral part of this pillar. In circularity, the main opportunity lies in establishing recycling pathways for industrial scrap, permanent magnets, and the recovery of rare earths from tailings, red mud, and other mineral waste. This is a complementary yet strategic front because it combines supply security, innovation, material efficiency, and the potential to reduce environmental liabilities. Although still in its infancy in Brazil, it already makes sense as part of NRES's industrial architecture.

The international literature presents several cases of REE recovery from mining waste, ranging from nickel and bauxite (Takeda and Okabe, 2022) to copper and iron ore. Furthermore, the economic and socio-environmental viability of recovering certain REEs through electronics recycling has been amply demonstrated (Rezaei et al., 2025). For Brazil, this represents a significant window of opportunity, as there is ample availability of this material in the country, and given the trend of growing demand and limited supply, the recycling of REEs has become a critical strategy for ensuring the long-term sustainability of resources.

Analysis: Pathways and Milestones for REE Recycling

Recycling typically involves the stages of pre-processing and final processing. The former involves disassembly, sorting, and crushing, while final processing involves chemical transformations to extract the target metals. A variety of advanced metallurgical techniques, including pyrometallurgy, hydrometallurgy, and bioleaching, have been implemented to recover REE from complex waste streams. The challenge is to identify the best technology that maximizes recovery while minimizing environmental impact.

Atanda et al. (2026) present the advantages and disadvantages of the different technological routes, concluding that pyrometallurgy is the most efficient but comes with high economic and environmental costs, whereas biometallurgy (biosorption) and deep eutectic solvents are more cost-effective, including from an ecological standpoint. However, they emphasize that technological challenges remain.

Takeda and Okabe (2022) discuss the use of Scandium, one of the light rare earth elements (REEs) that enhances the properties of aluminum alloys used in the aerospace and automotive industries, among others. Extraction occurs from nickel smelting residues, which originate from lateritic nickel deposits (obtained through hydrometallurgical processes and leaching) and from bauxite processing.

In general, the discussion on the circular economy is based on Material Flow Analysis (MFA) together with Life Cycle Assessment (LCA), which have shaped the development of the conceptual framework for R&D&I and enable the identification and quantification of flows between the different stages of production and consumption. According to Chen and Zeng (2022), there has been a rapid increase in interest in this reuse, a trend reinforced by Atanda et al. (2026) as they highlight the various international policies that establish quantities and targets. However, the production and use of recycled materials face several challenges, such as: 1) controlling potential toxicity; 2) issues associated with cross-border flows (primarily illegal e-waste); 3) unbalanced policies and regulations in the international market, among others.

Among the leading countries, the following stand out: the European Union, with explicit regulations regarding recycling targets; the United States, with dedicated funding for this area; and Japan, which has been developing programs in this area for years. In addition to the European legislation already mentioned, the following are noteworthy:

1. The U.S. Department of Energy's Critical Minerals and Materials Program supports pilot and demonstration studies for the recovery, refining, and supply chains of REE magnets from mining waste. It has provided \$135 million in funding for demonstration facilities for the extraction and recycling of REE.
2. Japan's Policy on Efficient Resource Use and China's "Green Manufacturing" Initiatives promote the recovery of REE from municipal and industrial waste streams to strengthen resource resilience.
3. The 2023 U.S.-Japan Critical Minerals Agreement commits to circular approaches and supply chain cooperation, such as REE.
4. Formal recycling centers in Europe and Japan use automated disassembly, emissions filtration systems, and appropriate hazardous waste disposal protocols to reduce the release of pollutants. ISO-certified recycling facilities adhere to international standards (e.g., ISO 14001) that ensure worker safety and minimize environmental emissions.

In summary, there are four common elements in successful cases: i) technological intensity; ii) financial resources; iii) qualified human resources; and iv) regulations that provide legal certainty for investors. In this regard, to advance circularity and the recycling of rare earths, an interesting possibility would be to create a program with a special financing line to be operated by the Brazilian Industrial Research and Innovation Company (EMBRAPII) in partnership with research centers (R&D&I) and companies, focused on finding technological solutions—both for the utilization of mining tailings (defining the route with the least impact and greatest benefit) and for expanding recycling (improving reverse logistics legislation, design, optimal technological routes, etc.). This program should have explicit goals, allocate financial resources, and create opportunities to mobilize human and technological resources, which are the fundamental building blocks of a national REE strategy.

For Brazil, this suggests that a gradual shift toward the downstream sector should not be viewed merely as manufacturing based on primary raw materials, but rather as a platform that integrates primary production, secondary supply, waste reuse, and technological learning in recycling. In summary, NRES should aim to transition from midstream to downstream in a process of increasing sophistication: first, metals, alloys, magnetic powders, and semi-finished magnets; then, permanent magnets, components, and functional materials; and, throughout this trajectory, increasing integration with anchor sectors and circularity. This approach allows the country to move toward higher-value-added segments without, from the outset, setting goals that are incompatible with its current capacity base.

Guidelines

- selectively focus on metals, alloys, magnetic powders, and semi-finished magnets as an intermediate step with greater industrial viability;
- link the strategy to anchor sectors such as electric mobility, renewable energy, robotics and automation, healthcare, defense, semiconductors, and advanced electronics;
- structure instruments around specific technological challenges, such as separated NdPr oxides, magnetic alloys, permanent magnets, and magnet recycling;
- incorporate anchor-demand mechanisms, including technology-based public procurement, institutional orders, and instruments for competitive import substitution;
- establish recycling pathways for industrial scrap, permanent magnets, tailings, red mud, and other mineral waste as part of the NRES industrial architecture;
- promote integration between the circular economy, material efficiency, and the reduction of environmental liabilities, thereby strengthening supply security and sustainability;
- treat circularity as a structural component of the gradual downstream transition, rather than as an isolated policy.

Axis 6. Governance, Sustainability, and Territorial Development

Objective: To ensure that the expansion of the Brazilian rare earths supply chain occurs with institutional coordination, social legitimacy, territorial development, and socio-environmental sustainability consistent with a long-term national strategy.

International experience and national analysis converge in showing that progress in the rare earths sector cannot be sustained solely by mineral competitiveness, economic incentives, or technological capacity. In a sector associated with significant socio-environmental risks, regulatory sensitivity, and concentrated territorial impacts, governance and territorial sustainability are structural prerequisites for the strategy.

Environmental, social, and corporate governance (ESG) practices, as presented in the stakeholder review, address mining in a broad sense. In the case of REEs, the main distinguishing feature is that they are associated, to a greater or lesser extent, with radioactive minerals such as uranium or thorium (Kamenopoulos and Agioutantis, 2013; Dostal, 2025; Rezaei et al., 2025).

Historically, traditional methods of REE extraction have been environmentally harmful, as well as economically costly due to their complex, multi-step procedures and the handling of radioactive materials. This adds an additional layer of socio-environmental concerns due to the risks of contamination and acidification of soils and water bodies (surface and groundwater), atmospheric emissions, impacts on the health and safety of the public both inside and outside the facility, and the disposal of tailings, among others. Given the complexity of all the stages involved in the extraction and processing of REE, there is a clear need for a strong connection between production and the science, technology, and innovation (STI) system, supported by a vast network of researchers working to develop solutions.

Thanks to its pioneering spirit, China has already established an extensive learning curve in REE technology, combined with its strong tradition in Research and Development—the country boasts the greatest technological advances and innovations for processing REE with the highest efficiency and lowest environmental impact today. However, it is also the country with the most reported cases of environmental and human contamination caused by the extraction and processing of REEs (Rezaei et al., 2025). France has made significant progress in neutralizing radioactive elements during the extraction, separation, and purification of REEs at all stages of the production cycle, including recycling. Canada also has a body of research on radioactivity and acid drainage.

With regard to social issues and respect for human rights, the mining sector has at its disposal a series of principles, protocols, and standards of best practices, of which the most widely used by companies are: 1) the UN Guiding Principles on Business and Human Rights (2011); 2) the Initiative for Responsible Mining Assurance (IRMA), which aims to promote more ethical, sustainable, and responsible mining, emphasizing fair labor practices and fair conditions regarding occupational health and safety, as well as community health and safety; areas affected by mining and conflicts or high-risk areas; safety measures; artisanal and small-scale mining; cultural heritage; 3) International Council on Mining and Metals (ICMM) with the

Human Rights Due Diligence Guidance; and 4) the Global Reporting Initiative (GRI), which is among the most widely adopted, as in the case of the Mining Sector Standard. These protocols are generally still voluntary, but if effectively implemented, they enable the achievement of high standards and stronger global collaboration, which opens a genuine window of opportunity to incorporate respect for human rights at all levels of decision-making. It should be emphasized that this is not merely about preventing harm, but rather about actively contributing to resilient communities, fairer economies, and a safer and more sustainable future for all.

In addition to adopting these guidelines, the development of ongoing participatory processes has also proven to be a key element in ensuring the social legitimacy of mining projects. The participatory process strategy is based on the premise that it is essential—both for the present and the future of mining in the region—to create permanent spaces for collaborative dialogue, in which communities, government regulatory agencies, and companies can exchange information, build trust, and adjust their decisions based on the perspectives and contributions of their stakeholders. These spaces foster a multisectoral dialogue capable of broadening consensus, reducing conflicts, and strengthening the territorial governance of projects.

As for protocols specifically designed for critical minerals—including REEs—the Critical Minerals Action Plan stands out. Proposed by the G7 Summit—comprising the leaders of the world’s seven most industrialized and democratic economies (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States, as well as the European Union, which also participates as a permanent guest member), in 2025 in Canada. The Plan promises to ensure compliance, through adherence to legal requirements, with internationally recognized human rights standards and fundamental labor principles and rights, as established in the UN Conventions.

As for the governance structure, in terms of public regulation, the Canadian Sovereign Fund for Critical Minerals—originally established with CAD\$2 billion—stands out; it even provides for the possibility of the country holding an equity stake in REE projects. Indonesia also has legislation requiring foreign mining companies to transfer at least 51% of their shares to Indonesian interests. These examples demonstrate ways to achieve greater sovereignty and national participation in the exploitation of REEs.

In general, mining has both positive and negative effects on the regions where it takes place. Among the negative effects are socio-environmental impacts, pressure on the cost of living, conflicts over land ownership and use, and, in some contexts, an exacerbation of public safety issues. Among the positive effects, the most notable are the stimulation of the local economy, increased demand for labor, the creation of jobs and income, higher government revenues, and, as a result, the potential to strengthen public policies and regional investments. In the case of REE mining, this equation tends to be more complex. Since it is generally a relatively small-scale activity, the direct economic benefits may prove to be more limited, while the potential presence of radioactive elements tends to heighten the perception of risk and social sensitivity regarding negative impacts.

From this perspective, local development does not automatically result from the establishment of mining operations, but rather from the existence of capacities, instruments, and institutional arrangements capable of enhancing its positive effects and mitigating its adverse effects (Table 56). It is, therefore, an agenda that must be guided by a vision of long-term territorial sustainability, consistent with the Sustainable Development Goals.

TABLE 56

Negative and Positive Impacts of Mining and Recommended Actions

Indicators	Actions to enhance positive effects	Actions to Mitigate Adverse Effects
Socio-environmental impacts	Communication policy regarding the types of impacts and the policies adopted to prevent, mitigate, or offset them	Measures to prevent, mitigate, and compensate for impacts must be discussed with the affected population The government must establish a policy on financial guarantees for mine closure
Rise in the cost of living	Strategic planning by the mining municipality to identify potential sources of cost increases and adopt measures to address them	Inclusion and income programs for vulnerable populations who will be most affected by inflation
Increase in violence	Violence prevention programs in mining areas	Strengthening public safety intelligence to prevent the escalation of violence, including traffic-related violence
Conflict over land ownership and use	Nonviolent communication and compensation programs tailored to the types of conflicts and the ways to prevent, mitigate, or compensate for them	Establish Mining-Free Zones
Involuntary Displacements	Adoption of Free, Prior and Informed Consent (FPIC) (ILO Res. 169) Resettlement program carried out with the participation of those affected	Resettlement in conditions better than those of the original housing, financial compensation, and socioeconomic and psychosocial support
Increased employment and income	Expand the hiring of local or regional labor (set targets), along with policies to improve the skills of the local workforce	Social inclusion and gender equity programs
Increased public revenues—with an emphasis on CFEM	Strategic planning for the effective use of CFEM funds. Allocate them to policies that prevent dependence on the mining sector	Strengthening governance through social oversight of mining revenues
Socio-environmental constraints	Strengthen existing policies and structures so that the policy gains autonomy	Avoid merely checking off a “checklist”; instead, ensure investments are integrated with other policies
Policies for integration among business, community, and government	These policies should be linked to other public policies, such as education, sanitation, connectivity, mobility, and economic diversification, etc.	Promote dialogue with the government and society to define priorities

Source: Prepared by the authors based on Enríquez and Ferraz (2023).

Socio-environmental impacts: The issue of the risk of radioactive contamination and the measures that will be adopted to mitigate it must be thoroughly clarified in order to avoid generating controversy, mistrust, and opposition to mining in these territories. Similarly, communication must be clear and informative regarding all other impacts so that the company can obtain the Social License to Operate (SLO). It is also important to consider the issue of financial guarantees for mine closure, as is already the practice in most countries (the U.S., Canada, Argentina, etc.); France has established measures for compensation and redress for damages caused by mining, covering both environmental damage and harm to public health.

Rising cost of living: According to mayors of mining towns, the cost of living in these cities is significantly higher than the regional average, due to the imbalance between the supply and demand for factors of production. This calls for public policies to counteract the effects of inflation on low-income individuals, who are the most vulnerable.

Increased violence: The international literature indicates that the arrival of mining projects, particularly in remote regions, is accompanied by an increase in violence, especially against women and girls (Mancine & Sala, 2018; Widana, 2019; Borges et al., 2024; Mishra et al., 2024; Cambaco et al., 2025). This occurs because large amounts of financial resources circulate in mining regions, which ultimately attract a large influx of people seeking new opportunities. Thus, a safe environment is essential; without it, there can be no development.

Conflict over land ownership and use: The growing demand for new mining areas has fueled conflicts, given that mining competes with other existing forms of land use and occupation. Hence the importance of nonviolent communication programs and compensation measures, tailored to the specific types of conflicts and the ways to prevent, mitigate, or compensate for them. One of the demands of social movements is that Mining-Free Zones be established through public policies.

Involuntary displacement: This is one of the most negative effects, as it affects every aspect of the lives of the people who will be relocated. The adoption of Free, Prior and Informed Consent (FPIC), in accordance with ILO Resolution 169, to which Brazil is a signatory, is a demand that must be considered. In addition to the implementation of a resettlement program developed with the participation of those affected, the new housing must be of a higher standard than their original homes and must include financial compensation as well as socioeconomic and psychosocial support.

Increased employment and income: This results from increased investment, but the local population does not always take advantage of this opportunity. In this regard, it is necessary to set goals to expand the hiring of local or regional labor, along with training policies and programs for social inclusion and gender equity. Additionally, it is necessary to consider the importance of policies for adding value—from the mine to the magnet—because even if not all stages take place locally, the process has a positive impact on the mining region.

It is important to note that employment projections must be linked to the

mine's life cycle, which generally follows a normal curve, with few jobs created during the exploration phase, a significant increase during the construction phase, a reduction during the operational phase, and a total decline during the mine closure phase (Figure 18); this dynamic must be clearly communicated to the affected municipality. Case studies indicate that, during the construction phase, there is a large influx of labor from other regions; an example of this is research on lithium mining in Chile, which shows that the total workforce in the municipality increased by 150%, yet the increase in local employment was only 16% (Liu and Agusdinata, 2020). During the operational phase, depending on the level of economic diversification, employment tends to rise in the service and retail sectors as well. A key factor associated with sustaining local employment is ensuring that projects aimed at economic diversification occur simultaneously with the mine's development, as this fosters a culture that counteracts dependence on mining.

FIGURE 18

Labor Employment During the Phases of Mining Development



Source: based on Enríquez and Ferraz, 2023.

Increase in public revenues, particularly from the CFEM: the local community considers the 2% CFEM rate to be disproportionate. Due to the small scale of operations, the financial return to the public coffers has fallen far short of local expectations, and this has sparked negative reactions and calls for a review of these rates. But in addition to the CFEM, which is a type of royalty, there are other taxes that also benefit the municipality through mining (Tax on Services of Any Nature—ISSQN, ICMS transfers, licenses, and fees). Since the CFEM is not a tax, there are no restrictions on its use; hence the importance of strategic planning to ensure the proper allocation of this revenue—which is volatile and pervasive—toward policies that prevent dependency and strengthen local governance through public oversight of these funds.

Socio-environmental constraints: These are requirements imposed during the environmental licensing process. To meet them, companies create a checklist without considering the need to strengthen existing policies and structures so that investments

related to these conditions are integrated with other policies and can be sustained over time, rather than only as long as the company provides the funding.

Company–Community–Government Integration Policies: Adopting an integrated approach, rather than isolated corporate projects, maximizes positive impacts, as community engagement works best when linked to the productive development of the region—such as fostering local suppliers, training the workforce, and promoting economic diversification aligned with municipal plans. Thus, corporate social responsibility (CSR) initiatives must be aligned with the municipality’s other public policies, such as education, sanitation, connectivity, mobility, and economic diversification. It is important for companies to foster an ongoing dialogue with the government and society to define priorities.

Development of local suppliers, social investment, and regional preparation for the post-mining era: In addition to the factors discussed above, strengthening local development in mining regions also stems from the ability to: i) mobilize local and regional suppliers of goods and services; ii) support capacity-building initiatives; and iii) contribute to the creation of more sustainable economic alternatives in the region that will endure even after mining operations cease. This is particularly relevant in supply chains such as the rare earths sector, where the physical volume produced tends to be relatively low, and direct tax revenues may not be sufficient, on their own, to sustain a robust path of local development.

In the case of Minaçu, evidence gathered in the field indicates that Serra Verde has been working with the municipality to support initiatives aimed at local socioeconomic development, with a focus on expanding income-generating opportunities and self-sufficiency beyond mining. Serra Verde’s sustainability report ⁹⁰ outlines Corporate Social Investment policies aimed at “building and enhancing the socioeconomic capacity and well-being of communities located near its operations.” In addition, the company states that, as part of its operating license, it monitors its impacts on socioeconomic development, provides support and capacity-building assistance to local government and rural communities, and contributes to improvements in local infrastructure.

Other examples in the mining industry have proven to be successful initiatives that can inspire best practices for the rare earths sector. According to the 2023 Sustainability Report from the Brazilian Metallurgy and Mining Company (CBMM),⁹¹ 96% of the products and services needed for operations were purchased in Brazil; Minas Gerais accounted for 43% of the national volume of purchases; and, out of an annual procurement budget of R\$ 2.8 billion, 52% involved companies from Minas Gerais, with 13% coming from suppliers in Araxá. These results highlight the potential for local economic development through the integration of suppliers into the mining value chain, with positive effects on job creation, income circulation, and business growth in these regions. The company also reports social investments totaling R\$ 39 million in 2023, with a primary focus on

90. <https://svpm.com.br/wp-content/uploads/2024/11/SVG-Sustainability-Review-Final-web-copy2.pdf>

91. <https://cbmm.com/pt/sustentabilidade/relatorios-de-sustentabilidade>

children and adolescents in the municipality, as well as workforce training and entrepreneurship initiatives in partnership with local institutions. In addition, other mining companies have similar programs. Anglo American reported that, in 2025, it and its contractors generated more than R\$ 100 million in purchases from local parent companies in the Minas-Rio System region, contributing to the circulation of income and the strengthening of small businesses in the vicinity of the operation. Although this is a different supply chain from that of rare earths, it is evident that the integration of local suppliers into the production chain can serve as a significant driver of regional development when linked to business training programs, access to procurement opportunities, and ongoing support.⁹²

For the rare earths supply chain, this trend has direct strategic implications. Even if more sophisticated stages of processing or manufacturing are not located in the mining municipality, the NRES can generate more robust territorial benefits if it incorporates explicit guidelines for the development of local and regional suppliers, structured social investment, and preparation for the post-mining period. Such initiatives include:

- i. map categories of goods and services with the greatest potential for local procurement;
- ii. create supplier training programs in partnership with Senai, Sebrae, technological institutes, and subnational governments;
- iii. promote mechanisms for competitive local content and monitoring of local and regional procurement;
- iv. strengthen municipal economic planning capacities;
- v. support territorial strategies aimed at reducing future dependence on mineral revenue;
- vi. promote technology-sharing mechanisms between anchor companies and local suppliers, including cooperative innovation projects, technical team exchanges, joint development of industrial solutions, and support for applied research in partnership with ICTs and local companies.

In emerging supply chains such as REE's, where direct fiscal returns may be relatively modest in the early stages, strengthening the local supplier base and developing economic alternatives beyond mining may be some of the most concrete ways to expand the socioeconomic legacy of the activity in the region. In addition to business training and local hiring, mechanisms for technological cooperation can help expand local productive and technological capacities, thereby facilitating the more qualified integration of domestic suppliers into the value chain. To monitor the effectiveness of local development, Table 57 presents indicators and objectives:

92. <https://ibram.org.br/noticia/anglo-american-movimenta-r-100-mi-compras/>

TABLE 57

Initiatives to Strengthen the Local Economy

Dimension	Objective	Suggested indicators	Sources / References
Local Infrastructure and Public Services	Assess pressures and legacies on urban infrastructure and services	Demand for housing; pressure on health, education, safety, and sanitation; compensatory investments; quality and coverage of public services	Municipal governments; state and municipal departments; IBGE; companies
Public revenue and CFEM	Measuring the impact of mining activity on local tax revenue	Share of CFEM in municipal revenue; trends in own-source revenue; fiscal dependence on mining; composition of public revenue	ANM; National Treasury; city governments; Courts of Auditors
Employment and income	Capturing the direct and indirect effects of mining on employment and income	Direct and outsourced jobs; share of local formal employment; total payroll; trends in average income; employee turnover; workforce qualifications	RAIS/CAGED; IBGE; companies; labor departments
Development of local suppliers and production networks	Measuring the activity's capacity to generate economic and technological spillovers in the region	Percentage of total contract value awarded to local suppliers; percentage of total contract value awarded to regional suppliers; number of qualified and contracted local suppliers; annual value of local and regional purchases; number of suppliers supported by training programs; categories of goods and services with the greatest potential for local procurement; number of cooperative innovation projects between anchor companies and local suppliers; technology partnerships with ICTs; technology transfer initiatives; supplier technology development programs; specialized technical exchanges or training between companies and local suppliers	Corporate sustainability reports; development departments; Sebrae; Senai; business associations; municipal governments; ICTs; universities; innovation agencies
Economic diversification and post-mining legacy	Assess whether mining builds lasting capacities in the region	Contribution of non-mining sectors to local GDP; creation of new businesses; support for entrepreneurship; economic diversification programs; post-mining planning	Municipal governments; state governments; Sebrae; IBGE; companies
Training and human capital	Determine whether the activity contributes to technical training and local labor market integration	Number of courses offered; people trained; partnerships with Senai, Federal Institutes (IFs), and universities; integration of qualified local labor; apprenticeship programs	Senai, Sebrae; Federal Institutes (IFs); universities; companies; Departments of Education and Labor
Land-use planning and land use	Identify the effects of mining on land use and land-use conflicts	Unplanned urban expansion; pressure on environmentally sensitive areas; alignment with master plans; land and land-use conflicts	Municipal governments; environmental agencies; land registry offices; National Institute of Colonization and Agrarian Reform (INCRA); IBGE
Public participation and territorial governance	Measuring the quality of mechanisms for dialogue and transparency	Existence of local forums; mechanisms for listening and consultation; transparency regarding revenues and investments; community participation in decision-making; channels for complaints and conflict resolution	Companies; municipal governments; Public Prosecutor's Office; local councils; civil society organizations

Dimension	Objective	Suggested indicators	Sources / references
Human rights and vulnerable groups	Assess distributional impacts and risks on specific populations	Impacts on traditional communities; displacement; access to water; food security; perception of risk; safeguards and mitigation measures	Government agencies; Public Defender's Offices; Public Prosecutor's Office; companies; local organizations
Local socio-environmental sustainability	Linking local development to environmental quality and territorial legitimacy	Monitoring of water, soil, and air; waste management; public perception of impacts; existence of emergency plans; remediation mechanisms	Environmental agencies; companies; universities; municipal governments; civil society

Source: Prepared by the authors.

The experience reported in Minaçu suggests that, in addition to job creation and CFEM revenue generation, strategic mineral projects can play a significant role in strengthening regional development. This is essential for generating lasting benefits even after mining operations have ceased. In the case of Serra Verde, evidence gathered during field visits points to initiatives supporting the municipality's local socioeconomic development, expanding income opportunities and long-term self-sufficiency, as well as Corporate Social Investment policies aimed at enhancing the socioeconomic capacity of nearby communities, and support and capacity-building for local government and rural communities.

Experiences from other sectors and supply chains underscore the importance of this type of initiative. The case of CBMM in Araxá was mentioned earlier. Vale, meanwhile, reported that its "Partilhar" program has engaged more than 370 suppliers, generating over 31,000 local jobs and R\$960 million in local spending. These examples suggest that strengthening the local economy depends not only on the mining operation itself, but also on the ability to coordinate local procurement, supplier training, social investment, and long-term planning.

Among the central elements of this pillar is the need to strengthen public communication, social participation, and effective conflict management. It is recommended that a communication policy be established regarding the types of impacts and the measures adopted to prevent, mitigate, or compensate for them, as well as to engage in dialogue about these actions with the affected population. In this context, the participatory process should be understood by companies not only as a tool for obtaining a Social License to Operate (SLO), but as part of a planned, ongoing, and proactive approach to impact management. For communities, these mechanisms should serve as permanent channels for communication and listening, allowing for the expression of questions, critical concerns, and suggestions related to the actual or potential impacts of mining on the territory. Emphasis is also placed on the need for Free, Prior and Informed Consent; resettlement with the participation of those affected and under conditions better than their original housing; financial compensation; and socioeconomic and psychosocial support in cases of displacement. These elements demonstrate that territorial governance cannot be reduced to formal licensing: it involves trust, predictability, information, and the capacity for social negotiation.

Another essential component is strengthening local capacity to capture value and build lasting economic legacies. As illustrated above, the economic value generated by local purchases of goods and services, the capacity-building of suppliers, and the revitalization of local supply chains can be as significant as—or even more significant than—the direct impact of the payroll. Thus, the importance of municipal strategic planning, inclusion and income programs, the strengthening of local public policies, infrastructure development, communication with the public, and mechanisms to strengthen the local economy is emphasized. In this regard, NRES should link the expansion of the supply chain to the promotion of local procurement (whenever possible), supplier development, professional training, and economic diversification in mining regions.

In high-risk industries facing increasing international scrutiny, social and environmental standards, risk management, mine closure guarantees, transparency, traceability, and participatory governance are becoming key factors in the sector's competitiveness. This is especially relevant for Brazil, which seeks to position itself as a reliable supplier in an international environment that is sensitive to supply security, sustainability criteria, and due diligence.

Finally, the governance and territorial development pillar must be integrated with NRES's inter-institutional coordination. Territorial sustainability depends not only on good business practices, but also on coordination among the federal government, states, and municipalities; environmental agencies; regulators; science and technology institutions; companies; and civil society. Without such coordination, issues such as licensing, tailings management, radioactivity, urban planning, infrastructure, public safety, and the use of mineral revenues tend to be addressed in a fragmented manner, undermining the strategy's effectiveness. Strengthening public governance thus emerges as a key element in transforming isolated initiatives into a consistent and legitimate national policy.

Guidelines

- Integrate governance, sustainability, and territorial development as structural conditions of the NRES rather than as a secondary agenda;
- use Table 57 as a practical reference to guide responses to socio-environmental impacts, cost of living, violence, territorial conflicts, involuntary displacements, and the strengthening of local economies;
- strengthen public communication, social participation, territorial dialogue, and mechanisms for Free, Prior and Informed Consent, where applicable;
- promote local procurement, supplier development, professional training, and economic diversification in mining regions as a structural driver to foster local economic development through integration into the value chain;
- establish financial guarantee policies for mine closure, impact mitigation, and post-mining planning;
- incorporate ESG standards, traceability, transparency, and risk management as part of the Brazilian supply chain's competitiveness and international legitimacy;

- strengthen coordination among the federal government, states, municipalities, regulators, environmental agencies, companies, and civil society to avoid fragmentation and increase the strategy's territorial effectiveness.

4.3. National Goals for the Brazilian Rare Earths Supply Chain

The NRES must translate Brazil's strategic ambition into quantitative, time-bound, and verifiable goals. Without goals, the strategy risks remaining merely declarative, limited to identifying opportunities, bottlenecks, and general intentions. With targets, it functions as a tool for public-private coordination: it guides regulatory priorities, reduces the dispersion of efforts, signals potential scale to investors, organizes financing instruments, directs the development of national capabilities, and allows for monitoring the implementation of the policy over time.

In the case of rare earths, this need is particularly relevant because the value chain is long, technologically complex, and marked by significant asymmetry between geological endowment, mineral production, chemical separation, metallurgy, magnet manufacturing, and end uses. Brazil possesses significant geological resources, a relatively inexpensive and low-carbon electricity mix, accumulated mining expertise, and growing international attention. As noted above, Brazil already accounts for 23.1% of global REE resources, totaling 21 Mt in mineral reserves, and has made significant progress in geological research, with an increase in exploration permits and announced investments in the sector.

This position, however, should be viewed as a strategic opportunity in the making, not as a consolidated advantage. The national supply chain is in transition: the upstream sector shows more concrete signs of progress; the midstream sector remains the main industrial and technological bottleneck; and the downstream sector still concentrates on pilot projects, demonstration projects, or small-scale initiatives.

The national goals proposed in this section do not constitute a selection, recommendation, or prioritization of specific companies or projects. They define systemic parameters to guide public policy, and it will be up to future instruments to establish objective, transparent, and equitable eligibility criteria based on technical maturity, economic competitiveness, socio-environmental performance, traceability, technological alignment, and effective contribution to the NRES's national goals.

The central logic is to combine pragmatism and ambition. Brazil should not limit itself to the role of an exporter of minimally processed mineral products. At the same time, it should not set, in the short term, the maximalist goal of internalizing the entire value chain and becoming an export hub within a few years. The recommended path should be gradual, selective, and mission-driven: consolidate a competitive scale of mineral production, convert a significant portion of production into domestic or allied separation and refining capacity, develop technological expertise in alloys and magnets, and, progressively, build industrial capacity in downstream segments associated with strategic sectors.

4.3.1 Strategic rationale for the goals

National goals must fulfill six main functions. First, they must set a benchmark for the country's ambition, enabling Brazil to move beyond being viewed merely as a holder of geological potential and position itself as a relevant, reliable, and technologically advanced supplier. Second, they must coordinate public and private decisions around common priorities. Third, they should guide financing instruments, guarantees, credit, support for innovation, and international cooperation. Fourth, they should organize the development of human capital and technological infrastructure. Fifth, they should allow for periodic monitoring and course correction. Sixth, they should link productive growth to sustainability, traceability, territorial development, and value addition.

This approach is consistent with the nature of the global rare earths market. The critical importance of rare earths stems from the concentration of processing, refining, and manufacturing capacities, as well as from the strategic significance of their ability to transform geological resources into production, processing, manufacturing, innovation, and competitive integration into global value chains with higher added value.

The key strategic transformation for Brazil will occur when a growing portion of mineral production is converted into capacity for separation, refining, alloys, magnets, and industrial applications. Upstream expansion is a necessary but not sufficient condition. Without a midstream sector, the country may be able to increase production volume, but it will remain dependent on third parties to qualify products, define specifications, capture margins, and access more sophisticated industrial markets. Without a selective downstream sector, the Brazilian value chain will remain vulnerable to external value capture.

4.3.2 Goals for the upstream sector: scale, competitiveness, and supply security

The proposed long-term goal for the upstream sector should be for Brazil to account for 20% of global REE production by 2040. Considering the projected global production of 378.5 kilotonnes per annum (ktpa) of TREO in 2040, according to 2025 data from Argus Media, this ambition implies Brazilian production of approximately 75 ktpa of TREO. Within this total, it is recommended to set a minimum sub-target of 15 ktpa of NdPr + DyTb, reflecting the central role of magnetic elements in the supply chain for permanent magnets and the sector's economic value.

This goal should be treated as strategic and contingent, not as an automatic projection. Its achievement will depend on the conversion of projects into operations, the quality of licensing, the availability of financing, cost competitiveness, price stability, and logistics infrastructure. The goal is not simply to produce more REE, but to produce it better: with lower socio-environmental risk, greater traceability, a better profile of magnetic elements, greater economic competitiveness, and greater adherence to processing routes in Brazil or in allied supply chains.

The indicative trajectory should distinguish the first wave of projects at a more advanced stage of development from the long-term national ambition. Projections based on

data provided by companies indicate that the first wave could bring Brazilian production to a level exceeding 35 ktpa of TREO in the early 2030s, with associated production of approximately 12.5 ktpa of NdPr + DyTb. This foundation is sufficient to demonstrate the plausibility of Brazil entering the global market on a significant scale, but it is not yet enough to reach the target of 75 ktpa by 2040.

Thus, the long-term goal will require a second wave of projects, expansions, and new competitive assets capable of adding approximately 40 ktpa of TREO to the projected production base for the first half of the 2030s. This second wave must be selective. NRES should not indiscriminately promote any project related to rare earths, but rather prioritize—using objective criteria—those assets that demonstrate greater economic competitiveness, a better ESG profile, higher relative content of magnetic elements, lower regulatory complexity, lower carbon intensity, greater capacity for integration with the midstream, and an effective contribution to supply security. The development of a project evaluation and prioritization matrix can help establish classifications based on transparent, reviewable criteria applicable not only to the upstream sector but also to the various links in the supply chain. Based on this classification, it would be possible to guide access to public support instruments—such as financing, tax incentives, guarantees, diplomatic support, participation in hubs, technology procurement, and R&D&I programs—thereby transforming the status of “strategic project” into an objective classification linked to specific conditions. The governance of this process could involve interministerial and technical bodies, with periodic reviews capable of incorporating technological, regulatory, and geopolitical changes, while also preserving the possibility of future reassessment of projects that were not initially prioritized.

TABLE 58

Production Targets for Upstream

Time Horizon	Indicative TREO production and workforce	Strategic Interpretation
2027–2029	35 ktpa; at least 3,500 jobs	Launch or consolidation of the first wave of projects in more advanced stages
2030–2033	40 ktpa; at least 3,900 jobs	New projects, currently still in the mineral exploration phase, begin operations

Source: Prepared by the authors.

The upstream goal is expected to produce three strategic effects. First, to position Brazil as one of the main platforms for supply diversification outside of Asia. Second, to ensure sufficient scale to enable domestic or allied separation and refining capacity. Third, to allow the country to act simultaneously as a reliable exporter, a producer-consumer of strategic inputs, and a platform for technological and industrial development.

4.3.3 Midstream Goals: Separation, Refining, and Value Addition

The national goal for the midstream sector should be to install 40 kt TREO/year of oxide separation capacity by 2040, including at least 10 ktpa of NdPr + DyTb. This goal is lower than the mineral production goal because it is reasonable to expect that there will be technical limitations and specific commercial arrangements under which part of the production is directed to another country. The distinction is important: mineral production measures the capacity to extract, process, and produce marketable material; separation capacity measures the industrial capacity to convert mixed streams into individual oxides with higher value added.

The proposed path for the midstream sector should consist of two phases. In the short term (2027–2029) and medium term (2030–2033), it is recommended to aim for 25 ktpa of separation capacity, linked to the first wave of mineral production and to projects with greater technical, economic, and regulatory maturity. In the medium and long term, it is recommended to add 10 to 15 ktpa of additional capacity, contingent upon the selection of a second wave of projects and the availability of feedstock, offtakes, financing, and solid technology partnerships.

The target of 40 ktpa should not be interpreted as a requirement for a single plant, nor as an obligation to process all produced material domestically. Brazil can structure this capacity through modular arrangements, plants integrated with specific assets, central processing facilities, partnerships with technology centers, and agreements with allied countries. The decision must be based on economic, regulatory, and strategic considerations. The goal is to ensure that the country has sufficient capacity to qualify products, negotiate offtakes on better terms, reduce external vulnerability, develop technological expertise, and capture a larger share of the value in the value chain.

International experience shows that making the midstream viable requires risk-mitigation tools along the supply chain (de-risking). In the Brazilian context, the most realistic strategy is to integrate Brazilian projects and capabilities into international arrangements for demand, offtake, financing, guarantees, and supply security, in which consumer markets and strategic partners can structure long-term contracts, procurement mechanisms, commercial guarantees, or financial support associated with supply chain diversification. Since strategic supply and offtake contracts typically require lengthy negotiation and due diligence cycles, dialogue with potential international buyers should begin as early as the initial stages of project development. In this process, institutions such as the Ministry of Foreign Affairs (MRE), the Ministry of Mines and Energy (MME), ApexBrasil, and NRES's coordination structures can contribute to the international promotion of Brazilian projects, the standardization of technical information, and coordination with multilateral banks and risk mitigation mechanisms associated with supply chains for critical minerals.

TABLE 59

Production Targets for the Midstream

Time Horizon	Total separation capacity	NdPr + DyTb	Critical condition
2027–2029	Qualitative goal: pilot plant and demonstration plant	Qualitative goal: qualified routes and products	Qualitative goal: technology scaling and licensing
2030–2033	Quantitative target: 25 ktpa TREO/year	Quantitative target: 6–7 ktpa	Qualitative goal: FID for one or more commercial capacities
2034–2040	Quantitative target: 40 ktpa TREO/year	Quantitative target: 10 ktpa	Qualitative target: feedstock, offtake, financing, and stable operation

Source: Prepared by the authors.

4.3.4 Downstream targets: permanent magnets and anchor sectors

The national target for the downstream sector should be the production of 5 ktpa of permanent magnets by 2040, with a trajectory of 2 ktpa in the medium term and an additional 3 ktpa in the long term. This target should be presented as selective, progressive, and geared toward industrial learning. The objective should be to build capacity in segments where there is a plausible connection between the availability of inputs, technological expertise, domestic or regional demand, anchor sectors, and international partnerships. A scenario is envisaged in which part of the production (~60%) is expected to meet the domestic demand estimated below for selected sectors, as well as the demand from other sectors (such as the technology sector), considering the projected growth in these segments, in addition to meeting international demand—particularly taking into account the strategic opportunity to serve regional markets with limited local production, especially in Latin America.

The production of permanent magnets is significant because NdFeB magnets account for a major portion of the strategic value of rare earths. Neodymium, Praseodymium, Dysprosium, and Terbium are essential for high-efficiency applications in electric vehicles, wind turbines, automation, defense, healthcare, sensors, and industrial equipment. At the same time, building downstream capacity outside of Asia is slower and more demanding than upstream expansion, as it depends on technical expertise, quality control, a stable supply of oxides or alloys, access to technology, qualification with buyers, and integration with specific industrial supply chains.

Preliminary estimates⁹³ prepared as part of this study indicate that the initial domestic demand mapped for magnetic REEs in selected sectors is on the order of 1.1 kt/year of NdPr + DyTb. This figure is significant for two reasons. First, it demonstrates that

93. The estimates were based on a conservative approach to accounting for the sectoral items currently considered most relevant in the industry, that is, they focused on the production of wind turbines (considering a median mix of offshore and onshore turbines), electric and hybrid vehicles (production and gradual replacement of the current fleet), and products related to retail consumption, primarily cell phones, computers, tablets, air-conditioning motors, televisions, and displays in general. In other words, there is a range of other items that were not included in this preliminary calculation, as well as items intended for export that could significantly increase production.

there is a potential local demand base associated with end products such as wind turbines, electric and hybrid vehicles, electronics, and industrial equipment. Second, it shows that the target of 5 ktpa of permanent magnets should not be justified solely by import substitution. It should be understood as a strategy for industrial learning, selective support for anchor sectors, and export integration into related supply chains.

Therefore, the downstream target should begin with intermediate stages: alloys, magnetic powders, semi-finished magnets, prototypes, pilot lines, and components for specific applications. The transition to finished permanent magnets should occur progressively, as the country develops capabilities, attracts technology partners, and establishes anchor demand.

Priority sectors should include wind energy, electric mobility, industrial automation, defense, healthcare, advanced electronics, semiconductors, sensors, and high-efficiency industrial equipment. Brazilian domestic demand alone will likely not be sufficient to absorb the full scale required for a competitive magnet industry. Therefore, the downstream sector should be conceived as a platform for international and regional integration, not merely as an import substitution policy.

TABLE 60

Production Targets for the Downstream Sector

Time Horizon	Permanent Magnet Production Target	Predominant Industrial Phase
2027–2029	Qualitative Goal: Pilot lines, prototypes, and qualification	Qualitative goal: alloys, magnetic powders, and semi-finished magnets
2030–2033	Quantitative goal: 2 ktpa	Qualitative goal: semi-finished magnets and magnets for industrial niches
2034–2040	Quantitative goal: 5 ktpa	Qualitative goal: permanent magnets and components in anchor sectors

Source: Prepared by the authors.

4.3.5 Cross-cutting goals: technology, human capital, sustainability, financing, and governance

The goals for each link in the chain will only be feasible if accompanied by cross-cutting goals. These goals must create the systemic conditions for Brazil to convert its geological potential into productive, technological, and industrial capacity.

The first cross-cutting goal should be the internalization of critical capabilities for testing, experimentation, and the definition of processing routes. By 2030, Brazil should be capable of conducting, within its national territory, all bench-scale and pilot-scale tests necessary for defining REE processing routes, including mineralogical characterization, leaching, desorption, precipitation, purification, separation, impurity control, mass balance, and effluent management

and tailings, reagent testing, and evaluation of intermediate products. By 2033, this capacity should include processes involving minerals containing NORM (such as thorium and uranium), under defined regulatory protocols and within authorized laboratory infrastructure. This goal is central to reducing external dependence at a critical stage of project development, in order to shorten the wait time for results—which leads to longer project development timelines—and to accelerate the national technological learning curve.

Based on the analysis conducted in Section 3.6.2.1, which focused on estimating the operational workforce needs for the rare earths supply chain of companies currently on the verge of production, it was observed that, by the year 2040, approximately 10,000 positions will be needed to meet supply demands. This figure, however, can be viewed as a conservative estimate, since balanced labor markets tend to have a supply of jobs equal to or greater than industrial demand. Furthermore, when considering the possibility of new companies entering the market—which are still in the early stages of feasibility studies—the number of jobs required by the industry is likely to be even higher.

In this regard, the second cross-cutting goal should be the development of specialized human capital. It is recommended that an initial goal be set to create at least 10,000 new cumulative enrollment slots by 2040 in technical, technological, higher education, and continuing education programs related to the rare earths supply chain. This goal should include chemical engineering, metallurgical engineering, mining engineering, materials engineering, geology, chemical technicians, mining technicians, hydrometallurgical plant operators, and specialists in radiation protection, environmental control, industrial automation, instrumentation, maintenance, analytical quality, and industrial process management. The number should be coordinated with the Ministry of Education (MEC), SENAI, Federal Institutes, universities, the Coordination for the Improvement of Higher Education Personnel (CAPES), the National Council for Scientific and Technological Development (CNPq), MCTI, MDIC, MME, and the private sector; however, their inclusion is essential to prevent the labor shortage from becoming a bottleneck as significant as funding or technology.

The third cross-cutting goal should be sustainability, traceability, and social acceptance. By 2030, all projects deemed relevant to the NRES should, at a minimum, have a socio-environmental and governance assessment, including basic mechanisms for traceability of origin, emissions intensity indicators, a water management plan, a territorial relations plan, and a tailings management plan. For larger projects or those at a more advanced stage of operation, it is recommended that, by that time, these instruments already be structured according to auditable ESG standards compatible with international markets. By 2040, the goal should be for 100% of Brazilian production relevant to strategic REE supply chains to be covered by traceability mechanisms and socio-environmental reporting compatible with international markets, with the gradual incorporation of smaller projects and those at less advanced stages of operational maturity.

The fourth cross-cutting goal should be regulatory predictability, especially with regard to NORM (primarily thorium and uranium), environmental licensing, and chemical processing. Brazil must urgently and as a matter of priority establish a simple, predictable, standardized, coordinated, and technically consistent regulatory framework for REE projects,

covering mining, leaching, precipitation, chemical separation, radioactivity, waste management, and the disposal of byproducts. This regulatory framework should promote greater procedural clarity, institutional coordination, and legal certainty, helping to reduce regulatory uncertainties, provide greater predictability in review and licensing processes, and foster greater efficiency and speed consistent with the technical and socio-environmental complexity of the projects. By 2029, the country should have clear NORM guidelines applicable to the rare earths supply chain, with coordination among the Ministry of Mines and Energy (MME), the National Mining Agency (ANM), the National Nuclear Energy Commission (CNEN)/National Nuclear Safety Authority (ANSN), Ibama, state environmental agencies, the Ministry of Science, Technology, and Innovation (MCTI), the Ministry of Development, Industry, Trade and Services (MDIC), and the Brazilian Development Bank (BNDES).

The fifth cross-cutting goal should be financing and bankability. By 2028 at the latest, Brazil should establish a financing framework for projects and capabilities within the REE supply chain, with coordinated access to the BNDES, FINEP, the National Fund for Scientific and Technological Development (FNDCT), climate funds, the IDB, the World Bank, export credit agencies, development banks, and private equity. This framework should prioritize long-term credit, guarantees, support for innovation, incentive debentures, subsidies for pilot plants and demonstrators, incentives for structuring offtakes, and integration with international demand mechanisms.

BOX 1

Summary of National Targets by Link in the Chain

Link or dimension	Current Situation	2027–2029 Target	2030–2033 Target	2034–2040 Target	Indicators
Upstream	Production resumed and first wave of projects under development	~35 ktpa TREO	~40–45 ktpa TREO	75.7 ktpa TREO	ktpa TREO; number of operations; exportable production
Magnetic elements	Production still concentrated on mixed products	~12.5 ktpa NdPr + DyTb	~14–15 ktpa NdPr + DyTb	≥15 ktpa NdPr + DyTb	ktpa NdPr + DyTb; MREO/TREO content; basket value
Midstream	No established commercial-scale separation	Pilot plants, demonstration, and qualification	25 ktpa separation	40 ktpa separation	ktpa of installed capacity; utilization rate; qualified products
Separated magnetic oxides	Non-existent or nascent capacity	Route and product qualification	6–7 ktpa NdPr + DyTb	10 ktpa NdPr + DyTb	ktpa of separated oxides; offtake agreements
Downstream	Pilot projects and technology initiatives	In-depth mapping of domestic demand; prototypes, alloys, powders, and semi-finished magnets	2 ktpa magnets	5 ktpa magnets	ktpa magnets; sectors served; qualified buyers
Technology testing	Scattered and incomplete capacity	Nationalize critical bench and pilot-scale testing	Include routes involving associated NORM/thorium/uranium	Operate continuous technological infrastructure	Number of testable routes in Brazil; authorized laboratories
Human capital	Limited supply of skilled labor	National training plan	5,000 cumulative enrollment slots	10,000 cumulative enrollment slots	Enrollment slots created; certified professionals; active courses
Sustainability	Standards under development	Traceability in relevant projects	Standardized certification and reporting	100% of strategic production is traceable	% of production tracked; carbon intensity; water indicators
Sustainability	Socioeconomic monitoring scattered	Development of a framework of socioeconomic indicators to be monitored	Monitoring of socioeconomic indicators; creation of territory-specific micro-indicators	Monitoring of socioeconomic indicators and territorial micro-indicators	Set of socioeconomic indicators and micro-indicators under monitoring; measurement of social impact
Circularity	[In its early stages] Reverse logistics for WEEE is under development, and recycling of magnets/REE is still limited to pilot projects, with no significant industrial capacity	Map secondary sources; expand reverse logistics; encourage and scale up pilot projects for REE recycling	Expand pilot and pre-commercial projects for secondary recovery of REE	Scale up commercial operations for secondary recovery of REE; limit waste exports	Volume of WEEE collected (metric tons/year); recovery rate (%); installed capacity (metric tons/year); REE recovered (metric tons/year); % of recycled content in the supply

Source: Prepared by the authors.

4.3.6 Indicators for monitoring and periodically reviewing targets

The proposed targets should be monitored by the MME through a dedicated working group, which should draw on the contributions of other public agencies and research institutions to monitor and track the targets. The review should take place every two years, with an interim assessment in 2030 and a strategic review in 2033. This review should consider price trends, the actual implementation of projects, global demand, domestic demand, export restrictions, technological advances, environmental performance, availability of financing, regulatory timelines, and the implementation of public policies.

BOX 2

NRES Monitoring Indicators

Dimension	Indicator	Unit	Frequency	Suggested Responsible Party
Mineral production	TREO produced	ktpa	Annual	MME/ANM
Magnetic elements	NdPr + DyTb produced	ktpa	Annual	MME/ANM
Phase 1 of primary production expansion	Actual production from projects in the most advanced stage	ktpa	Annual	MME/ANM
Phase 2 of primary production expansion	Additional projects with technical and regulatory maturity	number/ ktpa	Annual	MME/ANM
Oxide separation	Installed separation capacity	ktpa TREO	Annual	MME/MDIC
Value addition	Domestically processed domestic production	%	Annual	MME/MDIC
Magnetic oxides	Production of separated NdPr + DyTb	ktpa	Annual	MME/MDIC
Downstream	Production of alloys, magnets, and permanent magnets	ktpa	Annual	MDIC/MCTI
Domestic demand	Estimated consumption of NdPr + DyTb by key sectors	tpa	Annual	MDIC/EPE/MME
Human capital	Places created in technical, technological, and higher education programs	number	Annual	MEC/SENAI/MCTI
Technological tests	Fully testable processing routes in Brazil	number	Annual	MCTI/MME
Radiation Protection	Laboratories and pilot plants authorized to conduct NORM testing	number	Annual	ANSN/MCTI
Funding	Funds Raised	R\$/US\$	Semiannual	BNDES/Finep/MME

Commercialization	Production with an offtake agreement or long-term contract	ktpa/%	Semiannual	MME/Companies
International integration	Projects linked to allied supply chains	Number	Annual	MME/MRE/MDIC
ESG	Production with traceability and certification	%	Annual	MME/MMA
Energy	Renewable energy share of operational consumption	%	Annual	Companies/EPE
Carbon	Emissions intensity and offsets	tCO ₂ e/t of product	Annual	Companies/MME
Region	Skilled jobs created	Number	Annual	Companies/MTE
Suppliers	Percentage of local suppliers	% Purchases	Annual	Companies/state governments
Circularity	REE recovered from secondary sources	tpa	Annual	MCTI/MDIC
Governance	Average time to license relevant projects	months	Annual	MME/licensing agencies

Source: Prepared by the authors.

The adoption of these indicators will allow NRES to be monitored in an objective and adaptive manner. The targets should be viewed as a tool for coordination and guidance, not as an unconditional promise of production. If international prices fall below sustainable costs, if projects do not reach a final investment decision, if separation technology is not scaled up, if demand for magnets evolves differently than expected, or if international financing instruments do not materialize, the targets will need to be recalibrated.

The key point is that Brazil has a real, but time-limited, strategic window of opportunity. Demand for alternatives to Chinese supply chains is growing; governments and international buyers are using public and private instruments to mitigate risk in critical projects; and consumer companies are seeking traceable, sustainable, and geopolitically reliable sources. NRES must take advantage of this window to position the country on three complementary fronts: as a major mineral producer, as an emerging platform for separation and refining, and as a selective participant in alloys, magnets, and industrial applications. The goal of 20% of global production by 2040 will only have full strategic value if it is linked to the ability to transform part of that production into separated oxides, magnetic materials, technological expertise, skilled human capital, and permanent industrial capabilities. This is the leap that distinguishes a mineral strategy from a national development strategy.

4.3.7 Integration and Harmonization with Existing Planning Instruments

For the NRES to become institutionalized and evolve into state policy, its goals must be progressively incorporated into the Brazilian government's formal instruments for planning, budgeting, sectoral coordination, and monitoring. NRES must align with the Multi-Year Plan (PPA), the Budget Guidelines Law (LDO), and the Annual Budget Law (LOA), so that its priorities are translated into programs, targets, indicators, budgetary actions, and verifiable outcomes. In the 2028–2031 cycle of the PPA, it is recommended that the targets for production, separation, technological capacity-building, human resources development, traceability, and territorial development related to rare earths be incorporated into a cross-cutting agenda covering critical minerals, strategic industrial chains, and supply security.

At the sectoral level, the NRES should be coordinated with the National Mining Plan 2050 and overseen by the National Council for Mineral Policy, under the leadership of the MME. This coordination will allow national targets for primary rare earth production to be monitored over the long term, aligned with Brazilian mineral policy, and reviewed periodically. The same logic can guide future mechanisms for coordinating and prioritizing strategic projects related to Critical and Strategic Minerals (CSM), including consideration of the instruments provided for in Bill 2780.

The strategy can also contribute to objectives associated with the Climate Plan and Brazil's climate commitments under the NDC, given the role of rare earths as strategic inputs for energy transition technologies, such as wind turbines, electric vehicles, high-efficiency motors, and storage and electrification systems. Brazil's potential gains additional significance given the predominance of renewable sources in the national electricity mix, especially when compared to more carbon-intensive mixes (such as in China), which may provide competitive advantages for the processing, separation, and manufacturing of permanent magnets with lower emissions intensity. Added to this are potential emissions avoided through nearshoring and the reduction of long international logistics routes. In this context, quantitative estimates of avoided emissions and the potential climate contributions of the Brazilian rare earths supply chain may constitute a relevant topic for future studies.

The institutionalization of NRES should also be incorporated into industrial policy, science and technology, and defense instruments. Under the “New Industry Brazil” initiative, rare earths should be treated as critical inputs for the energy transition, digital transformation, advanced materials, and the qualified international integration of Brazilian industry. In the national science, technology, and innovation policy, priority should be given to laboratory and pilot-scale capabilities for defining processing routes, including those involving associated NORM (especially thorium and uranium). In defense planning instruments—the National Defense Policy (PND), the National Defense Strategy (END), and the National Defense White Paper (LBDN)—rare earths should be recognized as strategic inputs for technological autonomy, industrial resilience, and supply security for the Defense Industrial Base.

Given the importance of rare earths to the energy transition—especially in technologies such as wind turbines, electric vehicles, high-efficiency motors, and advanced electrification systems—the NRES must also be aligned with the Climate Plan and the Brazilian targets established in Brazil's Nationally Determined Contribution (NDC).

This institutional framework will prevent the NRES from remaining an isolated sectoral document. Instead, it will allow its goals to be integrated into medium- and long-term planning instruments, linking mineral policy, industrial policy, science and technology, defense, the public budget, and regional development. The MME should act as the lead agency for the NRES, with interministerial coordination and periodic monitoring by the CNPM and, as appropriate, by the CIMCE, taking into account the progress of the National Policy on Critical and Strategic Minerals.

TABLE 61

Coordination instruments to be established by the CNPM

Instrument	Function	Methodology
Establish an interministerial executive coordination mechanism for NRES, aligned with the future national governance framework for Critical and Strategic Minerals.	Monitor targets, coordinate measures, coordinate actions, and ensure the advancement of NRES in a manner integrated with national policies on Critical and Strategic Minerals	An interministerial and interdisciplinary executive body, led by the MME and integrated into the planned national governance structure for Critical and Strategic Minerals
Establish a technical mechanism for the strategic monitoring of critical and strategic minerals within the framework of the national governance structure planned for the sector, in coordination with the GSI/CREDEN	Support the strategic monitoring of the policy on Critical and Strategic Minerals from the perspectives of national security, industrial resilience, and geopolitical interests	A technical body providing support and advice, coordinated with the future national governance framework for Critical and Strategic Minerals
Multi-Year Plan (PPA)	Medium-term planning and government targets	Incorporate the NRES's targets into outcome-based programs, cross-cutting agendas, and indicators for the 2028–2031 cycle
Budget Guidelines Law (LDO)/Annual Budget Law (LOA)	Prioritization and annual budget	Create budgetary measures for R&D, technology testing, capacity building, and governance
PNM 2050	Long-Term Mineral Planning	Incorporate NRES as a thematic agenda for critical minerals and rare earths
CNPM	Strategic Coordination of Mineral Policy	Approve a resolution to monitor NRES targets
CTAPME / Pró-Minerais	Government coordination for strategic minerals	Update equitable criteria for classifying relevant projects
New Industry Brazil	Industrial policy through 2033	Link REE to the energy transition, digitalization, advanced materials, and defense

National Strategy for Science, Technology, and Innovation (ENCTI)	National Science, Technology, and Innovation Policy	Prioritize laboratory infrastructure, pilot plants, process routes, and technical training
PND / END / LBDN	Defense Planning and Strategic Autonomy	Recognize REE as a critical input for supply security and the Defense Industrial Base

Source: Prepared by the authors.

4.4. Enabling Conditions

The strategic opportunities identified in the assessment and in the NRES do not automatically materialize simply because reserves exist or mining operations are underway. Their viability depends on a set of enabling conditions that span the entire chain and which, in the Brazilian context, are just as important as the existing geological, industrial, and institutional assets. In other words, transforming the mineral base into productive, technological, and territorial capacity will depend less on the mere availability of mineral resources and more on the ability to create a regulatory, financial, industrial, and socio-environmental environment compatible with the high-value-added links in the value chain. The challenge is to establish the conditions for these priorities to move forward with predictability, bankability, and legitimacy.

4.4.1 Regulatory and Institutional Conditions

The first prerequisite is the creation of a regulatory and institutional environment that is more predictable, coordinated, and aligned with the specific dynamics of the rare earths supply chain. The report's analysis shows that a significant portion of the obstacles perceived by stakeholders stems not only from the technological or economic risks of the projects, but also from the fragmentation between mineral, environmental, and radiological licensing; uncertainty regarding the division of authority between the federal government and the states; and the absence of a clear solution to critical regulatory issues, especially NORM. Without a more robust institutional response to these issues, the trend is toward increased regulatory risk, litigation, and the cost of capital for these projects.

In this context, regulatory predictability and simplification should be treated as a strategic asset for NRES. This involves defining procedures, institutional responsibilities, and technical criteria more clearly for projects involving natural radionuclides, thereby reducing the current disconnect between preliminary classification, environmental licensing, and subsequent reassessment by the nuclear regulatory authority. Currently, NORM classification initially depends on self-reported data provided by the companies themselves and can only be reviewed at later stages by the competent authority. When this occurs, there is a risk of conflict with licensing already conducted by another jurisdiction, which increases legal uncertainty and encourages litigation.

Accordingly, NRES should support the creation of an integrated procedural protocol for projects with the potential presence of NORM, involving ANM, environmental agencies, and the nuclear authority—

from the initial stages. This would make it possible to reduce the sequential and reactive approach that currently predominates and replace it with a more coordinated framework. It is also recommended that the strategy provide for early assessment of critical risks, integrated analysis of socio-environmental impacts, and consideration of cumulative impacts and those of pre-existing projects, especially in more sensitive areas. This guidance is already reflected in the report's set of actions, which proposes fast-track processes based on objective criteria, national environmental standards, and prior assessment of critical risks as tools for reducing uncertainty and territorial overload.

The issue of NORM requires specific attention. In the case of monazite deposits, the lack of a solution for the byproduct thorium acts as a structural barrier to the viability of some of the projects. It is not enough to offset radiological costs if there is no clear definition for the disposal, storage, or strategic use of thorium. Therefore, NRES should plan, in the short term, to establish a working group to address the handling of thorium, with the participation of the Ministry of Mines and Energy (MME), the National Nuclear Energy Commission (CNEN)/National Nuclear Safety Authority (ANSN), the Ministry of Foreign Affairs (MRE), and the Ministry of Finance, with a mandate to present an operational solution within a defined timeframe.

Among the alternatives, the following stand out: a centralized repository managed or accredited by the nuclear regulatory authority, with thorium treated as a strategic reserve of the Union; regulated in-situ storage at audited facilities; future integration into the Brazilian nuclear program; or negotiation of exports to nuclear partners, subject to specific safeguards. Among these options, the centralized repository appears to be the fastest way to overcome the current regulatory impasse.

In addition to the radiological agenda, NRES should address regulatory governance more broadly. This is the case with mergers and acquisitions of REE mineral assets, which have frequently been the subject of challenges and litigation⁹⁴. This includes creating an interministerial body to coordinate strategy, establishing a national timeline with mandatory targets and milestones, defining clearer criteria for prioritizing investments based on market intelligence, and making progress toward building an integrated legal framework for critical minerals and rare earths. It is also necessary to strengthen the institutional capacities of the ANM, environmental agencies, and the nuclear regulatory authority, as regulatory predictability depends not only on regulations but also on the operational capacity to implement them.

4.4.2 Tax and Financial Conditions

The second enabling condition is the creation of a tax and financial environment compatible with the vertical integration of the supply chain. Projects involving separation, refining, metallization, alloys, magnets, and recycling require capital-intensive investment, a long technological maturation period, and greater demand predictability than conventional mining. In this context, the economic framework applicable to the rare earths supply chain cannot be identical to that typically applied to purely extractive projects. NRES must, therefore, combine tax relief measures, support for productive investment, risk mitigation, support for pilot plants and demonstration facilities, and hybrid funding mechanisms designed to bridge the gap between mining and industrial processing.

94. <https://cksonline.com.br/nunes-marques-vai-relatar-no-stf-acao-que-tenta-barrar-venda-de-mineradora-de-terras-raras/>

First, it is recommended that the investment phase be exempt from taxes, with a suspension of the Contribution on Goods and Services (CBS) and the Tax on Goods and Services (IBS) on the acquisition of machinery, equipment, materials, and services intended for the establishment or expansion of processing, chemical separation, refining, and metallization plants, with conversion to a zero tax rate upon proof of commencement of operations. At the same time, it is recommended that the Import Tax (II) and Tax on Industrialized Products (IPI) be reduced on imported equipment and inputs for which there are no domestic equivalents. These measures directly address the cost of implementing the intermediate and advanced stages of the supply chain and reduce the initial disadvantage of Brazilian projects compared to already mature supply chains abroad.

Second, the NRES should provide for operational tax exemptions for chemical reagents and critical process inputs used in refined processing, the separation of individual oxides, the transformation into metals and alloys, and the manufacture of magnets and components. It is believed that this list can be updated periodically by an interministerial ordinance issued by the MME, MCTI, and MDIC, thereby avoiding excessive rigidity and allowing for adaptation to technological and industrial developments in the supply chain. This type of instrument is particularly important because the operating costs of the midstream and downstream sectors in Brazil tend to be impacted by low initial scale, dependence on foreign technology, and competition with already established suppliers.

Third, it is recommended that a financial-tax credit for R&D be established, which can be offset against federal taxes, focused on mastering critical processes in processing, metallization, alloy formulation, magnets, and radiological management. It is suggested that differentiated multipliers be used according to technological criticality: individual separation of Nd/Pr and Tb/Dy with a higher multiplier; radiological management and NORM treatment also with an increased multiplier; and mandatory requirements for minimum R&D spending, agreements with ICTs, regional allocation, and human resources training. Incorporating this mechanism into the NRES is important because it makes support for innovation more aligned with the real challenges of the supply chain and more effective than generic deductions.

Fourth, the strategy should reduce the cost of acquiring and localizing critical foreign technology. Thus, we propose an exemption from Withholding Income Tax (IRRF) on royalties, licenses, and technical assistance related to technology localization, especially in separation and metallization, precisely because part of the technology available outside China is still controlled by a few holders and accessed through costly licensing arrangements. Additionally, it is suggested that support be provided for the acquisition and localization of technology through joint ventures, licensing, and specific financial instruments. NRES should encourage that public incentives aimed at attracting foreign investment be, whenever possible, linked to mechanisms for technology absorption and development in Brazil, including cooperation with Brazilian ICTs, human resources training, R&D&I activities, operational capacity building, and the gradual development of local suppliers. The proposal is not to establish mandatory technology transfer requirements, but rather to structure instruments capable of stimulating the gradual internalization of knowledge, productive learning, and the strengthening of national capabilities throughout the supply chain.

Fifth, the NRES should incorporate traditional instruments to stimulate productive investment, such as a 75% reduction in Corporate Income Tax (IRPJ) on operating profits from industrial processing activities of REE for a fixed term, along the lines of the Amazon Development Authority (Sudam) and the Northeast Development Authority (Sudene), and super-accelerated depreciation for separation, metallization, and radiological control equipment. These mechanisms are particularly useful for shortening the payback period (the time required to recover the capital invested in a project or business), improving bankability, and offsetting the additional risk of investments in vertical integration. Also worth considering are incentive debentures for mining and processing, as well as a sector-specific fund or downstream development fund—managed with the possibility of foreign and multilateral participation—aimed at financing CAPEX, equity, demonstration projects, and radiological costs.

Sixth, the strategy should include explicit instruments for supply chain de-risking and hybrid financing. Hybrid financing represents a significant advantage, in addition to price and demand guarantee mechanisms, public contracts, and funds with foreign and multilateral participation. It is believed that the ideal design combines repayable credit, grants, temporary equity participation, demonstration support, and market guarantee instruments. This is especially important for the midstream and downstream sectors, where uncertainty lies not only in the technology but also in scale and the development of a buyer base.

Finally, specific provisions must be incorporated to address costs associated with NORM. It is proposed to provide a 50% financial credit on documented costs related to radiological compliance, including licensing, containment and monitoring equipment, waste management, training, and decommissioning.

The vertical integration of the Brazilian rare earths supply chain requires a coordinated set of tax and financial instruments capable of reducing the cost of capital, mitigating technological and market risks, and creating economic conditions compatible with the establishment of plants for separation, refining, metallization, alloy production, magnet manufacturing, and recycling. Box 3 summarizes the main enabling instruments identified in the report, organized according to their strategic role in strengthening the supply chain.

BOX 3

Tax and financial instruments enabling the vertical integration of the REE supply chain

Instrument	Proposed Description	Strategic Objective	Timeframe	Key agencies/stakeholders
Tax Exemption During the Investment Phase (CBS/IBS)	Reduce the CBS and IBS tax rates on the purchase of machinery, equipment, materials, and services intended for the establishment or expansion of advanced processing, chemical separation, refining, and metallization plants, with the tax rate reduced to zero upon proof of commencement of operations	Reduce initial CAPEX and facilitate the establishment of plants in the stages with the highest value added	Short-term	Ministry of Finance/ Ministry of Development, Industry, Trade and Services
Operational tax exemption (CBS/IBS)	Reduce the CBS and IBS tax rates on chemical reagents and process inputs used in refined processing, separation of individual oxides, transformation into metals and alloys, and the manufacture of magnets and components, with a dynamic list updated by interministerial ordinance	Reduce OPEX in the midstream and downstream stages and increase the competitiveness of domestic production	Short-term	Ministry of Finance/MME/MDIC
Tax deferral until after the ramp-up phase	Defer federal taxes levied on the construction of mineral separation, refining, and processing plants until the post-ramp-up operational phase	Reduce entry risk and alleviate financial pressure during the first years of operation	Short-term	Ministry of Finance/Ministry of Development, Industry, Trade and Services
Financial-tax credit for R&D	Create a financial credit calculated based on R&D expenditures aimed at mastering critical processing, separation, metallization, alloys, magnets, and radiological management pathways, offsettable against federal taxes, with differentiated multipliers according to technological criticality	Accelerate national technological mastery and reduce foreign dependence in critical areas	Short-term	Ministry of Finance/MCTI
Exemption from withholding income tax (IRRF) on foreign technology	Exempt royalties, licenses, and technical assistance related to technology localization in separation, metallization, and other critical processes in the supply chain from withholding income tax	Reduce the effective cost of acquiring critical technology available outside of China	Short-term	Ministry of Finance
Income Tax Incentives (IRPJ/CSLL)	Reduce the IRPJ for companies engaged in the separation of REE oxides, the production of alloys, and magnets for a fixed term, following a model similar to the Sudam/Sudene model	Improve project viability, shorten the payback period, and encourage vertical integration within the country	Short-term	Ministry of Finance
Super-accelerated depreciation	Allow 100% depreciation in the first year for critical separation, metallization, and radiological control equipment related to vertical integration of the supply chain	Increase the attractiveness of productive investment and reduce the cost of capital	Short-term	Ministry of Finance
Compensation for radiological costs (NORM)	Discuss the feasibility of creating a financial compensation mechanism or tax credit for documented radiological compliance costs, including licensing, monitoring, containment equipment, waste management, training, and decommissioning	Reduce the additional burden imposed on projects involving NORM, particularly in monazite deposits	Medium	CNEN/Ministry of Finance
Subsidized credit lines for CAPEX/OPEX	Expand long-term credit lines at favorable rates for the implementation and operation of separation, refining, alloy, magnet, and recycling plants	Enable industrial scaling and reduce financial barriers in the midstream and downstream sectors	Short-term	BNDES
Support for pilot plants and demonstration facilities	Finance pilot plants, demonstration units, and pre-commercial batches, including through state equity and non-repayable instruments	Reduce technological risk and support the transition from bench-scale to pilot-scale to industrial scale	Short-term	BNDES/Finep/Embrapii
Hybrid funding and multilateral/foreign participation	Allow foreign and multilateral capital participation in funding structures for midstream and downstream sectors, combining credit, equity, grants, and guarantees	Increase financing capacity, share risk, and accelerate vertical integration	Medium	MME/BNDES
Rare Earth Downstream Development Fund (FFDTR)	Create a sector-specific fund focused on financing CAPEX, equity, demonstration projects, and radiological costs for industrial transformation projects	Provide financial support for the consolidation of the supply chain beyond the upstream sector	Short-term	MME/BNDES
Incentivized debentures for mining and processing	Regulate the use of incentive debentures for mining, mineral processing, and mineral transformation projects linked to the REE supply chain	Expand the scope of private financing and reduce long-term funding costs	Short-term	Ministry of Finance/CVM
Price, demand, and offtake guarantees	Structure price floors, offtake agreements, and demand guarantee mechanisms, including through the use of public procurement and long-term contracts	Mitigate market volatility and increase the economic predictability of projects	Medium	MDIC/BNDES/Defense/ MME
Temporary tax exemption on vertically integrated products	Provide for a temporary tax exemption on products processed throughout the value chain, with a focus on downstream and higher-value-added products	Increase the initial competitiveness of domestic vertical production	Short-term	Ministry of Finance
Support for technology acquisition and localization	Create financial instruments for joint ventures, technology licensing, and the internalization of critical know-how	Strengthen technology absorption and accelerate domestic industrial learning	Medium	BNDES/Finep

Source: Prepared by the authors.

Taken together, these instruments show that the vertical integration of the REE supply chain in Brazil will not depend on a single, isolated incentive, but rather on a combined framework of tax relief, credit, risk mitigation, support for innovation, hybrid financing, and economic predictability.

4.4.3 Technological and industrial conditions

The third enabling condition is the ability to transform accumulated knowledge into effective industrial capacity. The country already possesses significant scientific and laboratory expertise, but still faces major difficulties in transitioning from proof of concept to pilot plant, industrial demonstration, and commercial scale. In the rare earths sector, this gap is particularly critical because the supply chain depends on complex chemical routes, specialized equipment, metrology, quality control, radiological safety, and seamless integration between applied research and industrial operations. Therefore, NRES's progress will require an active policy of technological scaling, human resource development, and strengthening of the supplier ecosystem.

Technology scaling: Research support must be explicitly linked to pilot plants, demonstration facilities, pre-commercial batches, and the industrial qualification of processes and products. Without this, the country is likely to retain strong scientific capabilities but lack industrialization capacity. In other words, Brazil's challenge is not merely to develop production routes, but to test them, validate them, standardize them, and prove their viability under conditions that closely resemble actual operations.

Integration between ICTs and businesses: Coordinate SENAI, IPT, CETEM, universities, research institutes, and companies into results-oriented consortia. This integration should be institutionalized through mission-driven calls for proposals, consortia with explicit technological goals, shared infrastructure, and mechanisms for businesses to adopt the developed solutions. The goal is to bridge the gap between science and production, ensuring that technological efforts are not confined to the academic environment.

Training and Retention of Specialized Human Resources: In a sector that combines separation chemistry, extractive metallurgy, process engineering, automation, mineral characterization, and radiological safety, the human resources bottleneck cannot be treated as a secondary issue. NRES must combine graduate studies, technical training, professional specialization, and practical experience in pilot and industrial settings. This is particularly important for creating a national critical mass and reducing dependence on imported proprietary technology packages.

Development of the base of equipment, supplies, reagents, and know-how: NRES must implement a policy for developing critical suppliers and supporting the gradual internalization of technical and process capabilities.

4.4.4 Territorial, Social, and Socio-Environmental Conditions

The fourth enabling condition is the establishment of territorial, social, and socio-environmental legitimacy for the supply chain. Competitiveness does not depend solely on geology, technology, and

financing; it also depends on the ability to operate with social legitimacy, prevent conflicts, distribute benefits more effectively, and reduce territorial disparities associated with mining.

Social legitimacy: The expansion of the mining sector requires effective public communication, consultation, participatory mechanisms, and the ability to address local concerns regarding water, tailings, potential radioactivity, infrastructure, and the quality of public services.

Local development: In addition to creating jobs and generating CFEM revenue, strategic mineral projects can play a significant role in strengthening regional development. The case of Minaçu is particularly instructive in this regard: the experience reported there demonstrates Serra Verde's initiatives aimed at supporting local socioeconomic development, with a view to expanding income opportunities and fostering long-term self-sufficiency. The strategic message is clear: NRES must link the implementation of the supply chain to medium- and long-term territorial planning, and not merely to the immediate effects of the mining operation.

Local procurement and supplier qualification: The strengthening of the region depends not only on the mining operation itself, but also on the ability to coordinate local procurement, supplier qualification, social investment, and long-term planning.

Strategic use of the CFEM and other mineral revenue instruments: NRES should encourage states and municipalities to treat the CFEM not merely as current revenue, but as a foundation for economic diversification, post-mining planning, and the strengthening of local capacities. It is suggested that the CFEM be used for economic diversification and capacity-building to develop local development plans, with the aim of reducing excessive dependence on extractive activities and building more enduring legacies.

Post-mining planning: Territorial sustainability requires planning for long-term benefits even after operations have ceased, which involves financial guarantees, environmental restoration, economic development of the territory, and institutional preparedness of municipalities. In other words, local development cannot be synonymous with temporary dependence on minerals. It must be treated as a territorial transition strategy throughout the project's life cycle.

Environmental monitoring and socio-environmental safeguards: Monitoring of water, soil, and air; tailings management; emergency plans; remediation mechanisms; and collaboration among companies, environmental agencies, universities, municipal governments, and civil society (see Appendix IV—guide to practices for positive impact).

4.5. Strategic partnerships

The rare earths agenda must also be an agenda for cooperation. A comparison of China, the United States, the European Union, Australia, Canada, India, Indonesia, and Malaysia shows that competitiveness in rare earths is not built solely on the basis of mineral reserves or production, but through a combination of public policy tools, technological expertise,

financing, institutional coordination, and international partnerships aimed at reducing vulnerabilities and strengthening domestic capacities. In the case of Brazil, this means treating strategic partnerships not as a secondary pillar of the NRES, but as a functional mechanism to accelerate the consolidation of the supply chain and reduce structural bottlenecks in the segments where the country remains most vulnerable.

The main lesson is that the most effective international cooperation is not that focused solely on exporting concentrates or opening markets for mineral production, but rather that which contributes to building capacity in processing, refining, manufacturing, innovation, and circularity. Thus, Brazil's strategy should prioritize the establishment of international partnerships aimed at the joint development of technological and industrial capabilities.

In this context, NRES's strategic partnerships can be structured based on a functional approach, in order to organize a cooperation portfolio aligned with the priority needs of the Brazilian rare earths supply chain. This portfolio may encompass, among other aspects, financing and risk mitigation instruments, cooperation in processing and refining, support for technological innovation and industrial scaling, coordination with end-user markets and manufacturing, initiatives related to circularity and secondary sourcing, as well as mechanisms for governance, traceability, and supply security. Under this approach, partnerships are no longer viewed merely as vehicles for international integration but come to play a structural role in the progressive strengthening of segments still in the process of consolidation within the national supply chain, with particular relevance to the advancement of selective midstream and gradual downstream development.

Based on the benchmarking, it is evident that China remains the only player fully integrated from upstream to downstream, with mineral scale, technological expertise, refining, magnet manufacturing, and industrial coordination. Australia and Canada have strong mining capabilities and are making progress in building capacity, but still face financing and infrastructure bottlenecks. The United States and the European Union are concentrating their efforts on reindustrialization, refining, manufacturing, recycling, and public risk mitigation instruments. Malaysia, for its part, has established itself as an international processing hub, including through collaboration with the Australian mining sector. These experiences suggest that Brazil's strategy should seek cooperation with different partners on a selective basis, depending on the link in the chain, the type of capacity desired, and the instrument to be mobilized.

In the area of **financing and de-risking**, the most relevant partnerships are those capable of supporting CAPEX, pilot plants, demonstration projects, operational ramp-up, and long-term contracts. This study indicates that countries such as the United States and Australia have been combining public risk mitigation instruments, credit, offtake agreements, and government support to rebuild or expand links in the supply chain. For Brazil, this underscores the importance of deepening cooperation with export credit agencies, development banks, multilateral funds, and government partners willing to structure hybrid financing and share risk in the most capital- and technology-intensive segments.

In the field of **processing and refining**, partnerships should focus on building capacity in separation, purification, metallization, and alloys. The report's assessment is clear

by indicating that Brazil's bottleneck lies less in mineral resources and more in the intermediate and industrial stages of the supply chain. For this reason, the most relevant partnerships are not necessarily those that merely ensure the purchase of mineral production, but rather those that contribute to the development of plants, production routes, product qualification, engineering, and operational training. This includes cooperation with public and private actors capable of providing technology, training, process engineering, and industrial integration for selective projects involving NdPr, metals, and alloys, and, at the appropriate time, Dy/Tb and more sophisticated products.

In the field of **technological innovation**, strategic partnerships should support the translation of science into industrial capacity. Benchmarking shows that the United States, the European Union, the United Kingdom, and Canada have been investing in models that integrate applied research, demonstrators, mission-driven R&D, recycling, and innovation in materials and magnets. For Brazil, this suggests cooperation with universities, technology institutes, laboratories, and foreign companies in areas such as separation, metallization, alloys, magnets, circularity, metrology, certification, and radiological management—always with a focus on local knowledge absorption and human resource development.

In the field of **end-use markets and manufacturing**, partnerships should bring the rare earths supply chain closer to the most dynamic industrial sectors. The report already identifies as anchor sectors: electric mobility, renewable energy, robotics and automation, healthcare, defense, semiconductors, and advanced electronics. NRES must, therefore, seek partners who not only purchase processed materials but can also integrate Brazilian production into higher-value-added value chains, create anchor demand, and support the upgrading of products and components. This means that strategic partnerships must also be designed with a focus on industrial and manufacturing integration, not just on foreign trade.

In the field of **circularity**, international partnerships can accelerate the development of recycling pathways, waste reuse, the recovery of permanent magnets, and the use of secondary sources. Benchmarking shows that the European Union, the United Kingdom, and the United States have been treating circularity as a strategic component of supply security and industrial policy. For Brazil, this agenda is particularly relevant because it allows for the integration of sustainability, innovation, liability reduction, and the creation of industrial capacity in emerging niche markets.

Finally, strategic partnerships should contribute to **governance and supply security**. This includes cooperation on traceability, standards, certification, risk management, regulatory certainty, and the convergence of methodologies. In supply chains that are increasingly sensitive to geopolitics and due diligence, cooperation agreements and arrangements that enhance the predictability, traceability, and reliability of the Brazilian supply chain can become a significant competitive advantage. This is particularly relevant in a context where countries and blocs have been seeking to reduce vulnerabilities without compromising on sustainability and governance requirements.

In summary, the NRES should guide strategic partnerships based on three core criteria. The first is **functional alignment**: each partnership must address a specific bottleneck in the Brazilian supply chain. The second is **strategic selectivity**: cooperation must be aligned with the

NRES's priorities, particularly midstream operations, metals, alloys, magnets, recycling, and regulatory certainty. The third is the **development of domestic capabilities**: the ideal partnership is not one that merely extracts and exports, but one that shares risk, transfers knowledge, trains people, qualifies products, expands the market, and strengthens Brazil's presence in the higher-value-added segments of the supply chain. A concrete example of this type of arrangement is the partnership between Brazilian Rare Earths (BRE) and the French company Carester, which combines the supply of concentrates in Brazil, the establishment of separation capacity in the country, and long-term off-take agreements, linking market access with local industrial development. Thus, these partnerships cease to be merely a diplomatic complement and become a direct instrument of NRES's industrial, technological, and territorial policy.

In this context, it is essential that Brazil's strategy be based on an open and diversified approach to cooperation. Building partnerships with multiple countries and blocs expands Brazil's negotiating capacity, reduces geopolitical vulnerabilities, and promotes the diversification of export markets, in addition to enabling multiple pathways for the full development of national capabilities. This approach allows the country to access different technologies, sources of financing, and industrial arrangements, while avoiding the concentration of risks and strengthening strategic autonomy in the conduct of mineral and industrial policy.

Based on international benchmarking, it is suggested that NRES's strategic partnerships should be guided less by a generic approach to bilateral relations and more by a functional assessment of the capabilities that different countries and blocs have already established along the rare earths supply chain. It is worth noting that Brazil's diplomatic tradition of pragmatic equidistance allows the country to maintain a neutral position in geopolitical disputes while simultaneously forging strategic partnerships with multiple actors. This stance enhances its ability to prioritize national interests, especially in the technological field, facilitating cooperation and technology transfer. Box 4 identifies, among the cases analyzed in the report, those that most closely align with each of the priority axes of the Brazilian strategy, in order to support a more discerning selection of partners and cooperation arrangements.

BOX 4

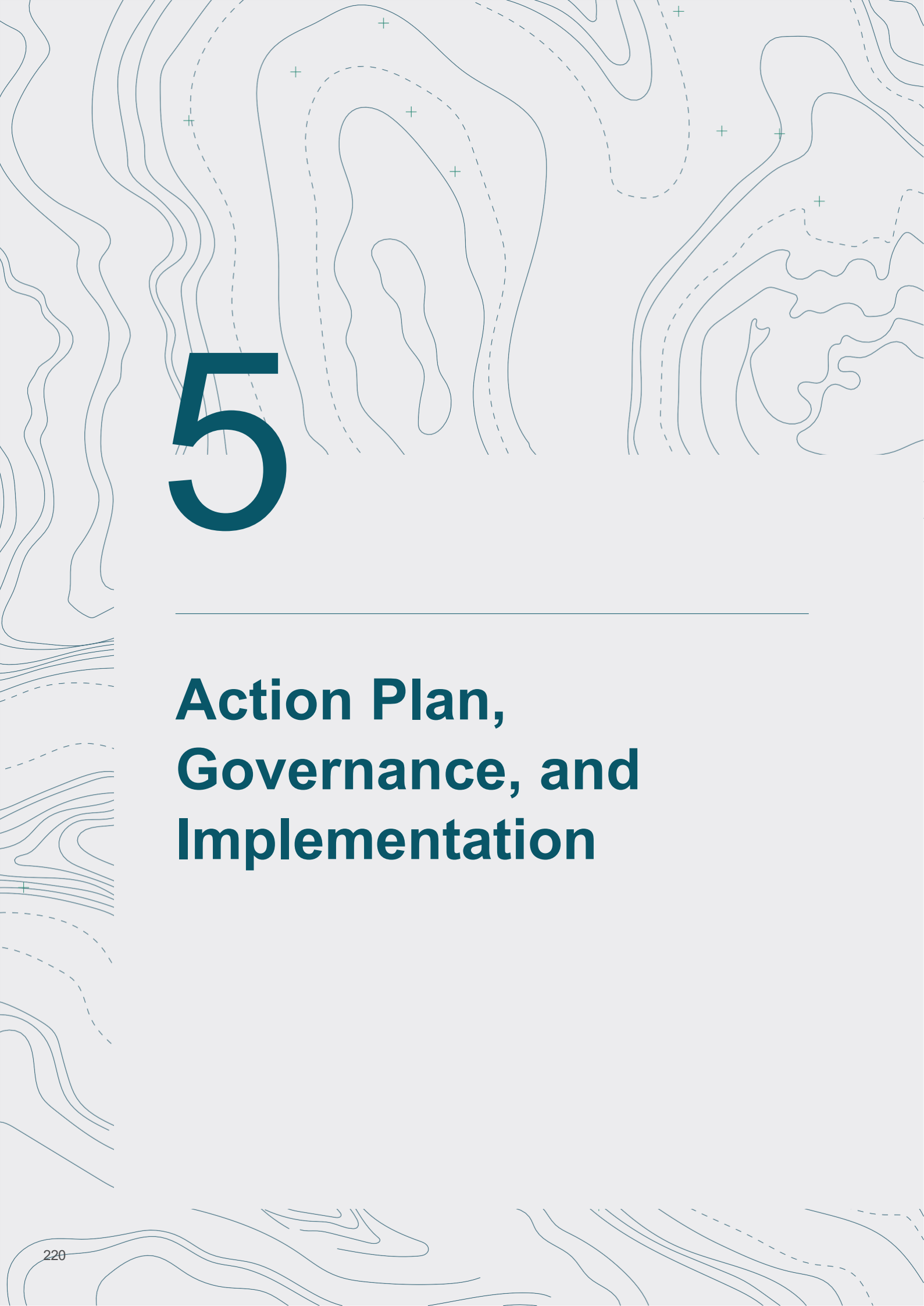
Countries/blocs with the highest alignment with NRES's priority areas

Country / bloc	Where the experience is most useful for Brazil	Strategic observation for NRES
China	Separation, refining, industrial integration, technological mastery, and vertical integration	It is the primary benchmark for scale and supply chain integration, particularly in the midstream. The key lesson is not to replicate the Chinese model in its entirety, but to recognize that leadership requires industrial coordination, continuous R&D, and mastery of the intermediate and final stages
United States	De-risking, strategic acquisitions, public financing, rebuilding "magnets," and industrial policy	The U.S. experience is particularly aligned with NRES in its use of risk mitigation tools, funding, and industrial policy to rebuild missing links, especially in the midstream and magnets

European Union	Refining, recycling, and integration of industrial policy, sustainability, and supply security	The EU aligns closely with the NRES on issues of circularity, regulation, targets, and the integration of industrial transition and sustainability. It serves as an important benchmark for the circularity pillar and for enabling regulatory conditions
United Kingdom	Innovation, recycling, development of technological niches, and specialized pathways	The UK model is more useful for innovation niches, recycling, and specific technological applications than for large-scale mineral or industrial applications
Australia	A robust mineral base, long-term contracts, government support for refining, and a gradual transition toward vertical integration	This is likely the case that most closely resembles Brazil's situation, given the combination of a strong geological base and progressive expansion into refining, supported by contracts, public policy, and international integration
Canada	Institutional coordination, enabling infrastructure, financing, and ecosystems for critical minerals	Canada is particularly aligned with the NRES on the issues of governance, coordination, funding, and ecosystem development, even though its REE chain remains in the process of consolidation
India	Industrial policy, protection of domestic supply, incentives for manufacturing, and strategic use of international agreements	The greatest alignment lies in the use of industrial policy to link critical minerals to domestic manufacturing and supply security, which is valuable for the NRES's anchor-sector agenda
Indonesia	Value-added instruments and a focus on domestic industrialization	This is a useful case study, primarily as a selective reference and a cautionary example: it demonstrates the potential of such instruments nationalists focused on value creation, but also the risks of weak regulatory coordination and technological inadequacy
Malaysia	Processing hub, logistics, specific regulations, and integration with external supply chains	The key takeaway lies in learning how to develop a processing hub framework, even without a large domestic mineral base, which is directly relevant to Brazil's selective midstream design

Source: Prepared by the authors based on Table 2 of the international benchmarking study and the NRES's pillars/guidelines.

This analysis reinforces the idea that NRES's partnership policy must combine pragmatism and selectivity. Brazil does not need to fully replicate the trajectory of any single country. The most promising approach is to build a cooperation portfolio that combines—depending on the focus area and time horizon—examples in financing and de-risking, processing and refining, innovation and scaling, manufacturing and end-user markets, circularity, and governance. Under this approach, partnerships come to function as instruments for the progressive strengthening of national capabilities, rather than merely as channels for mineral exports.



5

Action Plan, Governance, and Implementation

The effectiveness of the National Rare Earths Strategy will depend on the ability to translate its guidelines into time-bound priorities, coordinated actions, concrete tools, and implementation mechanisms. The analysis presented throughout this report shows that Brazil already possesses significant assets—a substantial geological base, a growing pipeline of projects, technical and scientific expertise, international interest, and initial signs of industrial development—but also faces structural gaps in regulation, financing, technological scaling, institutional coordination, and territorial legitimacy. In this context, the NRES can only produce concrete results if it is accompanied by an action plan capable of organizing the transition from the identified potential to the progressive development of national capabilities throughout the value chain.

The action plan aims to translate NRES's strategic priorities into an implementation roadmap, outlining the timeframe, enabling instruments, governance, and monitoring. To this end, it is based on the recognition that the rare earths supply chain will not advance uniformly across all links and that the country is unlikely to achieve international competitiveness in all segments in the short term.

The implementation of the strategy must, therefore, follow a selective, phased, and mission-driven approach, distinguishing between what can and should be prioritized in the short term, what requires maturation in the medium term, and what is projected as a long-term consolidation horizon. This approach is consistent with the report's assessment, according to which the greatest immediate potential lies in consolidating the upstream sector and structuring a selective midstream, while a more sophisticated downstream sector and advanced circularity should be built gradually and cumulatively.

The timeline proposed in this chapter should not be interpreted as a rigid sequence, but rather as a way to prioritize, reduce fragmentation, and increase coherence in the mobilization of public instruments. Across all timeframes, the implementation of the NRES will require coordination among mineral policy, industrial policy, science and technology, financing, regulation, and territorial development. It will also require strong coordination among the federal government, states, municipalities, the private sector, science and technology institutions, funding agencies, and civil society. For this reason, the action plan presented here is accompanied by proposals for governance, regulatory and tax/financial agendas, and monitoring mechanisms, in order to ensure that the strategy is monitored, reviewed, and adjusted over time.

5.1. Short-, medium-, and long-term

The implementation of NRES must follow a phased approach consistent with the current maturity of the Brazilian rare earths supply chain, the risks associated with each link in the chain, and the capacity to mobilize public and private resources. Rather than seeking to internalize the entire supply chain simultaneously, the strategy should combine pragmatism and ambition, prioritizing actions capable of generating cumulative effects.

This means consolidating, in the short term, the mineral base and the enabling tools for industrial advancement; and expanding, in the medium term, the national processing capacity,

transformation, and integration with user sectors; and, in the long term, to consolidate a more integrated, resilient, and technologically sophisticated supply chain, with a greater presence in magnets, components, and advanced circularity.

Short term

In the short term, NRES's central priority should be to consolidate the material, institutional, and regulatory foundations of the strategy. This means, first and foremost, supporting the consolidation of a competitive, reliable, and sustainable upstream sector by accelerating the maturation of viable projects, increasing regulatory predictability, and deepening geological and sectoral intelligence. The goal, within this timeframe, is to transform the current pipeline into an effective production base, bridging the gap between mineral potential and reliable supply capacity. At the same time, the short term should be dedicated to establishing the enabling conditions for the supply chain: institutional coordination, regulatory arrangements for NORM, strengthening the financing and risk mitigation environment, supporting selective processing routes, implementing the tax and financial instruments necessary for vertical integration, and fostering coordination among mining, innovation, and industrial policy.

In this context, the most realistic industrial priority is to begin selective midstream processing, focusing on intermediate products and routes of relatively lower complexity—especially higher-purity carbonates and oxides—and, progressively, selective separation, with priority given to NdPr. In the short term, efforts should also concentrate on creating de-risking tools, supporting pilot plants and demonstration facilities, structuring the inter-institutional framework for radioactivity and thorium by-products, and harmonizing regulatory initiatives across mining, environmental protection, and radiation safety. At the same time, it is recommended to launch recycling programs for industrial scrap, mineral waste, and other concentrated sources of secondary supply, laying the groundwork for a circular economy without immediately relying on complex post-consumer reverse logistics chains. In summary, the short term should be dedicated to removing the main entry barriers and laying the groundwork upon which the rest of the strategy can move forward.

Medium term

In the medium term, NRES should gradually shift its focus from consolidating the mineral segment to expanding national capacity in the intermediate segments and strengthening links with industrial user sectors. While the short term is marked by preparation, coordination, and the removal of bottlenecks, the medium term should be a time for consolidating the midstream sector in a selective manner and for initial industrial densification. This includes expanding separation and refining, advancing in metals, alloys, and semi-finished magnets, and consolidating regional processing and innovation hubs. The rationale behind this strategy is to enable Brazil to move beyond operating solely as a potential supplier of mineral raw materials and begin building a more robust presence in higher-value-added intermediate products.

This period should also be marked by the strengthening of anchor demand and the integration of the rare earths supply chain into priority sectors, such as electric mobility,

renewable energy, automation, healthcare, and defense. Progress in the medium term will depend on the coordination among processing projects, support tools, buyer sectors, and infrastructure for demonstration and industrial qualification. At the same time, the consolidation of regional hubs in areas with a higher density of projects, infrastructure, and technological capabilities is likely to be decisive in preventing fragmentation and expanding economies of scale. The medium term should be the time to transform sectoral efforts into productive density and accumulated industrial know-how.

Long term

In the long term, NRES should seek to consolidate a more integrated supply chain, linking mining, separation, refining, metallurgy, magnets, recycling, and industrial applications with higher value added. This vision includes advancements in permanent magnets, magnetic components, functional materials, and advanced circularity, as well as Brazil's greater integration into global supply chains that are less dependent on external processing. This is the stage at which the strategy ceases to be merely an agenda for strengthening the upstream and selective midstream sectors and begins to take shape as a more comprehensive industrial and technological positioning policy. Even so, this vision must be built progressively, building on the capabilities effectively accumulated in previous periods.

Furthermore, circularity must move beyond being a complementary approach and become a structural component of the country's supply security through the recycling of permanent magnets, the reuse of industrial and urban waste, the integration of manufacturing and reverse logistics, and greater use of secondary sources. Within this same timeframe, Brazil will be able to seek a more robust position as a reliable partner in higher-value-added value chains, combining its mineral base, processing capabilities, intermediate production, industrial applications, and sustainability and governance standards compatible with the most demanding markets. The long term, therefore, should not be understood as merely a subsequent stage, but as a horizon for consolidating a trajectory of productive, technological, and territorial densification, built in a selective and coordinated manner.

Thus, organizing priorities into short-, medium-, and long-term categories allows for a balance between realism and strategic ambition. It recognizes, on the one hand, that Brazil is not starting from scratch and already possesses significant assets; on the other hand, that the transition from geological endowment to a higher value chain will require continuous coordination, appropriate tools, and cumulative learning. From this perspective, the timeframe of the NRES does not merely reflect a chronological sequence but rather a logic of progressively building national capacities. It is this logic that guides, in the following sections, the matrix of priority actions, the regulatory and tax/financial agenda, governance, and the mechanisms for monitoring the strategy.

Box 5 summarizes NRES's priorities by time frame, organizing the implementation of the strategy in a phased manner consistent with the current maturity of the Brazilian rare earths supply chain.

BOX 5

NRES Priorities by Time Horizon

Time Horizon	Core Priorities	Associated Strategic Objective
Short term	Consolidation of a competitive upstream sector; deepening of geological and sectoral intelligence; structuring of an inter-institutional framework for NORM; creation of de-risking instruments; support for selective pathways prioritizing NdPr; implementation of tax and financial instruments; strengthening of institutional coordination; launch of industrial scrap and mineral waste recycling programs; harmonization of regulatory initiatives	Remove entry bottlenecks, transform mineral potential into a reliable production base, and create the enabling conditions for industrial advancement along the value chain
Medium term	Expand national separation and refining capacity; advance in metals, alloys, and semi-finished magnets; consolidate regional processing and innovation hubs; strengthen anchor demand; integrate the supply chain with priority sectors such as electric mobility, renewable energy, automation, healthcare, and defense	Strengthen the value chain at intermediate stages, increase value capture, and connect mineral production to industrial processing and end-user markets
Long term	Consolidation of an integrated supply chain encompassing mining, refining, metallurgy, magnets, and recycling; advancements in permanent magnets, components, and functional materials; incorporation of circularity as a structural element of the strategy; greater integration of Brazil into global supply chains with higher value added and supply security	Reposition Brazil as a reliable, competitive, and technologically advanced partner in global rare earth supply chains

Source: Prepared by the authors.

This analysis reinforces the view that NRES must combine short-term pragmatism with the progressive development of industrial, technological, and territorial capabilities in the medium and long term, avoiding both the dispersion of efforts and the adoption of goals incompatible with the country's current foundation.

The potential impacts resulting from the implementation of the NRES's goals and priorities go beyond the strictly mineral or industrial sphere, extending to economic, social, environmental, and geopolitical effects associated with Brazil's integration into global supply chains for critical and strategic minerals. Box 6 provides a concise summary of the relationship between some of the main proposed national goals and the expected impacts of the strategy across different dimensions.

BOX 6

Expected Impacts of the National Rare Earths Strategy (NRES)

Dimension	Related Goals	Expected Impacts
Economic	Achieve 20% of global REE production (approx. 75.7 ktpa TREO) by 2040, including a target of 15 ktpa of NdPr + DyTb; develop industrial separation capacity of 25 ktpa by 2033, expanded to 40 ktpa by 2040; achieve production of 5 ktpa of permanent magnets by 2040	Expansion of mineral production and domestic value addition; attraction of investments; strengthening of local and regional suppliers; gradual development of industrial capabilities in separation, metallurgy, and magnets; increase in public revenue and CFEM collections; promotion of technology internalization and productive diversification in mining regions
Social	Training of a cumulative total of 10,000 specialized professionals by 2040; strengthening of local and regional capacities associated with the REE supply chain	Creation of direct and indirect skilled jobs, including in remote regions; strengthening of local economic development through the integration of suppliers and services into the mineral supply chain; improvement of local infrastructure and public services; support for land-use planning and economic diversification; increased likelihood of obtaining and maintaining the Social License to Operate (LSO) based on the perception of net benefits to society; Continuous implementation of mechanisms for territorial dialogue, CPLI, and mitigation of social impacts associated with the implementation of projects
Environmental	Ensure that 100% of strategic production is covered by traceability mechanisms, socio-environmental monitoring, and auditable ESG standards by 2040; expand initiatives for circularity and the secondary recovery of critical minerals	Relative reduction in the carbon intensity of the Brazilian supply chain compared to supply chains relying on more fossil-fuel-based energy mixes; promotion of renewable energy use, traceability, and environmental management; strengthening of the circular economy and the recovery of critical minerals from waste; adoption of robust standards for tailings management, radiological monitoring, and NORM control; mitigation of risks associated with soil and water contamination; and reduction of CO ₂ and other greenhouse gas emissions
Geopolitics and Strategy	Consolidate Brazil's position as a competitive supplier and reliable partner in strategic global supply chains related to the energy transition, the defense industry, and advanced technologies; expand the international integration of Brazil's REE supply chain	Reduction of external dependence on critical inputs in consumer markets; geographic diversification of global supply chains; strengthening of Brazil's supply security and international negotiating capacity; expansion of technological, industrial, and diplomatic cooperation; positioning of the country as a strategic actor in a context of growing geopolitical competition and the "weaponization" of critical minerals

Source: Prepared by the authors.

5.2. Matrix of Priority Actions

The implementation of NRES requires a matrix of priority actions capable of translating the strategic axes into concrete initiatives, with a timeframe, defined institutional leadership, coordination among partners, and the selection of tools compatible with the supply chain's risk profile and maturity. The following matrix consolidates the action plan currently scattered throughout the report, preserving the recommendations already formulated and organizing them in a way that facilitates their implementation, monitoring, and inter-institutional coordination. In line with the assessment and the contributions incorporated into the report, the prioritized actions concentrate on consolidating the upstream sector, strengthening selected midstream activities, progressively advancing the downstream sector, establishing regulatory and financial conditions for vertical integration, promoting technological advancement, and building territorial and socio-environmental legitimacy.

BOX 7

Matrix of Priority Actions for Implementing the NRES

Action	Time Horizon	Strategic Axis	Lead Agency	Partners	Tool	Expected Outcome
Promote an increase in public geological research focused on REE in the most suitable areas	Short-term	Axis 1	SGB	ANM, states, ICTs	Institutional/Information	Improve the quality of information and guide public and private decision-making
Establish a Portfolio of Strategic REE Projects in the upstream, midstream, and downstream sectors	Short-term	Axis 1	MME	SGB, ANM	Institutional/sector intelligence	Facilitate the identification of promising projects for the various policies to be implemented
Conduct a detailed survey of columbite and tantalite concentrate production in Brazil to investigate the potential for REE production	Short-term	Axis 2	ANM	CPRM	Institutional	Complete a survey and estimate of REE production that may be occurring without oversight
Conduct a survey of the domestic industry that directly or indirectly requires REE, particularly LREE	Short-term	Axis 5	MDIC	CNI	Institutional	Mapping of implicit demand in the refractory and catalyst industries, among others.

Establish a Thorium Working Group (GT-Tório) with a mandate to present a disposal strategy within six months	Short	Axis 6	MME	CNEN, MRE, Ministry of Finance	Institutional	Define an operational solution for thorium as a byproduct
Create subsidized financing and economic grant programs to develop process routes for the separation and refining of REE, with a focus on Nd, Pr, Dy, and Tb	Short	Axis 3	MDIC/MME	BNDES, Finep, companies	Financial/industrial	Reduce the cost of capital for companies that take on the challenge of developing separation and refining process routes
Promote integration and technical exchange among research centers capable of conducting R&D and testing	Short	Axis 4	MCTI	Senai, IPT, Cetem, universities	Institutional	Align the innovation ecosystem with industrial demand
Promote technical exchanges between Brazilian and foreign research centers to build domestic capacity for conducting process route testing, U/Th treatment, etc.	Medium	Axis 4	MCTI	Cetem, IPT, universities	Institutional	Reduce external dependence for conducting tests, shorten the time required to obtain results, and define process routes
Create financial and tax credits for R&D that can be offset against federal taxes	Short	Axis 4	Ministry of Finance/MCTI	ICTs, companies	Tax	Accelerate national technological leadership in critical areas
Reduction of the CBS/IBS tax rate on CAPEX allocated for the construction or expansion of separation, refining, and metallization plants	Short	Axis 3	Ministry of Finance/MDIC	MME	Tax	Reduce implementation costs and enable vertical integration
Reduce II and IPI taxes on imported equipment and inputs for which there are no domestic equivalents	Short	Axis 3	Ministry of Finance/MDIC	MME	Tax	Reduce CAPEX for links with higher value added
Establish a strategic monitoring mechanism for critical and strategic minerals aligned with the national governance framework set forth in Bill 2780/2024	Short	Axis 6	GSI	MD	Institutional	Monitor this issue from the perspective of national security and geopolitical interests, in coordination with national governance of Critical and Strategic Minerals

Reduce the CBS/IBS tax rate on critical reagents and inputs used in the processing and manufacturing of magnets	Short	Axes 3 and 5	Ministry of Finance/ MME/ MDIC	—	Fiscal	Reduce midstream and downstream operating expenses
Implement an integrated system for sharing information among the ANM, environmental agencies, and other public entities, utilizing data already available in official databases	Short	Axis 6	ANM	MMA, Ibmama, state agencies	Institutional	Reduce regulatory red tape, avoid redundant requests for information from entrepreneurs, and expedite the processing of applications
Conduct a survey of defense industry companies that require components made from REE-derived materials	Medium	Axis 5	Seprod/ MD	Abimde	Financial/Industrial	Conduct a quantitative survey of potential industrial demand driven by national defense needs
Conduct a survey of domestic suppliers with the potential to enter the rare earths supply chain, by category, production capacity, and region	Medium	Axis 4	MDIC	Sebrae, Senai, ABDI, industrial associations	Industrial/regional development	Map production capacities and opportunities for integrating local and regional suppliers into the REE value chain
Conduct a survey of qualified professionals, courses, laboratory infrastructure, and technical training capacities related to the REE supply chain	Medium	Axis 4	MCTI/ MEC	SENAI, IFs, universities, CNEN/ANSN	Scientific and technological training	Identify gaps and existing capabilities in strategic areas such as chemistry, hydrometallurgy, geology, metallurgy, and radiation protection
Create a system for recording and registering royalties, streaming agreements, and offtake agreements under mining rights	Short	Axis 1	Ministry of Finance	Federal Revenue Service	Regulatory	Encourage the use of royalty and streaming agreements as a means of financing mineral exploration
Reduce the withholding income tax (IRRF) rate on royalties paid that were incurred during the mineral research phase	Short	Axis 1	Ministry of Finance	Federal Revenue Service	Fiscal	Promote the use of this mechanism as a form of private financing for mineral exploration

Allocate R\$ 200 million through mineral exploration investment funds (BNDESPar Model) for the development of rare earth projects	Medium	Axis 2	BNDES	MME, Capital Markets	Financial	Increase funding for early-stage projects
Promote investment vehicles for the acquisition of subordinated debenture shares encouraged (MME Ordinance No. 120/2025 and Decree No. 11,964/2024)	Short	Axis 2	BNDES/ Finep	MME, Capital Markets	Financial	Expand long-term private funding
Implement accelerated depreciation for projects involving the separation and refining of oxides, the production of metal alloys, and magnets	Short	Axis 3	Ministry of Finance	—	Fiscal	Improve the competitiveness of projects and attract investment
Implement a 75% reduction in the IRPJ/CSLL tax rate for projects involving oxide separation, metal alloy production, and magnets	Medium	Axes 3 and 5	Ministry of Finance	—	Fiscal	Improve the competitiveness of projects and attract investment
Strengthen coordination among MME, MDIC, MCTI, BNDES/Finep, ANM, and environmental agencies	Short	Axis 6	MME	MDIC, MCTI, BNDES, Finep, ANM, MMA	Institutional	Integrate mineral, industrial, technological, and regulatory policies
Launch recycling programs for industrial scrap and secondary sources	Short	Axis 5.	MMA/ MDIC	companies, ICTs	Fiscal/R&D	Create a foundation for circularity and secondary sourcing
Consolidate regional processing and innovation hubs	Medium	Axes 3 and 4	MME/ MDIC	States, ICTs, companies	Institutional/territorial	Concentrate capabilities, reduce dispersion, and expand economies of scale
Regulate phased-in PPB by product category (oxides - metals - alloys - magnets)	Medium	Axis 5	MDIC	MME, Finance	Regulatory/Industrial	Prevent incomplete skipping of stages and guide vertical integration
Establish mechanisms to guarantee price and demand	Medium	Axis 5	MDIC/ BNDES	Federal Government	Market	Reduce market risk and support offtake

Establish special terms for long-term credit lines for projects involving oxide separation and the production of metal alloys and magnets, backed by offtake agreements.	Medium	Axis 5	MDIC	Defense, energy, mobility, health-care	Market	Economically sustain the gradual downstream transition
Integrate the supply chain with priority strategic sectors	Medium	Axis 5	MDIC	User sectors	Institutional/industrial	Link REE to industrial and sectoral policy
Create programs integrated with the Ministry of Education (MEC) for technical and scientific training	Medium	Axis 4	MEC/MCTI	Universities, institutes	Institutional/financial	Build a critical mass of human resources for the chain
Establish a long-term national strategy for technological development in REE	Medium	Axis 4	MCTI/MDIC	ICTs, companies	Institutional	Provide predictability for national technological efforts
Move forward with the ANM restructuring agenda	Short	Axis 6	MME	ANM, MMA, states	Institutional	Enhance regulatory capacity and legal certainty
Establish a national training and exchange program for employees of state environmental licensing agencies aimed at harmonizing interpretations, exchanging experiences, and strengthening capacities regarding the rare earths production chain	Medium	Axis 6	Federal Government	ANM, MMA, States	Institutional	Increase regulatory and operational capacity
Create the Rare Earths Supply Chain Development Fund (FFDTR)	Medium	4.3.2 Tax and Financial Conditions Axis 5	MME/BNDES	Multilateral, foreign capital	Financial	Support CAPEX, equity, and grants in midstream and downstream

Support technology acquisition and internalization through joint ventures and licensing	Medium	Axis 4 / 4.3.2 Tax and financial conditions	BNDES/ Finep	companies, international partners	Financial	Accelerate the adoption of critical know-how
Consolidate the integrated mining-refining-metallurgy-magnets-recycling chain	Long-term	Integration of Axes 2 through 5	MME/ MDIC	MCTI, BNDES, companies	Integrated	Build a more robust national presence across the entire priority supply chain
Make progress in permanent magnets, components, and functional materials	Long-term	Axis 5	MDIC	companies, ICTs, user sectors	Industrial/technological	Expand presence in higher value-added segments
Structurally incorporate circularity	Long-term	Axis 5	MMA/ MDIC	companies, municipalities	Institutional/industrial	Transform recycling and secondary sources into a stable component of the supply chain
Sign international agreements to position Brazil as a reliable and competitive partner in global value chains with higher added value	Medium	Integration of Axes 2 through 6	MME/ MRE/ MDIC	International partners, private sector	Strategic/Diplomatic	Raise Brazil's international standing beyond the extractive sector

Source: Prepared by the authors.

The matrix above shows that the implementation of NRES does not depend on a single, isolated measure, but rather on the coordination of regulatory, fiscal, financial, industrial, technological, territorial, and market actions. It also reinforces that the strategy's effectiveness will require strong coordination among the Ministry of Mines and Energy (MME), the Ministry of Development, Industry, and Trade (MDIC), the Ministry of Science, Technology, and Innovation (MCTI), the Ministry of Finance, the Brazilian Development Bank (BNDES)/Finep, the National Mining Agency (ANM), environmental agencies, the competent authority on radioactivity, states, municipalities, companies, and technology institutions, in line with the governance framework already outlined in the report. For this reason, the following sections detail precisely the three institutional pillars of the action matrix: the regulatory and institutional agenda, the tax and financial agenda, and the governance and monitoring mechanisms necessary to track its implementation.

5.3. Regulatory and Institutional Agenda

The implementation of NRES requires a regulatory and institutional framework capable of reducing uncertainty, coordinating responsibilities, and making the decision-making environment more predictable for rare earths mining, processing, and industrial transformation projects. The analysis presented throughout this report shows that a significant portion of Brazil's bottlenecks stems not only from technological or financial limitations, but also from fragmentation among

mineral, environmental, and radiological licensing; the coexistence of federal and state initiatives that are not always coordinated; the lack of a specific solution for NORM; and the lack of clarity regarding institutional responsibilities at critical stages of the chain. In this context, NRES's regulatory agenda should be treated as a structural dimension of public policy, with the following priorities:

1. **A specific regulatory solution for NORM.** The report identifies this issue as one of the main sources of uncertainty for projects involving natural radionuclides, especially in monazite deposits, and already calls for the creation, in the short term, of an interagency framework to address it. It also recognizes the need for a specific definition of nuclear regulation in this regard, which remains pending. Without such a solution, a significant portion of these projects will continue to face regulatory and economic barriers that reduce their bankability and discourage investment.
2. **Coordination among the ANM, environmental agencies, and the radiation regulatory authority,** with the goal of moving beyond the sequential and reactive approach that currently prevails. The report's analysis is quite clear in pointing out that, in the mining sector, NORM assessment is a required step in projects and that the classification of the level of radioactivity is performed by the National Nuclear Safety Authority based on CNEN Standard NN 4.01. The problem identified is that this preliminary classification relies on information provided by the companies themselves—which is self-reported—and can lead to differing licensing decisions between IBAMA and state agencies. Since more detailed analyses by the competent authority tend to occur only at later stages, if the project is reclassified into a more sensitive category, a conflict may arise with licensing already conducted at another level, creating legal uncertainty and increasing the likelihood of litigation. NRES's regulatory agenda should therefore prioritize mechanisms for early coordination among ANM, environmental agencies, and other stakeholders relevant to the environmental licensing process—as well as the radiological authority—ideally even before the environmental licensing process itself begins.
3. **Harmonization between the federal government and the states.** The report notes that states such as Minas Gerais and Goiás have been making rapid progress in creating their own regulations and conducting environmental licensing for REE projects. This subnational leadership is significant, but when not accompanied by clear criteria for coordination with federal authorities, it can raise questions about the appropriate authority, the adequacy of the procedures adopted, and the legal stability of the projects themselves. NRES's institutional agenda must address this issue through national coordination protocols, a clearer definition of jurisdictions, and the creation of qualified decentralization arrangements capable of reconciling federal action with regulatory certainty.
4. **Reducing conflicts and legal uncertainty** associated with the licensing and implementation of projects. The set of actions already outlined in the report provides an important foundation for this. Among the proposed measures are:

Establish a fast-track process for strategic projects, based on objective criteria; define national standards for environmental requirements and certification; establish an early assessment of critical risks—radioactivity, water, and communities—prior to licensing; require an integrated assessment of socio-environmental impacts and public services; incorporate analyses of cumulative impacts and those of pre-existing projects; and integrate watersheds as planning units. These measures are important because they shift regulation from an exclusively procedural approach to a more substantive approach focused on regulatory quality, with a greater capacity to anticipate risk, harmonize criteria, and reduce future litigation. Additionally, considering potential conflicts of jurisdiction among federal entities, the NRES may provide for formal mechanisms for coordination and administrative dispute resolution prior to judicial proceedings, especially on issues such as NORM, the classification of radioactive materials, the licensing of projects with interstate impacts, the shared use of water resources, and the distribution of revenues associated with mining activities. In this context, inter-institutional technical bodies, with the participation of competent federal and state agencies, could issue coordinated technical opinions, harmonize regulatory interpretations, and mediate administrative disputes, thereby reducing legal uncertainty, overlapping requirements, and the risks of protracted litigation.

Strengthening mechanisms for territorial consultation and social participation.

5. The report already provides for formal mechanisms for free, prior, and informed consultation. It also recommends including civil society in mine closure plans and creating systems for the continuous monitoring of socio-environmental and health indicators. Incorporating these instruments into the regulatory and institutional agenda is essential for reducing conflicts, enhancing legitimacy, and ensuring that the expansion of the REE supply chain does not proceed in isolation from the territorial and social conditions of the locations where projects are implemented.

6. **Institutional strengthening of the ANM and environmental agencies**, as well as—in line with the report's own assessment—the competent authority on radioactivity. The current set of actions already identifies the institutional strengthening of the ANM and environmental agencies as a medium-term priority, alongside building the environmental licensing capacities of states and municipalities. This effort is crucial because regulatory predictability depends not only on regulations but also on the administrative and technical capacity to implement them. In the case of rare earths, this includes the capacity to evaluate projects involving NORM, analyze cumulative impacts, coordinate with water and land-use planning, conduct qualified inspections, monitor the life cycle of operations, and manage complex licensing and mine closure processes. Without this institutional strengthening, the strategy risks creating new obligations without expanding the government's capacity to fulfill them, leading to delays in the implementation of new projects.

In addition to these areas, the regulatory and institutional agenda should incorporate broader measures to coordinate the implementation of the NRES. The report proposes the creation of a permanent interministerial coordination body, led by the MME, with participation from the MDIC, MCTI, Ministry of Finance, BNDES/Finep, ANM, environmental agencies, and the competent authority for radioactivity. It also suggests establishing a national timeline with mandatory targets and milestones, creating a mechanism for prioritizing investments based on market intelligence, intensifying efforts to attract investment, and, in the medium term, advancing the development of an integrated legal framework for critical minerals and rare earths. These elements should be addressed as part of NRES's institutional agenda, as they are what enable the transformation of sector-specific recommendations into coordinated public policy.

In summary, NRES's regulatory and institutional agenda must combine four simultaneous initiatives: i) a specific solution for NORM; ii) stronger coordination among ANM, environmental agencies, and the radiological authority; iii) federal harmonization and the reduction of gray areas of jurisdiction; and iv) strengthening of public participation and the State's institutional capacity. Under this approach, regulation is no longer viewed merely as a source of cost or delay but begins to function as infrastructure for predictability, trust, and quality of implementation. **It is precisely this shift that will reduce legal uncertainty, improve the bankability of projects, and provide a more solid institutional foundation for the advancement of Brazil's rare earths industry.**

5.4. Tax and Financial Agenda

NRES's tax and financial agenda must be guided by a central objective: to create an economic environment compatible with the gradual vertical integration of the Brazilian rare earths supply chain. The report's analysis shows that mining alone will not be sufficient to reposition Brazil within global value chains. The transition to separation, refining, metallization, alloys, magnets, and recycling requires more sophisticated tools than those typically used in conventional mining, due to the higher technological content, price volatility, small initial scale, dependence on critical technology, and the gap between proof of concept and industrial-scale operation. In this context, the tax and financial agenda must be designed to reduce the cost of capital, mitigate risk, support technological scaling, and make the transition from the upstream sector to higher-value-added segments economically viable.

The first priority on this agenda is the creation of **tax instruments designed to encourage vertical integration**. The report already outlines measures such as a temporary tax exemption on vertically integrated products, incentives contingent on a **Basic Production Process (PPB) tiered by product category**—oxides, metals, alloys, and magnets—and a reduction in the IRPJ tax on operating profits from the processing of REE for a fixed term, based on a model inspired by the Sudam/Sudene arrangement. Together, these instruments are intended to make domestic mineral processing more attractive than the simple export of less-processed products.

The second measure involves **tax relief during the investment phase** through the suspension of the CBS (Contribution on Goods and Services)/IBS (Tax on Goods and Services) on CAPEX—machinery, equipment, and services—intended for the construction or expansion of separation, refining, and metallization plants, with the tax rate converted to zero after operations begin. It is also suggested that import taxes be waived for machinery and inputs and, more broadly, that the II and IPI taxes on imported equipment and inputs for which there are no domestic equivalents be reduced to zero, in addition to deferring federal taxes until the plant's post-ramp-up phase. These measures all serve the same purpose: to lower the barrier to entry in the intermediate and advanced stages of the supply chain, shorten the payback period for investments, and enhance the bankability of projects still in the implementation phase.

The third area of focus is the creation of **specific credit lines for midstream operations, metallization, alloys, magnets, and recycling**. The report already proposes expanding subsidized credit lines for downstream CAPEX and OPEX, with an initial focus on separation and refining, as well as providing financial support for the production of alloys and magnets and encouraging the recycling of permanent magnets. It also suggests the creation of a **Rare Earth Downstream Development Fund (FFDTR)**, with the capacity to finance CAPEX, equity, and radiological costs, in addition to allowing for foreign and multilateral participation in downstream financing. These elements should form the financial core of NRES, as they allow for the combination of credit, equity participation, grants, and other hybrid funding instruments for projects at different stages of maturity.

The fourth front is **risk mitigation**, without which vertical integration is unlikely to move forward. The report explicitly recommends mechanisms to guarantee price and demand, off-take agreements with strategic sectors, and possible government equity support for pilot plants, as well as financing for early-stage junior companies and instruments designed to share risk. It is suggested that price floors and long-term offtake contracts for strategic sectors be evaluated to address the volatility characteristic of critical minerals. It also proposes expanding non-repayable grants and credit lines for the pre-production phase, revising the rules governing mining guarantees, and creating a risk-sharing fund with participation from major mining companies. Taken together, these measures acknowledge that the main problem is not merely a lack of capital, but the mismatch between the risk profile of the supply chain and the financial instruments traditionally available in the country.

The fifth priority is **support for pilot plants, demonstration facilities, and pre-commercial batches**. The report treats this agenda as a key condition for industrial advancement, proposing funding for pilot plants and demonstrators by FINEP, Embrapii, and BNDES, including government equity investments in projects that are critical for technological scaling. This guideline must be maintained in the tax and financial agenda, because the gap between the laboratory and commercial scale is one of the main bottlenecks in the Brazilian supply chain. In this regard, public policy must combine repayable and non-repayable instruments, as well as hybrid funding, to enable separation, metallization, alloys, magnets, and recycling processes to move beyond the demonstration phase and advance toward industrialization.

The sixth area of focus is the development of **specific instruments for acquiring foreign technology and licensing patents**. The report suggests an exemption from withholding income tax on

royalties, licenses, and technical assistance related to technology localization, as well as financial support for joint ventures and for the acquisition and localization of technology. It is proposed that withholding income tax be exempted on remittances abroad related to the use of patents, technology licenses, and technical assistance employed in the processing of rare earths in Brazil, subject to compliance with World Trade Organization (WTO) rules and the need for prior review by the Foreign Trade Chamber, especially to avoid undue conditioning on export targets. The rationale behind this measure is clear: to reduce the effective cost of accessing critical separation, metallization, and processing technologies still controlled by a few suppliers outside China.

In addition to these six areas, the tax and financial agenda should include complementary measures such as **super-accelerated depreciation** for critical separation, metallization, and radiological control equipment; **a tax credit for R&D expenditures** that can be offset against federal taxes; **a deduction for socio-environmental investments exceeding the legal minimum from the CFEM and IRPJ tax bases**; and **incentive debentures for mining and processing**, with a broader scope than under current regulations. In the case of the financial-tax credit for R&D, we suggest the establishment of differentiated multipliers for processes, products, individual Nd/Pr and Tb/Dy separation, and radiological/NORM management, in addition to mandatory R&D matching funds, agreements with ICTs, regional allocation, and capacity building. These elements can be fully incorporated into the NRES as part of the framework for stimulating industrial innovation.

Finally, the tax and financial agenda must be aligned with the regulatory and institutional agenda, particularly with regard to the costs associated with **NORM**. The report proposes financial compensation mechanisms for costs associated with NORM (such as thorium and uranium). It is considered appropriate to offer credit or a specific fund for radiological compliance as a way to reduce the regulatory burden on participating projects. However, it is emphasized that this instrument will only be fully effective if accompanied by a clear institutional solution for thorium as a byproduct. This means that the financial agenda cannot be separated from the regulatory agenda: financing, taxation, and institutional predictability must advance in a coordinated manner.

In summary, NRES's tax and financial agenda should combine **investment tax breaks, support for phased implementation, hybrid funding, risk mitigation, incentives for innovation, and instruments for technology internalization**—always with a focus on making the gradual vertical integration of the supply chain economically viable. More than just a set of isolated incentives, this involves structuring an economic framework consistent with the specific challenges of the rare earths sector in Brazil. It is this framework that will make it possible to bridge the gap between mineral resources, industrial processing, and strategic integration into global value chains with higher added value.

5.5. Governance and Coordination

Although it has existed for only a short time, the effective creation of the CNPM through Decree No. 11,108 of June 29, 2022,⁹⁵ fulfilled a long-standing demand of the mining sector—to have an interministerial decision-making body capable of establishing guidelines and objectives aligned with the entire government leadership.

The CNPM consists of 18 ministers of state, officials from an agency linked to the mining sector (SGB-CPRM), and four invited guests (representatives of state and municipal governments, civil society, and academia), whose positions are currently vacant. Because it is composed of the highest levels of government, the CNPM meets only once a year. It began operating in October 2025, when it issued six resolutions (Box 7).

BOX 7

Resolutions of the National Council for Mineral Policy (CNPM)

CNPM Resolution	Purpose
Resolution No. 1, dated October 17, 2025	Approves the Internal Rules of Procedure of the National Council for Mineral Policy (CNPM) and provides other measures.
Resolution No. 2, dated October 17, 2025	Establishes a Working Group to conduct a study on inspection fees and sector-specific charges levied on the mineral sector and on incentive mechanisms to promote the use of mineral resources.
Resolution No. 3, dated October 17, 2025	Establishes a Working Group for the purpose of analyzing and drafting proposals for public and legislative policies aimed at developing the production chain for critical and strategic minerals in the country.
Resolution No. 4, dated October 17, 2025	Establishes a Working Group on Sustainable Development in Mining.
Resolution No. 5, dated October 17, 2025	This resolution establishes the priorities of the Brazilian Mineral Policy and sets forth the guidelines for the development of the planning instruments referred to in Article 3 of Decree No. 11,108, dated June 29, 2022.
Resolution No. 6, dated October 17, 2025	Establishes a Working Group to conduct a diagnostic study on the oversight of mining activities in Brazil.

Source: MME-CNPM⁹⁶

Of particular note is Resolution No. 3, which establishes a working group (WG) specifically focused on Critical and Strategic Minerals in Brazil. The WG is coordinated by the Ministry of Mines and Energy (MME), with participation from the Ministries of Science and Technology, Finance, the Environment, Foreign Affairs, the Chief of Staff's Office, the Institutional Security Office (GSI), and the Ministry of Agriculture. Article 3 of the Resolution establishes the WG's authority to develop and implement a work agenda aimed at proposing public policies.

95. http://legislacao.planalto.gov.br/legisla/legislacao.nsf/Viw_Identificacao/DEC%2011.108-2022?OpenDocument

96. <https://www.gov.br/mme/pt-br/assuntos/conselhos-e-comites/cnpm/resolucoes-do-cnpm/2025>

Thus, the CNPM has been carrying out its executive functions and has delegated to the working groups the task of conducting studies, analyses, and developing policy proposals to be approved—or rejected—by the Council. These working groups, which are more technical in nature, include representatives from all relevant ministries, ensuring governmental legitimacy and technical coordination. In this sense, the working groups serve as an important forum for debate, institutional alignment, and the formulation of proposals, although they do not have a permanent mandate to coordinate the implementation, monitoring, and ongoing execution of policies associated with the NRES. The CNPM, being a high-level body much more focused on defining strategic guidelines, is unlikely to assume this operational role of continuous monitoring. The Interministerial Committee for the Analysis of Strategic Mineral Projects (CTAPME), which, in theory, could assume this role, was created specifically to support processes related to the environmental licensing of mining projects considered strategic, with a more restricted scope and a specific sectoral focus. Furthermore, it has not met since 2023; with the new environmental licensing policy, this committee has become obsolete. Bill No. 2780/2024, currently under consideration, provides for the creation of the National Council for the Industrialization of Critical and Strategic Minerals (CIMCE), with responsibilities related to the prioritization, monitoring, and institutional coordination of projects considered strategic.

There has been virtually unanimous agreement among the more than 40 different representatives of interest groups interviewed that the success of NRES will depend on an effective governance system, with efficient coordination and the capacity to monitor goals, coordinate institutions, and promote alignment among the various instruments and partners involved in implementing the strategy. In this context, this study does not necessarily propose the creation of a new autonomous deliberative body, but rather the strengthening of a permanent technical and executive coordination body capable of supporting the operationalization of NRES in an integrated and continuous manner, in coordination with existing structures and the instruments provided for in Bill 2780/2024.

The CNPM will play a decisive role in the NRES; however, the proposed actions and goals must be implemented and monitored in practice. The proposal for a Technical Chamber—or equivalent body—capable of building on the experience accumulated by the existing working groups fulfills this role by carrying out ongoing functions of coordination, monitoring, and inter-institutional collaboration. This body could also help institutionalize ongoing mechanisms for participation in and monitoring of the strategy by incorporating representatives from civil society, businesses, the scientific community, subnational governments, and user sectors, thereby expanding the reach of the actions, their territorial legitimacy, and the predictability of their implementation.

Thus, the implementation of NRES will require a governance framework capable of continuously coordinating the various instruments, institutions, and decision-making levels involved in the development of Brazil's rare earths supply chain. The analysis presented in the report shows that the strategy's effectiveness will depend less on the existence of isolated initiatives and more on the ability to coordinate—around common objectives—the six strategic axes of NRES: geological knowledge and sector intelligence; a competitive, reliable, and sustainable upstream sector; a selective midstream sector as the core of the strategy; critical technologies,

innovation and industrial scaling; gradual downstream development, anchor sectors, and circularity; and governance, sustainability, and territorial development. In this context, governance should be conceived as a permanent mechanism for policy coordination, executive coordination, monitoring of implementation, and adjustment of the strategy over time.

The report recommends that NRES be implemented through a **permanent interministerial coordination body**, led by the Ministry of Mines and Energy. This body should build upon the foundation already established by the working groups by bringing together the Ministry of Development, Industry, Trade and Services (MDIC), the Ministry of Science, Technology, and Innovation (MCTI), the Ministry of Finance, the Brazilian Development Bank (BNDES)/Finep, the National Mining Agency (ANM), environmental agencies, and the competent authority for radioactivity, with the responsibility of coordinating the strategy's pillars, monitoring indicators, tracking the action plan, and proposing periodic adjustments. It is also recommended that this structure incorporate permanent mechanisms for multisectoral participation, including thematic consultations, regional workshops, and periodic processes for reviewing and monitoring the strategy, ensuring transparency, legitimacy, and adaptability over time. This platform is responsible for aligning priorities, reducing fragmentation, monitoring the implementation of actions, and ensuring coherence among mineral policy, industrial policy, innovation, financing, licensing, and territorial development.

To track whether coordination is progressing positively over time, it is important to consider specific coordination indicators from the outset, such as: monitoring the frequency with which relevant ministries meet to discuss issues related to NRES and related topics, such as vehicle electrification, renewable energy, industrial digitization, defense, etc.; monitoring whether joint decisions are being made; tracking the implementation status of proposed actions (dashboard); and monitoring the existence of bottlenecks that are hindering progress toward NRES goals, among other things.

Under this arrangement, the **MME** is responsible for the political coordination of the strategy. This role stems from its position in steering mineral policy and the ministry's central role in the strategic minerals agenda. It is the MME's responsibility to ensure the overall coherence of the NRES, lead coordination among federal agencies, monitor the progress of priority projects, and ensure that the strategy remains guided by a combination of supply security, value addition, sustainability, and the national interest. In practice, the MME must act as the political and organizational hub of the NRES, responsible for ensuring the integration of the various instruments mobilized by the strategy.

The **MDIC** should lead the coordination of the NRES with industrial policy and end-user sectors. The strategy must link the REE chain to electric mobility, renewable energy, automation, healthcare, and defense, while also using industrial demand and strategic procurement as market-building mechanisms. In this context, it is up to the MDIC to ensure that instruments for neo-industrialization, support for mineral processing, and stimulation of anchor sectors are aligned with NRES's priorities, especially in advancing selective midstream development, gradual downstream development, and circularity. The MDIC's role is, therefore, to transform the rare earths strategy into an effective industrial policy agenda.

The **MCTI**, **FINEP**, **CNPq**, and **science and technology institutes** should be responsible for the

innovation, applied research, and technological scaling axis. This institutional framework is responsible for supporting the development of critical technological capabilities, the implementation of pilot plants and demonstrators, and the development of processes for separation, metallization, alloys, magnets, and recycling, as well as for supporting the training of specialized human resources. In terms of NRES's governance, this means that these actors must serve as the technical and scientific core of the strategy, coordinating R&D priorities, mission-driven calls for proposals, testing and demonstration infrastructure, and mechanisms to foster collaboration between ICTs and companies.

The **BNDES** and other public financiers should play a central role in structuring financing for NRES and risk mitigation instruments. Financial institutions play an important role in creating de-risking instruments, supporting pilot plants and demonstration facilities, financing CAPEX and OPEX for midstream and downstream operations, and developing hybrid funding for vertical integration. In terms of strategy governance, this means that BNDES, FINEP, and other financiers should operate in coordination with the Ministry of Mines and Energy (MME), the Ministry of Development, Industry, Trade and Services (MDIC), and the Ministry of Finance to structure instruments compatible with the different stages of the supply chain, thereby reducing the gap between mining, industrial processing, and the consolidation of new production segments.

The **ANM, environmental agencies**, and the **competent authority on radioactivity** should form the regulatory core of NRES. The current fragmentation among mineral, environmental, and radiological licensing is one of the main sources of institutional uncertainty for the chain, especially in projects involving NORM. Therefore, the strategy's governance framework must provide for close coordination among these institutions in order to reduce jurisdictional conflicts and procedural inefficiencies, as well as to harmonize and simplify procedures and support the implementation of the regulatory and institutional agenda already detailed in the previous section. The institutional strengthening of the ANM and environmental agencies, as outlined in the report's actions and guidelines, should be understood as an integral part of this governance framework.

States and municipalities with relevant projects should be integrated into the federative governance of the supply chain. It is considered essential to create specific mechanisms for federative and territorial coordination, especially in areas with a higher concentration of projects. This participation is essential because the concrete effects of the NRES are felt at the local level: licensing, infrastructure, water use, relations with communities, supplier development, use of the CFEM, and planning for local economic diversification. The governance of the NRES, therefore, cannot be exclusively federal. It must establish stable channels of coordination with subnational governments in order to align national priorities with territorial capacities and challenges.

In support of the interministerial body, the report also recommends the creation of a **specialized Technical Chamber with an advisory role**, involving the private sector, research centers, funding agencies, civil society, and subnational entities. This council should serve as a forum for informed dialogue, the production of technical input, and the monitoring of emerging challenges in the supply chain. It will also function as a complementary governance mechanism, allowing for the incorporation of technical knowledge, a territorial perspective, and broader dialogue without replacing the decision-making coordination of the interministerial core. This is

an important tool for reducing information asymmetries, enhancing legitimacy, and supporting periodic strategy reviews.

In operational terms, NRES's governance must fulfill at least five functions. The first is **strategic coordination**, ensuring alignment among the six pillars of the strategy. The second is **executive coordination**, monitoring the action plan, timelines, and the mobilization of regulatory, financial, and industrial instruments. The third is **regulatory coordination**, liaising with the ANM, environmental agencies, and the competent authority on radioactivity. The fourth is **federal and territorial coordination**, integrating states and municipalities relevant to the strategy's implementation. The fifth is **consultative and technical-social coordination**, through the Technical Chamber, ensuring the production of input, dialogue with relevant stakeholders, and monitoring of emerging challenges. This functional division helps prevent overlap between levels and clarifies the implementation architecture of the NRES.

In summary, the governance of NRES must combine centralized political leadership, ongoing interministerial coordination, an integrated regulatory core, a structured technological framework, funding, and active federal and territorial coordination and governance. This architecture is necessary to transform NRES into a state policy geared toward the progressive building of capacities throughout the value chain. Without this arrangement, the strategy tends to reproduce the fragmentation already identified in the assessment. With it, Brazil's capacity to integrate mining, processing, innovation, financing, and territorial development into a more coherent, gradual, and sustainable trajectory is enhanced.

BOX 8

NRES Governance and Coordination Architecture

Governance Center	Lead Role
MME	NRES's Policy Coordination and Overall Strategy Coordination
MDIC	Link to industrial policy, user sectors, and market development
MCTI/Finep/CNPq/ICTs	Innovation, applied R&D, technological scaling, and human resources development
BNDES and public funders	Funding, de-risking, demonstrators, and support for vertical integration
ANM / environmental agencies / competent authority on radioactivity	Regulatory coordination, licensing, enforcement, and institutional security
States and municipalities	Federal and territorial governance, local development, and coordination through the CFEM
Advisory Technical	Technical guidance, broad-based dialogue, and monitoring of emerging challenges

Source: Prepared by the authors based on the final report.

5.6. Monitoring and indicators

The implementation of the NRES must be accompanied by a monitoring system capable of measuring, on a periodic and comparable basis, not only the evolution of mineral production but also the industrial, technological, territorial, and socio-environmental progress of the Brazilian rare earths supply chain. The report itself already establishes that the strategy must be monitored using clear indicators that are periodically revised, which is consistent with the gradual, selective, and coordinated nature of the NRES. Rather than merely tracking the expansion of the upstream sector, monitoring must assess whether the mineral base is effectively being converted into productive, technological, and institutional capacity across the priority links in the supply chain.

From this perspective, the first set of indicators should track the evolution of the mineral and industrial production base. This includes the **number of projects in operation and under development**, the **installed capacity for beneficiation and refining**, and the **production of metals, alloys, and magnets**. These indicators are important because they make it possible to assess whether NRES is succeeding in transforming the mineral pipeline into operational capacity and, above all, whether the country is moving from the extractive stages to the intermediate and industrial segments of the value chain.

A second set of indicators should track progress in the areas of innovation, technological scaling, and financing. Suggested indicators include those for monitoring **R&D expenditures** and the **number of technology demonstrators**, as well as the **volume of investments attracted** and the **number of projects supported by risk mitigation instruments**. These indicators are particularly relevant because they make it possible to measure whether the strategy is succeeding in bridging the gap between research, pilot projects, demonstrations, and industrial scale, while also assessing the effectiveness of the tax and financial policies in attracting capital and supporting the consolidation of the supply chain.

A third set of indicators should track progress on the regulatory and institutional agenda. The report already highlights, among the recommended indicators, the **regulatory proposals addressing NORM**, which is fully consistent with the centrality of this issue to the implementation of the strategy. Monitoring this indicator will make it possible to verify whether NRES is succeeding in addressing one of the main regulatory bottlenecks in the chain, reducing legal uncertainty, increasing predictability, and creating more favorable conditions for projects involving natural radionuclides.

A fourth set of indicators should track the progressive incorporation of circularity and secondary supply. It is recommended to monitor the **share of secondary sources and recycling**, which makes it possible to verify whether the strategy is successfully integrating industrial scrap, mineral waste, material reuse, and recycling to an increasing extent into the structure of the national supply chain. This monitoring is important because circularity, as designed by NRES, is not treated as a secondary concern but as a progressively fundamental component of the supply chain's competitiveness, supply security, and sustainability.

Finally, the NRES monitoring system should include **socio-environmental and territorial** indicators, as well as indicators related to **the use of the CFEM and local economic**

diversification strategies. This foundation is particularly important because it underscores that the success of NRES should not be measured solely by the number of metric tons produced or the amount of investment attracted, but also by the supply chain's ability to generate more robust territorial benefits, reduce conflicts, and enhance its social legitimacy over time.

In terms of monitoring governance, it is recommended that NRES's permanent interministerial coordination body be responsible for tracking indicators, which reinforces the need to treat the monitoring system as part of implementation rather than as a subsequent or ancillary step. Under this logic, indicators should serve not only for accountability but also for periodically adjusting the strategy, making it possible to identify persistent bottlenecks, recalibrate instruments, and prioritize actions in line with the evolution of the supply chain. Monitoring should function as a mechanism for strategic learning within NRES.

BOX 9

Priority Monitoring Indicators for NRES

Dimension	Priority Indicators
Mineral Production and Pipeline	Number of projects in operation and under development
Midstream and industrial capacity	Installed separation/refining capacity; production of metals, alloys, and magnets
Innovation and scaling	R&D expenditures; number of technology demonstrators
Financing and capital attraction	Volume of investments attracted; number of projects supported by risk mitigation instruments
Regulation and predictability	Projects with a regulatory solution for NORM
Circularity	Share of secondary sources and recycling
Territory and socio-environmental factors	Socio-environmental and territorial indicators
Local development	Use of the CFEM and local economic diversification strategies

Source: Prepared by the authors.

5.7. Executive Conclusion

The National Rare Earths Strategy must be based on a realistic assessment. Brazil possesses **a significant geological base, a growing pipeline of projects, relevant scientific capabilities,** and **a favorable international environment** amid the reconfiguration of global value chains. These attributes place the country in a unique position to expand its

strategic relevance in the sector and act as a competitive supplier and reliable partner in value chains undergoing transformation.

At the same time, the report's central point is that the decisive issue for Brazil lies not only in expanding mineral production, but in **converting mineral potential into national capacity**. The analysis shows that the Brazilian supply chain still exhibits low industrial density and heavy external dependence in its most sophisticated segments, especially in the midstream and downstream sectors. For this reason, the NRES should not limit itself to expanding the upstream sector, nor should it rely on promises of complete and immediate industrialization. The path outlined by the report itself is different: to progressively build capabilities in processing, mineral transformation, innovation, circularity, institutional coordination, and territorial development.

From this perspective, NRES should be implemented as a **gradual, selective, coordinated, and territorially legitimate** strategy. Gradual, because the Brazilian supply chain will not advance uniformly across all links and requires a phased approach compatible with the sector's current maturity. Selective, because the country will need to concentrate resources and efforts on the segments most closely aligned with its mineral base, its capabilities, and its potential markets. Coordinated, because the strategy's effectiveness will depend on the coordination among mining, industry, science and technology, financing, regulation, and territorial development. And territorially legitimate, because the expansion of the value chain will only be sustainable if accompanied by adequate governance, regulatory predictability, socio-environmental monitoring, and a more robust distribution of benefits in mining regions.

Transforming this geological advantage into national capacity will require not only projects, but also a coherent framework for regulation, financing, risk mitigation, technology internalization, and institutional predictability. Ultimately, the success of NRES will depend on Brazil's ability to use its mineral base as a platform to build, over time, greater productive, technological, and territorial density in the rare earths supply chain.

In summary, the report points to a clear strategic direction: Brazil should not choose between being merely an exporter of mineral resources or unrealistically seeking to fully replicate the supply chains currently dominated by other actors. The most robust path is one that combines selectivity, a gradual approach, institutional coordination, support for productive intensification, and a commitment to territorial legitimacy. It is this path that gives meaning to the NRES and that can enable the country to transform its geological endowment into effective national capacity, with greater economic, technological, and strategic relevance throughout the rare earths value chain.

5.8. Topics for Further Exploration and Future Implementation Phases

Although this study sought to develop comprehensive guidelines for the National Rare Earths Strategy (NRES), some issues require further exploration in complementary studies and future implementation phases. Among these, the following stand out:

- detailed specifications on the functioning of the governing bodies and estimates of the operational and institutional costs associated with NRES governance—including coordination structures, monitoring systems, technical training, the production of strategic studies, and institutional strengthening of public agencies—as well as potential sources of funding to sustain these capabilities;
- quantitative studies on the potential contribution of the Brazilian rare earths supply chain to climate and industrial goals, including estimates of avoided emissions associated with the processing and manufacturing of magnetic materials in Brazil, taking into account Brazil's predominantly renewable electricity mix;
- regional and municipal-level territorial analyses and an evaluation of shared industrial hub models for the processing and separation of REE, taking into account logistical, industrial, energy, technological, and socio-environmental capacities;
- regional-scale analyses (beginning with Latin America) of the demand for REE and permanent magnets, the potential supply of scrap and products for large-scale recycling, as well as comparative analyses of the labor market and Brazil's competitive advantages;
- conducting specific technical-economic studies for representative projects in the rare earths separation sector in Brazil, including sensitivity analyses of critical variables;
- Development of a national matrix for evaluating and prioritizing projects and capacities within the REE chain, using transparent and reviewable criteria applicable to the different links in the chain.



A

Appendices

Appendix I

List of stakeholders consulted

Stakeholder	Sector	Consultation Method		
		Interview	Workshops	Field Visit
NATIONAL ACTORS				
Chamber of Deputies (Office of Representative Arnaldo Jardim)	Government/ Regulator	X		
Federal Senate	Government/ Regulator			X
Ministry of Mines and Energy	Government/ Regulator	X	X	
Ministry of Defense	Government/ Regulator		X	
National Mining Agency	Government/ Regulator	X	X	
São Paulo State Environmental Agency (CETESB)			X	
Institutional Security Office	Government/ Regulator	X		
Ministry of Defense/Secretariat of Defense Products	Government/ Regulator	X		
National Nuclear Safety Authority	Government/ Regulator	X	X	
Government of Minas Gerais State Secretariat for Economic Develop- ment (SEDE/MG)	Government/ Regulator	X	X	
Government of Goiás Secretariat of Industry, Commerce, and Services (SIC/GO)	Government/ Regulator	X	X	
Minaçu City Hall (GO)	Government/ Regulator	X		X
Poços de Caldas (MG) – Municipal Department of the Environment	Government/ Regulator	X		X
Ibama	Government/ Regulator	X		
Energy Research Company	Government/ Regulator	X	X	
Alliance for the Pedra Branca APA	Associations/ Civil Society	X	X	
Climate and Society Institute	Associations/ Civil Society		X	
Institute for Socioeconomic Studies	Associations/ Civil Society		X	
Terra Viva Água Rara	Associations/ Civil Society		X	

Brazil Climate Center	Associations/ Civil Society		X	
E+ Institute for Energy Transition	Associations/ Civil Society		X	
Socio-Environmental Institute	Associations/ Civil Society		X	
Invest Minas	Investors/ funders	X		X
Brazilian Mining Institute (IBRAM)	Associations/ Civil Society	X	X	
Center for Management and Strategic Studies (CGEE)	Associations/ Civil Society		X	
Mining Industry Union of the State of Goiás and the Federal District	Associations/ Civil Society	X	X	
Critical Minerals Association (AMC)	Associations/ Civil Society	X	X	
Infra Agency	Associations/ Civil Society		X	
Mining Observatory	Associations/ Civil Society		X	
MAM – Movement for Popular Sovereignty in Mining	Associations/ Civil Society	X	X	
National Institute of Rare Earths,	Associations/ Civil Society		X	
ADIMB	Associations/ Civil Society	X	X	
University of São Paulo (USP)	Academia/Technology Centers		X	
SGB - Geological Survey of Brazil	Academia/Technology Centers	X	X	
Alves Faria University Center	Academia/Technology Centers		X	
Getúlio Vargas Foundation (FGV)	Academia/Technology Centers		X	
Cetem	Academia/Technology Centers	X	X	
Senai – Lagoa Santa (MG)	Academia/Technology Centers	X	X	X
Federal University of Juiz de Fora	Academia/Technology Centers		X	
Federal University of Rio de Janeiro	Academia/Technology Centers		X	
IPT-SP	Academia/Technology Centers	X	X	
Federal University of Minas Gerais	Academia/Technology Centers	X	X	X
Finep	Academia/Technology Centers	X		
Amazul	End-user industry	X	X	
New Wave	End-user industry	X		

Bamburra Planejamento Estratégico e Economia Mineral	Private sector		X	
BMJ Consultores	Private sector		X	
BMA Advogados	Private sector		X	
Teiú Energia	Private sector			
Aclara	Mining and Processing Companies	X		
Viridis	Mining and Processing Companies			X
Brazilian Rare Earths	Mining and Processing Companies	X		
Rare Earths Americas	Mining and Processing Companies		X	
Serra Verde	Mining and Processing Companies	X	X	X
St. George Mining	Mining and Processing Companies	X		
CBMM	Mining and Processing Companies	X	X	
Meteoric Resources NL (MG)	Mining and Processing Companies	X		X
INTERNATIONAL PLAYERS				
Australian Embassy in Brazil	Government/Regulator	X		
Embassy of Brazil in Kuala Lumpur	Government/Regulator	X		
Embassy of Brazil to China	Government/Regulator	X		
British Consulate-General	Government/Regulator	X	X	
Delegation of the European Union to Brazil – EEAS	Government/Regulator	X		
International Council on Mining and Metals (ICMM)	Associations/ Civil Society	X		
Mining Association of Canada	Associations/ Civil Society	X		
Columbia University	Academia/Technology Centers	X		
Carester	Mining and Processing Companies	X		
International Energy Agency (IEA)	Multilateral	X		
World Economic Forum (WEF)	Multilateral	X		
OECD	Multilateral	X		

Appendix II

Methodology

Problem tree analysis helps in formulating solutions to complex problems. This diagram presents a logical hierarchy, facilitating the analysis of scenarios, in which it is possible to: (i) identify the central problem (symbolized by the tree trunk); (ii) assess the causes or roots of the problem; (iii) assess the effects caused by these problems (represented by the branches);⁹⁷ and, finally, (iii) develop solutions, strategies, and objectives aimed at resolving it, by structuring a solution tree.⁹⁸

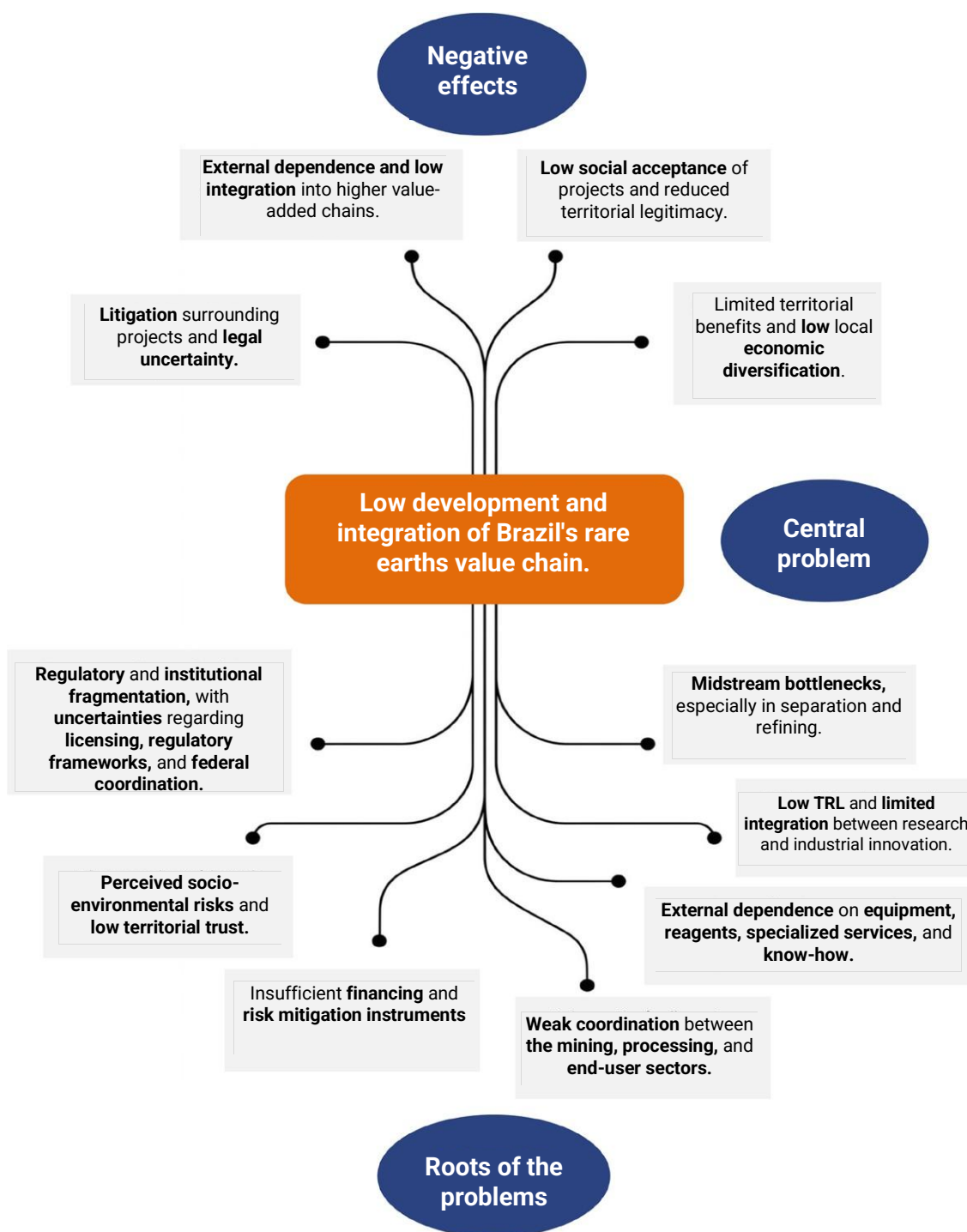
The first step in developing a problem tree is to define a specific central problem (AusAID, 2003). The central problem defined for the analysis **of** this project is the **low level of development and integration of the rare earths value chain in Brazil**. Based on this, the main causes of the central problem—represented as roots—and its effects or impacts—represented as branches on the problem tree—were identified through the literature, interviews, and field visits. The entire problem tree is represented by a system of boxes interconnected by lines or arrows, as illustrated in the figure below:

97. <https://www.ircwash.org/sites/default/files/Mahanty-2004-Collaborating.pdf>

98. It may also be known as an objective tree.

FIGURE 19

Problem tree



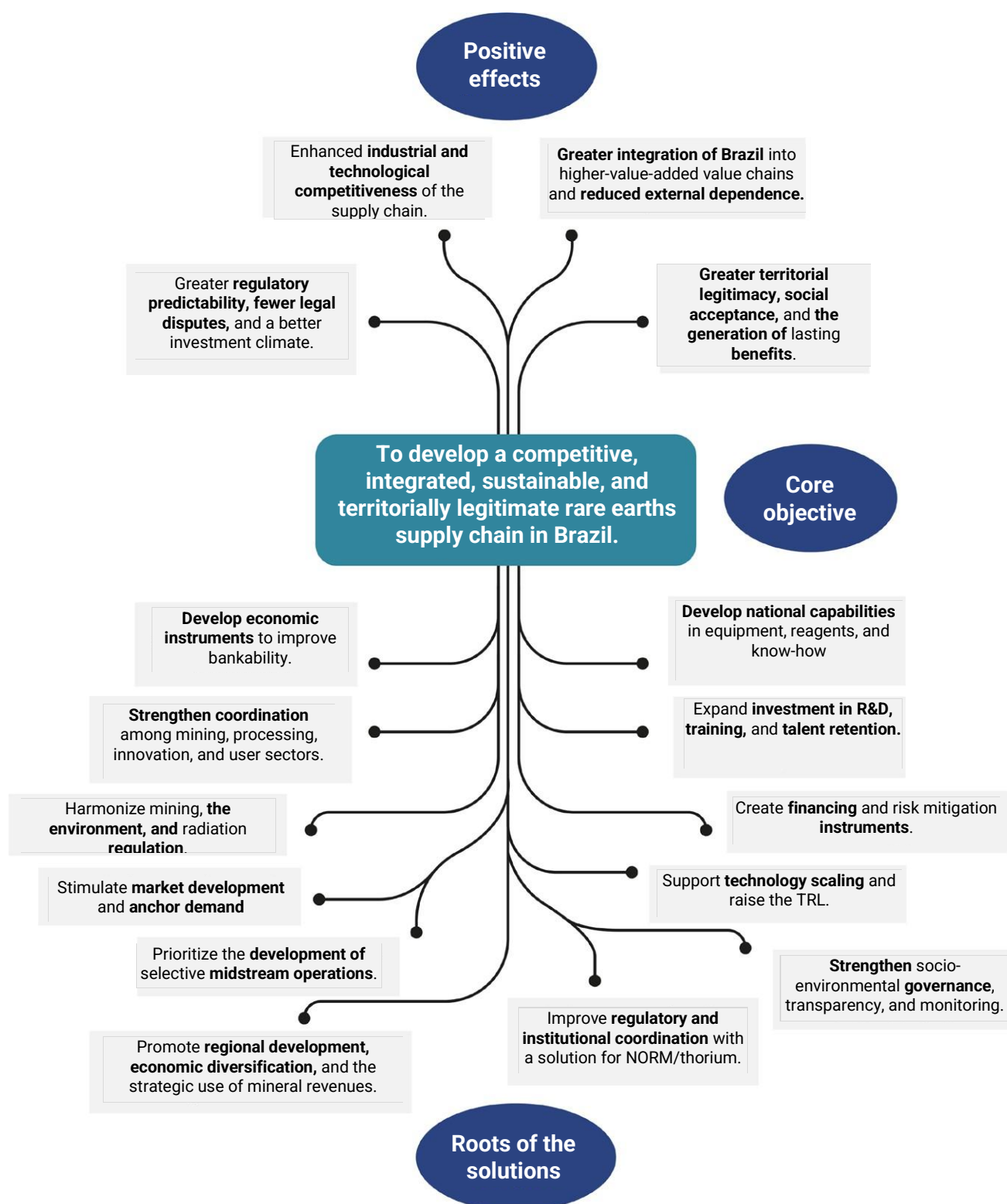
Source: Prepared by the authors.

The process of developing the problem-and-solution tree also involved consulting the strategic plans and national mining policies of the countries analyzed, as well as corporate data extracted from institutional websites and company reports. At the same time, the objectives and key areas for the REE sector are detailed through a tree focused solely on solutions. The figure below summarizes these results: the base of the tree

consists of the “roots of the solutions,” while the trunk represents the central goal to be achieved, and the branches illustrate the positive impacts of resolving the identified problems:

FIGURE 20

Solution Tree



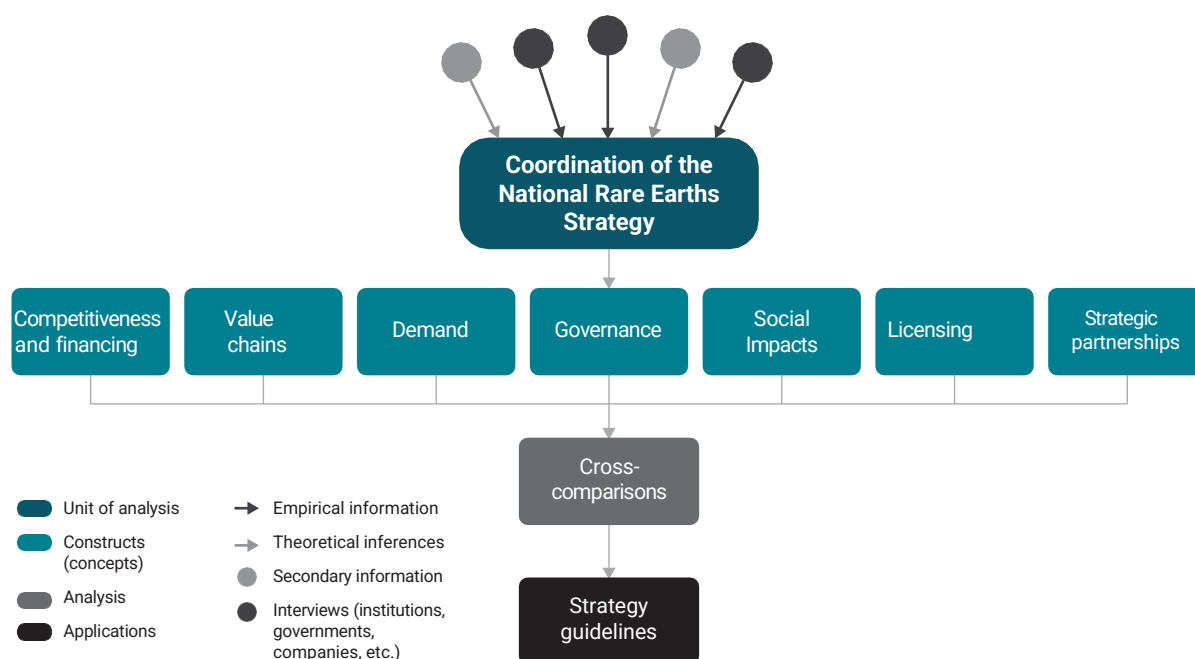
Source: Prepared by the authors.

Following internal discussions, workshops, interviews, and exchanges among stakeholders, the analysis aimed to present solutions in the form of recommendations for the NRES.

The figure below summarizes the methodological approach for identifying the type of research⁹⁹ the unit of analysis,¹⁰⁰ obtaining primary and secondary data for analysis and their selection criteria¹⁰¹ for interviewees, concepts addressed, and methods for comparing findings (Appendix III):

FIGURE 21

Framework for Defining the Methodological Approach and Selecting Interviewees



Source: prepared by the author.

Consultation with stakeholders, in general, helped validate the findings identified in the literature. Throughout the study, this phase was divided into different modalities, including individual interviews, field visits, and workshops. Interviews were conducted with all the stakeholders listed above using customized, semi-structured interview guides. The field visits took place during the second week of March (March 9–12) in the following municipalities: Minaçu (GO), Belo Horizonte (MG), and Poços de Caldas (MG). In addition, visits were made to the following stakeholders: InvestMinas, Meteoric, the Minaçu (GO) City Hall, the Poços de Caldas (MG) Department of Economic Development, Senai, Serra Verde, the Federal University of Minas Gerais (UFMG), and Viridis.

A 2-hour online workshop with the leading civil society organizations involved in

99. Yin, R. K. (2001). Case Study: Planning and Cases. In Bookman. Le Livro.

100. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104(July), 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>

101. Luna Filho, B. (1998). Basic Steps in the Development of Research Protocols. *Arquivos Brasileiros de Cardiologia*, 71(6), 735–740.

mining issues, held on April 7, served as a public consultation to gather input from the third sector and ensure that its concerns are taken into account. The discussions focused on three main topics: concerns about socio-environmental risks, enabling conditions for responsible mining, and social participation throughout the supply chain.

A 2-hour virtual multisectoral workshop was organized with all stakeholders identified in Brazil—totaling approximately 60 stakeholders—and took place in the second half of April. During the event, the diagnostic analysis, the hypotheses developed for the solutions tree, the key recommendations, and the preliminary structure of the NRES were presented. The goal was to collect feedback in an organized and collaborative manner, using participatory methodologies such as the World Café and Miro. Participants were divided into three affinity groups based on the following themes: geological mapping, upstream operations, and licensing; processing, R&D, and the industrial chain; and governance and social and environmental responsibility.

Appendix III

Recommendations with Practices for Positive Impact

The following recommendations were developed based on the Ishikawa diagram, which illustrates and summarizes what has already been presented regarding policy gaps and best practices to strengthen the National Rare Earth Strategy (NRES). The diagram seeks to establish a causal relationship between the dependent variable—the National Rare Earths Strategy—and the dimensions and variables that determine the success or failure of this strategy. Key dimensions include: the environment, society, government, businesses, territory, the science and technology system, global geopolitics, and the market; these dimensions, in turn, break down into dozens of critical variables.

The **Environment** dimension is broken down into indicators that relate to other topics addressed in this study, in which the primary concern is the risk of radiation and the resulting contamination of soil and water, which can severely affect people's lives. In this regard, it is essential to consider reference levels and best practices for mitigating radiation. There is also concern regarding the generation of tailings and the reduction of CO₂ and other gas emissions into the atmosphere (Table 62). It is assumed that the national REE strategy will only be successful if environmental safeguards are respected, as these safeguards will ensure the sustainability of the mining project throughout its useful life, thereby preventing legal challenges that could bring the projects to a standstill.

TABLE 62

Indicators and References for the Environment Dimension

Variable	Indicator	Reference
Contamination by Radionuclides	Type of radioactive mineral Qty/ton	CNEN, ANSN
Heavy metal contamination	Type of heavy metal, e.g., barium, beryllium, copper, lead, manganese, zinc, sulfide minerals, carbonate minerals, fluorine, asbestos, etc. Amount/metric ton	Ibama
Emissions of CO₂ and other gases and particulates	X ppm	SEEG
Tailings generation	X qtq/t	
Water quality	% eutrophication % acidification	ANA

Source: Prepared by the authors (2026).

Societal Dimension: Although not mandatory, society will be more likely to grant the Social License to Operate (SLO) to the extent that it perceives mining to be generating net benefits for society, as reflected in increased employment and income, poverty reduction, and violence control, among other factors. Furthermore, it is important that the socio-environmental conditions of environmental licensing align with public policies aimed at improving the education and health systems, since these services become severely overburdened when a new project is implemented, particularly in remote areas (Table 63). Finally, it is essential to conduct prior, free, and informed consultation (CPLI), or to secure social acceptance, in order to avoid future legal challenges that could later bring the project to a standstill.

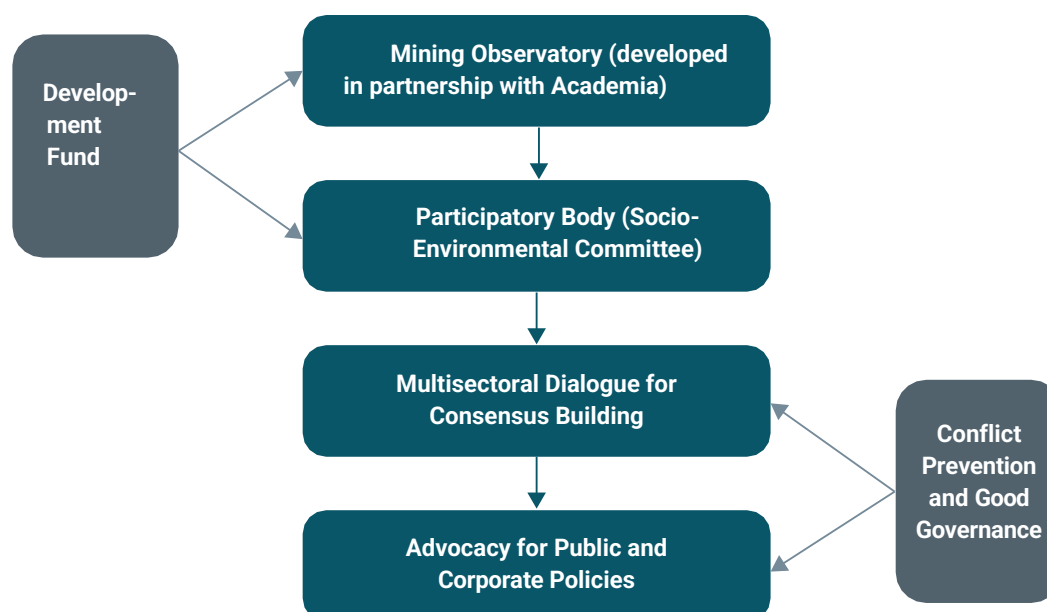
For participatory processes to be effective, NRES must address recurring challenges associated with information asymmetry, inequalities in technical and political capacity among stakeholders, the exclusion of vulnerable groups, and limitations in transparency and funding for participatory bodies. In this context, it is recommended that permanent mechanisms for territorial dialogue be strengthened, accompanied by capacity-building and socio-environmental literacy initiatives, independent technical support, and the active inclusion of youth, women, Indigenous peoples, Quilombolas, traditional populations, and rural communities that may be affected. It is also recommended that participatory processes be supported by independent technical observatories—linked, for example, to universities, research centers, or neutral entities—capable of enriching public debate with evidence-based analysis, reducing information asymmetries, and strengthening the socio-environmental and territorial monitoring of projects. For example, Lagem/UFGA created the Barcarena Sustainable Development Observatory, which serves this purpose and can serve as a model.

In addition, localized participatory mechanisms can help reduce information asymmetries and strengthen the transparency and social legitimacy of projects, especially when combined with clear and timely responses from companies to the questions and findings raised by social monitoring bodies. Both the Participatory Entity and the Observatory can initially be funded by the mining company through a fund established for this purpose. However, as the process matures, it can seek other sources of funding, such as a portion of the CFEM collected by the municipal government itself. This strengthens one of the pillars of the triad of good governance: social participation.

The figure below outlines the design of a participatory process based on Aledo and Gomes (2018), the UNDP report (Pareja et al. 2019), and the research conducted by the Laboratory for Studies on Governance in Mining Municipalities (LAGEM) at the Federal University of Pará (UFPA).

FIGURE 22

Design for a participatory process for the NRES



Source: Prepared by the authors.

TABLE 63

Indicators and References for the Society Dimension

Variable	Indicator	Reference
Employment	% of local workforce employed	RAIS/CAGED/MTE
Income	Percentage increase in household income	IBGE
Poverty	Percentage reduction in poverty	CadUnico Observatory
Violence	No. of homicides per 10,000 inhabitants	Atlas of Violence
Education	Number of Enrollments per School	INEP
Health	Number of doctors per 10,000 residents	DataSUS
Socio-environmental constraints	Policy constraints	Environmental Agencies (Ibama, State Departments of the Environment)
CPLI	Consultation conducted	Ibid.
Public participation	Existence of permanent mechanisms for dialogue and participatory monitoring	Environmental agencies / territorial agreements / local observatories
Social inclusion	Participation of vulnerable groups in participatory processes	Participation reports / territorial bodies

Source: Prepared by the authors.

The **government**, as the administrator of the mineral resources belonging to the federal government, plays a central role in the success of the NRES by establishing regulations, enacting laws and decrees, and influencing oversight agencies (Table 64). However, its success depends on leadership and coordination to set priorities and ensure that goals are met.

TABLE 64

Indicators and References for the Government Dimension

Variable	Indicator	Reference
Environmental Licensing Policies	Policies Implemented	Ibama
Oversight bodies	Resource Allocation Qualified Personnel	ANM, Ibama, ANSN, CPRM, etc.
Drafting and implementation of legislation	NRES launched	MME
Definition of Priorities	Priority defined	Sovereignty, competitiveness, sustainability, leadership, value creation, etc.
Goal Setting	Goals defined	Production, processing, market penetration, minimum prices, subsidies, and tax incentives; progress in the R&D&I system
Government Participation in the Activity	% of shares acquired	BNDES

Source: Prepared by the authors.

Companies are the beneficiaries of public asset concessions. In the case of mineral resources, although they are exploited in a highly regulated private market subject to various external risks, their dynamics are strongly influenced by technological barriers and market concentration, which approaches a near-monopolistic scenario dominated by a single country (Table 65).

TABLE 65

Indicators and references for the “Companies” dimension

Variable	Indicator	Reference
CSR in cooperation with governmental and nongovernmental institutions	No. of CSR projects	Environmental Agencies (Ibama, State Environmental Secretariats)
Circularity	% recycled content; % of waste recycled; material intensity (kg/t); % of water reused; waste generated (kg/t); circularity index (MCI) ¹⁰²	Environmental Agencies (Ibama, State Environmental Secretariats)

102. <https://www.ellenmacarthurfoundation.org/material-circularity-indicator>

Competitiveness	% share of the domestic market % of international market share	MDIC
Compliance	% of targets met	
Access to the mine's Research and Development areas	% research success rate	CPRM-SGB ANM
Social License	% of actions carried out,	Environmental Agencies (Ibama, State Environmental Secretariats)
Investments	\$ in internal and external funding	
Innovation	% of innovation per year	MCTI

Source: Prepared by the authors.

Territory: A national strategy must recognize that REE mining must leave a positive socioeconomic legacy in the region where it takes place. Since the municipality hosting the mining operation is the area most affected, this legacy must be clearly defined for the municipality where the mining front is located (Table 66). Mining will leave a positive legacy if it can contribute to improving the municipality's overall infrastructure. Therefore, it is important that, in addition to the collection of the CFEM, other alternatives for the distribution of benefits be developed, supporting land-use planning and respect for local culture and traditions.

TABLE 66

Indicators and benchmarks for the Territory dimension

Variable	Indicator	Reference
Infrastructure	No. of infrastructure facilities km of paved roads % of sanitation network expanded % increase in electrification % increase in connectivity, other	Development Departments
CFEM	Proper Collection	ANM
Distribution of benefits	No. of additional measures for benefit distribution, for example, the creation of a Local Development Fund, Strategic Plans, a Development Observatory, etc.	Development Departments
Public Revenue	% increase in municipal public revenue	Municipal Finance Department SICONFI
Land Use Planning	Land Use and Planning Instruments	Departments
Respect for local culture and traditions	No. of incentive projects	Departments of Culture

Source: Prepared by the authors.

Science, Technology, and Innovation (STI): Given the complexity and technological challenges present at every stage of the REE production chain, it is essential that production dynamics advance in close coordination with a robust STI system. This system must be supported by stable sources of research funding and by the training of highly qualified human resources, at both the higher education and technical levels. Furthermore, it requires the backing of solid cooperation focused on the transfer and co-creation of technologies, specifically tailored to the needs of local industry (Table 67).

TABLE 67

Indicators and benchmarks for the STI dimension

Variable	Indicator	Reference
Annual research funding	Annual funding	MCTI, BNDES
Human Resources: Quantity and Quality	% of new PhDs and postdocs working in these fields	MCTI, MEC, Senai
	% of new technicians trained	
	Number of technical professionals trained in the field of REEs	
	Number of certifications issued by Senai for technical qualifications in the field of REEs	
R&D&I	Number of partnership agreements with companies to generate innovations	MCTI, universities, research centers, companies
International Cooperation	Number of active cooperation agreements per year	MRE, ABC, universities, research centers
Research networks – number and density	No. of research networks	MCTI, universities, research centers, companies
	No. of results (patents, technology transfer, projects, etc.)	

Source: Prepared by the authors.

Global geopolitics: The dynamics of the REE market have proven to be highly sensitive to the global geopolitical environment, especially with regard to what has been termed “weaponization”—that is, its use for militarization purposes. The dominance of China and other major demand centers with production potential must also be monitored to ensure an effective national strategy; for although Brazil has no direct control over these dynamics, the country must track them in order to neutralize their effects (Table 68).

TABLE 68

Indicators and References for the Global Geopolitical Dimension

Variable	Indicator	Reference
Hegemony of the “majors”	China’s market share (%)	IEA
Weaponization	Percentage increase in demand due to the war	IEA
Growth in demand for new technologies	Percentage increase in demand for new technologies	IEA
Imposition of export taxes	Percentage change in export tax rates	UNCTAD
Imposition of import and export quotas	Percentage limit on export and import quotas	UNCTAD

Source: Prepared by the authors.

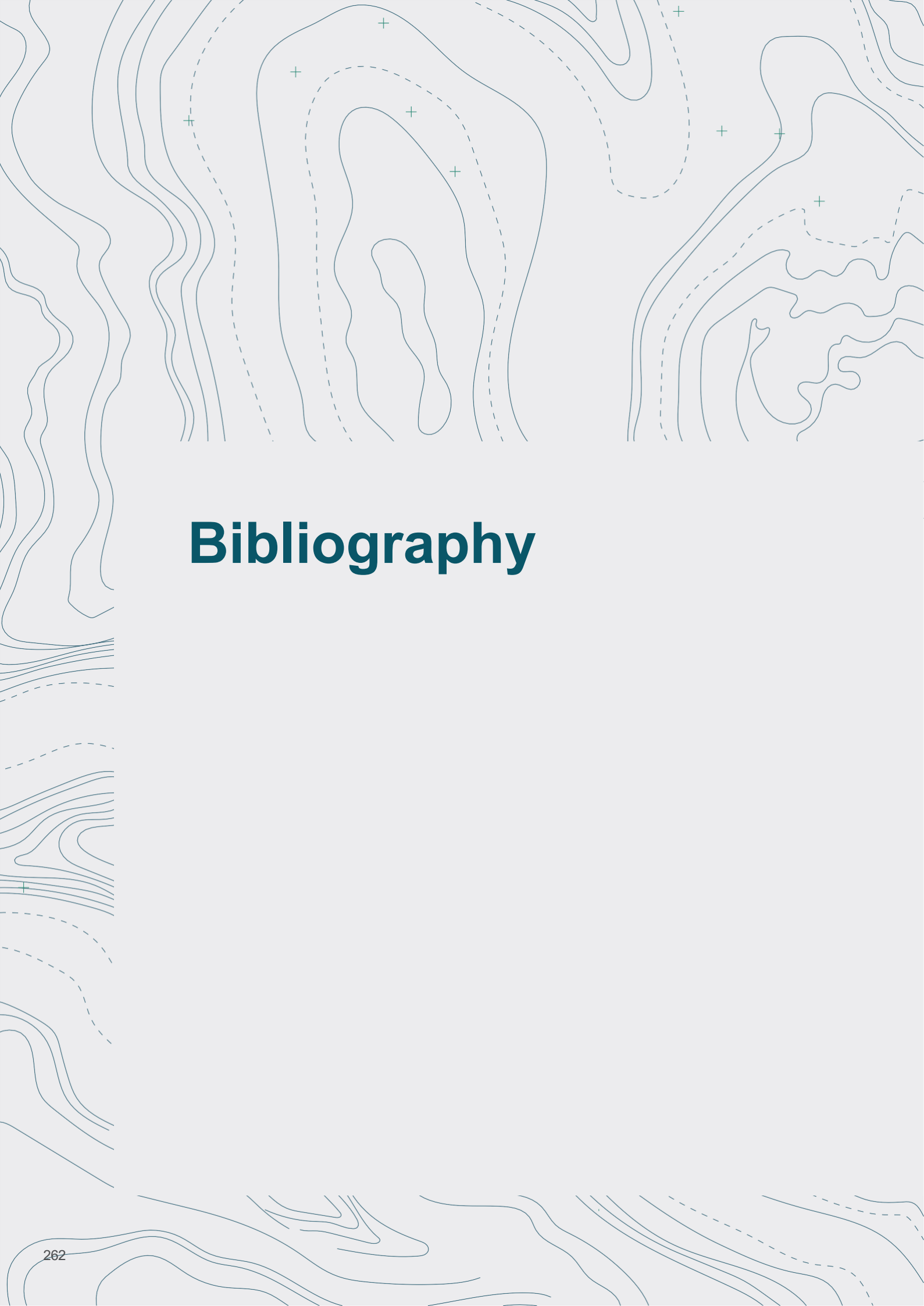
Because this is **a market** with monopolistic and oligopolistic characteristics, measures that reinforce barriers to entry are frequently used, such as price manipulation, supply restrictions, the imposition of tariffs and non-tariff measures, as well as restrictions on technology transfer. Conversely, growing demand acts to encourage new entrants into the market as a way to avoid excessive dependence on a single supplier. This aspect is beyond the direct control of a National Rare Earths Strategy (NRES); however, its dynamics profoundly affect its success, and therefore it is essential to closely monitor the trends in the indicators (Table 69).

TABLE 69

Indicators and References for the Market Dimension

Variable	Indicator	Reference
Tariffs and non-tariff measures affecting markets	Amount % increase in costs	UNCTAD
Supply	Supply growth rate	UNCTAD
Prices	Price growth rate	UNCTAD
Dynamics of demand-side sectors	Growth rate of demand-side sectors	UNCTAD

Source: Prepared by the authors.

The background of the page is a light gray topographic map. It features various contour lines, some solid and some dashed, representing different elevations. Scattered across the map are several small green plus signs (+).

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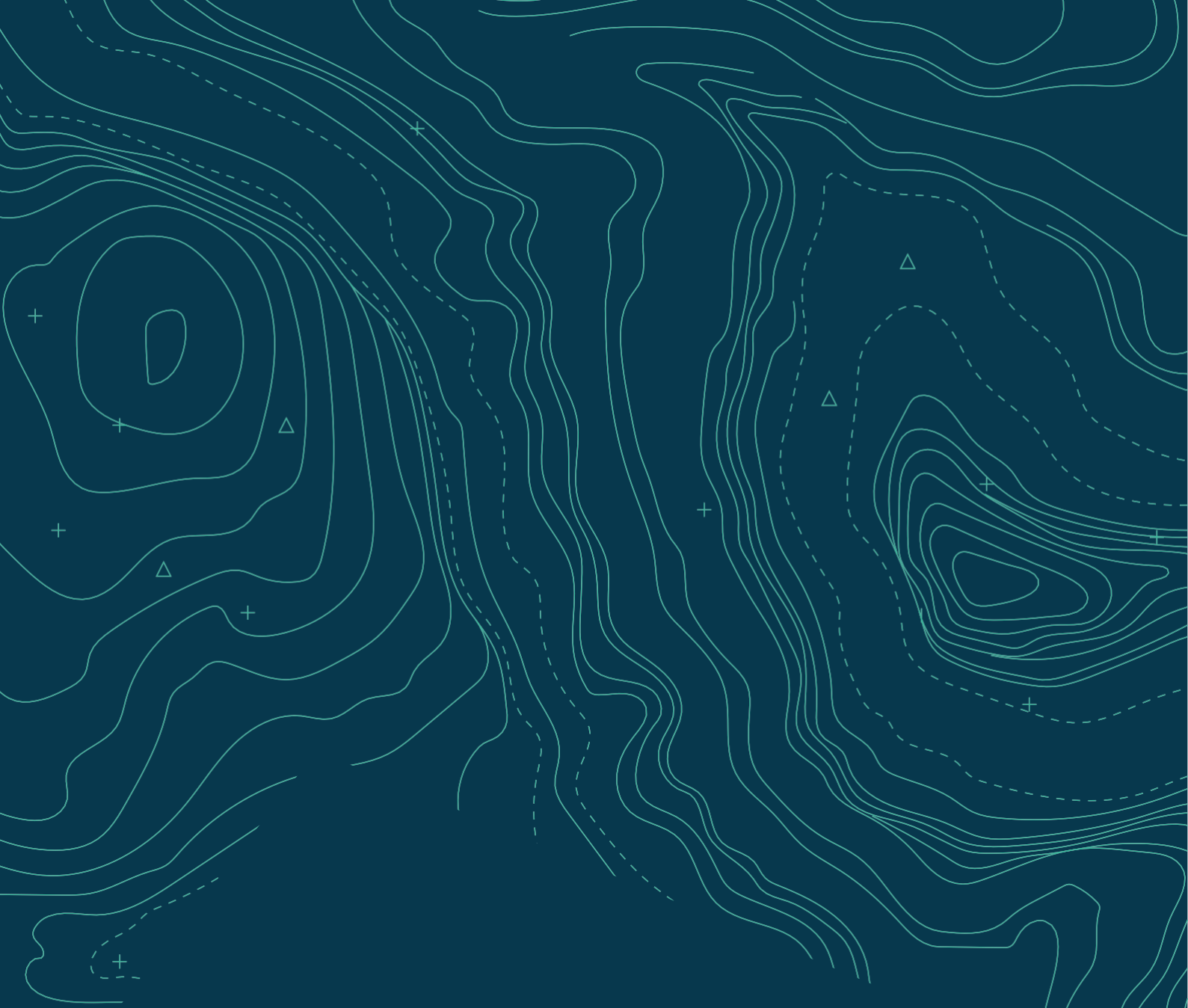
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