REVISTA TÓPICOS
ISSN 2965-6672 | Qualis A2

CLIMATE CHANGE, THE GLOBAL ENERGY TRANSITION, AND STRATEGIC AND CRITICAL MINERALS: BRAZIL'S ROLE IN ADDRESSING THREE CHALLENGES FACING THE INTERNATIONAL COMMUNITY IN THE 21ST CENTURY

AS MUDANÇAS CLIMÁTICAS, A TRANSIÇÃO ENERGÉTICA GLOBAL E OS MINERAIS ESTRATÉGICOS E CRÍTICOS: O PAPEL DO BRASIL ANTE TRÊS DESAFIOS DA COMUNIDADE INTERNACIONAL NESTE SÉCULO XXI

Ciências Sociais Aplicadas • 20/11/2026

REGISTRO DOI: 10.70773/revistatopicos/794962874

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ABSTRACT

This study addresses Brazil's role in confronting three challenges facing the international community in the twenty-first century. It describes contemporary climate change, characterizes the global energy transition, assesses the role of strategic and critical minerals in this transition, and, finally, examines Brazil's position in relation to the climate, energy, and mineral challenges of the twenty-first century. This research adopted a qualitative approach to analyze how Brazil could strengthen its position within the international community and promote national development by simultaneously leveraging its competitive advantages in the climate, energy, and mineral sectors. The methodological procedure consisted of a literature and documentary review, which involved consulting sources classified into four categories: (1) those describing contemporary climate change; (2) those characterizing the global energy transition; (3) those assessing the role of strategic and critical minerals in the energy transition; and (4) those examining Brazil's role in addressing the three challenges undertaken by the international community in the twenty-first century. The studies indicated that Brazil has the potential to advance its economic, technological, energy, and mineral sectors, while also becoming an important participant in the energy transition within the international system.

Keywords: Climate Change; Energy Transition; Strategic Minerals; Critical Minerals; Brazil; Development.

RESUMO

Este trabalho aborda o papel do Brasil ante três desafios vividos pela comunidade internacional neste século XXI. Descreve as mudanças climáticas contemporâneas; caracteriza o processo de transição energética global; avalia a participação dos minerais estratégicos e

críticos na transição energética; e, por fim, demonstra o papel do Brasil ante estes os desafios climático, energético e mineral neste século XXI. Esta pesquisa adotou uma abordagem qualitativa para analisar o quando o Brasil poderia projetar-se no concerto das nações e fomentar seu desenvolvimento nacional por alinhar simultaneamente vantagens competitivas no tocante às temáticas climática, energética e mineral. O procedimento utilizado foi a revisão da literatura e documental, que envolveu a consulta a fontes classificadas em quatro categorias: (1) as que descrevessem as mudanças climáticas contemporâneas; (2) fontes que caracterizassem o processo de transição energética global; (3) as que avaliassem a participação dos minerais estratégicos e críticos na transição energética; e (4) aquelas fontes que demonstrassem o papel do Brasil ante os três desafios assumidos pela comunidade internacional neste século XXI. Os estudos apontaram o quanto o Brasil teria condições de melhorar os campos econômico, tecnológico, energético e mineral além de ser um importante partícipe da transição energética no sistema internacional.
Palavras-chave: Mudanças climática; Transição energética; Minerais Estratégicos; Minerais Críticos; Brasil; Desenvolvimento.

1. INTRODUCTION

The First Industrial Revolution, which began in England in the mid-eighteenth century, brought about the country's rapid economic growth, driven, among other factors, by the use of coal for energy production. Owing to its high combustion capacity, this mineral resource became the main fuel for the English industrial sector, particularly for steam-powered machinery.

The economic gains, political strengthening, and consolidation of international trade resulting from the rapid transformations across several industrial sectors in England enabled the Industrial Revolution to spread throughout Europe and subsequently to other continents. Consequently, the global production system gradually expanded through advances in manufacturing processes.

To meet the growing demand for manufactured goods, a new global energy complex emerged: petroleum. Like coal, this so-called “black gold” is a non-renewable fossil energy source. Through intensive chemical processing, known as refining, petroleum is converted into fuels such as gasoline, diesel, and aviation kerosene, which supply transportation systems, as well as into energy sources for electricity generation in thermoelectric power plants.

By the mid-twentieth century, the intensive use of non-renewable energy sources had begun to reveal the environmental consequences of fossil fuel combustion. The release of greenhouse gases and other pollutants into the atmosphere indicated that the growing intensity of fossil fuel consumption was affecting the planet's ecosystems. From that point onward, the international community began taking its first steps toward recognizing and raising awareness of the increasingly evident effects of global warming.

As evidence of climate change became increasingly apparent across all continents, manifested in various natural phenomena, the perception of the need for an energy transition gained momentum. This transition involved moving away from a high-carbon energy system toward one increasingly based on renewable sources.

Within this context, numerous technological innovations emerged, contributing to the development of an industrial infrastructure dedicated to renewable energy generation. Alongside this rapid transformation, production systems faced a substantial increase in demand for the raw materials required to manufacture the components and equipment needed for an energy system capable of mitigating the causes of climate change. These materials are natural resources extracted from the Earth's subsurface, namely, minerals.

Consequently, the energy transition was found to extend beyond environmental concerns, also shaping a broader process of scientific, technological, mineral, and economic restructuring. This development reflects the fact that the simultaneous integration of renewable energy, essential minerals, and low-carbon technologies is reshaping geopolitics within the international system.

Regarding the research methodology, a qualitative approach was adopted. In terms of research procedures, the study was based on bibliographic and documentary research involving national and international publications, scientific articles, Brazilian government agencies, international organizations, multinational institutions, and websites. The consultation and consolidation of these sources made it possible to identify and examine the main issues addressed in this study.

Accordingly, the general objective of this research was to analyze Brazil's role in addressing the climate, energy, and mineral challenges faced by the international community in the twenty-first century. Based on this analysis, the study also seeks to provide political and economic institutions with information that may

support a comprehensive understanding of the country's development prospects amid the intense and disruptive global transformations currently underway.

To achieve this purpose, the following specific objectives were established: to describe contemporary climate change; to characterize the global energy transition process; to assess the role of strategic and critical minerals in the energy transition; and to examine Brazil's position in addressing the climate, energy, and mineral challenges of the twenty-first century.

To this end, the article was structured into four sections, designed to provide a comprehensive analysis of Brazil's role in addressing three challenges within the international context during the first half of the twenty-first century. The first section, the Introduction, presents the central theme of the study. The second section, Methodology, describes the research approach, including the data collection and analysis procedures. The third section, Theoretical Framework, describes contemporary climate change, characterizes the global energy transition process, assesses the role of strategic and critical minerals in this transition, and, finally, examines Brazil's position in relation to the three challenges within the international system.

The final section, Conclusions, summarizes the main findings of the research and provides political and economic institutions with information to support a better understanding of the implications for Brazil's development amid the intense global transformations currently underway.

2. THEORETICAL FRAMEWORK

This theoretical framework was organized into four subsections. The first aimed to describe contemporary climate change. The second sought to characterize the global energy transition process. The third subsection assessed the role of strategic and critical minerals in the global energy transition. Finally, the fourth examined Brazil's role in addressing the climate, energy, and mineral challenges of the twenty-first century.

2.1. Contemporary Climate Change

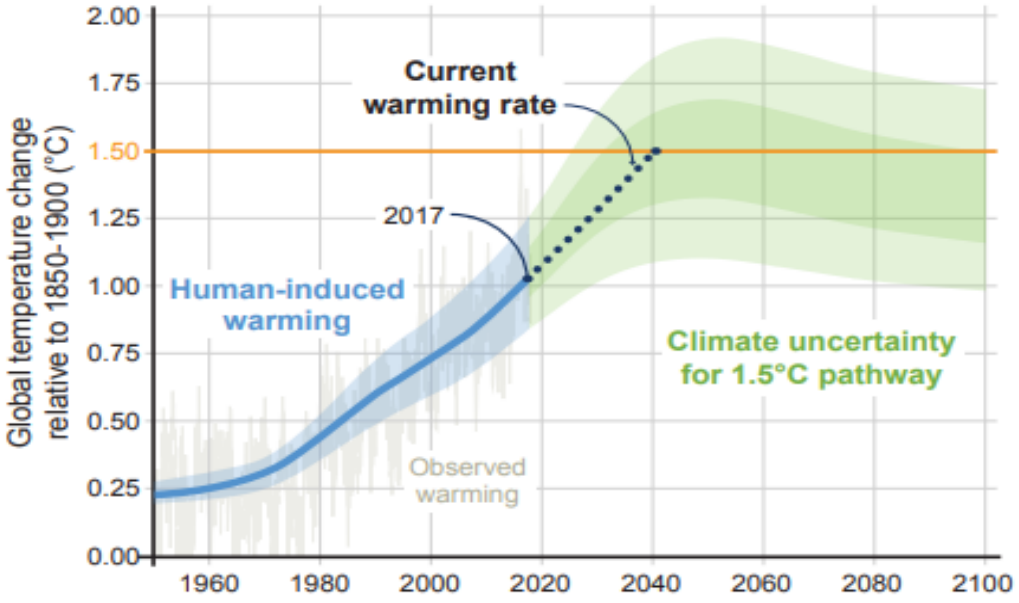
Global warming is already a reality on the planet, as climate change has been accompanied by extreme events occurring with unprecedented frequency, directly affecting the socioeconomic conditions of millions of people.

One proposed solution is to reduce fossil fuel production, accelerate the energy transition through increased renewable energy generation, and decarbonize the economy to mitigate the environmental disasters that have been occurring across all continents (Barbosa and Gomes, 2024).

In light of these aforementioned conditions, it is worth highlighting the 21st Edition of the Global Risks Report 2026, published by the World Economic Forum. The study asked participants about their perceptions of the global outlook across five risk categories: social, technological, environmental, economic, and geopolitical.

The results indicated that, over the next decade, environmental risks were perceived as generating the greatest pessimism among all categories, with nearly three-quarters of participants expressing a turbulent or stormy outlook (WEF, 2026).

Figure 1. Projections of global warming caused by human activities



Source: IPCC (2022).

According to the Intergovernmental Panel on Climate Change (IPCC), human-induced global warming had reached approximately 1°C above pre-industrial levels (1850–1900) by 2017. If current fossil fuel-based economic activities persist, global temperatures are projected to reach 1.5°C around 2040, as illustrated in Figure 1 (IPCC, 2022).

Scientifically established evidence indicates that greenhouse gases act like a blanket, trapping heat near the Earth's surface, warming the planet and driving climate change. Under the Paris Agreement, countries committed to reducing their greenhouse gas emissions. However, despite a few isolated peaks, global emissions have increased steadily since the 1850s, reaching a record of nearly 58 billion tonnes in 2024 (Raven, 2026).

The World Meteorological Organization (WMO) warned that global temperatures would likely remain at record levels between 2025 and 2029, substantially increasing risks to societies and economies. Projections indicate that each year during this period could be

approximately 1.2°C to 1.9°C warmer than the 1850–1900 average. There is an 86% probability that at least one year between 2026 and 2030 will surpass 2024 as the warmest year on record. Notably, every fraction of additional warming intensifies heatwaves, rainfall, droughts, ice loss, ocean warming, and sea-level rise, further aggravating damage to ecosystems worldwide (WMO, 2026; UNU, 2026).

As temperatures rise, the likelihood of irreversible changes to the planet also increases. Some of their potential consequences are presented in Table 1 (Raven, 2026).

Table 1. Effects of global warming

Scenario	Consequences
If global warming reaches 2°C	Almost all warm-water corals are very likely to die, devastating the reefs that sustain coastal ecosystems.
If temperatures rise by 3°C	The Greenland and West Antarctic ice sheets would likely collapse, causing sea levels to rise and flooding the coastlines of certain countries.
With global warming of 4°C	The Amazon rainforest could transform into a savanna, depriving the planet of an important source of oxygen and further aggravating the climate crisis.

Source: United Nations Environment Programme (Raven, 2026).

In 2024, the National Aeronautics and Space Administration (NASA) published the article “Too Hot to Handle: How Climate Change May Make Some Places Too Hot to Live”. Based on satellite data, the agency estimated that certain regions of the world could become uninhabitable within 30 to 50 years as a result of global warming.

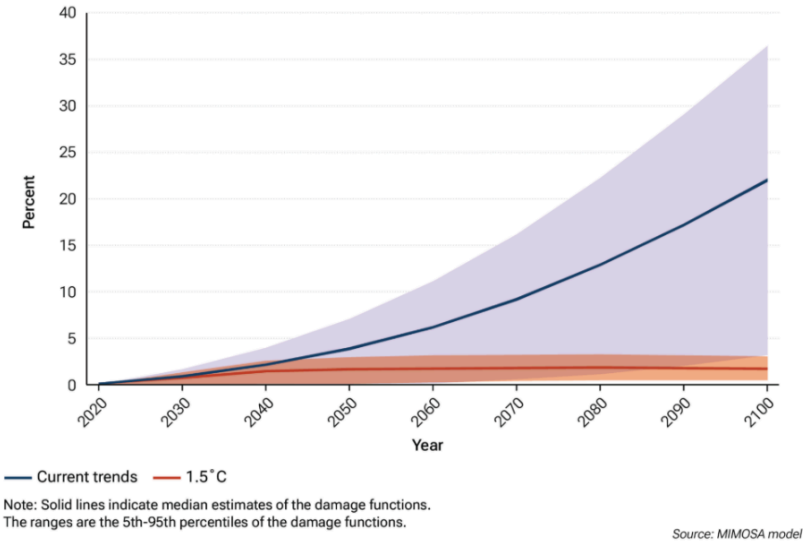
The most vulnerable areas were identified as South Asia, the Persian Gulf, and the Red Sea region by approximately 2050, followed by eastern China, parts of Southeast Asia, and Brazil by 2070 (NASA, 2024).

In 2025, recurrent and intense heatwaves, with temperatures considerably exceeding 40°C, affected extensive areas of North, Central, and South America. In October of that year, Hurricane Melissa, the first Category 5 hurricane ever recorded in Jamaica, caused 45 deaths and economic losses estimated at approximately US$8.8 billion, equivalent to around 41% of the country's gross domestic product (GDP) (WMO, 2026a).

A positive development is that, although greenhouse gas emissions have continued to increase globally, they have declined or are expected to decline in some countries, including Australia, China, Japan, and South Korea. There is hope that, as countries improve energy efficiency and move away from fossil fuels, emissions will decrease further. However, experts warn that the pace of this transition must accelerate substantially (Raven, 2026).

In addition to their devastating effects on ecosystems, climate change impacts the global economy directly. Studies estimate that it could reduce global GDP by 22% by 2100, as represented by the blue line in Figure 2. Under this scenario, approximately US$133 trillion in economic output would be lost (Raven, 2026).

Figure 2. Aggregate global GDP losses resulting from climate impacts



Source: United Nations Environment Programme (Raven, 2026).

Europe experienced widespread climatic anomalies, with temperatures above the average across at least 95% of the continent. According to the Copernicus Climate Change Service, part of the European Union's Space Programme, the continent is warming twice as fast as the rest of the world. These conditions have contributed to more intense wildfires, which burned approximately 1,034,550 hectares, the largest area ever recorded (Ec, 2026).

Copernicus recently released global climate data for April 2026, highlighting the prevailing climatic conditions on Earth. Among other findings, the report identified April 2026 as the third warmest April on record globally, with an average temperature of 14.89°C, which was 0.52°C above the average for April during the 1991–2020 reference period. April 2024 remains the warmest on record, followed by April 2025. Furthermore, the temperature was 1.43°C above the estimated average for the 1850–1900 period, which is used to define pre-industrial levels (Copernicus, 2026).

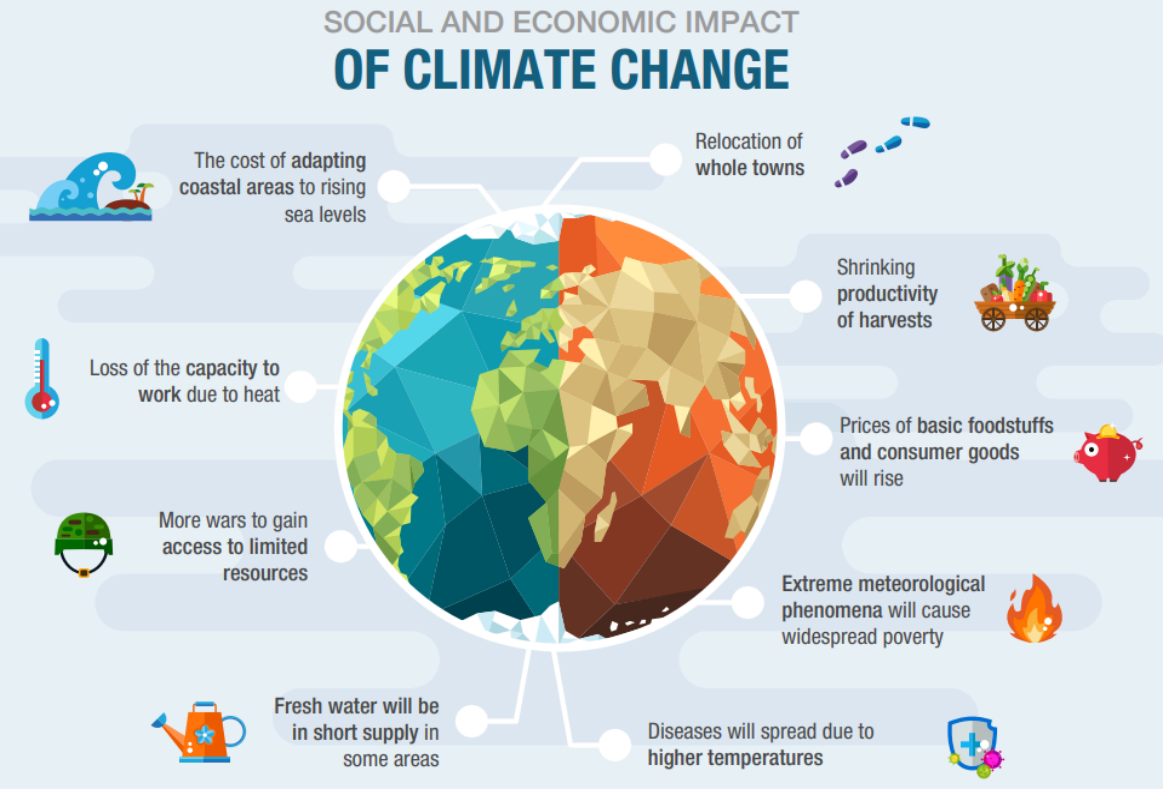
The report also emphasized the urgency of reducing greenhouse gas emissions across Europe, strengthening resilience to climate

impacts, and accelerating the transition to clean energy through renewable sources and improved energy efficiency (Ec, 2026).

According to the WMO report, sea levels along the Atlantic coast have been rising faster than the global average in the tropical and Caribbean regions. Furthermore, ongoing ocean warming and acidification have intensified risks to marine ecosystems and fisheries (WMO, 2026a).

Extensive research demonstrates that climate change requires an integrated, multisectoral response. Mitigation measures should strengthen greenhouse gas emission reductions through the development of clean energy, forest conservation and restoration, low-carbon agriculture, and the transition to a circular economy. At the same time, other measures should focus on increasing resilience in ecosystems, water resources, infrastructure, and public health. Climate-resilient development depends on innovative technologies, appropriate policy frameworks, and sufficient financial investment (Sarun, 2025).

Figure 3. Socioeconomic effects resulting from climate change



Source: Iberdrola (2026).

Finally, declining agricultural production, resulting from adverse and extreme weather events, limited access to drinking water, the increased spread of diseases associated with high temperatures, coastal flooding, and rising food prices, among other factors, are examples of the effects that various societies are already experiencing or may face as a consequence of climate change (Figure 3). These phenomena can generate severe socioeconomic impacts (Iberdrola, 2026).

Thus, the effects of global warming on the environment and human societies have led the international community to encourage and promote an energy transition process aimed at gradually reducing dependence on fossil fuels and replacing them with renewable energy sources. This long-term process is regarded as one of the strategies for ensuring a more sustainable planet for future generations.

2.2. Global Energy Transition Process

The history of civilization provides numerous examples of energy transitions, understood as progressive transformations in the composition of energy sources used to generate heat, provide lighting, and produce mechanical power in response to the needs of each period.

Over time, these changes have involved the replacement of dominant primary energy sources with alternatives capable of providing more efficient and higher-quality energy services (Jannuzzi, 2024).

The use of coal during the First Industrial Revolution in the eighteenth century and petroleum in the nineteenth century created conditions for energy to contribute to the economic growth of several countries.

However, because these energy sources are fossil-based, their non-renewable combustion has generated several environmental consequences. Accordingly, a new energy transition, currently underway and directed toward a low-carbon economy, has become a priority for numerous countries (Barbosa and Gomes, 2024).

The unsustainability of fossil fuels and their adverse environmental impacts have compelled the world to pursue cleaner energy sources. Many countries have been prioritizing the reduction of greenhouse gas emissions and the development of renewable energy sources as strategies for achieving sustainable development (Emmanuel and Ngabala, 2026).

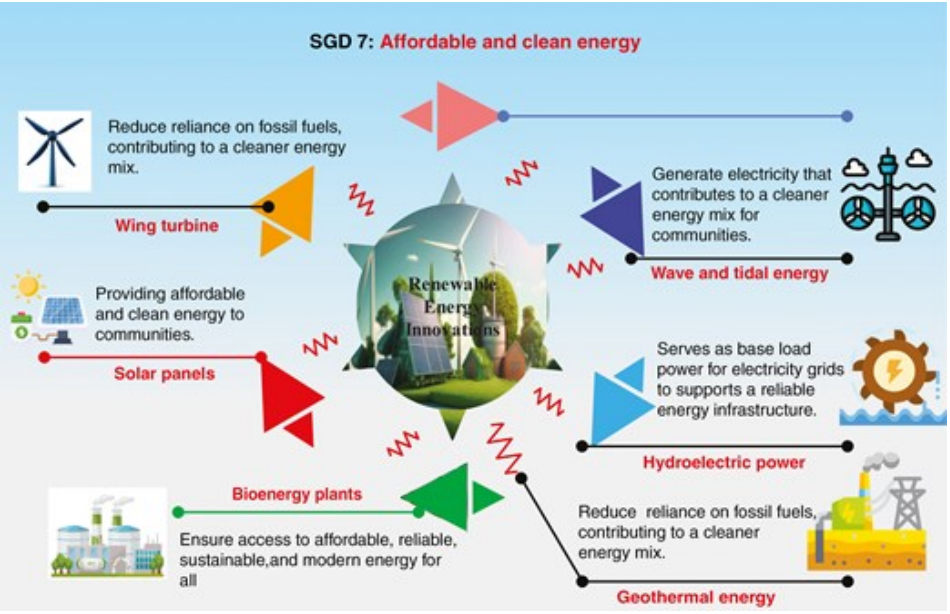
The available data illustrate the extent to which the planet's ecosystems have been exposed to high levels of atmospheric pollution. To provide an indication of the magnitude of this problem,

global energy-related CO_2 emissions have increased substantially, reaching 37.4 billion tonnes (Ashraf and Sagheer, 2025).

The rapid expansion of industrial development has been accompanied by increased emissions of polluting gases. This situation has prompted the international community to undertake efforts to mitigate their effects through an energy transition capable of curbing global warming and its consequences (Barbosa and Gomes, 2024).

It is important to highlight the United Nations Sustainable Development Goals (SDGs), which provide a comprehensive strategy for addressing a broad range of global challenges. Goal 7 (Figure 4) emphasizes the recognition of, and growing need for, access to clean and affordable energy (Kyei; Boateng and Frimpong, 2025).

Figure 4. Sustainable Development Goal 7 (Affordable and Clean Energy)



Source: Kyei, Boateng and Frimpong (2025).

There is international consensus that the energy transition involves increasing the share of renewable energy sources, prioritizing

energy efficiency, and promoting new pathways for converting primary energy into other energy carriers, such as hydrogen production (Jannuzzi, 2024). The International Renewable Energy Agency (IRENA) has stated that the expansion of renewable energy represents one of the main driving forces behind current economic transformations, requiring new models of international cooperation and new forms of productive integration (IRENA, 2023).

This context highlights the pressing need to pursue environmentally cleaner and ecologically sustainable energy generation alternatives to petroleum-derived fuels. These concerns were also addressed in the 19th edition of the Global Risks Report 2024, published by the World Economic Forum, whose questionnaire was directed to 1,500 global leaders and more than 200 subject-matter experts. One of its conclusions reflected the perception of a world facing a dangerous climate crisis (WEF, 2024).

Renewable energy sources, including solar, wind, hydropower, biofuels, and other sources such as geothermal and nuclear energy, are central to the transition toward less carbon-intensive and more sustainable energy systems. Installed generation capacity has expanded rapidly over the past decade, driven by policy support and substantial cost reductions, particularly in solar photovoltaic and wind technologies. The deployment of renewable energy in the electricity and transportation sectors is considered one of the main factors contributing to keeping the increase in the global average temperature below 1.5°C (Valavanidis, 2024).

According to IRENA, a pathway consistent with the 1.5°C target would require the accelerated expansion of renewable energy and improvements in energy efficiency, with direct implications for

investment flows, job creation, and industrial competitiveness (IRENA, 2023). Beyond their environmental benefits, investments in renewable energy represent an opportunity to mitigate the effects of global warming. Countries that recognize the importance of investing in renewable energy infrastructure may gain a competitive advantage in the global market (Kyei; Boateng and Frimpong, 2025).

Furthermore, the current energy crisis, aggravated by Russia's actions in Ukraine, has highlighted the urgent need for the European Union to reduce its dependence on fossil fuels. Diversifying and securing alternative energy supplies, while prioritizing cleaner options such as renewable sources, has become a significant concern for European countries (Atstāja, 2025).

It is also worth noting that renewable energy technologies, particularly wind and solar photovoltaic systems, have undergone rapid advances in technological development, production capacity, and energy-economic efficiency. These developments indicate a significant trend toward the accelerated replacement of fossil fuels by renewable energy sources (Shi and Zhao, 2025).

Consequently, another global challenge has emerged for the international community. The rationale is straightforward: as countries increase their targets for reducing carbon dioxide emissions, demand for raw materials, including minerals, is expected to rise sharply to manufacture components and equipment associated with the energy transition (World Bank, 2017; Castro et al., 2024). These considerations help explain why strategic and critical minerals, alongside the energy transition, have become increasingly important to sustainable, economic, industrial, and technological development.

2.3. The Role Of Strategic And Critical Minerals In The Energy Transition

Recent technological transformations and innovations have highlighted mineral production as one of the major drivers of the global energy landscape's restructuring, whose dominant focus is the transition from traditional energy sources to renewable energy sources (Castro et al., 2024).

Technologies aimed at decarbonizing the planet demonstrably require substantial quantities of minerals. Examples include the exponential growth in rechargeable battery production, driven by the expansion of electric vehicle fleets and the increased deployment of solar and wind power generation (Brasil, 2025c). Furthermore, the International Energy Agency (IEA) has projected that global demand for critical minerals will increase rapidly over the coming decades as decarbonization policies expand (IEA, 2024).

Demand is estimated to increase by a factor of four to six by 2040, meaning that the consolidation of the energy transition will profoundly reshape the geopolitical and commercial landscape of mineral resources. Elements such as lithium, cobalt, nickel, copper, graphite, and rare earth elements are essential for manufacturing low-carbon technologies and are considered strategic resources in the 21st century (IEA, 2022).

The manufacturing of photovoltaic panels, wind power generators, and fuel cells, among other technologies, depends on a wide range of metallic materials with varying levels of supply availability (Castro et al., 2024). Moreover, certain minerals are also essential for manufacturing components used in the capture, storage, and

transmission of energy generated from renewable sources, thereby constituting key elements in maintaining low-carbon production chains (IEA, 2020).

To provide a clearer understanding of this trend, between 2017 and 2022, nickel demand increased by 40%, while cobalt demand rose by 70%. For the world to fully adopt renewable energy and achieve net-zero greenhouse gas emissions, the use of energy transition minerals would need to increase sixfold by 2040 (UNEP, 2024). Lithium demand is expected to be nine times higher, while graphite demand is projected to nearly triple by 2050 (Brasil, 2025c).

Thus, the market for minerals used in the energy transition has enormous potential. With appropriate policies and safeguards in place, the extraction of these resources could usher in a new era of sustainable development by creating jobs and helping countries reduce poverty. Under certain conditions, energy transition minerals could have a transformative impact on some countries (UNEP, 2024).

2.4. Brazil's Role In Addressing Climate, Energy, And Mineral Challenges

Regarding climate issues and the energy sector, Brazil occupies a privileged position that has been effectively leveraged. These competitive advantages provide the country with significant opportunities to capitalize on its natural resources and assume a prominent position in the global energy transition process.

First, Brazil's extensive territorial area and abundance of natural resources have enabled the country to generate most of its electricity from hydropower. In addition, the country has made substantial investments in other renewable sources, such as wind

and solar energy, consolidating its leadership in energy sustainability in Latin America (Santos et al., 2024 and IEA, 2025). According to the Brazilian Wind Energy Association, the Northeast region accounts for 85% of the country's total wind power generation. Of the 534 wind farms operating nationwide, 430 are located in this region (ABEEólica, 2022).

Another important aspect is energy complementarity, which involves integrating hydropower with wind and solar energy sources (Severian, 2024). Data from the Ministry of Mines and Energy indicate that these two renewable sources account for 23.7% of the country's total electricity generation. Furthermore, in 2024, renewable sources accounted for up to 88.2% of electricity generation, a figure significantly higher than the global average and placing Brazil among the countries with the cleanest electricity matrices worldwide (Brasil, 2025a).

Significant recognition has come from the International Energy Agency, which has acknowledged Brazil's position as a leader in the global energy transition. According to the agency, the country's extensive renewable energy resources, strong biofuels sector, and ambitious climate commitments provide distinct advantages for the development of a low-carbon economy. This assessment is reinforced by Brazil's implementation of a comprehensive National Energy Transition Policy aimed at achieving net-zero greenhouse gas emissions by 2050, supported by the Energy Transition Plan and the Energy Transition Forum (IEA, 2025).

Second, Brazil is well positioned to become a major exporter of Green Hydrogen, given its favorable climatic conditions for generating electricity from wind and solar sources (Oliveira, 2022).

These conditions provide the country with a significant opportunity to play an important international role by supplying this fuel at competitive prices and meeting the demands of foreign markets (McKinsey, 2022).

These prospects were corroborated by the Hydrogen Council, which estimated that Brazil could become an important global player in the Green Hydrogen sector, regarded as the fuel of the future, within a market projected to reach US$ 2.5 trillion by 2050, representing approximately 20% of global energy demand (Martins, 2021 apud Barbosa and Gomes, 2024). Another relevant consideration concerns Europe, where greater emphasis has been placed on using hydrogen to decarbonize industrial activities and heavy-duty transportation, including buses and trucks (Oliveira, 2022).

Furthermore, a comparison between Brazil's electricity matrix and the global electricity matrix reveals that the country is ahead of most nations in terms of renewable energy participation. While the global average is approximately 30%, Brazil's share exceeds 80% (Santos et al., 2024).

Another noteworthy aspect is Brazil's active participation in international agreements and initiatives, which enables the country to consolidate and expand its renewable electricity matrix and, consequently, facilitate its progress toward an energy transition (Santos et al., 2024).

On the other hand, achieving a more sustainable and resilient national energy system requires substantial investments in infrastructure. Furthermore, public policies should incorporate mechanisms to finance innovation systems and modernize

production chains, including research and development of new technologies (Jannuzzi, 2024).

Another relevant consideration is the risk of expanding energy generation without developing an industrial complex capable of supporting this new energy model. Such a situation could place Brazil in a position of dependence on highly industrialized nations that dominate the technologies required for this new energy and production paradigm. In other words, having renewable energy sources alone is insufficient; it is also necessary to master the technologies that harness these resources (Severian, 2024).

In conclusion, Brazil has a unique opportunity to become a global leader in the clean energy sector. Its renewable-based electricity system and worldwide leadership in bioenergy provide distinctive competitive advantages that could be leveraged to establish new industries, create millions of jobs, and improve living standards, thereby benefiting Brazilian society as a whole (IEA, 2025).

Regarding the mineral sector, the emerging global order and the geopolitics of critical minerals, characterized by the pursuit of technological autonomy, also offer Brazil a window of opportunity. This prospect is supported by growing global demand driven by the energy transition, which positions the country as an important player on the international stage. With significant mineral reserves, Brazil has considerable potential to expand its participation in global value chains while promoting sustainable economic development (Viana, 2025).

From an economic perspective, the mineral sector plays a significant role in Brazilian exports. This assertion is supported by the fact that,

over recent decades, the mineral production chain has accounted for between 2.5% and 4% of national GDP (Cebri, 2025). In 2024 alone:

a. The sector recorded revenues of R$ 270.8 billion and a trade balance surplus of US$ 34.9 billion, representing a 47% surplus (Cebri, 2025); and

b. The surplus generated by the Mineral Extractive Industry (US$ 34.14 billion) offset the US$ 2.21 billion deficit recorded by the Mineral Processing Industry (Bezerra, 2025).

Furthermore, Brazil is home to significant deposits of niobium (Minas Gerais and Amazonas), graphite (Minas Gerais and Bahia), nickel (Bahia and Goiás), lithium (Minas Gerais and Ceará), copper (Pará), and rare earth elements (Minas Gerais, Goiás, and the northern region of the country). This mineral wealth, combined with the country's geopolitical stability and export-oriented profile, makes Brazil an attractive partner for major powers seeking to diversify their supply chains. It also provides a solid foundation for developing domestic and regionalized production chains (Karas, 2025 and Viana, 2025).

It is worth highlighting that the Brazilian Mining Institute considers the recently signed trade agreement between the Southern Common Market (MERCOSUR) and the European Union (EU) a significant opportunity for Brazilian mining and the national economy. According to the institute, the agreement would expand access to the European market, creating favorable conditions for attracting investments amid growing global demand for strategic minerals (Conexão Mineral, 2026).

The export, processing, and industrialization of these minerals could ultimately contribute to reducing global greenhouse gas emissions through the expansion of electric vehicles, wind and solar power generation, energy storage systems, and electricity distribution networks in countries importing Brazilian minerals (CEBDS, 2025). In international trade, particular emphasis is placed on lithium, whose production has increasingly been directed toward markets associated with the manufacture of electric vehicle batteries, energy storage systems, and electronic devices (Karas, 2025).

In addition to lithium, Brazil has proven reserves of vanadium, tantalum, bauxite, and graphite, among other strategic minerals (Table 2). The development of these mineral deposits could help integrate the country into a value chain with significant added-value potential, generating high-income employment opportunities (Brasil, 2025c).

Table 2. Brazilian Reserves of Strategic Minerals for the Energy Transition.

Mineral	Reserve 2024 (t)	World(t)	Participation	Ranking
Lítio	**1.370.000**	**30.000.000**	**4,4%**	**6°**
Cobre	**11.200.000**	**980.000.000**	**1,1%**	**12°**
Níquel	**16.000.000**	**130.000.000**	**12,3%**	**3°**
Nióbio	**16.000.000**	**17.810.000**	**89,9%**	**1°**
Terras raras	**21.000.000**	**90.000.000**	**23%**	**2°**
Cobalto	**70.000**	**11.000.000**	**0,6%**	**9°**
Vanádio	**120.000**	**18.000.000**	**0,6%**	**5°**

Grafita	**74.000.000**	**290.000.000**	**25,5%**	**2°**
Urânio	**280.000**	**6.070.000**	**4,6%**	**8°**
Manganês	**270.000.000**	**1.700.000.000**	**15,9%**	**4°**
Alumínio (bauxita)	**2.700.000.000**	**29.000.000.000**	**9,3%**	**5°**

Source: Ministry of Mines and Energy (Brazil, 2025).

The Ministry of Mines and Energy is, not surprisingly, promoting the implementation of a National Policy on Critical and Strategic Minerals, with the following objectives (Brasil, 2025b):

a. Expand geological knowledge and mineral exploration;

b. Strengthen production and mineral processing;

c. Integrate production chains;

d. Reduce external vulnerability, particularly regarding imports of essential minerals; and

e. Ensure the country's sovereignty and competitive autonomy within the context of the energy and technological transition.

On the other hand, according to the Brazilian Mining Institute, Brazil has the potential to participate in higher value-added segments of mineral production chains, thereby reducing its historical dependence on exported primary commodities (IBRAM, 2025). This assertion is consistent with Baumann (2025), who stated that the country's international integration remains strongly linked to the

export of primary goods, restricting its ability to capitalize on the economic benefits arising from technological transformations in the global landscape.

Unfortunately, under the current national circumstances, more than 85% of critical minerals are exported in their raw form or with limited processing. This extractive model reflects the absence of an industrial policy coordinated with mineral policy, resulting in Brazil's peripheral position within global value chains (Santos, 2023). Consequently, adding value to mineral resources remains a major challenge, requiring Brazil to focus on vertical integration of the production chain through investments in mineral processing within its national territory (CNI, 2024).

Therefore, maintaining economic models based solely on commodity exports could undermine the advantages associated with a low-carbon economy, since adding value, processing minerals locally, and strengthening technological capabilities are essential to maximizing economic gains and mitigating the historical asymmetries that characterize international relations in the mineral sector (Maldonado-Ibarra et al., 2024).

Finally, Brazil has a robust geological foundation and an established extractive industry; however, it faces substantial challenges in capturing the greater economic and strategic benefits of the emerging mineral economy. Accordingly, expanding its importance in the critical minerals value chain will depend on its ability to implement integrated policies that promote the vertical integration of mineral production, with an emphasis on innovation and industrialization, strengthen institutional and financing capacities,

and align the mineral, industrial, environmental, and scientific and technological sectors (Karas, 2025).

Thus, converting this natural wealth into lasting technological, social, and economic power is crucial to overcoming the resource curse that affects almost all developing nations. Gaining control over such a strategic value chain is an urgent responsibility for ensuring Brazil's security and autonomy, both in the present and in the future (Santos, 2025).

3. METHODOLOGY

The approach adopted in this study was qualitative in nature, as its primary objective was to analyze Brazil’s role in addressing the climate, energy, and mineral challenges undertaken by the international community in the twenty-first century.

This approach is widely recognized in the scientific community for its ability to provide contextual analyses, enabling, in this study, an understanding of the contributions to the country’s development amid a period of intense and turbulent global transformations. Furthermore, qualitative research focuses on the interpretation and understanding of dynamic phenomena, making it particularly relevant to macro-level scenarios involving climate change, the energy transition, and mineral resources that drive technological, environmental, social, and geopolitical transformations in the first half of the twenty-first century.

Regarding the methodological procedures, the study was classified as bibliographic research. This type of research is based on the careful analysis of previously published scientific works, which constitute one of the foundations of scientific knowledge

development. According to Pereira et al. (2018), bibliographic research can consolidate theoretical and methodological frameworks by bringing together and interpreting significant contributions on a specific topic. Yin (2016) further argues that this method enhances the analytical robustness of research by grounding discussions in established theories.

To conduct this review, the research sources were selected and classified into four categories: (1) sources describing contemporary climate change; (2) sources characterizing the global energy transition process; (3) sources assessing the role of strategic and critical minerals in the energy transition; and (4) sources examining Brazil's role in addressing the three challenges undertaken by the international community in the twenty-first century.

The classification of these sources provided a broader understanding of the global context in which Brazil is situated and how the country could take advantage of these circumstances to foster its development. The bibliographic and documentary reviews were conducted using national and international publications, scientific articles, Brazilian government agencies, international organizations, multinational institutions, and websites. This approach ensured a broad range of knowledge reflecting the extent to which the country could benefit from this scenario of intense climate, energy, and mineral transformations.

4. FINAL CONSIDERATIONS

The first half of the 21st century has been characterized by a series of challenges that have prompted the international community to reorganize the global order. Among other issues, rapid and

disruptive technological, economic, and environmental transformations have become priorities for several countries.

Issues such as global warming, the energy transition, renewable energy production, and the exploration of essential minerals have become part of diplomatic and trade agendas across all four continents, reshaping global geopolitics. These matters have been addressed in international forums and given greater priority in discussions among political leaders and senior policymakers, given their potential to shape the future directions and development of nations.

Extreme climate events, such as ocean warming, rising sea levels, heavy rainfall, droughts, ice loss, and heat waves, have affected ecosystems worldwide, prompting countries to focus on strengthening ecosystem resilience, conserving water resources, and improving socioeconomic infrastructure.

To reduce greenhouse gas emissions and mitigate the consequences of global warming, several countries have been strengthening their energy transition efforts by expanding renewable energy production, developing urban mobility, and promoting low-carbon technologies.

The results achieved through the gradual transition from fossil fuels to renewable energy sources have been made possible, among other factors, by the exploration, beneficiation, processing, and industrialization of strategic and critical minerals. These natural resources are indispensable and irreplaceable in the manufacture of various high-value-added equipment and components essential to energy systems. However, owing to their geographical

concentration, growing global demand, and limited availability across a small number of countries, new challenges and diplomatic, economic, and technological variables have emerged within the geopolitical context, resulting in a substantial reorganization of global supply chains for these mineral resources.

It was within these climate, energy, and mineral contexts that Brazil's role in the international arena was examined. Given its geographical position and extensive territorial area, the country has accumulated several competitive advantages associated with its natural resources, enabling it to generate most of its electricity from renewable sources. In the mineral sector, Brazil possesses significant deposits of essential minerals, including rare earth elements, making it a desirable partner for major global powers.

The recently signed agreement between MERCOSUR and the EU represents, among other opportunities, a significant prospect for Brazilian mining to gain access to the European market, creating favorable conditions for attracting investments and strengthening the national economy.

Thus, the findings indicate that the research achieved its objectives by providing a comprehensive understanding of how Brazil, owing to its privileged position, is favorably placed to stand out on the international stage. This position results from the country's combination of abundant natural resources (solar radiation, wind, and water), an electricity matrix with a substantial share of renewable sources (solar, wind, hydropower, among others), geological diversity, and the presence of various minerals within its territory that are essential for low-carbon technologies.

Interestingly, the research demonstrated that the global energy transition, aimed at mitigating the effects of climate change, is no longer an agenda exclusively concerned with ecosystem preservation. It has also become intrinsically interconnected with economic restructuring, the promotion of disruptive technologies, and the reorganization of geopolitics worldwide.

In this regard, the qualitative approach, based on a literature review and documentary analysis, was fundamental in demonstrating the extent of Brazil's competitive advantages, which could provide the country with a privileged position among nations in addressing climate, energy, and mineral challenges. These conditions could contribute to national development and foster research into high-value-added technologies, with the potential to improve the country's environmental, industrial, economic, and scientific and technological profile.

Finally, considering the evidence presented in this study, future research should investigate the specific role of Strategic and Critical Minerals in shaping the current reconfiguration of Global Geopolitics and the New Global Energy Order.

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