RENEWABLE ENERGY AND ECONOMIC COMPETITIVENESS: INNOVATIVE STRATEGIES FOR A SUSTAINABLE FUTURE

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ABSTRACT

The growing demand for sustainable energy sources has driven the transition to renewable energy, integrating economic development and environmental preservation. In this context, innovative strategies are essential to strengthen the competitiveness of the energy sector by promoting efficiency, innovation, and sustainability. This study adopts a qualitative approach, which is crucial for deepening analyses in the field of renewable energy and economic competitiveness. To conduct this research, two fundamental methodological procedures were employed: a literature review and documentary research. The general objective of this study is to analyze how renewable energy can enhance economic competitiveness through innovative strategies that promote sustainability and socioeconomic development. The analysis of public policies revealed that well-structured government incentives are essential for fostering investments and ensuring the expansion of renewable energy participation in the global energy matrix.

Keywords: Energy sources. Government incentives. Public policies. Competitiveness. Economic development.

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INTRODUCTION

The growing concern with sustainability and the need to diversify the energy matrix have driven the global transition to renewable energy sources. Given the challenges posed by climate change, the depletion of fossil resources, and the volatility of energy markets, it is essential to adopt innovative strategies that reconcile economic growth with environmental preservation.

In this context, renewable energy emerges as a key driver of economic competitiveness, providing greater energy security, long-term cost reduction, and new investment opportunities. Furthermore, the integration of advanced technologies and sustainable business models is reshaping the energy sector, making it more efficient and resilient. However, achieving this transition requires the implementation of appropriate public policies and incentive mechanisms that support the expansion of renewable energy and attract strategic investments.

This study adopts a qualitative approach, which is essential for in-depth analyses in the field of renewable energy and economic competitiveness. Two fundamental methodological procedures were employed: a literature review and documentary research.

The general objective of this study is to analyze how renewable energy can enhance economic competitiveness through innovative strategies that promote sustainability and socioeconomic development. The specific objectives are as follows: - Examine the relationship between the adoption of renewable energy, environmental sustainability, and economic growth, highlighting the benefits and challenges of this transition. - Investigate the role of technological innovation and new business models in advancing the renewable energy sector and generating competitive advantages. - Evaluate the impact of public policies and economic incentives on the expansion of the sustainable energy matrix and the attraction of investments in the sector.

To deepen the discussion, this article is structured into four sections. Initially, the introduction presents the context and relevance of the topic. Next, the methodology section details the research procedures adopted. The theoretical framework is organized into three subsections that address (i) the role of renewable energy in sustainability and economic growth, (ii) technological innovation and sustainable business models in the energy sector, and (iii) public policies and economic incentives for the expansion of these sources. Finally, the conclusion summarizes the main findings of the study and suggests directions for future research.

METHODOLOGY

This study adopts a qualitative approach, which is essential for deepening analyses in the field of renewable energy and economic competitiveness. In the scientific context, qualitative research enables a comprehensive understanding of complex phenomena by considering different perspectives and interpretations (González, 2020).

This approach facilitates a detailed analysis of innovative strategies in the energy sector, providing relevant insights for the formulation of sustainable policies and practices. Two fundamental methodological procedures were employed in this study: a literature review and documentary research. The literature review was conducted based on the analysis of 30 scientific sources, most of which are classified as Qualis A. The literature review is a critical research procedure in scientific inquiry, as it allows for the construction of a solid theoretical framework while identifying advancements and gaps in academic production related to renewable energy and economic competitiveness.

According to Carvalho (2020), the literature review enables the mapping of existing knowledge, contributing to the consolidation of new approaches and perspectives in the investigated field. Additionally, documentary research was carried out, focusing on the analysis of official documents from the National Electric Energy Agency (ANEEL), the Institute for Applied Economic Research (IPEA), the Organization for Economic Co-operation and Development (OECD), and the International Renewable Energy Agency (IRENA).

Documentary research plays a crucial role in obtaining detailed and official information on regulations, guidelines, and energy policies, providing concrete data for understanding the investigated scenario. According to Souza and Giacomoni (2021), this methodological procedure allows for the exploration of primary sources that are essential for building a theoretical and empirical framework grounded in the reality of policies and practices—an equally applicable principle in the context of renewable energy.

Thus, the combination of a literature review and documentary research enhances the robustness and reliability of this study, enabling a well-founded and critical approach to innovative strategies for a sustainable future in the renewable energy sector.

THEORETICAL FRAMEWORK

The theoretical framework of this research is structured into three subtopics, each addressing essential aspects for understanding the role of renewable energy in economic competitiveness and sustainability.

The first subtopic, "The Role of Renewable Energy in Sustainability and Economic Growth," explores the contributions of renewable sources to sustainable development and their impact on the global economy.

Next, the second subtopic, "Technological Innovation and Sustainable Business Models in the Energy Sector," examines how technological advancements and new business models drive the adoption of renewable energy.

Finally, the third subtopic, "Public Policies and Economic Incentives for the Expansion of Renewable Energy," discusses governmental strategies and financial incentives that foster the growth of the sector. This structure provides a comprehensive and well-founded approach to the topic, offering an integrated perspective on the dynamics driving the energy transition toward a more sustainable future.

THE ROLE OF RENEWABLE ENERGY IN SUSTAINABILITY AND ECONOMIC GROWTH

The transition to renewable energy sources represents a crucial element for environmental sustainability and economic growth. Renewable energy sources such as solar, wind, and biomass play a fundamental role in reducing the environmental impacts caused by fossil fuels, as they mitigate greenhouse gas emissions and decrease air pollution (Sotto et al., 2019; Rossi et al., 2024).

The adoption of these alternative sources also directly influences sustainable organizational development, creating new opportunities for companies seeking to integrate socio-environmental responsibility into their corporate strategies (Tachizawa, 2019).

The relevance of this topic was highlighted in 2015 when Heads of State and Government gathered at the United Nations headquarters (USA) to establish the new Sustainable Development Goals (SDGs), consolidated in the 2030 Agenda. SDG 7 (Affordable and Clean Energy) aims to significantly increase the share of renewable energy in the global energy mix by 2030 (UN, 2015).

Furthermore, strengthening the role of renewable energy reinforces the concept of the "sustainability tripod," introduced by John Elkington, which emphasizes the balance between economic, social, and environmental factors. Also known as the Triple Bottom Line, this concept underscores that for a business to be sustainable, it must be financially viable, socially equitable, and environmentally responsible, always striving to maintain this balance (SEBRAE, 2022).

However, achieving this energy transition requires effective public policies and economic incentives to make the implementation of these technologies viable and competitive in the global market. Beyond environmental benefits, the use of renewable

energy stimulates economic growth by generating green jobs and reducing dependence on imported fossil fuels (OECD, 2022a).

Studies indicate that the expansion of the renewable energy sector can lead to significant GDP growth in various nations, strengthening production chains and fostering technological innovation (Nunes et al., 2024). According to the World Resources Institute (WRI), Brazil's GDP could increase by R$2.8 trillion by 2030, generating approximately two million more jobs compared to the business-as-usual scenario.

This transition would open innovation opportunities in renewable energy, transportation, biofuels, and construction (WRI, 2020). Additionally, when comparing Brazil with OECD countries, the renewable energy sector shows significant growth potential, contributing to the diversification of the energy matrix and enhancing national energy security (Gutierrez, 2022).

Nevertheless, the large-scale adoption of these technologies still faces challenges such as high initial installation costs and the need for adequate infrastructure for energy distribution and storage. Given this scenario, it is crucial that governments and businesses develop innovative strategies to enable the expansion of renewable energy. Policies such as tax incentives, subsidies for research and development, and investments in infrastructure are essential to drive this transition (Ceretta, Sari, & Ceretta, 2018).

Moreover, establishing public-private partnerships can foster more efficient solutions to the challenges faced by the energy sector, ensuring a more resilient and sustainable economy in the long term. In this context, a comparative analysis of renewable energy investments and the economic impacts of the transition is presented in Table 1, based on data from the OECD (2022a), illustrating the relationship between economic growth and energy sustainability in different countries.

Table 1 – Economic Growth and Energy Sustainability.

Country	Investment in Renewable Energy (US$ billion)	GDP Growth (%)	Green Jobs Created
Brazil	25	3.2	1.5 million
Germany	40	2.8	2.1 million
USA	60	2.5	3.4 million
China	90	5.1	5.8 million
India	35	4.0	2.3 million

Source: OECD (2022a)

This table demonstrates how different nations have invested in renewable energy and the resulting economic impacts, highlighting the importance of the energy transition for economic growth and the creation of sustainable jobs.

TECHNOLOGICAL INNOVATION AND SUSTAINABLE BUSINESS MODELS IN THE ENERGY SECTOR

Article 7, Paragraph 7 of the Paris Agreement underscores the importance of international cooperation on climate issues, promoting the reduction of technological and financial disparities between the Global South and North. This includes actions such as information sharing, institutional arrangements, strengthening R&D, and exchanging best practices (FKA, 2022).

In this context, technological innovation plays a central role in advancing the renewable energy sector by enhancing its competitiveness and fostering sustainable business models. Emerging technologies, such as advanced energy storage systems, smart grids, and the digitalization of energy systems, have improved efficiency in the generation, distribution, and consumption of renewable energy (Hille, Althammer, & Diederich, 2020).

According to the International Energy Agency (IEA), after 2030, decarbonization efforts will increasingly depend on technologies that are not yet available (IEA, 2021, as cited in Barbosa & Gomes, 2024).

For this progress to continue, humanity must pursue objectives that include reducing natural resource consumption, minimizing waste and emissions, optimizing production processes, and decreasing energy and water usage. Furthermore, clean technologies must be implemented, supply chain management must be improved, and logistical and transportation efficiency must be enhanced. In the context of product eco-innovation, the focus is on mitigating environmental impact throughout the entire product lifecycle, from conception to final disposal.

As noted by Triguero, Moreno-Mondéjar, and Davia (2013), this approach involves modifications in both product design and characteristics as well as its modes of use. The environmental impacts caused by companies are directly linked to excessive consumption of natural resources and energy, as well as the generation of solid, liquid, and gaseous waste. These factors, combined with the quality of life provided by the built environment, reflect the interdependence between the construction industry and the environment. In this context, research on sustainable solutions is essential to promote a paradigm shift in the sector (Brazil, 2022).

The principles observed in nature illustrate that the waste of one species can serve as resources for another, while the sun functions as the primary energy source. This model fosters the creation of value cycles for materials, products, producers, and transporters, prioritizing the use of renewable energy sources and minimizing both waste generation and the consumption of finite resources.

According to Weetman (2016), the pillars of the circular economy include considering waste as inputs for new processes, strengthening resilience through diversity, utilizing renewable energy sources, and adopting a systemic approach. The adoption of renewable energy sources, such as clean energy, aims to reduce natural resource consumption and minimize environmental impacts.

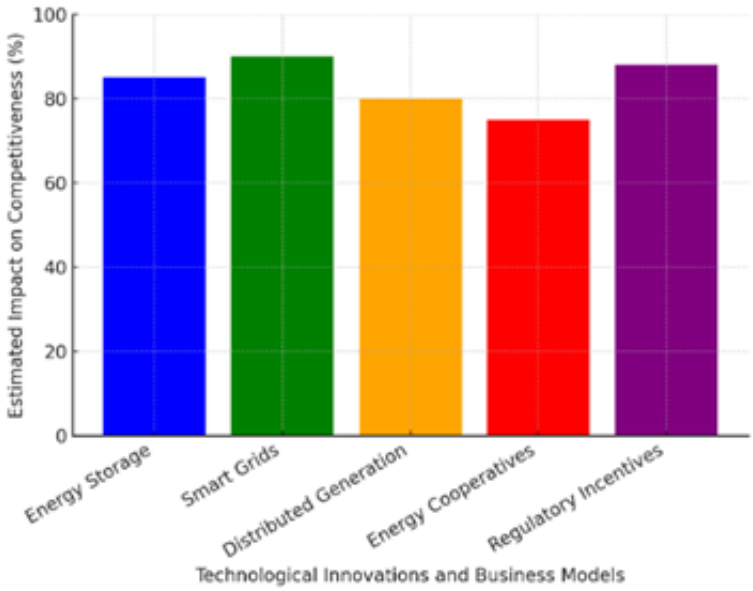
Additionally, empirical studies collect and analyze concrete, measurable, and observable data to test hypotheses, validate theories, and address specific research questions related to this field. One example is high-capacity lithium-ion batteries, which enable efficient storage of energy generated by intermittent sources such as solar and wind, thereby reducing dependence on fossil fuels (Caldeira et al., 2024).

Furthermore, the digitalization of energy infrastructure has facilitated the development of smart grids, optimizing electricity distribution and consumption in real-time, leading to greater stability and reduced energy waste (Koeller et al., 2020).

In this way, technological innovation directly contributes to increasing the share of renewable energy in the global energy mix, making these sources more accessible and economically viable. Alongside technological advancements, the emergence of new sustainable business models has played a crucial role in transforming the energy sector. Energy cooperatives and decentralized energy markets exemplify initiatives that democratize access to renewable energy, allowing consumers to produce, store, and trade electricity autonomously (Levino, Araújo, & Amorim, 2022).

Figure 1 illustrates the impact of technological innovations and business models on the renewable energy sector.

Figure 1 - The Role of Technological Innovations and Business Models in the Competitiveness of Renewable Energy



Source: Hille, Althammer, & Diederich (2020)

The concept of prosumers, where individuals and businesses simultaneously act as both producers and consumers of energy, has been expanding with the growth of distributed generation technologies and local storage systems (Etzkowitz & Zhou, 2017).

This model reduces dependence on traditional utilities and encourages the adoption of renewable energy sources at a local scale, promoting a more equitable and sustainable energy transition. Furthermore, incentive policies and adequate regulations are essential to consolidating these new market models, ensuring legal security and economic viability for the involved stakeholders (OECD, 2022b).

Another relevant aspect for the advancement of the renewable energy sector is the relationship between innovation and regulation, as well-structured public policies can enhance the positive impact of new technologies. Studies indicate that adequate regulatory instruments, such as research and development subsidies, feed-in tariffs, and tax incentives, play a crucial role in accelerating innovation in energy technologies (Ribeiro, 2019).

Additionally, the collaboration between universities, industries, and governments has been a determining factor in the consolidation of the sector, in accordance with the Triple Helix model (Etzkowitz & Zhou, 2017).

The convergence of these sectors drives applied research and the development of more efficient and sustainable technological solutions, fostering a continuous cycle of innovation. Therefore, the adoption of strategic policies and ongoing investments in

technological innovation and sustainable business models are essential to ensure the competitiveness of renewable energies and their effective integration into global economies.

PUBLIC POLICIES AND ECONOMIC INCENTIVES FOR THE EXPANSION OF RENEWABLE ENERGIES

The expansion of renewable energy in Brazil is significantly influenced by public policies and economic incentives implemented to drive the sector forward. The diversification of the Brazilian energy matrix, with an emphasis on utilizing renewable sources such as solar and wind energy, reflects a strategic priority both nationally and internationally. In this context, public policies play a crucial role by establishing a regulatory framework that favors sustainable development, as well as incentivizing investments for the modernization and expansion of the energy sector (Myszczuk & Silva, 2019).

Public Policies in Brazil for Renewable Energies

Brazilian legislation has been fundamental in promoting solar photovoltaic energy, particularly regarding distributed generation. According to Pinheiro, Carvalho, and Machado (2023), Brazilian public policies, such as the Distributed Generation Development Program (ProGD) and resolutions from ANEEL, encourage the adoption of low-cost and sustainable technologies (ANEEL, 2021; 2025).

These programs aim not only to reduce dependence on fossil sources but also to foster the sector's competitiveness, ensuring the integration of renewable energies into the market. The Brazilian government, through tax incentives and facilitated financing, has stimulated the installation of photovoltaic systems in both residential and large industrial settings, expanding the use of these technologies. However, legislation regarding renewable energies in Brazil also faces challenges, such as the need to update regulations in response to the rapid evolution of technologies in the sector.

Morais et al. (2024) discuss that the state's role in diversifying the Brazilian electric matrix requires more dynamic legislation that encompasses new technological solutions and seeks greater integration of renewable energies across different regions of the country. The Renewable Energy Law, for example, aims to create a conducive environment for investments in the sector, promoting research and development, and providing tax incentives for companies in the field.

Economic Incentives and Investments in the Renewable Energy Sector

The United Nations recommends that governments prioritize access to clean energy as a political imperative by defining ambitious goals, plans, and policies, as well as implementing specific projects to achieve access to clean energy. Detailed implementation plans for both on-grid and off-grid solutions should be supported by public investments and backed by technical and financial resources from the international community to achieve tangible progress (UN, 2022, p. 97).

Thus, consistent with the UN recommendations, economic incentives, such as subsidies and tax exemptions, have proven to be effective tools for fostering the expansion of renewable energies. In the global context, the International Renewable Energy Agency (IRENA, 2020) points out that investments in renewable energies have generated positive effects in terms of employment and economic growth. Transitioning to a more sustainable energy matrix not only reduces carbon emissions but also creates a virtuous cycle of job generation and technological innovation.

In Table 2, a comparison is observed between public policies that incentivize solar photovoltaic energy in Brazil and other countries.

Table 2 - Comparison between Public Policies for Solar Photovoltaic Energy Incentives in Brazil and Other Countries

Aspect	Brazil	Other Countries
Tax Incentives	Exemptions on ICMS and IPI for consumers and producers of solar energy (Pinheiro et al., 2023)	Subsidies and tax exemptions in EU countries, such as Germany and Spain
Sector Regulation	ANEEL resolutions and federal laws (Morais et al., 2024)	Flexible legislation and local incentives in countries like Denmark
Public Investments	ProGD and incentives for distributed generation (Pinheiro et al., 2023)	Green financing programs as seen in the US and Asian markets
Social and Economic Impact	Job creation in solar panel installation (Irena, 2020)	Creation of sustainable jobs in leading renewable energy countries like Germany

Source: Pinheiro, Gomes, e Machado (2023)

Moreover, Gramkow (2020) highlights the importance of strategic investments to drive large renewable energy projects, such as the "Big Push," which aim to create transformative impacts for sustainable development. When well-directed, such investments can be decisive in accelerating the energy transition, especially when associated with public policies that promote inclusion and social equity.

FINAL CONSIDERATIONS

The present research fully achieved its objectives by analyzing how renewable energies can enhance economic competitiveness through innovative strategies focused on sustainability and socioeconomic development. Through literature review and documentary research, it was possible to examine in detail the relationship between renewable energies, environmental sustainability, and economic growth, as well as to investigate the role of technological innovation and sustainable business models in the energy sector. Additionally, the impacts of public policies and economic incentives on the expansion of a sustainable energy matrix and the attraction of investments were evaluated.

The results obtained in the theoretical framework reinforce the importance of renewable energies for sustainability and economic growth, highlighting the environmental and economic benefits of transitioning to clean and renewable sources. Furthermore, it was found that technological innovation and new business models play an essential role in facilitating this transition, driving energy efficiency and sector competitiveness. Finally, the analysis of public policies revealed that well-structured government incentives are fundamental to fostering investments and ensuring the increased participation of renewable energies in the global energy matrix.

In light of the findings of this study, it is recommended that future research delve deeper into the socioeconomic impacts of the energy transition in different regional contexts, as well as investigate new approaches for implementing effective public policies to incentivize the sector. Additionally, it is suggested that studies explore the relationship between technological innovation and the generation of sustainable jobs within the renewable energy sector, thus contributing to a broader debate on the challenges and opportunities of this energy transformation.

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