Assessing The Viability Of Investment: An In-Depth Analysis Of The Brazilian Renewable Energy Sector

By

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An Undergraduate Thesis submitted in partial fulfillment of the requirements for the

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May 2024

ABSTRACT

Over the past decade, the renewable energy landscape globally has undergone significant transformations. Driven by the need for energy security, national goals, and a push toward net-zero emissions by 2050, the sector has seen substantial shifts. Geopolitical conflicts, such as the Russia-Ukraine war, and rising tensions in the Middle East have intensified concerns about energy security in a world where energy demand continues to grow. This research seeks to identify the factors that have transformed the Brazilian renewable energy sector and to explore potential areas for future investment.

The study examines the renewable energy sector in Brazil from an investment perspective, focusing on the rapid growth in wind and solar energy capacity from 2015 onwards, based on a detailed compilation of primary sources dating back to 2000 (Silva et al., 2023, p. 31). Despite the ongoing energy transition in Brazil, there remains a significant disparity in scholarly attention compared to global discussions, with existing literature either focusing on the historical engineering aspects of energy transitions or the social impacts of renewable energy in Brazil (Silva et al., 2023, p. 25).

Aiming to bridge this gap, the study integrates technological advancements in renewable energy with energy finance insights. The objective is to equip investors with a comprehensive understanding of the policy framework, market dynamics, and associated risks. This involves analyzing country-specific data, reviewing government policies, and conducting case studies on key companies within the sector.

The research is structured into three phases:

1. Macroeconomic Overview and Historical Context: This section provides an overview of Brazil's macroeconomic environment and the historical development of its renewable energy sector, including the roles of government and key stakeholders. It utilizes a variety of primary sources, such as Brazil's annual Ten-Year Energy Expansion Plan and records from relevant governmental and international conferences.
2. Comparative Analysis of Renewable Energy Companies: Focusing on the debt structures of four companies, this phase examines the evolution of their financial strategies through an analysis of financial documents from 2022. Key financial metrics and profitability ratios assess the attractiveness of the companies.
3. Risk Assessment and Financing Mechanisms: This segment conducts a thorough risk assessment and explores financing mechanisms in the renewable energy sector, addressing risk diversification, the role of financial institutions, and public-private partnerships. It aims to connect theoretical concepts of renewable energy finance with practical applications, providing insights into the effectiveness of current financial strategies.

By analyzing the historical evolution and recent developments in Brazil's energy sector and assessing investment opportunities, this study contributes valuable insights for strategic decision-making and the sustainable development of Brazil's energy infrastructure.

Keywords: renewable energy, brazil

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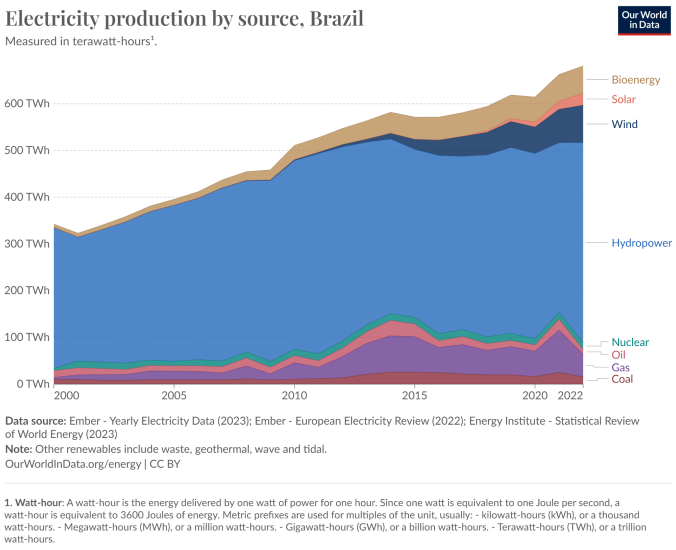
INTRODUCTION: BRAZIL AS A KEY ENERGY PLAYER

Energy serves as a fundamental pillar in Brazil, crucial for both industry and daily life. Historically, the country has relied heavily on hydropower, benefiting from its abundant natural resources. Over the past decade, however, there has been a strategic shift towards diversifying energy sources away from hydroelectric power, driven by the need for energy security and economic growth.



Between 2015 and 2017, Brazil's economy contracted 7.4 percent, influenced by fluctuating commodity prices and a significant national scandal. As part of its response, the government sought to invigorate the energy sector by encouraging foreign investment (Financial Times 2017). Additionally, in 2015, the government initiated auctions for wind and solar contracts as part of their ten-year energy plans, leading to a significant increase in renewable energy production.

The global transition towards renewable energy is driven by international agreements, technological advancements, and the imperative to mitigate climate change. Brazil is uniquely positioned to not only navigate its energy transition but also to influence the global shift towards sustainability. This could potentially position Brazil as a leader in this transformation. According

to Pereira et al. (2023), Brazil's success in this endeavor will depend on the government's response, the availability of investment, and the development of the oil and gas sector, with scenarios ranging from highly beneficial to non-beneficial outcomes for the country.

Hypothesis

This research hypothesizes that the Brazilian renewable energy sector will emerge as a compelling area for investment. By integrating financial analysis, market trends, and policy insights, this study aims to provide valuable information while addressing potential risks. The research anticipates that a comparative analysis of two renewable energy companies, using data from Global Compustat, Bloomberg, and SDC, will reveal insightful patterns and trends. These insights are expected to be instrumental in evaluating investment prospects within the dynamic landscape of Brazilian renewable energy.

Data & Methods

This study will conduct a descriptive analysis of the business and capital structures of two selected publicly traded energy companies in Brazil. Utilizing data from Global Compustat, Bloomberg, and SDC, this methodology will ensure a comprehensive examination of key financial indicators. The analysis will explore business operations and financial intricacies, focusing on historical performance, return on investment, net present value, internal rate of return, capital expenditure, leverage, and profitability ratios. This approach is designed to uncover detailed insights into the renewable energy sector's dynamics in Brazil, contributing to a nuanced understanding essential for informed investment decisions.

BRAZIL MACROECONOMIC OVERVIEW

Brazil, the largest economy in Latin America and the second-largest in the Americas has exhibited resilience with steady GDP growth since recovering from the 2020 recession. Projected to reach a GDP of 2.25 trillion USD by 2024, Brazil's economic landscape appears robust (World Bank, 2024). However, the country faced significant economic challenges beginning in 2014, primarily due to declining commodity prices and political scandals that culminated in impeachment proceedings and reduced investment levels (New York Times 2014). This period of economic downturn was marked by a declining GDP, but recovery has been ongoing since 2017, although the pace of recovery has varied. After the recession in 2020, there was a recovery, with a growth of 4.99% in 2021, followed by 2.91% in 2023. For 2024, the projected GDP growth is estimated to be around 1.5%, suggesting a moderating growth trajectory (World Bank Open, 2024).

Today, Brazil is classified as an upper-middle-income mixed economy (World Bank 2023). Its strong export capacity, particularly in commodities like soybeans and crude petroleum, highlights its integral role in global trade. Brazil's major trading partners include China, with trade valued at $90.1 billion, and the US, at $36.6 billion (OEC,2022). Despite a strong export performance, Brazil's current account balance remains in deficit, reflecting broader economic challenges.

The financial health of Brazil is underscored by its international credit ratings: Standard & Poor's rates Brazil at BB with a stable outlook, Moody’s at Ba2 with a stable outlook, and Fitch at BB

with a stable outlook (Trading Economics, 2024). These ratings reflect a cautiously optimistic view of Brazil's economic stability.

In infrastructure and energy, Brazil's status as an upper-middle-income country supports substantial foreign direct investment inflows, enhancing its capabilities in these sectors. The country has demonstrated significant improvements in business conditions, particularly as the Central Bank of Brazil has embarked on a monetary easing cycle, reducing interest rates to stimulate economic growth and investment in infrastructure projects.

Interest rates in Brazil have been declining, with the Central Bank consistently reducing its benchmark rate by 50 basis points since August 2023, signaling a commitment to maintain this trajectory. This monetary policy is anticipated to support further rate reductions through the latter half of 2024, stabilizing around 9% (Allianz, 2024).

However, project developers in Brazil face challenges, such as an inflation rate nearing 5%, which can lead to cost overruns, particularly in capital-intensive projects like the construction of new solar farms. The transition from imported, subsidized components to potentially higher-cost domestically produced components could increase costs further and affect the pace of solar energy development.

Brazil's solar energy developers are critical to the renewable energy landscape not only in Brazil but across Latin America. As Brazilian firms adjust their procurement strategies from imported

to domestically-produced solar panels and modules, this shift could influence the broader regional market, potentially leading to price increases and efficiency shifts (REUTERS, 2024).

The macroeconomic environment in Brazil, characterized by its efforts to reform and stabilize its economy, presents challenges and opportunities for the energy sector. The government's push for indirect tax reform, aimed at simplifying the tax system and enhancing business productivity, reflects broader efforts to improve the investment climate and support infrastructure development (HBS, 2007).

Investor confidence in Brazil's fiscal policies remains cautious. Public debt at 74 percent of GDP is considered high for an emerging economy, raising concerns about future fiscal stability and its impact on investment (Financial Times, 2024). This cautious outlook emphasizes the need for Brazil to maintain fiscal discipline to attract and sustain investment in its energy and infrastructure sectors.

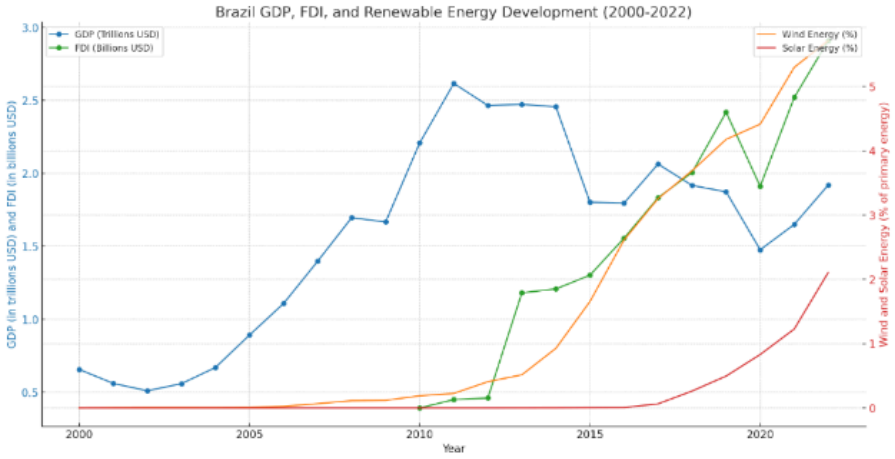
Overall, Brazil's macroeconomic scenario presents a complex but promising landscape for the development of its energy sector, with significant implications for infrastructure development and international investment.

BRAZILIAN ENERGY SECTOR OVERVIEW

Recently, Brazil's renewable energy sector has experienced significant growth. From 2011 to 2021, Brazil’s electricity generation increased by an average growth rate of 2.4% per year,

largely driven by solar power, which saw an increase of 199%, and wind power, which increased by 40%, alongside a 13% increase in fossil fuels (EIA, 2023).

Between 2019 and 2021, the Brazilian Ministry of Mines and Energy reports that Brazil's energy sector received almost 500 billion reais (US$85 billion) in investments, covering electricity generation, power transmission, and new energy sources (Government of Brazil, 2021). This can lead one to believe that these investments are largely contributing to the growth.



- Blue line with circles: Represents the GDP in trillions of USD.
- Green line with circles: Represents the FDI in billions of USD.
- Orange line with crosses: Represents the percentage of primary energy from wind.
- Red line with crosses: Represents the percentage of primary energy from solar.

By 2024, wind, solar, and gas are expected to see the most growth, while hydroelectric plants are anticipated to decline by 5%, as other renewable and alternative energy sources like waste-to-energy and hydrogen gain momentum. With Brazil's energy demand remaining among the world's largest, there are significant opportunities for investors in both conventional sources and renewables(Government of Brazil, 2021).

The regression analysis revealed that the impact of FDI on Wind Energy had an R-squared of 0.077, indicating that FDI only explains about 7.7% of the variability in wind energy development. The P-value of 0.035 suggests that the coefficient for FDI is statistically significant, albeit the level of influence is small. For the impact of GDP on Wind Energy, the study found an R-squared of 0.034, showing even lower explanatory power, with GDP explaining only about 3.4% of the variability. The P-value of 0.168 indicates that the influence of GDP on wind energy development is not statistically significant.

Regarding Solar Energy, the impact of FDI yielded an R-squared of 0.010, very low, suggesting that FDI explains only about 1% of the variability in solar energy development, with a P-value of 0.323 indicating that the influence of FDI on solar energy is not statistically significant. Similarly, the impact of GDP on Solar Energy resulted in an R-squared of 0.034, which, like its impact on wind energy, shows that GDP explains only a small portion of the variability in solar energy development. The P-value of 0.168 shows that the influence is not statistically significant.

These results suggest that both FDI and GDP have had minimal impact on the development of wind and solar energy in Brazil over the past 22 years, with only wind energy showing a slight statistically significant response to FDI. These findings could indicate that other factors, particularly government policies, technological advancements, and international renewable energy trends, have been more influential in Brazil's renewable energy landscape. As such, the study seeks to better understand the importance of policy by analyzing the changes in the entire energy sector to identify where renewable energy can experience the most growth.

Nonrenewable Energy

Petroleum and Liquids

Petroleum plays a major role in the Brazilian energy sector and economy. Brazil's emergence as the 7th largest oil producer globally in 2023 underscores its strides towards energy self-sufficiency. The pre-salt mines which were first discovered in 2006, located in the Santos Basin, allowed Brazil to become self-sufficient in petroleum (Financial Times, 2023). Favorable regulatory policies, including government subsidies and tax reforms, along with the combined expertise of Petrobras and joint venture partners, and technological advancements, have led to a significant decrease in costs. Recently, pre-salt breakevens have fallen from $70 per barrel in 2014 to less than $35 in 2022, attracting greater private-sector participation(Enverus, 2024). In 2022, Brazil reached an average oil production of 3.02 million barrels per day, a 2.47% increase from the previous annual record set in 2020 (The Brazilian National Agency for Petroleum, Natural Gas and Biofuels, 2022).

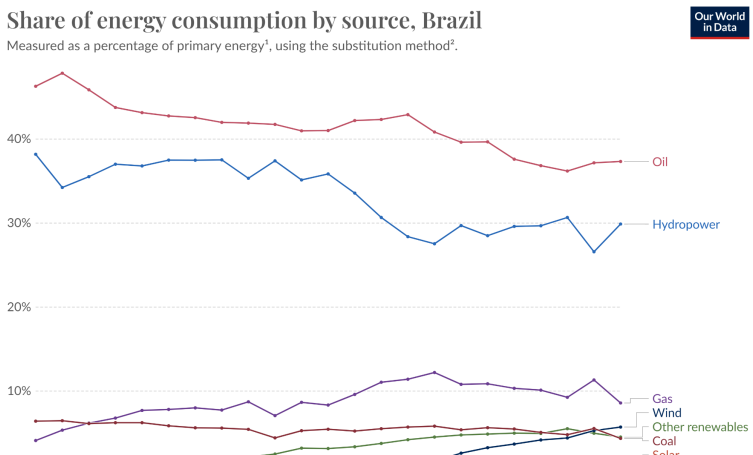
Additionally, as of 2022, crude petroleum stood as Brazil's second-largest export, valued at $43.1 billion, while refined petroleum ranks as the fourth largest at $12.9 billion (UN Comtrade Database). Despite Brazil's status as a significant oil producer, the country still relies on imports, notably diesel. Brazil has increased its diesel imports from Russia by 4,600%, soaring from $95 million to $4.5 billion in 2023 (Financial Times, 2024). Some of this necessity arises from exporting crude oil for processing in refineries abroad and then re-importing the production (Gomes, 2020). Gomes attributes this to the lack of investment in domestic refineries and the fact that Brazilian oil is considered too heavy, which explains why even the discovery of Pre-Salt offshore reserves did not change this scenario. The Brazilian government has cited market

dynamics and the laws of supply and demand as reasons for purchasing discounted oil and diesel specifically from Russia (Financial Times, 2024). Yet, this situation notes the importance that petroleum products still play in the country and for the foreseeable future. Investment in this sector is still underway as indicated on the ten-year energy plans. Under Lula, its state-controlled oil major Petrobras is investing to boost refinery capacity (Financial Times, 2024). The fact remains that much of the Brazilian economy, including agriculture and transportation, depends on diesel.

Brazil has a continued future in petroleum. Brazil is expected to become a large oil-exporting country, and revenues from domestic oil production are expected to increase dramatically (de Oliveira, 2008; Petrobras, 2009). Oil abundance has prompted the view that Brazil can take advantage of the lower cost of domestic crude to speed up industrialization and mitigate social, regional, and environmental problems.

Natural Gas and LNG

Brazil had 13.4 trillion cubic feet (Tcf) of natural gas reserves as of January 2023, the fourth highest in Central America and South America(EIA, 2023). Brazil's natural gas market faces some challenges including the far distances between offshore natural gas fields and the coast as well as limited natural gas pipeline infrastructure. Making Brazil a net importer of natural gas and liquefied natural gas (LNG). The majority of gas is transported via pipeline from Bolivia or through LNG imports from the U.S (Reuters, 2024). The Bolivia–Brazil GASBOL pipeline is the longest natural gas



pipeline in South America. One notable aspect of this new era is the steady decline in Brazil's natural gas imports which has decreased from 19.1 billion cubic meters in 2015 to 6.1 billion cubic meters in 2024 (ANP, 2024). The majority of natural gas is used by industry and not the electricity sector. This decrease in demand also happens as the country boosts its hydroelectric capabilities as well as solar and wind capacity. One exception to this trend was in 2021 when imports rose to compensate for decreased hydroelectric production due to drought conditions. A possible addition of complexity to the natural gas situation is that natural gas imports from Bolivia may not be available after 2029 (Reuters, 2024). One alternative to this is to import natural gas from Argentina but several problems have presented themselves such as Bolivia blocking the use of the GASBOL pipeline and the lack of Argentina's commercial framework and infrastructure to export natural gas (Reuters, 2024).

The Brazilian New Gas Law, approved in 2020, aims to make the market more competitive by liberalizing the sector to create a more efficient system (EIA, 2023). Yet this is still in its development as Petrobras is currently Brazil’s largest natural gas producer, accounting for 64.8% of Brazil’s natural gas production as of July 2023 (ANP).

Yet, Brazil is currently witnessing the construction of new natural gas infrastructure. According to a study by the EPE, there are plans for at least 23 new LNG terminals in Brazil. Two of these terminals are already under construction, while another 10 are in the licensing phase, and 11 are undergoing initial studies. Additionally, three terminals are already operational in Bahia, Rio de Janeiro, and Ceará, intending to provide flexibility in natural gas availability (EPE, 2023). The infrastructure being built, like the new GE Verona Porto de Sergipe combined-cycle gas power

plant, will contribute to energy security in Brazil by helping to meet increasing energy demands and transform the country's power delivery system. With a generation capacity of 1,516 MW, Sergipe will be the largest natural gas power plant in Latin America, capable of satisfying up to 15% of the energy demand in Northeast Brazil alone (Gevenova, 2017). These plans show that there is ample opportunity to develop infrastructure due to rampant demand.

Coal

Brazil has the most coal reserves in Central America and South America, with 7.3 billion short tons as of 2021. This quantity is equivalent to 257 times the annual consumption in Brazil (EIA, 2021). 98% of the coal produced is used for industrial purposes. However, Brazil's coal is unsuitable for use in the domestic steel industry due to its high ash content and low calorific value (OECD, 2020). Consequently, only 26% of domestic coal production is consumed domestically while the remainder is exported. Looking forward there is a limited growth opportunity in this sector beyond the current scope.

Renewable Energy

The renewable energy transition in Brazil has a long history, starting in 1901 with the construction of the first large hydroelectric power plant in São Paulo, which quickly grew to a capacity of 27,379 kW (Ackerman, 1955). In 2018, Brazil announced its goal to source 45 percent of its energy from renewables by 2030, with 23 percent from wind, solar, and biomass. According to the Energy Research Company (EPE), in 2019, 83% of the electric energy generated in Brazil came from renewable sources, with hydropower leading at approximately 63.4% (EPE, 2020). Currently, Brazil's electricity matrix is 84% renewable, showcasing a strong commitment to sustainable sources (ANEEL, 2023). However, there's an expected reduction in

hydroelectric generation's share from 83% in 2021 to 46%, as Brazil diversifies away from this drought-susceptible source (EPE, 2021). Wind and solar are the fastest-growing energy sources, with wind accounting for 10% and solar for 2% of Brazil's generating capacity in 2020. These numbers are projected to rise to 30% and 17% by 2040, largely due to the lower cost of energy produced from these sources (McKinsey, 2021).

With its abundant natural resources, Brazil has significant potential to expand its renewable energy capacity, positioning itself among the sector's leaders. According to ONS, Brazil's solar capacity factor at 28 rivals that of arid nations, while the extensive coastline offers optimal conditions for wind projects with one of the highest onshore wind capacity factors in the world (Mckinsey, 2022). The growing market has attracted substantial foreign direct investment, despite Brazil's historical inclination toward protectionism, which remains evident. Nevertheless, there are instances where a more accommodating approach has been adopted to stimulate growth within the sector.

Hydroelectric

Brazil is a major global producer and consumer of hydroelectric power. In 2024 it remained the largest receivable energy source at 109.949 MW of installed capacity (ANEEL/ABSOLAR 2024). It accounted for about 62.87% of electric production in 2022 (Ember, 2022). From 2005 to 2022, hydroelectric production has fluctuated between 337 and 427 billion kWh (IEA, 2021). However, this relatively stable system requires a reliance on gas-fired units and other thermal power plants to meet peak loads. These additional reserves address seasonal variations in river flows and provide backup when low water levels constrain hydroelectric output (Reuters, 2024). Brazil boasts an abundance of rivers and has constructed many large-scale hydroelectric plants,

most of Brazil's hydropower capacity is located in the north, within the Amazon River Basin. While electricity demand centers are mainly along the southeastern coast (IEA, 2021). In addition to having to travel large distances, the dams bring up environmental concerns.

The Itaipu Dam, located on the Paraná River between Brazil and Paraguay, is the world's third-largest hydroelectric plant. It has 20 generating units, each with a nominal capacity of 700 megawatts, totaling 14 GW of installed capacity. Brazil owns 7 GW of this capacity (EIA, 2021). The dam is managed by the Binational Itaipú, consisting of ELETROBRÁS (Centrais Elétricas Brasileiras S.A. of Brazil) and ANDE (Administración Nacional de Electricidad of Paraguay). Brazil consumes about 93% of the electricity generated by Itaipú, with excess electricity sold from Paraguay as per the terms outlined in Annex C of the Itaipu treaty (Financial Times, 2017). Originally negotiated in 1973, the treaty stipulated that the countries had to sell excess energy to each other at the cost of production, which is around $9 per MWh. However, this has led to controversy and prompted renegotiations since it is much lower than the market price. Since 2009, Itaipú has supplied its power to Paraguay and Brazil at USD 22.6 per kWmonth.

In August 2022, authorities from Brazil and Paraguay announced a reduction in the price of energy from the binational Itaipu power plant from US$ 22.60 to US$20.75 per kilowatt (Mercopres, 2022). Technically, the treaty expired in 2023 and was scheduled to be renegotiated by then, once the debt obligation of the initial capital of USD 100 million was paid off, but no new agreement has been reached to date (IMF, 2021). The final cost of the project ended up being significantly more because of inflation and currency devaluation. Treaty negotiations are expected to last another set of years, but country leaders are aiming to negotiate them as soon as

possible, and they appear optimistic about the process. In the absence of the debt service cost, which constituted around 60 percent of the total cost in 2019, the price charged by Itaipú would be lowered by a similar percentage without additional changes.

However, if Paraguay's focus on sustainable and economic development continues this may lead to changes. If Paraguay moves forward with plans to use excess energy to manufacture green hydrogen, Brazil could lose access to its previously inexpensive energy source (Columbia Review, 2023).

Yet there are still other significant hydroelectric projects in Brazil, such as the Belo Monte Dam, located on the Xingu River in the state of Pará. It has the fifth-highest installed hydroelectric capacity, at around 11,233 MW (EIA, 2021).

All face similar challenges of capital-intensive upkeep and drought sensitivity. Maintenance for the Itaipu Dam is scheduled to be completed under three contracts. The first contract involves the supply of systems, equipment, materials, and services for the generation units, centralized control, auxiliary electrical and mechanical services, 500-kV GIS substation, complementary infrastructure, dam, and spillway. It also includes drafting the executive project and supervision services. This is the largest contract. Qualified groups for the first package include Consorcio Andritz Hydro-ABB, Consorcio CATI (Voith Hydro-Siemens-Tractebel Engineering), and Consorcio GE (GE Energías Renovables-Grid Solutions Transmisión de Energía). Package one was open to firms based in Brazil, while packages two and three were open to firms based in Paraguay (Hydroreview, 2020).The second contract consists of the supply of materials and

equipment for general auxiliary services. The third contract involves electromechanical disassembly and assembly services.

The total value of the project, estimated at US$660 million, was paused due to COVID-19 but resumed in September 2020. GE Renewable Energy's Hydro and Grid Solutions businesses have jointly signed the first contract partnered with the Paraguayan partner companies CIE and Tecnoedil for the second and third (Gevernova, 2022). The power plant upgrade work is expected to span 14 years (Power Technology, 2022). In 2021, GE also won the contract for the Operation & Maintenance of the Igarapava Hydroelectric Plant Rio Grande in the Paraná River Basin, between the states of São Paulo and Minas Gerais in Brazil (Global Energy, 2021).

Brazil has not fully exploited its hydroelectric capacities. It has not seen the construction of a large hydro plant since the Belo Monte complex in the northern state of Para, five years ago. The Belo Monte project faced significant environmental opposition due to its impact on the Amazon rainforest and Indigenous communities, leading to displacement and environmental damage along the Xingu River. This opposition resulted in policies that prohibit new large hydropower plants with reservoirs. Despite this, industry leaders have expressed concerns about these restrictions, arguing that they limit the potential benefits of traditional hydropower by forcing reliance on run-of-the-river power plants, which have their drawbacks.

Nevertheless, hydro dams are increasingly competing with solar and wind power, which are seen as cheaper and more easily deployable alternatives. Despite the environmental challenges associated with hydro projects, Brazil has at least seven hydroelectric power projects with

pending studies that could resume in the coming years, potentially adding around 2.4 GW of capacity. In a shift from traditional large-scale dams, companies are now proposing smaller pumped-storage hydro plants, also known as "reversible" dams. These plants, which do not require large reservoirs, help balance the variability of wind and solar energy by pumping water to an upstream reservoir during periods of low demand and generating power during peak demand times.

However, the regulatory framework for these pumped-storage projects remains underdeveloped. These facilities can offer up to 300 MW capacity, significantly less than Belo Monte's 11.2 GW. As an alternative, small hydro generators, with capacities ranging from 5 MW to 30 MW each, are being considered as more sustainable, lower-impact options (Reuters 2024).

Solar

The Brazilian solar energy market is one of the most attractive renewable sources. According to the Brazilian Association of Photovoltaic Solar Energy (Absolar), in 2024, the country reached 41.1 MW of operational power from photovoltaic solar energy, representing 18% of Brazil's energy matrix, surpassing wind energy at 29.786 MW and second only to hydroelectric at 109.949 MW (ANEEL/ABSOLAR 2024).

The solar sector has been the primary driver of renewable power growth in Brazil, with solar power's share of total electricity generation increasing from 0% to 3% between 2011 and 2021. A pivotal moment occurred in 2017 with the inauguration of three major solar farms: Nova Olinda in Piauí, Ituverava, and Parque Solar Lapa in Bahia, which ranks among the world's largest installations. By 2021, Brazil was 14th globally in installed solar power with 13 GW and 11th in

solar energy production at 16.8 TWh. As of 2022, the country boasted 168 operational solar projects, predominantly in the central and northeastern regions. To further promote solar power development, the Brazilian government has implemented incentives such as tax breaks, financing programs, and net metering regulations.

The segment is expected to see an annual growth of about 23% in photovoltaic capacity, reaching an estimated 68 GW by 2029 (ABSOLAR 2024). Micro and mini solar generation now plays a significant role, with 2,529,251 systems connected to the grid (ANEEL/ABSOLAR, 2024). These installations not only bolster the energy landscape but also qualify for credits from the electric energy compensation system.

In response to this rapid growth, the Brazilian government has implemented a new legal framework for Distributed Generation—electricity produced by consumers, such as through domestic solar panels. In 2012, a new legal act (Normative Resolution no. 482 from ANEEL) established ways for consumers to generate electricity using hydropower, solar, wind, biomass, or qualified cogeneration. In addition, specific financial loans for DG were given by BNDES and the national public bank of Brazil, Caixa Econômica Federal, charging lower interest rates for citizens to finance their projects. Also, in 2015, the DG Development Program for Electric Energy (ProDG) was launched to stimulate DG growth in Brazil (Amaral et al. 2016). Expanding lines of credit for industries in the productive chain of DG to improve technologies, innovation, and human resource promotion were the program’s main actions. All these measures towards the growth of DG helped its progress in recent years. More than 127 thousand consumers currently produce their energy, with a total capacity of around 1.6 GW, which represents 1% of the Brazilian electricity matrix (EPE 2020) Distributed generation has surged by 316% over the last two years, representing about 5% of Brazil's total electricity generation capacity at 8,550 MW by the end of 2021. The Energy Research Company forecasts that Distributed Generation will grow

by 30 GW over the next decade, with expected investments reaching BRL 120 billion between 2022 and 2031 (Government of Brazil, 2022).

Brazil currently holds 27% of the operating or under-construction solar capacity in Latin America, but it leads with 65% of the capacity in the pre-construction phase, making it the primary driver of solar development in the region (Reuters 2024). With 113,147 MW of solar capacity in the pre-construction phase, Brazil ranks second globally, behind only China (241,744 MW) (Reuters 2024). Solar generation is concentrated mainly in the south and southeast, particularly in São Paulo, Minas Gerais, and Rio Grande do Sul, which account for 36.5% of the total capacity (Absolar, 2024). As of October 2022, the average capacity factor is 23% (ONS). Some of the most irradiated Brazilian States are Minas Gerais (SE), Bahia (NE), and Goiás (CW), which have world irradiation level records.

In 2021, the Levelized Cost of Energy (LCOE) for solar energy was around R$ 145 - 184/MWh in the Southeast and R$ 129 - 169/MWh in the Northeast, with a projected decrease of 46% by 2040 (McKinsey 2021). Solar energy LCOE is expected to drop to USD 17-21/MWh by 2030 and USD 13-17/MWh by 2040, making it even cheaper than wind energy. The auction average price per MWh has decreased from USD 103 in 2012 to 32.34 in 2023 (CCEE/ABSOLAR, 2024). Additional opportunities exist in Brazil such as the potential to combine wind and solar energy at the same location, such as in the countryside of the states of Ceará, Piauí, and Bahia, to optimize hydrogen production projects (McKinsey 2021).

However, recent and impending changes to import taxes on panels and other solar components could significantly impact Brazil's low-priced solar sector. Beginning in 2023, the government

abolished previously established import subsidies on assembled solar panels, and starting in January 2024, revoked more than 300 temporary tax reductions on solar modules, mainly imported from China (Reuters 2023). The main aim of these measures is to stimulate demand for locally produced components and products, protect local jobs, and promote the growth of manufacturing sectors linked to clean energy development (Reuters 2024).

However, sustained growth in this sector depends on meeting aggressive timelines for new solar farm installations, rapid connections to the country's grids, and the successful implementation of new power pricing schemes that encourage solar generation, which had been typically promoted by the government. Additionally, solar developers in Brazil face similar challenges encountered globally; however, alternate subsidies continue and are being extended. The discounts that wind and solar projects receive for using the transmission and distribution systems will reach 11.5 billion reais ($2.32 billion) in 2024, according to Aneel general director Sandoval Feitosa (Reuters 2024). These subsidies for renewable sources are paid by taxpayers through the Energy Development Account (CDE), a tariff charge on Brazilians' electricity bills.

According to Absolar, these measures could trigger new investments in the photovoltaic sector, expected to exceed $8 billion in 2024 to meet the locally sourced demands (Reuters, 2023). In 2016, a factory capable of producing 400 MW of solar panels a year opened in Sorocaba in São Paulo, owned by Canadian Solar. A plan to build a solar panel factory in Rio Grande do Norte was announced by the Chinese manufacturer Chint in 2017. BNDES has focused on growing renewable industrial supply chains and has registered 147 photovoltaic solar kit system manufacturers, 8 photovoltaic inverter manufacturers, 12 solar tracker manufacturers, 8

photovoltaic module manufacturers, 5 battery manufacturers, and 3 string box manufacturers under FINAME, a financing program offered by BNDES to support the acquisition of machinery and equipment, as of 2024 (BNDES, 2024). With more investment and technological advances, funding can go further than it used to (IEA 2022). In 2021, several photovoltaic and financial solutions companies expanded their work in Brazil. Companies such as Absolar, Insole, Trina Solar, Alexandria, and Evolua Energia saw significant growth. In addition, traditional energy companies such as Shell and Norway's Equinor began to get involved.

Wind

Brazil's wind resources are significant, ranking 4th globally in wind electricity net generation in 2022, behind Germany (EIA 2022). With 2024 wind energy at 29.786 MW wind power is the fourth-largest source of electricity generation in Brazil after hydropower and natural gas and recently surpassed by solar. In 2021, Brazil had 21 GW of installed capacity and generated 71,500 GWh of wind power, accounting for 11% of the country's total electricity generation. By 2022, the installed cumulative wind energy capacity increased to around 24.16 GW.

The average capacity factor of wind farms in Brazil is over 50%, double the global average (Mckinsey 2021). Some areas, especially in Bahia State, have recorded average capacity factors exceeding 60% (SPE 2014). Wind power generation in Brazil has expanded in recent years due to government initiatives and private-sector investments, leading to increased competition and declining prices (Motor Intelligence, 2023).

The 2021 Levelized Cost of Energy (LCOE) for wind energy in Northeast Brazil is around R$ 119-142/MWh, projected to drop by 27% by 2040 (McKinsey 2021). International equipment

suppliers' increased competition also contributed to lower prices. By 2030, the LCOE for wind energy could reach USD 20-24/MWh, dropping to USD 17-21 by 2040 (McKinsey 2021).

Brazil's power sector regulator Aneel is influential in the electricity sector as it sets the details for PPAs. For the May 27, 2022 auction, A-4, which contracted electricity from hydro, wind, solar, and biomass-based thermal power projects initial contracting prices varied, with wind and solar having lower prices at BRL 225 (USD 45) per MWh for solar and wind compared to hydro and biomass-fired projects BRL 315 (USD 62) per MWh. 75,250 MW have registered with EPE for the bidding process, with 97.4% of the MW coming from wind and solar. The A-4 auction awarded power purchase agreements (PPA) with a 15-year term for wind and solar and a 20-year term for other sources, with power supply starting on January 1, 2026(Renewables Now, 2022). The government also raised the minimum generation capacity for wind turbines to qualify for an import tax exemption. Equipment with power above 7,500 kilovolt amperes (kVA) will continue to be exempt for the next year, compared with 3,300 kVA (Reuters 2023). In 2024 Petrobras plans to buy stakes in domestic onshore wind and solar projects to create a roughly 2 gigawatt renewable energy portfolio, after the previous asset sell-off (Reuters, 2024). This comes as the company seeks to kick-start its green energy transition at the behest of President Luiz Inacio Lula da Silva (Reuters, 2024).

China has become a significant player in Brazil's wind energy landscape, supplying turbine parts and investing in wind farms (IEA, 2013). China began supplying turbine parts back in 2012. This collaboration aligns with the shared interests of Brazil and China to reduce wind component

costs and foster the sector's growth. They have since partnered to create alliances such as the China-Brazil Center for Climate Change and Energy Technology Innovation (CCBCE).

From 2010 to 2014, several Chinese companies, including XJ Wind Power and CTGC, entered into agreements to develop wind projects in Brazil. In a milestone development in 2011, Desenvix, a Brazilian renewable power generating company, made history by being the first South American developer to acquire Chinese wind turbines. However, this collaborative effort faced a setback when Desenvix filed a court case against Sinovel, alleging the theft of turbine software codes from a former supplier. While the case, which involved the alleged presence of stolen codes in the purchased turbines, was dropped within a month, it underscored the challenges that may arise in foreign collaborations within the sector (Financial Times, 2012).

Other foreign companies investing in Brazil's wind energy sector include Canada’s Brookfield Energia Renovável, Italy’s Enel Green Power, France’s Engie, and local groups like CPFL Renováveis (Financial Times, 2017). Actis, a UK private equity company, has committed $1.4bn, with $900m already deployed in nearly 1,800MW of wind and solar power projects in Brazil through three companies: Atlantic, Echo Energia, and Atlas Renewable Energy. Echo focuses on wind power, while Atlas specializes in solar, contributing to Brazil's renewable energy expansion (Financial Times, 2017).

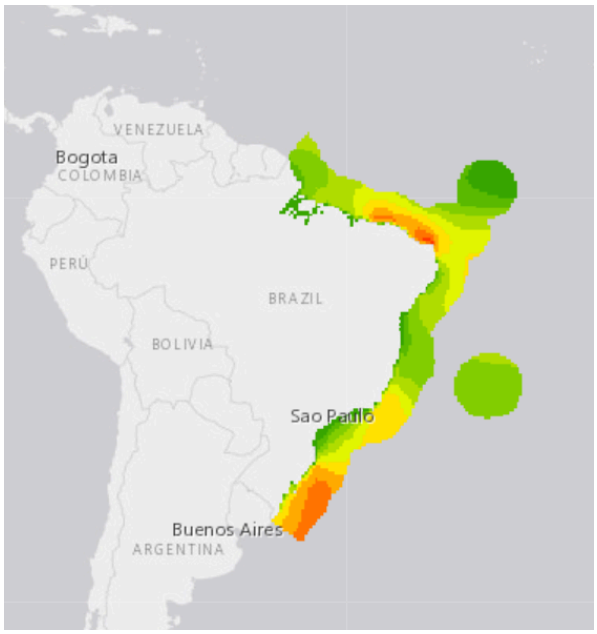
This will change From 2025, all imports of wind turbines will be subject to an 11.2% import tax.

The measure should benefit wind turbine manufacturers, who had complained of increased competition from imported products while the local industry shrank as some global companies stopped producing in Brazil (Reuters, 2023).

Onshore v. Offshore

Brazil has only onshore wind farms as of 2022 due to their lower costs and greater flexibility than offshore projects (EIA, 2023). Constructing an onshore wind farm takes two to three years and costs between $1 million and $2 million per project. In contrast, an offshore wind farm takes five to ten years to build and costs between $10 million and $50 million (The World Bank, 2020). The Brazilian Offshore Roadmap estimates that onshore takes an average of four to eight years for development, preconstruction, and construction whereas offshore takes seven to 11 years (PUPPIM, 2018).

The World Bank has identified three shelves with potential along Brazil's coast, all with average wind speeds exceeding 7 m/s:



1. The northeast coast (São Luis to Natal) has wind speeds up to 9 m/s, with a technical potential of 237 GW for fixed foundations.
2. The southeast coast (south of Vitória) has wind speeds up to 8.5 m/s with technical potential for 67 GW of fixed and 227 GW of floating foundations.

3. The southern coast (from Florianopolis to the Uruguayan border) has the best wind resources of over 9 m/s, with a potential of 173 GW for fixed foundations and 430 GW for floating (World Bank, 2019)

In 2012, Electrobras announced plans to partner with China Three Gorges Corporation (CTGC) to develop an offshore wind project in Jiangsu province, indicating potential synergies between Chinese offshore experience and Brazil's offshore wind development.

Private actors have emphasized the need for a more established framework and regulation. In 2020, the EPE began research by publishing the offshore roadmap for wind energy. In 2022, the Brazilian Senate passed a bill proposing a regulatory framework for offshore wind projects, Decree No. 10,946/2022. This Decree outlines the rules for allocating the use of 'physical spaces and natural resources' to generate energy from wind in inland waters, territorial sea, exclusive economic zone, and continental shelf under Brazil's domain. The Decree represents a significant milestone in the regulatory development of Brazil's offshore wind sector.
Furthermore, in November 2023, Bill PL 11247/18 was passed by the Brazilian Congress. This bill, which still requires approval from the Senate, allows offshore areas to be granted through authorization or concession by the federal government (Norton Rose Fulbright, 2023).

Brazil’s Institute for the Environment and Natural Resources (IBAMA) received 71 applications for offshore wind projects, totaling 176.6 GW in proposed capacity (Offshore Wind, 2022).

Mauricio Tolmasquim, Chief Energy Transition and Sustainability Officer at Petrobras stated that Petrobras expects the Brazilian government to hold its first auction for offshore wind areas in 2024 (Reuters, 2024). Many projects will be done in partnerships with other firms, with Petrobras' stake expected to be 50% or lower. Petrobras and Norwegian energy provider Equinor signed an agreement to evaluate the development of seven wind projects offshore Brazil (Reuters, 2023). These projects would deliver a combined capacity of 14.5 gigawatts of power, with production starting in six to ten years. The study phase of the project will last until 2028, focusing on wind conditions in the North and North East of Brazil, as well as regulatory and licensing requirements (Reuters, 2023). Prates added that Petrobras is looking forward to the approval of a regulatory framework for offshore wind by Brazil's Congress, which was expected by the end of 2023.

Shizen Energia do Brasil (6), SPE Bravo Vento(5), Shell Brasil Petróleo(6), Ventos do Atlântico(5), Bluefloat Energy do Brasil (7) and Equinor Brasil Energia (6) have all applied for environmental licensing projects for more than 14,000 MW (Ibama, 2023).

Biomass

Brazil's biomass and waste market generated 8% (approximately 51,435 GWh) of total electricity generation in 2021. As of 2020, approximately 92% of this electricity was generated by primary solid biofuels, 4% by industrial waste, 3% by biogases, and 1% by liquid biofuels. In 2021, Brazil's installed capacity from biomass and waste reached 16 GW, making it the world’s third-largest biomass and waste electricity generator. Due to the increased competitiveness of wind and solar generation, the share of biomass and waste electricity generation among non-hydroelectric renewables declined from 92% in 2011 to 37% in 2021.

The biomass power sector in Brazil is closely linked to the production of sugarcane ethanol, a key player in the transportation industry. Brazil, with the world's largest sugarcane crop, is also the top ethanol exporter globally. In response to the 1973 oil crisis, Brazil initiated the Pró-Álcool program in 1975. This government-funded program aimed to replace fossil fuels with ethanol in automobiles, successfully reducing the number of gasoline-fueled cars by 10 million and lessening the country's dependence on oil imports. Brazil boasts the largest fleet of flex-fuel vehicles globally, with flex-fuel vehicles accounting for 85% of cars on the road and 83% of new light vehicle sales in 2022(USDA 2020). Since 1977, Brazil has had a mandatory ethanol-use mandate, requiring a certain percentage of ethanol to be blended with gasoline.

As of 2022, Brazil had 230 biomass and waste power plants in operation, with 12 more announced to open. Brazil produced 451,000 barrels per day of fuel ethanol in 2021, accounting for 26% of global output (USDA 2020). However, a drought and low temperatures during the crop production cycle limited sugarcane productivity, leading to a 15% decrease in fuel ethanol production compared to 2020. Due to the seasonal nature of biofuel production, Brazil imports biofuels during off-peak periods to meet demand. In 2021, the country consumed 569,000 barrels per day, with bioethanol constituting 79% and biodiesel 21%.

Investment in corn ethanol production has grown, particularly in Brazil’s Center-West region, with an estimated production of about 2.5 billion liters in 2020/21. The sector is expected to expand, potentially reaching over 5.5 billion liters per year if all ongoing projects are completed (USDA 2020). The near-term investment outlook for liquid and gaseous biofuels depends

heavily on government policies (IEA 2021). Brazil's ethanol consumption is forecast to grow to 43 billion liters by 2029, supported by the country's carbon credits program, RenovaBio, with corn-based ethanol projected to expand to 8 billion liters by 2028 (USDA 2020).

Green Hydrogen

While less developed than other technologies, green hydrogen holds significant potential in Brazil, especially outside the electricity sector, similar to biomass. Although the technology is currently expensive, Brazil boasts competitive energy processes, an expansive renewable energy matrix, and a robust grid, creating ample scalability (BCG 2023). The Three-Year Plan 2023-2025 outlines actions that will pave the way for Brazil to establish itself as the largest and most competitive producer of low-carbon hydrogen in Latin America by 2035. The government has initiated programs such as the Fuel of the Future program to support this endeavor (IEA, 2023).

McKinsey's study in late 2021 concluded that Brazil is "one of the most competitive places in the world" for producing green hydrogen. Brazil's technical potential for hydrogen production exceeds 480 megatons per year, with $30 billion in announced projects for low-carbon hydrogen already underway as of 2023 (Brazil National Hydrogen Program Three-Year Work Plan, 2023-2025). The levelized cost of hydrogen in Brazil is estimated to reach around $1.50/kg by 2030. The total revenue opportunity from low-carbon hydrogen is projected to be between USD 15-20 billion by 2040, with the majority serving the domestic market, especially in trucking, steel production, and other energy-intensive industries. Currently, 87% of hydrogen production in Brazil comes from steam reforming of natural gas for domestic consumption in refineries and fertilizer factories (Brazil National Hydrogen Program Three-Year Work Plan, 2023-2025).

Currently, infrastructure is being built to aid this mission. Several Brazilian ports, including Pecém (Ceará), Suape (Pernambuco), Açu (Rio de Janeiro), and Rio Grande (Rio Grande do Sul), are mobilizing efforts to establish hydrogen production plants. Considering the projects announced until 2021, Brazil is poised to become one of the main global exporters of hydrogen by 2030 (IEA, 2022). In 2022, Shell and Brazil's Porto do Açu agreed to jointly build a 10-megawatt green hydrogen plant in Rio de Janeiro. The plant is expected to be completed by 2025 (Reuters, 2022).

The northeast region of Brazil, known for its favorable wind conditions, is expected to become a major hydrogen producer. Shell, among other major players, is developing a pilot plant expected to be operational by 2025. Green hydrogen projects worth around $30 billion have been announced, with additional revenue potential from exports to the US and Europe (Financial Times, 2024). McKinsey's study suggests that Brazil could capture 10-15% of global exports by 2030 (McKinsey 2021).

However, there are obstacles for green hydrogen to take off in Brazil. A regulatory framework is crucial to provide legal certainty for investments. Experts suggest that the government should create subsidies for this market. Alexandre Silveira, Brazil’s energy and mines minister, acknowledged the difficulty in funding large government subsidies due to budget constraints (Financial Times, 2024). Brazil is not the largest allocator of public money and this is the gap that private investment can fill (Energy Policy Tracker, 2021). The EU in June even pledged €2bn for green H2 production in the country (Financial Times, 2024).

To produce green hydrogen, Brazil needs to accelerate the expansion of its power infrastructure by 7% annually, which is 3 percentage points higher than the recent 4% annual expansion rate. By 2030, an additional 19-39 GW of power would be required, increasing to 129-178 GW by 2040 (Financial Times, 2024).

Nuclear

Nuclear energy contributed approximately 4% to Brazil's electricity generation in 2000 and in 2022 was about 2%. Eletronuclear, a subsidiary of Eletrobrás, holds a monopoly on nuclear power generation (EIA 2023). Brazil's nuclear power plants, Angra 1 and Angra 2, located in Angra dos Reis, Rio de Janeiro state, have a combined capacity of around 2 GW. Angra 1 has been operational since 1985, while Angra 2 started operating in 2001. Angra 3, initially planned in 1984, has faced delays but is expected to begin operating in 2028 with a capacity of 1.4 GW.

Brazil was the top generator of nuclear electricity in Central and South America in 2021, producing 15 billion kilowatt-hours (EIA 2023). These nuclear plants provide consistent baseload electricity, contributing to energy security and grid stability. Brazil possesses significant uranium reserves and can mine, process, and enrich uranium. The state-run Industrias Nucleares do Brasil (INB) is the country's only uranium producer. In 2022, a constitutional amendment allowed the private sector to enter the uranium industry.

Energy crisis in Brazil

Energy crisis in Brazil have been recurring. Notable instances include those in 1973, 2001-2002, and most recently in 2021-2022. Water reserves at hydropower plants hit their lowest level in 91

years in 2021 (Reuters, 2021). Low rainfall in early 2022 caused a 13% decrease in energy production at Itaipu during the first semester of 2022 compared to the same period in 2021, with electricity production dropping to 30,111 GWh from 34,535 GWh (Reuters, 2021). In September 2021, energy prices rose by 7%, raising concern about the impact of these crises on broader economic trends. The government's approach to energy shortages has been regulations that forced producers to ration electricity supply to consumers. This decision resulted in a sudden drop in GDP, reinforcing the belief among many that liberalization and privatization were detrimental to Brazil's economic development (IISD, 2010). A further concern about diversifying the energy matrix arises from scientific estimates suggesting that the flow of the Paraná River may further decline in 15-20 years (Naumann, Gustavo & Podesta, et. al. 2022).

KEY STAKEHOLDERS

Entity	Description
Ministry of Mines and Energy	The Ministry of Mines and Energy is a key government department in Brazil, tasked with the formulation and implementation of energy policies and plans. It collaborates with the Energy Research Office (EPE) to publish ten-year energy plans, conducts studies, selects offshore wind zones, and organizes related auctions, playing a pivotal role in promoting renewable energy development across Brazil.
National Energy Policy Council (CNPE)	National Council for Energy Policy (CNPE) to set energy industry policy and main guidelines focused on sustainable national development. It identifies key investment opportunities in renewable energy, energy efficiency, and the modernization of energy infrastructure, steering the strategic direction of the nation's energy sector.

Brazil Energy Research Enterprise (EPE)	The Energy Research Office (EPE) is a governmental institution in Brazil responsible for developing indicative energy plans. It identifies investment opportunities in renewable energy, including wind, solar, and biomass projects, and provides strategic guidance to the energy sector.
National Electric Energy Agency (ANEEL)	The National Electric Energy Agency (ANEEL) is the regulatory authority overseeing Brazil's electricity sector. It is responsible for implementing reforms to encourage private investment in renewable energy, modernizing the electricity grid, and ensuring a competitive market. ANEEL establishes rules and regulations to promote competition and effectively regulate the electricity sector.
Electric Energy Commercialization Chamber (CCEE)	The Electric Energy Trading Chamber (CCEE) regulates the commercialization of electric energy in Brazil. It plays a crucial role in facilitating the integration of renewable energy into the electricity market, promoting energy trading, and ensuring a stable energy supply across the country.
Agencia Nacional do Petroleo (ANP)	The National Petroleum Agency (ANP) is the regulatory agency tasked with overseeing oil exploration and production in Brazil. Established by Act 9.478 in 1997, ANP facilitates reforms to attract private investment in oil exploration, ensures regulatory compliance, and manages the auctioning of blocks for exploration. It plays a central role in the deregulation and restructuring of the oil sector.
National Petroleum Council (CNP)	The National Petroleum Council (CNP) oversees the entire oil industry in Brazil, playing a crucial role in shaping energy policies. It is instrumental in driving reforms to attract investment in oil exploration and production, promoting sustainable practices, and managing the country's oil resources. According to Peyerl et al. (2019), the CNP was responsible for nationalizing oil even before its discovery within Brazilian territory, highlighting its significant influence in the sector.
Petrobras	Petrobras, a partially state-owned company, was established in 1953 by the Brazilian Government to develop the domestic supply of petroleum products. Over the years, it has undergone numerous reforms aimed at improving efficiency, attracting investment in oil and gas exploration, and adapting to market changes. Initially set up as a monopolistic entity, Petrobras has been pivotal in shaping Brazil's petroleum industry.

BNDES	Brazilian Development Bank, responsible for financing development projects in Brazil. It provides funding for energy infrastructure projects, renewable energy initiatives, and modernizing energy systems.
Electrobras (furnas)	Electrobras Furnas, a subsidiary of Eletrobras, is responsible for operating hydroelectric power plants in Brazil.
Centrais Elétricas Brasileiras S.A. (Eletrobras)	Eletrobras, a state-owned company, was established to coordinate the development of Brazil's national power system, uniting several power utilities under its management.

Federal Government

The Brazilian government holds significant responsibilities in the energy sector, mandated by federal law to lead energy industry planning for the public sector and provide guidance for the private sector (EPE, 2014). Over the years, it has promoted energy development through various stages, encompassing subsidies and tariffs, funding through BNDES, strategic planning via Petrobras, advancing research, and awarding contracts.

Subsidies

Starting with the Getulio Vargas Government (1930–45), Brazil adopted import substitution policies to fuel industrialization, expecting energy to be cheap and abundant to support industrial growth (Lattimore and Kowalski, 2008). Early policies were centered on developing a national energy system with soft financing to establish infrastructure, particularly hydropower in the industrializing southeast. The 1973 oil crisis led to a policy shift, introducing new subsidies to

sustain economic growth and promote ethanol as a gasoline substitute, despite its economic inefficiencies (IISD, 2010).

After the second oil crisis in the late 1970s, the government required Petrobras to establish an oil price stabilization fund to counter crude oil price volatility (Lodi, 1993). Domestic oil prices were adjusted to keep Petrobras refinery costs stable. During this period, inflation was high, and energy prices were adjusted monthly with no relation to opportunity costs. The government committed to reimbursing Petrobras for any losses from underpricing through the oil-price fund. By the end of the 1980s, the fund had accumulated a substantial deficit, leading to challenges in financing Petrobras projects (IISD, 2010).

Post-1988, Brazil shifted towards a more liberal economic framework, ending import substitution policies and opening its market to international competition, especially in the oil sector to bring down prices yet kept ethanol requirements. The 1988 Constitution required competitive licensing for energy resources, leading to the liberalization of the Brazilian economy. By 1995, Petrobras' monopoly was dissolved, and Act 9.478 established a new regulatory regime for the oil industry, designed to expose Petrobras to fair competition and attract international oil companies (IISD, 2010).

Price liberalization has been in effect since 2002, significantly boosting oil exploration and production. Despite this, Brazil's oil import bill constituted a substantial portion of its current account deficit in 1999 due to increased demand at the subsidized price (Baker Institute, 2004). Privatization shifted control from government to private and sometimes foreign ownership.

Despite initial commitments to liberalization, in 2001 the government imposed a new levy (Contribuição de Intervenção no Domínio Econômico - CIDE) on the import and sale of petroleum products due to nationalist criticisms. This levy funded subsidies for ethanol producers, transportation costs for hydrocarbons and LPG for low-income families, environmental protection projects, and road construction.

While privatization reforms seemed comprehensive, Petrobras maintained a de facto monopoly in refining and transporting petroleum domestically. The company retained select areas for oil exploration before bidding commenced for rights in offshore basins, underscoring its enduring influence in the sector.

The 2002 energy crisis influenced election promises to review energy policy. Subsequent regulatory changes created cross-subsidies between power generators and electricity distributors. Plans to liberalize natural gas prices were delayed, affecting the development of gas-fired power plants. In 2008, amid rising global oil prices, subsidies for petroleum products were reintroduced to cushion the economy. Between 1973 and 2001, LPG subsidies accounted for a significant portion of refinery and retail prices, amounting to over US$3 billion, adjusted for inflation (IISD, 2010).

Potential loss of subsidies is under discussion as solar, wind, small hydropower plants, biomass, and qualified cogeneration currently benefit from at least a 50% discount on transport tariffs (transmission or distribution). The expansion of the Free Market for Electricity (ACL) in Brazil has leveraged the low costs of non-conventional renewable sources, supported by transport

subsidies and self-production incentives. While this approach has enhanced the integration of renewables into the energy matrix, the strategy, having met its initial goals, is said to expect revision since it increases charges that all consumers pay (CDE) and leads to higher tariffs in the regulated market (World Business Council for Sustainable Development, 2020).

In the context of modernizing Brazil's electric sector, opportunities to offset the loss of these explicit subsidies exist. The initial incentives for wind and solar energy aimed to enhance their competitiveness within the Brazilian energy system. The market consensus suggests these sources no longer require subsidies, reflected in a 2021 law aiming to phase them out. Despite this, subsidies are expected to increase. Between 2022 and 2023, Aneel approved 142 gigawatts of solar and wind projects eligible for discounts if operational within the specified timeframe (Reuters, 2024).

In 2024, President Lula signed a provisional presidential decree extending the deadline for wind and solar projects to access grid subsidies by an additional 36 months, intended to reduce tariffs using proceeds from the privatization of Eletrobras. The Minister of Mines and Energy stated this decree would facilitate over 30 gigawatts of clean energy in Brazil, potentially attracting R$165 billion in investments and creating over 400,000 jobs. However, the Brazilian Association of Energy Consumers (Abrace Energia) has calculated that this could lead to an annual increase in tariffs of up to R$4.5 billion. The association emphasized the need to evaluate these extensions alongside other measures that could structurally lower power prices (Valor International, 2024).

Petrobras

Petrobras was involved in a political scandal in 2014. In response, the industry began seeing changes, with smaller companies previously subcontracted by larger firms now seeking their own deals. José Martins, president of the Brazilian Construction Industry Chamber, stated, "We're changing the model so that more companies can participate. With more companies involved, competition increases, transparency improves, and the risks of past issues reoccurring are reduced." Despite these challenges, Petrobras remains a significant player in the renewable energy sector under President Lula's administration. By 2028, the company plans to invest $5.2 billion in solar and wind power, initially focusing on onshore plants while also exploring the potential for offshore wind development in Brazil. This was announced as part of Petrobras' new business strategy in November 2024 (Reuters 2024).

Government Contracts (PPAs)

Brazil is advancing its generation capacity through auction-based renewable energy procurement, with contracts typically lasting 15 to 30 years. These auctions facilitate the awarding of power purchase agreements (PPAs) to various generators, providing a competitive platform for developers to secure contracts for selling electricity to distribution companies, thereby reducing investment risks (WBCSD, 2019).

Energy Minister Alexandre Silveira recently highlighted an upcoming auction for developing transmission lines to transport solar and onshore wind energy from the northeast to stations in the south. This auction, with a minimum bid of 16 billion reais, is expected to catalyze up to 200 billion reais ($41.79 billion) in investments.

Additionally, Brazil has introduced the N5X, an energy exchange that represents a first in Latin America (Reuters, 2023). This exchange is designed to enhance operational efficiency and transaction volume between generators and customers by facilitating direct engagements and simplifying the process of securing PPAs. Dri Barbosa, CEO of N5X, noted that this new market structure aims to bridge the gap in the volume of power generation sold through financial products, which currently falls significantly below international averages. The introduction of N5X could provide more opportunities for virtual PPAs, potentially transforming the energy market landscape in Brazil (WBCSD, 2020).

Development Plans

Even before the energy transition, the government established yearly 10-year plans, forecasting and signaling future steps for its institutions.

In 2013, the Brazilian government set the National Plan for Adaptation to Climate Change, aiming to increase climate resilience across 11 sectors and thematic areas, with a focus on industry & mining, and infrastructure. In 2014, they published the Ten-Year Energy Expansion Plan (PDE) 2024, guiding actions to balance economic growth projections and energy supply expansion while ensuring energy security and environmental sustainability. This plan aims to maintain Brazil's significant share of renewable sources, with renewables expected to contribute around 86% of total electricity generation in 2024, including a significant increase in wind power capacity. The government has consistently published this ten-year plan yearly, adjusting its outlook. They have also published the Offshore Wind Roadmap and the Three-Year Plan for Green Hydrogen.

The Paris Agreement, established during COP 21 in 2015, mandates countries to submit non-binding nationally determined contributions (NDCs) outlining climate action plans covering both mitigation and adaptation measures. Brazil's climate-adaptive infrastructure initiatives trace back to COP21, where it articulated its Intended Nationally Determined Contributions (INDC). Brazil introduced an ambitious INDC, targeting a 37% reduction in GHG emissions below 2005 levels by 2025 and a further 43% reduction by 2030, along with an adaptation plan (UNFCC 2023).

Overall, these multi-year plans and research efforts have created a need to advance the sector while allowing for more seamless progress, aligning Brazil's energy strategies with global climate goals.

BNDES

In recent years, Brazil's renewable energy sector has seen substantial growth, driven largely by solar and wind power, with the Brazilian Development Bank (BNDES) playing a pivotal role in shaping this landscape through strategic financing policies.

The BNDES has historically supported the use of locally manufactured equipment in wind projects. This fostered domestic industrial growth and aligned with Brazil's protectionist measures. In December 2012, BNDES introduced a new methodology, replacing the earlier 60% national content requirement for manufacturers and project developers seeking BNDES financing. The revised system allows producers to qualify for preferential funding if they meet a minimum of three out of the following four criteria:

• manufacturing of towers in Brazil, with at least 70% of the steel plates manufactured in the country or domestically reinforced concrete;
• manufacturing of blades in Brazil in their own plant or that of a third party;
• assembly of the nacelle (main part of the wind turbine) in Brazil, in their own plant; and
• assembly of the hub (the part that houses the nacelle) in Brazil, with a domestic dye cast (BNDES, 2012).

This updated methodology not only provides more flexibility for project developers to meet tight deployment timelines but also aligns with Brazil's industrial policy objectives of building high-skilled technical capacity and expertise.

BNDES traditionally offered subsidy-like financing through loans at below-market rates to encourage growth. Its loans grew from less than 8 percent of GDP in 2007 to nearly 12 percent in 2015. The government is now backing changes that from January 2018 would require BNDES to base its standard lending rate on the five-year treasury rate, effectively marking it to market (Financial Times, 2017). Subsidized finance from BNDES that financial packages are no longer available as the government seeks to reduce a fiscal deficit set to 8 percent of GDP (Financial Times, 2017). This pullback from loaning could create a more competitive avenue for private investment to step in.

Additionally, the domestic content policies have their detractors, who argue that such requirements can inflate project costs and stifle competition. Despite these criticisms, the

requirement for a significant percentage of local content in projects eligible for BNDES financing underscores the government's intent to intertwine economic development with energy sector advancements.

Domestic content policies can make projects expensive by excluding competition from imports and data from the International Renewable Energy Agency show that Brazilian wind projects are generally more expensive than those in India and China. However, they are offset by more favorable wind conditions (Financial Times, 2017). The role of BNDES exemplifies the Brazilian government's strategic approach to developing its renewable energy sector, emphasizing not just the growth of energy capacity but also the integration of this growth with broader economic objectives.

World Bank

The World Bank Group (WBG) plays a crucial role in addressing the challenges and expanding the opportunities within Brazil's energy sector. Given the historical difficulties Brazil has faced in mobilizing adequate investment for its infrastructure development, the WBG's involvement is both strategic and multifaceted. Investment levels, hovering just over 2 percent of GDP, have proven insufficient to cover depreciation, exacerbated by cost overruns, delays, and complications arising from contract renegotiations, notably highlighted during economic crises and investigations such as Lava Jato. A core element of the World Bank's strategy is to catalyze infrastructure investment by facilitating private-sector engagement. This is crucial as limited infrastructure remains a significant bottleneck to private investment and economic growth in Brazil. The WBG's efforts are focused on expanding federal government programs to include:

Analytical Support and Advisory Services Technical AssistanceFinancial Innovations: Direct Investments.

The World Bank's involvement extends significantly into renewable energy and energy efficiency to combat climate change. This includes Policy Support: Investment in Energy Efficiency: Promoting energy conservation and enhancing the energy efficiency of industrial facilities and municipal services. This involves leveraging global climate funds such as the Climate Investment Funds (CIF), Green Climate Fund (GCF), and others to mobilize commercial financing and catalyze large-scale investments. Carbon Pricing Instruments: Working with the Ministry of Finance to develop economic instruments for emission reductions, focusing particularly on energy, industry, and agro-industry sectors.

Through the International Finance Corporation (IFC), the World Bank makes direct investments in the renewable energy sector, which aids in diversifying Brazil’s energy matrix. These investments adhere to international best practices for social and environmental standards, ensuring that growth in the energy sector is sustainable and responsible.

The World Bank Group’s comprehensive approach to supporting Brazil’s energy sector underscores its pivotal role in shaping a sustainable and efficient energy landscape. By addressing immediate investment needs and longer-term strategic reforms, the WBG is helping Brazil overcome its infrastructure challenges and achieve its ambitious goals for economic growth and environmental sustainability.

China

China has a substantial impact on Brazil's energy sector, primarily through oil exports and infrastructure investments. As of 2018, oil ranked as Brazil's second-largest export, valued at over USD 25 billion, largely due to demand from China (Brazil, 2019). Brazil is a key oil supplier not only to China but also to the USA, the European Union, and Mercosur countries, particularly Argentina. This places Brazil within the strategic energy interests of these regions.

The relationship between China and Brazil has evolved from focusing primarily on commodity exchange to encompassing broader investments in infrastructure. According to Kevin Gallagher, professor of global development policy at Boston University, recent developments signify a shift towards investments in infrastructure, banking, and the manufacturing sector. In a notable move, China committed $15 billion to a $20 billion bilateral fund primarily for infrastructure projects in Brazil in June of 2017, with Brazilian financial institutions adding the additional $5 billion. This fund was first proposed by Chinese Premier Li Keqiang during his 2015 visit to Brazil (Financial Times, 2017).

However, the operational practices of Chinese companies in Brazil have raised concerns. Brazilian officials have stressed the importance of these companies adhering to local labor requirements, environmental, and social standards. The regulatory environment in Brazil mandates that foreign companies cannot operate as they do domestically in China, ensuring adherence to Brazilian laws and standards.

Overall, China's engagement in Brazil's energy market is marked by significant financial investments and a strategic focus on securing energy resources and developing infrastructure, aligned with stringent local compliance requirements.

Case Study

For the case study, the paper will analyze four renewable energy companies.

1. Renova Energia S.A. operates as a renewable energy generation company in Brazil. It generates electricity through wind, solar, and hydroelectric plants. The company was founded in 2001 and is based in Sao Paulo, Brazil.
2. Serena Energia S.A. generates and sells renewable energy generated through electricity through wind, water, and solar sources. The company was formerly known as Omega Energia S.A. and changed its name to Serena Energia S.A. in December 2023. Serena Energia S.A. was founded in 2008 and is headquartered in Sao Paulo, Brazil.
3. AES Brasil Energia S.A., together with its subsidiaries, engages in the renewable energy generation business in Brazil. The company generates electricity through hydroelectric, wind, and solar sources. Its portfolio of assets has a total installed capacity of approximately 4.5 GW. The company was incorporated in 2020 and is based in Sao Paulo, Brazil. AES Brasil Energia S.A. operates as a subsidiary of The AES Corporation.
4. Auren Energia S.A. engages in the planning, construction, installation, operation, and maintenance of renewable energy generation assets in Brazil. It operates wind, solar, and hydroelectric energy generation systems with a total installed capacity of 3,030 MW. The company was formerly known as VTRM Energia Participacoes S.A. and changed its

name to Auren Energia S.A. in March 2022. Auren Energia S.A. is headquartered in Sao Paulo, Brazil.

The analysis provides a granular look at their financial health, operational efficiency, and strategic positioning within the renewable energy market, offering valuable insights for potential investors and industry analysts.

Renova Energia S.A. shows signs of financial challenges, with the smallest revenue among the companies at 206.403 million BRL and negative Earnings Before Interest and Taxes (EBIT) of -23.725 million BRL. This indicates possible operational inefficiencies or restructuring efforts. The company also exhibits a negative financing cash flow, suggesting difficulties managing financial obligations or restructuring debts. Despite a high Net Profit Margin of 382.04%, Renova has an Operating Margin of -1.15% and a negative Interest Coverage Ratio of -0.37, highlighting its struggles with profitability and debt management.

In contrast, Auren Energia S.A. demonstrates a dominant market position with the highest revenue at 5515.706 million BRL and an EBIT of 808.641 million BRL, underscoring its operational efficiency and strong market presence. However, it also shows the highest level of current liabilities among the companies, suggesting aggressive leveraging and potential risks associated with high debt levels. Despite these liabilities, Auren exhibits the highest Net Profit Margin at 55.25% and a significant Operating Margin of 14.67%, indicating effective cost management and profitability.

Serena Energia S.A. and AES Brasil Energia S.A. both show solid financial management. Serena, with a total revenue of 2436.675 million BRL and an EBIT of 528.36 million BRL, demonstrates profitability and efficient operations. It maintains a healthy liquidity position with a Current Ratio of 5.44 and has a modest Net Profit Margin of 1.34%. AES Brazil stands out for its robust profitability metrics, including a Gross Profit Margin of 45.06% and an Operating Margin of 23.67%. With a Net Profit Margin of 2.05% and an exceptionally high Current Ratio of 10.28, AES Brasil is well-equipped to handle financial obligations and invest in growth opportunities. All companies exhibit significant negative cash flows from investing activities, indicating ongoing investments in capacity expansion and technological advancements. This is consistent with aggressive growth strategies and the capital-intensive nature of the renewable energy sector. The robust positive net cash from financing activities seen in Serena and AES Brasil suggests effective financial strategies to support these expansions, possibly involving new debt or equity financing.

Through this analysis, it becomes evident that each company, despite operating in the same sector, adopts distinct financial and operational strategies. These strategies reflect their respective management’s approach to growth, risk, and sustainability in the competitive field of renewable energy. Understanding these nuances is essential for stakeholders to make informed decisions, align financial strategies with corporate performance, and gauge long-term growth potential within Brazil's renewable energy landscape.

In conclusion, the analysis suggests that investment in AUREN ENERGIA S A could appeal to those seeking stability and market leadership, while AES BRASIL ENERGIA S.A. offers growth potential aligned with significant investment activities.

Investment Risk

Investing in Brazil's energy sector presents significant opportunities and notable risks, primarily due to the country's political and economic landscape. Investors, particularly those from the US and Europe, are primarily concerned with the stability of regulatory policies and the likelihood of their continuity. Over the past two decades, the Brazilian power sector has experienced frequent policy shifts—corresponding with changes in governments—posing a challenge for long-term investments that typically span 20 to 30 years (Financial Times, 2017). This level of policy fluctuation is often viewed as untenable for investors seeking stable and predictable returns.

To attract necessary foreign investment, especially given Brazil's low domestic savings rate, some government-backed financial guarantees may be necessary to mitigate these "tail risks." A positive shift has recently been observed, however, as reflected in the increased competition during auctions for new transmission lines—a stark contrast to previous years where fewer bidders were involved (Financial Times, 2017). This change indicates a growing confidence in Brazil's market stability and future economic outlook.

Currency risk is another significant concern for foreign investors, particularly because power contracts in Brazil are denominated in the local currency, the Brazilian real (Financial Times, 2017). The fluctuating value of the real can significantly affect the profitability of foreign

investments. The currency has been relatively stable since 2020. Additionally. strategies such as using bridge loans and other financial instruments can help mitigate these risks by deferring equity calls and spreading the foreign exchange exposure over a more extended period (Financial Times, 2017). Additionally, most power concessions in Brazil are indexed to inflation, which helps reduce the currency risk over the long term.

In December 2021, Brazil passed Law No. 14,286/2021, establishing a new legal framework for the foreign exchange market and international capital movements. This law allows for the purchase and sale of electricity in foreign currencies and is expected to attract new international generators and financiers, particularly for projects like offshore wind farms that involve significant capital expenditure on imported equipment. The introduction of dollarized Power Purchase Agreements (PPAs) is also anticipated to lower current currency exposure and boost international project financing (Norton Rose Fulbright).

Despite these mitigating measures, the primary risk within Brazil's business environment remains its political instability (Alliance, 2024). This factor can drastically influence both existing and potential investments. Moreover, businesses often focus on the potential profits from entering developing markets while overlooking the "soft infrastructures," such as institutional contexts that are crucial for operational success (HBR). According to a McKinsey Global Survey of Business Executives, while the market size and growth are primary drivers for entering new countries, aspects like political and economic stability and structural conditions also significantly impact decision-making processes.

Finally, public infrastructure in Brazil is highly vulnerable to climate-related shocks, exacerbated by rapid and often unplanned urbanization (OECD). Rising temperatures and frequent droughts pose additional challenges to the energy supply, especially for hydroelectric sources, necessitating further investment in climate-resilient infrastructure.

Investors looking to engage with Brazil's energy sector must carefully weigh these risks against the potential for high returns. Comprehensive risk assessments, including evaluations of political stability, economic conditions, and the effectiveness of regulatory frameworks, are essential for making informed decisions that align with long-term investment goals.

Conclusion

In conclusion, the Brazilian renewable energy sector presents significant opportunities for growth and leadership within the global transition towards sustainable energy sources. However, potential investors must diligently assess the various risks tied to the political, economic, and regulatory landscapes. The investment success will hinge critically on the stability of Brazil's policy framework and the adept financial management of companies within the sector. Effective engagement with these factors is vital for capitalizing on Brazil's extensive renewable resources, thereby enhancing its energy security and economic resilience over the long term.

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