

Challenges of the Energy Transition in Brazil: Petrobras' Role in Climate Change and the Implementation of the 2024-2028 Strategic Plan

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Abstract

This article examines the challenges of the energy transition in Brazil and the role of Petrobras in this process, with a particular focus on the implementation of the 2024-2028 Strategic Plan. The energy transition, which is vital for mitigating climate change, entails the substitution of fossil fuels with renewable energy sources. Consequently, major energy companies, such as Petrobras, are obliged to adapt their operations in order to align with the global decarbonisation objectives. The research problem can be defined as follows: how can Petrobras reconcile its reliance on oil and gas exploration with the imperative of an effective energy transition, contributing to the reduction of greenhouse gas emissions and the development of low-carbon technologies? This article examines how Petrobras' Strategic Plan aims to facilitate this transition, evaluating the challenges and opportunities for the company and for Brazil. The deductive-analytical method was employed, with bibliographical and documentary research based on Petrobras reports and studies on energy transition. The conclusion reveals that, although Petrobras still relies significantly on oil, its investments in renewable energies and carbon capture technologies indicate a progressive shift towards sustainability, in line with global climate commitments.

Keywords

Climate Change, Energy Transition, Decarbonization, Petrobras, 2024-2028 Strategic Plan, Renewable Energies

1. Introduction

The objective of this article is to examine the implications of the energy transition

for the effort to combat climate change, with a particular emphasis on Petrobras' Strategic Plan for the period 2024-2028. The energy transition, which entails the substitution of fossil fuel sources with renewable ones, constitutes a pivotal topic in discourses pertaining to sustainability and global decarbonisation. In this context, Petrobras, as one of Brazil's largest energy companies, is restructuring its operations in order to align with international climate commitments, such as the Paris Agreement, which aims to limit the increase in global temperatures.

Climate change is one of the greatest global challenges, with impacts ranging from rising average temperatures to extreme weather events and loss of biodiversity. The transition to renewable energy is essential to limit global warming to 1.5°C, as set out in the Paris Agreement. In Brazil, the vast availability of natural resources puts the country in a strategic position to lead the energy transition, combining solar, wind and hydropower to mitigate climate impacts.

The significance of this study lies in the pressing need to comprehend the manner in which major oil and gas corporations, historically reliant on fossil fuels, are modifying their strategies to address the challenges posed by climate change. Brazil is uniquely positioned to spearhead the transition to a low-carbon economy due to its evolving energy matrix and vast renewable resources, including solar and wind energy. Petrobrás is a pivotal actor in this process.

The objective of this research is to examine how Petrobras' Strategic Plan for 2024-2028 aims to advance the energy transition, reduce greenhouse gas emissions and develop sustainable solutions. The specific objectives are as follows: 1) An analysis of Petrobrás' role in Brazil's energy transition; 2) An assessment of the extent to which the company's initiatives contribute to the mitigation of climate change; and 3) A discussion of the challenges and opportunities associated with decarbonising Brazil's economy. The central hypothesis of this article is that, although Petrobrás still relies heavily on oil production, its investments in renewable energies and carbon capture technologies indicate a gradual and progressive transition towards sustainability and decarbonisation, in alignment with global climate goals.

In order to address the aforementioned hypothesis, the article is structured into five main sections. The first section provides an introduction to energy transition and climate change. The second section examines the role of Petrobrás and its Strategic Plan 2024-2028. The third section outlines the initiatives and projects aimed at decarbonisation. The fourth section discusses the challenges and opportunities of this transition. Finally, the article concludes by discussing the need for a more sustainable energy paradigm that is aligned with global environmental commitments.

The scientific method employed is deductive-analytical, based on a bibliographical and documentary research approach, with analysis grounded in official Petrobrás reports, documents, and studies on energy transition and climate change.

2. The Energy Transition: Concepts and Importance

The energy transition is the process of replacing fossil fuels with renewable sources of energy. This is done with the aim of reducing the impact of human activity on the climate. The transition is guided by global goals such as the Paris Agreement, and it is driven by the electrification of energy sources and improvements in energy efficiency. It is a key strategy for reducing emissions in the industrial and transportation sectors. The transition also offers economic and social benefits, such as job creation and improved quality of life. This makes it a pillar of sustainable development.

2.1. Global Targets: The Paris Agreement and Commitments to Reduce Greenhouse Gas Emissions

The term “energy transition” is used to describe the gradual shift from a system based on fossil fuels, including oil, natural gas and coal, to one based on renewable energy sources, such as solar, wind, biomass and others. The principal aim of this process is to facilitate the decarbonisation of the energy matrix and to guarantee the long-term sustainability of energy sources. The energy transition is a direct response to global pressures to mitigate climate change and to reduce dependence on highly polluting fossil sources (Ministério de Minas e Energia, 2021). This concept entails a technological, political and economic transformation, necessitating a coordinated effort between governments and companies. The case of Petrobrás exemplifies this, as the company is seeking to align its operations with global decarbonisation targets (Petrobrás, 2024).

2.2. The Significance of Electrification and Energy Efficiency in Mitigating the Environmental Impact of the Industrial and Transport Sectors

The Paris Agreement, signed in 2015, represents a fundamental milestone for global climate action, establishing a commitment to limit the increase in global average temperature to below 2°C compared to pre-industrial levels, with efforts to limit the increase to 1.5°C (Ministério de Minas e Energia, 2023). In order to achieve these goals, the signatory countries have committed to the promotion of renewable energies and the implementation of policies designed to reduce greenhouse gas (GHG) emissions, as well as the encouragement of technologies such as carbon capture and storage (CCUS) (Petrobrás, 2023). In Brazil, the government has pledged to reduce emissions by 50% by 2030 and achieve carbon neutrality by 2050. These targets directly influence the strategies of companies such as Petrobrás (Ministério de Minas e Energia, 2021).

2.3. The Significance of Electrification and Energy Efficiency in Mitigating the Environmental Impact of the Industrial and Transport Sectors

The electrification of energy sources is a crucial instrument in the transition to a

more sustainable energy system, particularly in the transportation and industrial sectors, which are the primary contributors to greenhouse gas emissions (Ministério de Minas e Energia, 2021). One of the most viable solutions for reducing emissions in the transportation sector is the replacement of fossil fuel vehicles with electric vehicles (Petrobrás, 2024). In the industrial sector, the electrification of processes, coupled with enhanced energy efficiency, results in a considerable reduction in the carbon footprint, while simultaneously optimising the utilisation of natural resources. The objective of energy efficiency is to optimise the use of available energy, thereby reducing costs and preserving the environment (Ministério de Minas e Energia, 2021).

2.4. The Economic and Social Benefits of the Energy Transition

The energy transition presents a series of economic and social advantages. Notable among these benefits are the creation of new jobs in renewable energy sectors, technological innovation and sustainable infrastructure (Ministério de Minas e Energia, 2023). These jobs are directly related to the expansion of sectors such as solar and wind energy, which tend to generate long-term, more resilient jobs in a low-carbon economy (Petrobrás, 2023). Furthermore, a reduction in reliance on fossil fuels enhances energy security, thereby safeguarding countries from crises and fluctuations in international oil and gas prices. Furthermore, the energy transition presents an opportunity to reduce social inequalities, as it facilitates access to cleaner and more affordable energy sources for vulnerable communities. Furthermore, the enhancement of quality of life represents one of the most immediate consequences of the transition. The diminution of air and water contamination mitigates the likelihood of developing respiratory and cardiovascular illnesses, thereby enhancing public and environmental health (Petrobrás, 2024).

3. The Role of Petrobras in the Energy Transition

Petrobrás is strategically positioned to play a significant role in Brazil's energy transition, with the integration of renewable sources and the development of low-carbon technologies forming a key component of its 2024-2028 Strategic Plan. The objective of this plan is to align the company's actions with global decarbonisation commitments, while maintaining a focus on reducing its carbon footprint throughout the oil and gas production and exploration chain (Petrobrás, 2023).

3.1. Investments in Renewable Energy Sources

One of the principal objectives of the plan is to increase investment in renewable energies, with a particular emphasis on technologies such as offshore wind energy, solar energy and green hydrogen. Petrobrás has concentrated its efforts on increasing its involvement in these sectors as part of its diversification strategy, which aims to reduce reliance on fossil fuels and, concurrently, facilitate the advancement of a cleaner and more sustainable energy matrix (Petrobrás, 2024). Furthermore, the company is evaluating the economic and technical viability of

renewable energy projects, with a particular focus on offshore wind, which has significant growth potential in Brazil due to the country's extensive coastline (Ministério de Minas e Energia, 2021).

Petrobras has augmented its investment in renewable energies, which constitutes an indispensable component of its strategy for the transition to a more sustainable energy matrix. The 2024-2028 Strategic Plan places a premium on diversification of the energy portfolio, with a particular emphasis on the development of clean sources, including offshore wind energy, solar energy and green hydrogen. It is widely acknowledged that these technologies are fundamental to reducing greenhouse gas (GHG) emissions and ensuring a more sustainable energy matrix in the long term.

The potential for offshore wind energy, produced in wind farms situated offshore, represents a strategic opportunity for Brazil, given the country's extensive coastline and the significant potential it offers for generating energy from wind resources (Ministério de Minas e Energia, 2021). Petrobrás has invested in technical and economic feasibility studies with the objective of expanding its projects in this area, leveraging the experience acquired in offshore oil operations to optimise its wind energy operations (Petrobrás, 2024). Offshore wind energy represents an efficient solution with high generation capacity, and has the potential to complement renewable energy production in the country, which is already a world leader in this field.

Another key aspect of Petrobrás' energy transition strategy is investment in photovoltaic solar energy, which has emerged as one of the world's fastest-growing renewable energy sources in recent years. Solar energy offers a number of advantages, including its ease of implementation in diverse geographical regions and reduced installation costs resulting from technological advancements. Petrobrás has sought to expand its operations in this sector through partnerships and investments, capitalising on Brazil's potential for large-scale solar energy production, due to the country's high solar incidence (Petrobrás, 2024).

Another area of growing interest for Petrobrás is green hydrogen, which the company regards as a potential solution for decarbonising sectors that are more challenging to electrify, including heavy transport and the steel industry. Green hydrogen is produced by electrolysis of water, using electricity generated from renewable sources such as solar and wind power, resulting in a fuel that is free of carbon emissions (Ministério de Minas e Energia, 2021). The advancement of this technology, though still in its nascent stages, represents a pivotal element of Petrobrás' strategy to curtail emissions and furnish enduring energy solutions with minimal environmental impact.

The advancement of green hydrogen is in accordance with the directives established by the National Hydrogen Program (PNH2), which was initiated in 2021 with the objective of establishing Brazil as a leading global producer and exporter of green hydrogen (Ministério de Minas e Energia, 2021).

These investments by Petrobrás in renewable energies are pivotal to achieving

the climate targets set forth in the Paris Agreement, which mandate a significant reduction in greenhouse gas (GHG) emissions by 2030 and carbon neutrality by 2050. By investing in renewable energy sources such as wind and solar power, as well as green hydrogen, Petrobrás aims not only to reduce its reliance on fossil fuels but also to ensure its competitiveness in the context of a global transition towards a low-carbon economy (Petrobrás, 2024).

Although green hydrogen is a promising alternative for decarbonising industry and transport, it faces significant challenges. The high cost of production, due to the need for electrolysis and renewable sources, limits its competitiveness. In addition, storage and transport require specific infrastructure to ensure safety and efficiency. In Brazil, although the production potential is huge, technological development is still at an early stage and requires government incentives and international partnerships to accelerate its viability (Ministério de Minas e Energia, 2021).

3.2. The Development of Biofuels

A further significant element of the 2024-2028 Strategic Plan is the advancement of biofuels, including BioQAV (aviation biokerosene) and Diesel R100 (renewable diesel). Petrobrás has made investments with the objective of expanding its biofuel production capacities, thereby aligning its operations with global demands for fuels with lower pollutant emissions. These low-carbon products represent a promising alternative for reducing greenhouse gas emissions in the transport sector, particularly in aviation and road transport (Petrobrás, 2024).

3.3. Carbon Capture and Storage (CCUS)

Carbon capture and storage (CCUS) represents a significant technological initiative undertaken by Petrobrás with the objective of mitigating CO₂ emissions generated by its operational activities. The company already has the largest offshore CO₂ reinjection programme in the world, and continues to invest in the creation of CCUS hubs in Brazil, with the objective of reducing emissions during oil and gas exploration and production (Petrobrás, 2024). The deployment of this technology is pivotal to achieving the decarbonisation objectives, as it enables the company to maintain its operations in the oil and gas industry while curbing its impact on global warming (Ministério de Minas e Energia, 2021).

4. An Analysis of Brazilian Policies and Their Alignment with the Energy Transition

The Brazilian National Energy Transition Policy represents a pivotal initiative spearheaded by the Ministry of Mines and Energy (MME), which aims to establish the country as a global frontrunner in the utilisation of renewable energy sources. The policy provides explicit directives for the advancement of clean energy sources, including solar, wind, and green hydrogen. Its objective is twofold: to diminish reliance on fossil fuels and to foster sustainable economic growth, job creation,

and energy security (Ministério de Minas e Energia, 2021).

4.1. An Analysis of Brazil's Current Energy Matrix

Brazil is widely acknowledged for its diversified and low-carbon energy matrix, with 48% of its energy derived from renewable sources, including hydroelectric, solar and wind. This percentage is considerably higher than the global average of 15% of renewables, thus positioning Brazil as one of the most advanced countries in terms of clean energy use (Ministério de Minas e Energia, 2021).

Brazil's prominence in the energy transition is largely attributable to the country's geographical and natural characteristics. Brazil is the second largest producer of hydroelectric power in the world, with China being the only country that produces more (IEA, 2022). The country's favourable climatic conditions, including high solar incidence over a significant portion of the territory and consistent winds along its extensive coastline, provide an optimal setting for the advancement of solar and wind energy (Ministério de Minas e Energia, 2021).

Hydroelectric power remains the primary source of electricity in Brazil, accounting for approximately 60% of the country's total electricity generation (Ministério de Minas e Energia, 2021). This is attributable to the considerable hydroelectric potential of Brazil's basins, including the Amazon and the Paraná, which have extensive hydroelectric facilities. However, reliance on hydroelectricity also gives rise to challenges, including vulnerability to water crises, which have become more prevalent as a consequence of climate change.

In recent years, Brazil has diversified its energy matrix with growing investments in solar and wind energy, which have become the country's fastest-growing renewable sources. Solar energy has experienced exponential growth, with distributed generation projects and large-scale solar plants being constructed across various regions of the country, particularly in the Northeast (Petrobrás, 2024). In contrast, wind energy is concentrated primarily along the northeastern coastline, where the winds are both consistent and robust, and has emerged as one of the most promising technologies. Wind production has increased by more than 15 times over the past decade, representing a significant contribution to the growth in installed renewable capacity in Brazil (Ministério de Minas e Energia, 2021).

In comparison to other countries, Brazil has a relatively low dependence on fossil fuels, such as oil and coal, for the generation of electricity. The majority of fossil fuel consumption is concentrated in the transport and industrial sectors. However, the government and companies such as Petrobrás are working to decarbonise these sectors through investments in biofuels, fleet electrification and carbon capture and storage technologies (CCUS) (Petrobrás, 2024).

Brazil, with its predominantly renewable energy matrix, is in a favourable position to spearhead the global energy transition. The diversification of its energy sources and advances in renewable technologies provide a robust foundation for reducing greenhouse gas emissions and fulfilling the commitments made in the Paris Agreement. Such leadership not only serves to reinforce the country's energy

security, but also presents a range of economic opportunities. These include the attraction of foreign investment and the export of renewable energy technology and associated expertise (Ministério de Minas e Energia, 2023).

4.2. An Examination of Brazil's Commitments under the Paris Agreement

The Paris Agreement, which was adopted in 2015 during COP21, represents a global commitment to combat climate change. The main objective of the Agreement is to limit the increase in the global average temperature to below 2°C compared to pre-industrial levels, with additional efforts to limit this increase to 1.5°C. This discrepancy is of paramount importance in order to circumvent the potential for significant climate-related consequences, including extreme droughts, rising sea levels and loss of biodiversity (Ministério da Ciência, Tecnologia e Inovação, 2023).

In order to achieve these goals, the Agreement provides for Nationally Determined Contributions (NDCs), which are voluntary commitments made by each country to reduce greenhouse gas (GHG) emissions. Brazil has set itself ambitious targets, including a reduction in emissions by 37 per cent by 2025 and 43 per cent by 2030, based on 2005 levels, as well as a commitment to achieve carbon neutrality by 2050. These commitments inform national energy policies and exert a direct influence on the strategies of major corporations such as Petrobrás, which is pursuing the integration of renewable energies and the reduction of emissions through carbon capture and storage technologies (CCUS) (Petrobrás, 2024).

The energy sector plays a pivotal role in the discourse surrounding the Paris Agreement, given its status as the primary source of global greenhouse gas (GHG) emissions. This is largely attributable to the pervasive reliance on fossil fuels for electricity generation, heat provision and transportation. In order to achieve the aforementioned targets, a transition towards renewable energy sources, such as solar, wind and green hydrogen, is necessary. Furthermore, improvements in energy efficiency and the electrification of sectors, including transport and heavy industry, are essential (Petrobrás, 2024).

Brazil, with its renewable energy matrix comprising substantial hydroelectric, wind and solar energy capacities, is ideally positioned to spearhead this transition. Petrobrás has made investments in the development of renewable energy sources and the reduction of its dependence on fossil fuels. These investments are aligned with the company's 2024-2028 Strategic Plan, which includes the development of carbon capture utilization and storage (CCUS) technologies and the introduction of less polluting biofuels, such as BioQAV and Diesel R100 (Petrobrás, 2024). These endeavours form part of Brazil's strategy to reinforce its position as a global leader in clean energy, capitalising on the country's substantial natural resources.

Therefore, the Paris Agreement necessitates a transformation of the global energy sector. In the case of Brazil, the country's ambitious decarbonisation targets

and commitment to carbon neutrality by 2050 position it as a potential global leader in the transition to renewable energies. In this context, Petrobrás assumes a pivotal role, adapting its operational and investment strategies to advance climate objectives and promote a more sustainable energy matrix.

4.3. Potential Opportunities for the Brazilian Energy Sector and the Environmental Regulatory Framework

The Brazilian energy sector offers a favourable regulatory environment for the development of clean energy projects, particularly in areas such as offshore wind power and green hydrogen. Brazilian national policies are aligned with the global commitments set out in the Paris Agreement, which provides for the reduction of greenhouse gas (GHG) emissions and carbon neutrality by 2050 (Ministry of Mines and Energy, 2023). This context provides a robust foundation for advancing the energy transition and constitutes a pivotal element in the diversification of the Brazilian energy matrix.

It is evident that Brazil's environmental regulatory framework plays a pivotal role in facilitating this transition. The National Climate Change Policy (PNMC), established by Law No. 12.187/2009, defines targets and mechanisms for mitigating climate change, favouring the adoption of renewable energy sources and encouraging the development of projects that reduce GHG emissions (Brasil, 2009). Furthermore, the New Legal Framework for Basic Sanitation, established by Law 14.026/2020, encourages the utilisation of waste as an energy source, thereby promoting the deployment of biogas and other renewable resources in industrial processes (Brasil, 2020).

Brazilian Law 14.120/2021, which regulates the modernisation of the electricity sector, creates an even more favourable environment for the development of offshore wind and solar energy projects. This is achieved by facilitating environmental licensing and offering tax incentives for investments in renewable energy infrastructure (Brasil, 2021a). Concurrently, the Incentive Programme for Alternative Sources of Electricity (PROINFA) facilitates the incorporation of alternative energy sources, including wind, biomass, and small hydropower plants (PCHs), into the country's energy matrix (Ministério de Minas e Energia, 2023).

Brazil boasts considerable potential for offshore wind energy, largely due to its extensive coastline and the country's extensive experience in the offshore oil and gas sector. The government has enacted amendments to its environmental legislation, thereby facilitating the implementation of offshore wind projects in a manner that is environmentally sustainable, with a view to minimising any adverse impacts on the natural environment and ensuring the preservation of coastal areas (Ministério de Minas e Energia, 2021). The 2031 Ten-Year Energy Expansion Plan already projects a significant increase in installed wind energy capacity, including offshore projects, which could attract foreign investment to the sector (Petrobrás, 2024; Brasil, 2021b).

Green hydrogen has emerged as a promising solution for the decarbonisation

of sectors such as transport and heavy industry, which have proven to be challenging to electrify. Brazil, with its substantial renewable energy resources, offers an optimal setting for the large-scale production of green hydrogen through the utilisation of electricity derived from solar and wind energy sources (Ministério de Minas e Energia, 2021). The National Hydrogen Programme, initiated in 2021, aspires to transform Brazil into a leading global producer and exporter of green hydrogen, aligning the country with global decarbonisation objectives (Petrobrás, 2024).

The Brazilian regulatory environment, characterised by favourable legislation and a robust legal framework, presents an attractive proposition for foreign investment in the renewable energy sector. The streamlining of environmental licensing procedures for clean energy initiatives, coupled with fiscal incentives and legal safeguards, serves to reinforce Brazil's appeal in the context of the global energy transition (Brasil, 2021b). In light of these developments, companies such as Petrobrás are leveraging these opportunities to expand their involvement in renewable energy, aligning their operations with decarbonisation targets and contributing to sustainable development (Petrobrás, 2024).

5. Challenges and Opportunities of the Energy Transition

The energy transition, although a crucial step in addressing climate change, presents a range of challenges and opportunities for Brazil and companies in the sector, such as Petrobrás. This process necessitates a harmonious equilibrium between the incorporation of novel low-carbon technologies and the persistence of oil and gas operations, thereby ensuring a sustainable and gradual transition (Petrobrás, 2024).

5.1. Global Competitiveness in the Renewable Energy Sector

Brazil boasts considerable potential for offshore wind energy, largely due to its extensive coastline and the country's extensive experience in the offshore oil and gas sector. The government has enacted amendments to its environmental legislation, thereby facilitating the implementation of offshore wind projects in a manner that is environmentally sustainable, with a view to minimising any adverse impacts on the natural environment and ensuring the preservation of coastal areas (Ministério de Minas e Energia, 2021). The 2031 Ten-Year Energy Expansion Plan already projects a significant increase in installed wind energy capacity, including offshore projects, which could attract foreign investment to the sector (Petrobrás, 2024; Brasil, 2021b).

5.2. The Necessity for Significant Investment in Technological Infrastructure

In order to facilitate the expansion of renewable energy production capacity and the development of technologies such as carbon capture and storage (CCUS) and green hydrogen, Brazil will require significant investment in infrastructure. This

encompasses the modernisation of the electricity grid, the establishment of hydrogen production hubs and the adaptation of industrial facilities for the large-scale processing of biofuels (Petrobrás, 2023). It is crucial to attract foreign investment in order to render this infrastructure viable, given the necessity for financial and technological resources.

5.3. Gradual Adaptation to Balanced Energy Production

The transition to a cleaner energy matrix necessitates the maintenance of a balance between fossil fuels and renewable sources, particularly in the short and medium term. Petrobras is confronted with the dual challenge of maintaining its profitability from oil and gas production while simultaneously investing in renewable energy projects. It is imperative that this gradual adaptation is implemented in order to circumvent any adverse economic consequences and guarantee that the company can maintain its competitive edge throughout the transition period (Petrobrás, 2024).

Foreign investment in the renewable energy sector is essential if Brazil is to meet its climate change targets. Partnerships with multinational companies, such as Shell in offshore wind projects, provide access to capital and technology transfer. These collaborations strengthen the energy sector and increase Brazil's competitiveness as a global leader in renewable energy (Ministério de Minas e Energia, 2021).

5.4. The Reallocation of Assets Within the Portfolio and the Establishment of New Business Ventures

The energy transition presents Petrobrás and Brazil with a valuable opportunity to diversify their energy portfolio through investment in biofuels, solar energy, wind power and green hydrogen. This enables the development of novel business models and market segments, thereby establishing the country as a focal point for innovation in renewable energies and low-carbon technologies (Ministério de Minas e Energia, 2023).

5.5. Expansion of Biofuel Projects

The production of biofuels represents one of the most promising avenues for contributing to the energy transition, particularly within the context of the transport sector. It is evident that projects such as BioQAV (aviation biofuel) and Diesel R100 are pivotal in reducing emissions and advancing a more sustainable transport matrix (Petrobrás, 2024). This expansion represents a rapid and effective strategy, given Brazil's capacity to produce biofuels from biomass and agricultural waste.

5.6. The Potential for Brazil to Assume a Leading Role in the Export of Renewable Technologies and Products

Brazil is endowed with the natural and technological resources to become a global leader in the export of renewable products and low-carbon technologies, including

green hydrogen and wind energy equipment. The implementation of appropriate policies and continued investment in innovation will enable the country to attract investors and consolidate its role as a strategic supplier of renewable energies to the international market (*Ministério de Minas e Energia, 2023*).

Despite the considerable challenges inherent in the energy transition, including the necessity for substantial investment and the incremental adaptation of energy production, the prospects for Brazil remain equally promising. The diversification of the energy portfolio, the expansion of biofuel projects and the export potential of renewable technologies collectively position the country in a strategic position with regard to the global transition to a low-carbon economy. It is of great significance that companies such as Petrobras are playing an instrumental role in this process, aligning their operations and investments with the global climate goals and promoting a sustainable transition.

6. Final Considerations

The analysis of the energy transition and its alignment with Petrobras' Strategic Plan 2024-2028 demonstrates how Brazil is positioned to achieve a balance between its dependence on fossil fuels and the global imperative to shift towards renewable energy sources. As one of the country's largest energy companies, Petrobras plays a pivotal role in this transformation. The transition from oil and gas to solar, wind, and hydrogen energy is not merely an environmental necessity but also an economic opportunity. It offers Brazil the potential to become a global leader in the renewable energy sector and exporter of low-carbon technologies (*Petrobrás, 2024; Ministério de Minas e Energia, 2021*).

This research highlighted the challenges and opportunities inherent in the energy transition. While the requisite infrastructure investments and the necessity for gradual adaptation present considerable challenges, Petrobras' endeavours to diversify its portfolio through biotechnologies, CCUS (carbon capture, utilisation, and storage), and e-mobility projects reflect its long-term commitment to decarbonisation. The emissions reduction targets set out in the Paris Agreement—requiring a 50% reduction in emissions by 2030 and carbon neutrality by 2050—provide the strategic framework for the company's decisions and inform the alignment of national energy policies (*Ministério da Ciência, Tecnologia e Inovações, 2023*).

The findings serve to reinforce the assertion that Brazil's diversified energy matrix, comprising 48% renewables with a strong focus on hydropower, wind, and solar energy, provides the country with a solid foundation for the transition. Nevertheless, Petrobras' trajectory towards sustainability must meticulously circumvent the dual challenge of sustaining competitiveness in the fossil fuel market while advancing innovative renewable projects. The company's biofuel developments, in particular those pertaining to BioQAV and Diesel R100, represent a tangible step forward in the direction of a more sustainable transportation sector. Offshore wind and green hydrogen projects reflect the company's aspirations to

spearhead the export of clean energy (Petrobrás, 2024).

It becomes evident that the establishment of effective regulatory frameworks is of paramount importance in order to overcome the obstacles that impede the energy transition. Brazil's policies, exemplified by the National Policy on Climate Change (PNMC) and recent legislation supporting renewable energy projects, foster a conducive environment for foreign investments and technological innovation (Brasil, 2009, 2021a).

In conclusion, this study demonstrates that, despite the economic and technical challenges, Petrobras' strategic initiatives, which are aligned with national and international climate targets, reflect a progressive shift towards sustainability. The energy transition is not merely a matter of substituting fossil fuels with renewables; rather, it is an endeavour to establish a sustainable paradigm in which economic growth, environmental preservation, and social equity coexist harmoniously. It is evident that Brazil and Petrobras are well-positioned to assume a leadership role in renewable energy, contingent upon the continuation of strategic investments, regulatory support, and technological advancements that collectively propel progress towards a low-carbon future.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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