



Assessment of Energy Transition Policy in Brazil

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Abstract

Energy transition is currently vital for national development. Brazil has successfully navigated the energy transition. The country has achieved significant milestones through the development of large-scale hydropower; the expansion of biomass, wind, and solar energy; and the successful implementation of competitive electricity market policies alongside mechanisms to incentivize private investment. These results reflect a long-term strategic vision and the ability to flexibly leverage both domestic and international resources to achieve sustainability goals. This study analyzes Brazil's energy transition policies, evaluates their effectiveness, and identifies remaining limitations.

Keywords: Assessment, Energy Transition Policy, Brazil.

Original Research Article

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1. Introduction

Energy transition has become a global trend driven by climate change, emission reduction commitments, and the need to ensure energy security. For Brazil, this transition is shaped not only by domestic drivers but also by shifts in the international landscape. Global efforts to achieve carbon neutrality, expand renewable energy markets, and develop green finance have pressured Brazil to restructure its energy system (IEA, 2023; IRENA, 2023).

Brazil's energy transition began earlier than that of many other emerging economies, thanks to its abundant natural resources and a clean energy development strategy established in the 1970s. Brazil currently boasts one of the highest shares of renewable energy within the G20 (IEA, 2023). In 2023, renewable sources accounted for approximately 49% of Brazil's total primary energy supply—more than three times the global average of

around 15%—while 89% of its electricity was generated from renewable sources. This demonstrates that Brazil's energy transition extends beyond the power sector, gradually encompassing transportation, industry, and biofuel utilization, thereby fostering a low-emission energy system that is more resilient to international energy market shocks (IEA, 2023; EPE, 2024).

Brazil's energy restructuring has evolved through distinct phases. In the early 2000s, hydropower accounted for approximately 80–85% of national electricity generation, whereas wind and solar power played a negligible role. By 2024, the share of hydropower had declined to approximately 55–60%—not due to a drop in capacity, but rather the rapid expansion of new renewable energy sources. Wind power generation rose from less than 1% in 2005 to about 15–16% in 2024, while solar power grew from near-zero to approximately 8–10%, and



biomass remained steady at around 7–8%. Conversely, the shares of coal- and oil-fired thermal power gradually decreased, with these sources primarily utilized during periods of drought or water shortages affecting hydropower. This shift reflects a trend toward diversifying the power generation mix to reduce reliance on hydropower, enhance climate change resilience, and increase the flexibility of the power system (IRENA, 2024; EPE, 2024).

2. Research methodology

The specific research methods employed will be standard approaches in international economics, such as literature review and document analysis; synthesis and analysis; statistical methods; and comparative analysis.

Literature review method: This involves leveraging findings from prior studies to establish a foundation for the theoretical and practical value of the current project, while simultaneously identifying research gaps that need to be addressed to resolve the project's core problem.

Descriptive statistical method: The study utilizes statistical data and reports from reputable organizations and agencies. The data (comprising both figures and documents) are secondary sources, including: i) Studies and reports by Vietnamese and international scholars from universities and research institutes; ii) Studies, reports, and statistical materials from reliable sources such as the World Bank, the International Monetary Fund (IMF), the United Nations, and the World Trade Organization (WTO); and iii) Relevant published Vietnamese data and documents, including textbooks, specialized journals, and materials from policy-making and management agencies, research institutes, and universities.

Research data are collected and analyzed according to the following steps:

Step 1. Data collection: Data are gathered from the aforementioned sources in alignment with the defined objectives, in both hard-copy and digital formats. A list of these materials is provided in the References section.

Step 2. Data verification: Data are aggregated and verified against criteria ensuring accuracy, relevance, and timeliness. Cross-referencing and comparison are conducted to ensure high reliability for the subsequent analysis.

Step 3. Data analysis: Based on the compiled and screened data, the study conducts analysis, cross-referencing, comparison, and evaluation to derive lessons learned.

3. Discussion

Legal Framework for Energy Transition

Brazil's legal framework for energy transition was established relatively early and has evolved to align the goals of ensuring energy security, reducing greenhouse gas emissions, and fostering green growth. The cornerstone of the energy legal system is the National Energy Policy Law (Law No. 9.478/1997), which outlines principles for sector management, supply diversification, increased renewable energy utilization, and sustainable development. Building on this foundation, Brazil has enacted various specialized laws and strategies to accelerate the energy transition while integrating international climate change commitments into its national legal system.

One of Brazil's most notable policies is the National Biofuels Policy, established under Law No. 13.576/2017. This policy is considered a global pioneer in integrating biofuel market development with carbon credit mechanisms. Known as *RenovaBio*, the policy sets emission intensity reduction targets for the fuel sector, implements an environmental efficiency certification system for biofuel producers, and establishes Decarbonization Credits (CBIOS) to incentivize corporate investment in clean fuel production. A 2024 legal amendment further expanded the scope of participation for independent feedstock producers, refined market mechanisms, and enhanced transparency in carbon credit trading, thereby reinforcing the role of biofuels in Brazil's energy transition. This policy is recognized for simultaneously advancing three objectives: emission reduction, energy security, and the development of the agricultural economy.

In addition to biofuels, Brazil has developed a policy framework to promote renewable energy growth through competitive electricity auctions, investment incentives, and the liberalization of the electricity market. The government regularly conducts long-term auctions to select wind, solar, and hydropower projects at competitive costs, thereby lowering electricity generation expenses and attracting significant private investment. Concurrently, Brazil has implemented policies to encourage distributed solar power development, modernize the grid, expand transmission infrastructure, and enhance the use of digital technologies in energy management. These measures have propelled Brazil to become one of the world's fastest-growing markets for wind and solar energy while maintaining one of the highest shares of renewable energy among major economies (IEA, 2023; IRENA, 2023).

Recently, the Brazilian government has further expanded its policy framework to capitalize on emerging energy trends such as green hydrogen, offshore wind, and the low-carbon economy. The National Hydrogen Program and the Ecological Transformation Plan identify green hydrogen as a strategic industry, aiming to leverage abundant renewable energy resources to produce clean fuel for export. In parallel, Brazil has established a legal framework for offshore wind development to harness the vast potential along its Atlantic coast and attract international energy corporations to the sector. This marks a significant shift from a development model heavily reliant on hydropower to a more diversified energy mix that is better adapted to climate change. However, the process of formulating this legal framework has sparked debate; certain new regulations retain incentives for natural gas and coal to ensure energy security, raising concerns regarding the consistency of decarbonization goals.

Overall, Brazil's legal and policy framework for energy transition is relatively comprehensive, stable, and clearly market-oriented. A key strength of this system is the harmonious blend of administrative tools, market mechanisms, and investment incentives; notably, the RenovaBio program and the electricity auction mechanism stand out as successful models that offer valuable lessons for other developing nations. Brazil's policies not only foster

renewable energy development but also create jobs, boost the competitiveness of the clean energy sector, and improve access to international green finance. However, implementation effectiveness faces challenges such as reliance on oil and gas revenues, transmission infrastructure constraints, regional disparities in development capacity, and the inherent tension between economic growth and emission reduction goals. Consequently, moving forward, Brazil needs to refine its carbon pricing mechanisms, accelerate grid infrastructure development, increase investment in energy storage technologies, and ensure policy consistency to realize its sustainable energy transition objectives.

Implementation Results

After more than two decades of implementing energy transition policies, Brazil has achieved significant positive outcomes across economic, environmental, and energy security dimensions. First, the country has successfully established one of the cleanest electricity systems in the world. Approximately 89% of Brazil's electricity generation comes from renewable sources—far exceeding the global average of around 30%. This results in a carbon emission intensity for Brazil's power sector that is a mere fraction of that found in economies reliant on coal and natural gas (IEA, 2023). Furthermore, diversifying the power mix has mitigated the risks associated with over-reliance on hydropower amidst the increasing frequency of droughts caused by climate change. Economically, the energy transition has helped attract significant domestic and foreign investment into wind and solar power, biofuels, and transmission infrastructure. Brazil is currently the largest renewable energy investment market in Latin America and ranks among the top emerging economies for attracting green investment (IRENA, 2023). The growth of the renewable energy sector has created hundreds of thousands of new jobs in construction, equipment manufacturing, and power plant operations and maintenance, while also fostering the development of domestic supply chains and enhancing technological innovation capabilities. Furthermore, the robust expansion of biofuels and renewable electricity has contributed to reducing fuel

imports, improving the trade balance, and strengthening national energy security.

From a sustainable development perspective, Brazil's most notable success lies in the gradual establishment of a low-carbon energy system that simultaneously ensures economic growth and public access to energy. Brazil has achieved near-universal electricity access and is one of the few major economies with a power mix predominantly based on renewable energy (World Bank, 2023). However, the transition process faces ongoing challenges, such as reliance on oil and gas revenues, the impact of climate change on hydropower, transmission system constraints, and the need for substantial investment in energy storage technologies. Consequently, Brazil's focus for the coming period is shifting from merely expanding renewable energy capacity to enhancing power system flexibility, developing green hydrogen and energy storage, and modernizing the grid to ensure a more effective and sustainable energy transition.

Viewed in its entirety, Brazil's energy transition encompasses three major shifts. First, the shift from ensuring energy security through the development of hydropower and biofuels (1975–2000) to diversifying the energy mix and establishing a competitive electricity market (2001–2015). Second, the transition from a model of direct state investment to a state that fosters and regulates the market, utilizing mechanisms such as auctions, carbon credits, and investment incentives to mobilize the private sector. Third, the move from a primary focus on meeting domestic energy demand to an energy transition aligned with sustainable development, emissions reduction, and the enhancement of Brazil's international standing.

Through appropriate policy adjustments at each stage of development, Brazil has built one of the world's cleanest energy systems while establishing globally competitive industries in sectors such as biofuels, wind power, and solar energy. However, to achieve carbon neutrality by 2050, Brazil must continue to refine its carbon pricing mechanisms, modernize its power grid, develop energy storage technologies, and gradually reduce its reliance on oil and gas extraction. This demonstrates that Brazil's

energy policy not only builds upon past foundations but also undergoes continuous adjustment to adapt to changing domestic and international contexts.

In terms of energy mix, policy frameworks, and implementation outcomes, Brazil is considered one of the most successful emerging economies regarding the energy transition and serves as a model for renewable energy development in Latin America. Unlike many nations that are only just beginning to reduce their dependence on fossil fuels, Brazil established a renewable energy foundation decades ago through the development of hydropower and biofuels, subsequently expanding into wind, solar, and green hydrogen. Approximately 49% of Brazil's total primary energy supply comes from renewable sources—more than three times the global average—while about 89% of its electricity is generated from renewable sources (IEA, 2023). This positions Brazil as one of the few major economies with a low-carbon power system that simultaneously meets the demands of economic growth and expands energy access. Nevertheless, when the energy system is viewed in its entirety, the transition is not yet fully comprehensive, as oil continues to play a significant role in the primary energy mix and remains a major source of economic revenue. This demonstrates that Brazil is pursuing a phased energy transition model, combining robust clean energy development with the prudent exploitation of oil and gas resources to ensure economic growth and stability (IEA, 2023; IRENA, 2023).

Influencing factors

One of the most critical supporting factors is the country's abundant natural resources. Brazil possesses immense hydroelectric potential, high wind speeds in the Northeast, strong solar irradiance, and vast agricultural land, creating favorable conditions for the cost-competitive development of wind power, solar power, and biofuels. This is an advantage few nations enjoy and serves as the foundation for Brazil to maintain a high share of renewable energy over the long term (EPE, 2024).

A second factor is the stable institutional and policy framework. The Brazilian government has established a comprehensive policy system,

including the National Energy Policy Law, the PROINFA and RenovaBio programs, competitive electricity auction mechanisms, and strategies for green hydrogen and offshore wind development. These policies send clear market signals, attract private investment, and foster technological innovation and the development of a competitive energy market. Brazil's electricity auction model is recognized by many international organizations as one of the most effective mechanisms for reducing renewable energy development costs and mobilizing resources from across society (IEA, 2023).

In addition, the active participation of the private sector and the influx of international capital are crucial factors. Thanks to a relatively stable investment environment and significant market potential, Brazil has attracted substantial capital from global energy corporations and international financial institutions such as the World Bank, the Inter-American Development Bank (IDB), and the New Development Bank (NDB). This has contributed to accelerating the modernization of energy infrastructure, the development of new technologies, and the expansion of renewable energy capacity (World Bank, 2023).

4. Conclusion

Despite achieving significant milestones, Brazil's energy transition process still faces several limitations. First, reliance on the oil and gas sector remains a major challenge. Brazil is currently one of the world's largest oil producers, driven by its pre-salt oil fields, and oil and gas revenues play a vital role in the national budget and trade balance. Consequently, the phase-out of fossil fuels must be managed cautiously to avoid adverse impacts on economic growth, employment, and fiscal revenue. As a result, Brazil's energy policy seeks to balance renewable energy development with oil and gas extraction, rather than rapidly phasing out fossil fuels as some developed economies have done (IEA, 2023).

Another limitation is the power system's vulnerability to climate change. Although the country has diversified its electricity sources, hydropower still accounts for more than half of

national electricity generation. Prolonged droughts in recent years have lowered reservoir levels, forcing Brazil to increase reliance on natural gas and oil-fired thermal power plants to ensure a stable energy supply. This indicates that the energy transition process still requires support from solutions such as smart grid development, energy storage systems, and load management mechanisms to enhance the power system's resilience against the impacts of climate change (World Bank, 2023).

Furthermore, Brazil faces constraints regarding transmission infrastructure, regional disparities, and technological capacity. The majority of wind and solar power projects are concentrated in the Northeast, whereas electricity demand is primarily located in the Southeast, placing significant strain on the transmission system. The development of storage technologies, domestic equipment manufacturing, and a high-quality workforce has not kept pace with the rapid expansion of the renewable energy market. Additionally, balancing energy development, the protection of the Amazon rainforest, and social equity remains a major challenge for Brazil's long-term energy transition strategy.

It can be affirmed that Brazil has achieved a high level of energy transition based on criteria such as the share of renewable energy, the power sector's emission intensity, and the diversification of supply sources. This success stems from a combination of resource advantages, consistent policies, effective market mechanisms, and private sector participation. However, the transition remains an incremental process, as the economy still relies heavily on oil and gas and faces ongoing challenges regarding infrastructure, climate change, and the balance between economic and environmental goals. In the coming period, refining carbon pricing mechanisms, developing smart grids and energy storage technologies, and ensuring a "Just Energy Transition" will be decisive factors for Brazil to realize its goal of sustainable energy development and achieve net-zero emissions by 2050.

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