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Renewable Energy and Socio-Economic Transformation: Three Case Studies

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Abstract: Portugal's renewable energy transition plays a pivotal role in addressing climate change, enhancing energy security, and promoting sustainable development. This study examines the socio-economic impacts of renewable energy policies in Portugal from 2014 to 2022, with a focus on financial performance, employment trends, and gender equity. Utilizing financial assessments from the Orbis database and input–output analysis, the research examines three companies—EDP, E-Redes, and Logical Gravity—classified under NACE Rev. 2 code 3513. The study finds that investments in renewable energy improved profitability and solvency, especially during recovery phases, reflecting the sector's financial resilience. Larger firms like EDP experienced employment growth, while smaller firms faced more volatility, highlighting the need for targeted support. Despite progress, gender disparities and pay gaps persist, underscoring the need for gender-sensitive policies. This research provides valuable insights for policymakers seeking to ensure a just and sustainable energy transition, emphasizing strategic investments, workforce adaptation, and inclusivity.

Keywords: renewable energy policies; socio-economic impacts; employment trends; financial performance; gender equity; electricity sector

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1. Introduction

The transition to renewable energy is a critical strategy for mitigating climate change, ensuring energy security, and fostering sustainable development. In Portugal, renewable energy has become a central component of the national energy strategy, with the country's state-owned company, EDP, reporting that 100% of its electricity originates from renewable sources: 34.52% from hydropower, 65.14% from wind, and 0.34% from other renewable sources. This transition has significant socio-economic implications, particularly in terms of employment generation, financial performance, and gender equity. This study aims to explore the complex relationship between energy policies, employment trends, and financial resilience within Portugal's renewable energy sector from 2014 to 2022. Specifically, it examines how renewable energy policies have influenced employment patterns, gender disparities in the workforce, and the financial health of firms in the sector. The study seeks to answer the key research question: How have renewable energy policies in Portugal affected employment, financial stability, and gender equity in the sector?

To achieve this, the paper addresses the following research questions:

1. How have Portugal's renewable energy policies, from 2014 to 2022, impacted employment trends in the renewable energy sector?
2. What is the influence of Portugal's renewable energy transition on gender equity in the energy sector?

3. How have Portugal's renewable energy policies affected the financial stability and resilience of firms in the renewable energy sector?

Additionally, the study tests the following hypotheses:

H1: *Portugal's renewable energy policies from 2014 to 2022 have positively influenced employment trends in the renewable energy sector, leading to job creation and sectoral expansion*.

H2: *Gender disparities in the renewable energy sector in Portugal have decreased as a result of policies promoting gender equity and social inclusivity in the workforce*.

H3: *Renewable energy policies in Portugal have contributed to improved financial resilience in large and medium-sized companies in the sector, but small companies face more significant financial challenges*.

To address these questions, the study employs a multi-method approach, utilizing data analysis from the Orbis database and Quadros do Pessoal. This approach allows for a comprehensive evaluation of the socio-economic impacts of renewable energy policies. Additionally, input–output analysis is used to examine trends and key phases of growth in Portugal's energy sector, providing insights into the effects of renewable energy investments. Portugal's renewable energy transition has been marked by significant investments, particularly after the introduction of ambitious climate policies in the 21st century. These investments have transformed the energy landscape, offering an opportunity to analyze the socio-economic outcomes of such transitions. The importance of renewable energy as a tool to reduce carbon emissions and dependence on fossil fuels makes it crucial to assess its impact on economic sustainability, including employment trends and the financial stability of companies in the sector. The study argues that well-designed energy policies can drive both economic growth and job creation. However, challenges persist, such as the need for government subsidies and external economic pressures, such as the global financial crisis of 2008, which slowed renewable energy development in Portugal. A particular challenge remains the financial resilience of smaller companies in the sector. This research contributes to the existing literature by offering a detailed analysis of how renewable energy policies have influenced employment trends, financial performance, and gender equity within Portugal's renewable energy sector. While prior research has explored the economic impacts of renewable energy, this study provides new insights into gender dynamics and financial performance, especially within Portugal's unique energy transition context. Moreover, it captures the effects of both national and global socio-economic shifts between 2014 and 2022. By integrating financial data, labor market trends, and gender analysis, this paper offers a holistic view of the renewable energy sector's socio-economic impacts in Portugal. The findings are aimed at guiding policymakers in developing strategies that advance environmental sustainability while fostering economic resilience, job creation, and gender equity. Furthermore, the study emphasizes the importance of inclusive workforce policies, particularly in underrepresented areas such as technical and leadership roles, to ensure a more diverse and sustainable renewable energy sector.

2. Green Transition

Portugal's journey towards a green economy has evolved through several key phases, shaped by both domestic policies and broader European initiatives. These phases reflect the country's commitment to renewable energy, the impact of economic crises, and the recovery period following austerity measures. The following section outlines the key stages in Portugal's green transition, focusing on the periods from 2009 to 2022.

1. Early Renewable Energy Efforts (2009–2012). In the early years of the green transition (2009–2012), Portugal made significant strides in renewable energy, particularly in wind, solar, and hydropower sectors. The government introduced strong incentives for renewable energy generation, positioning Portugal as a leader in renewable energy adoption within Europe. This period saw a surge in investments, particularly in 2010 and 2013, possibly aligned with the country's commitment to increasing renewable energy penetration. These investments were pivotal as Portugal's energy landscape began its shift towards sustainability.

2. The Eurozone Crisis and Austerity Measures (2011–2014). The Eurozone financial crisis, which began in 2011, significantly impacted Portugal's economy, leading to austerity measures that constrained public spending across various sectors. Despite these challenges, the government maintained its focus on renewable energy development. However, the economic recession led to a slowdown in investment in some areas, with the energy sector being no exception. The year 2014, marked as an investment year, reflected the early signs of recovery from the crisis, with a renewed focus on growth and sustainability as Portugal began to emerge from the economic downturn. This period was critical in maintaining momentum for Portugal's renewable energy transition amidst a backdrop of financial hardship.

3. Economic Recovery and Energy Sector Modernization (2015–2019). Following the exit from the bailout program in 2014, Portugal entered a phase of economic recovery that laid the foundation for further renewable energy advancements. During this period, the government implemented the National Energy and Climate Plan (NECP) 2030, which set ambitious goals for energy efficiency and the expansion of renewable energy projects. Corporate investments, particularly in energy infrastructure and innovation, surged in 2018 and 2019, reflecting the positive economic environment and government policies that supported green growth. These years marked a turning point as Portugal began to solidify its role as a sustainable energy leader, with significant investments in both technological advancements and the scaling of renewable energy systems.

4. The COVID-19 Pandemic and Green Stimulus (2020). The global COVID-19 pandemic disrupted economies worldwide, but Portugal leveraged this crisis as an opportunity to reinforce its commitment to a green recovery. The European Union's Green Deal and recovery funds played a key role in directing resources toward sustainability and energy efficiency. Despite the challenges posed by the pandemic, the government and companies in the energy sector continued to prioritize green investments. The year 2020, identified as an investment year, is indicative of the sector's ability to maintain momentum in the face of economic disruptions, with a strong emphasis on building a sustainable post-pandemic economy.

5. Accelerated Green Transition under EU and National Initiatives (2021–2022). The years 2021 and 2022 marked an accelerated phase of green transition for Portugal, spurred by both EU-wide initiatives such as the Green Deal and national recovery plans, including the National Recovery and Resilience Plan (PRR). These plans emphasized decarbonization, energy efficiency, and the rapid expansion of renewable energy projects as central components of economic recovery. The EU's financial support through recovery funds provided an important boost for the energy sector, aiming to accelerate Portugal's transition to a greener economy. Despite a slight decline in investments in 2021, the period marked the beginning of a new wave of energy sector investments, with 2022 laying the groundwork for future growth, particularly in line with EU sustainability goals.

3. Literature Review

3.1. Financial Mechanisms and Technological Innovations in Energy Transition

The global transition to renewable energy has been shaped by various socio-economic and geopolitical factors, providing valuable lessons for countries like Portugal. Structural challenges such as external dependencies, financial constraints, and inadequate policies [1,2] have often undermined sustainability efforts, highlighting the need for localized solutions and targeted support to mitigate vulnerabilities and ensure equitable energy transitions [3,4]. This is particularly relevant for Portugal, where small firms face volatility [5], struggling to access financing and navigate complex market conditions effectively [6]. Such barriers emphasize the need for financial and strategic support to enhance the resilience of small- and medium-sized enterprises (SMEs) within the renewable energy sector.

Furthermore, the European Green Deal represents the European Union's comprehensive framework to transition to a climate-neutral economy by 2050, aiming to reduce greenhouse gas emissions, promote circular economy principles, and foster sustainable development. The deal encompasses various key policies, such as the EU Emissions Trading System (ETS), the European Climate Law, and the European Green Recovery Fund, which are designed to incentivize investments in green technologies and renewable energy [7,8]. Moreover, the Green Deal has emphasized the importance of achieving a just transition, ensuring that no region or group is left behind in the shift toward sustainability [9,10]. The Green Deal's focus on economic resilience is also reflected in the EU's efforts to stimulate green innovation and financing, with financial instruments like the EU Taxonomy Regulation and the Green Bond Standard encouraging private investment in sustainable projects [11]. Scholars argue that the Green Deal's success hinges not only on technological advancements but also on social inclusivity and gender equity in its implementation [12,13]. Additionally, the Green Deal is increasingly seen as an opportunity to foster cross-sectoral synergies, particularly between renewable energy, circular economy, and social policies, creating new job opportunities and supporting economic growth [14]. Despite its ambitious goals, critics highlight the challenges in balancing economic growth with environmental goals, particularly in the context of high upfront investments and the uneven pace of technological development [15,16]. Finally, some argue that integrating the Green Deal with broader global climate action efforts, such as the Paris Agreement, is crucial for ensuring the EU remains competitive while also addressing climate change [17]. The literature suggests that while the Green Deal offers significant opportunities, its implementation will require cohesive and coordinated action across policy, business, and societal sectors to realize its full potential [18].

The transition to renewable energy is heavily influenced by financial sustainability, which plays a critical role in advancing these projects. Financial mechanisms such as sustainable finance and green energy markets can drive investments, facilitating a transition to a low-carbon economy [19,20]. In this context, financial processes and investments are particularly significant in driving renewable energy projects in developing countries like Kazakhstan, where securing financial backing and managing financial risks are fundamental to project success [21]. The relationship between financial stability and stakeholder interests also underscores the importance of effective communication and collaboration in ensuring the long-term viability of renewable energy initiatives [22]. However, it is worth noting that the integration of financial institutions with renewable energy technologies in emerging economies can expedite this transition, but the banking sector in these regions may still face significant barriers, such as a lack of infrastructure and access to capital, which can slow progress [23]. Moreover, the environmental and economic benefits of renewable energy are well-documented. For example, life cycle costing (LCC) provides a financial framework that helps evaluate the long-term benefits of solar energy projects [24]. By contrast, the initial costs of implementing renewable energy solutions, especially in less developed regions, may still be seen as a financial burden, despite the eventual positive returns in terms of sustainability [25]. Therefore, it is crucial to strike a balance between immediate financial costs and the long-term economic and environmental returns from renewable technologies.

Technological innovation plays a vital role in the transition to sustainable energy. Advances in renewable energy technologies, such as heat pumps, solar thermal systems, and district heating, have shown potential to reduce energy consumption and emissions [26]. In this framework, the development of non-hydropower renewable sources, including solar, wind, and geothermal energy, is essential for diversifying the energy mix in regions like Central Asia, thereby enhancing energy sustainability [27]. The combination of these technologies offers promising solutions to meet diverse energy needs, particularly in areas with limited energy infrastructure. In addition, technological innovation in the banking sector, especially in emerging economies, is crucial for expediting the adoption of renewable energy. The integration of financial institutions with renewable technologies can play a pivotal role in this process [23]. However, despite the potential for technological optimization in energy systems [28], challenges related to initial investment and the need for government incentives remain. Government policies, such as long-term contracts and incentives, are necessary to strengthen the financial stability of renewable energy companies [29].

Energy transitions are not only technical and financial but also have significant social and economic implications. In particular, ensuring equity and social inclusion is essential during the shift from fossil fuels to renewables. Just transitions, which prioritize social fairness and inclusivity, ensure that no community is left behind [30]. Renewable energy adoption has the potential to contribute to local economic development, as evidenced by the case of Kenya, where renewable projects have supported environmental sustainability and social inclusion [31]. However, the transition could also deepen existing inequalities if marginalized communities, particularly women and rural populations, are not given equal access to renewable energy resources [32]. In this regard, advocating for gender-responsive energy policies, which benefit marginalized communities, especially women, is crucial [33]. In this context, female leadership has been shown to play an instrumental role in addressing climate change, reinforcing the importance of gender equality in sustainability initiatives [34]. Gender-diverse corporate boards, for example, are more likely to invest in renewable energy and adopt stronger environmental practices [26,35]. Moreover, gender-sensitive climate and energy policies are necessary to address the gendered impacts of climate change, especially in regions with stark gender disparities [36,37].

The integration of gender considerations into energy policies is increasingly seen as crucial for achieving a sustainable energy transition. Gender-sensitive energy policies have been found to improve energy access in regions like the Lower Mekong, where gender inequality in energy access remains a significant barrier [38]. In addition, gender-transformative approaches to energy governance, which focus on improving women's access to decision-making processes and resources, have been emphasized as a means to promote more inclusive and effective energy transitions [39]. However, there is a counter-argument that gender equality in energy governance is often sidelined in favor of more immediate economic concerns, such as financial and technological feasibility, leading to slower progress in gender-inclusive energy policies [40]. Moreover, renewable energy projects can also play a significant role in promoting gender equity and social inclusion by reducing energy poverty, particularly in rural areas [41]. These projects can help empower women by providing them with access to sustainable energy sources, thereby improving their social and economic conditions. However, the challenge remains that gender-sensitive policies and initiatives often require significant institutional support, which may be lacking in some countries, particularly those with weaker governance structures [32].

To sum up, the transition to renewable energy involves a complex interplay of financial, technological, social, and gender-related factors. While the potential for renewable energy to drive sustainable development is immense, it is essential to address the financial and social barriers that may hinder its adoption. Stakeholder engagement and inclusive energy policies, particularly those focused on gender equality, are crucial for ensuring that the benefits of renewable energy are shared equitably. In this framework, the role of technological innovation, financial stability, and social inclusivity cannot be overstated, as they are key to achieving a sustainable and just energy transition.

3.2. Gaps in the Literature

The existing literature on renewable energy transitions in Portugal and Europe offers valuable insights into the socio-economic impacts of these shifts, but there are several gaps that need to be addressed. First, while much of the literature focuses on the environmental and technological aspects of renewable energy, the socio-economic dimensions, such as gender equity and the financial resilience of firms within the renewable energy sector, remain underexplored. Specifically, there is a lack of detailed studies examining how renewable energy policies influence employment trends across different demographics, including gender, and how these trends vary over time in response to changing policies. Additionally, while some research has examined the financial sustainability of renewable energy projects, few studies have looked at the financial health of firms within the sector, particularly in the context of small- and medium-sized enterprises (SMEs), which often face different challenges compared to large corporations. This gap is especially important in understanding how policy decisions, such as subsidies and incentives, impact firms of varying sizes and their ability to thrive in a competitive market.

Another key gap in the literature is the lack of a comprehensive approach that integrates financial data, employment trends, and gender equity within the renewable energy sector. While individual studies have explored these areas separately, there is limited research that combines these elements to provide a holistic view of the socio-economic impacts of renewable energy policies. This is particularly important in the context of Portugal, where the country has made significant investments in renewable energy, but the socio-economic outcomes of these investments have not been fully examined in relation to gender dynamics and the financial resilience of firms. This study aims to fill these gaps by offering a multi-dimensional analysis that not only assesses the impact of renewable energy policies on employment and gender equity but also investigates the financial stability of firms in the sector.

Furthermore, much of the existing research on renewable energy transitions focuses on the technological and economic aspects, often overlooking the social and policy dimensions. This study contributes to the literature by incorporating a gender perspective, which is critical for understanding the inclusive nature of the renewable energy transition. By examining how gender disparities have been addressed through renewable energy policies, this research adds a new layer of understanding to the socio-economic impacts of the green transition. Additionally, the study provides a longitudinal analysis of the period from 2014 to 2022, capturing the effects of both national and global socio-economic shifts, including the recovery from the Eurozone crisis and the economic challenges posed by the COVID-19 pandemic. This temporal focus allows for a deeper understanding of how renewable energy policies have evolved and how they have shaped the socio-economic landscape in Portugal.

In summary, this study fills the gaps in the existing literature by offering a comprehensive analysis that integrates financial performance, employment trends, and gender equity in the context of Portugal's renewable energy transition. By focusing on the specific socio-economic impacts of renewable energy policies, this research contributes to a more nuanced understanding of the green transition and provides valuable insights for policymakers, industry leaders, and researchers interested in promoting a more sustainable and inclusive energy future.

4. Data and Methods

4.1. Data Sources

This study adopts a multi-dimensional approach to assess the socio-economic impacts of renewable energy policies on employment within Portugal's renewable energy sector. The analysis integrates data from the Orbis database (https://login.bvdinfo.com/R1/Orbis, accessed on 1 December 2024) [42], input–output analysis from world IO tables (https://www.rug.nl/ggdc/valuechain/wiod/, accessed on 1 December 2024) [43], and employment trends (Quadros do Pessoal available at https://www.gep.mtsss.gov.pt/, accessed on 1 December 2024) [44] to evaluate the relationship between energy policies and socio-economic outcomes.

The primary financial data source is the Orbis database, which provides extensive financial and employment data on global companies. The dataset includes key financial indicators, such as turnover, gross profit margin, net profit, return on equity (ROE), solvency, and current ratio, alongside employment figures. The study focuses on data from 2014 to 2022, specifically targeting the Portuguese energy sector. Initial filtering of the Orbis database identified 28 relevant records for Portuguese companies under NACE Rev. 2 code 3513 ("Distribution of Electricity"). Following additional checks for data completeness, three companies were selected for detailed analysis: EDP, E-Redes (a subsidiary of EDP), and Logical Gravity, Lda, a smaller renewable energy firm. The selection of these three companies was based on their representative roles within different sectors of Portugal's renewable energy transition. EDP is a major energy supplier, providing a comprehensive view of large-scale energy production and distribution. E-Redes, as a subsidiary of EDP, is involved in grid management and the distribution of electricity, thus offering insights into the infrastructure and technological advancements driving the renewable energy transition. Finally, Logical Gravity, Lda represents a smaller, innovative firm contributing to the sector's technological and market diversification in the renewable energy landscape. This selection ensures that the study captures a diverse spectrum of companies, ranging from large incumbents to smaller, more agile players contributing to Portugal's renewable energy transformation. The period of "I–O" analysis (2005–2016) is inconsistent with the period of financial performance analysis (2014–2022). The choice of 2005–2016 for the I–O analysis was based on the availability of historical data that provided insights into sector trends over a longer time frame.

4.2. Methodology

This research employs a mixed-methods approach, combining both financial performance analysis and input–output (I–O) analysis to assess the economic and financial sustainability of companies within the energy sector. The approach integrates quantitative and qualitative techniques to provide a comprehensive understanding of the sector's dynamics. The analysis focuses on three companies of varying sizes (EDP, E-redes, and Logical Gravity), evaluating key financial indicators from 2014 to 2022, and conducting an I–O analysis of energy sector supply and demand relationships from 2005 to 2016.

4.2.1. Financial Performance Analysis

The financial performance of three energy companies—EDP (large company), E-redes (medium-sized company), and Logical Gravity (small company)—was evaluated using key financial ratios, including return on equity (ROE), profit margin, current ratio, and solvency ratio. These ratios were analyzed to identify trends and financial health indicators over time, allowing for comparisons across different company sizes and operational scales.

- Return on equity (ROE) was used to measure the profitability and efficiency in generating returns for shareholders.
- Profit Margin indicated the efficiency of converting sales into profit, showing the ability to manage operational costs.
- Current ratio provided insights into liquidity, measuring the companies' ability to meet short-term obligations with available assets.
- Solvency ratio assessed the financial stability and long-term debt management, indicating the companies' ability to cover their long-term liabilities.

Financial data for each company was collected from annual reports and financial statements, and the trends in these indicators were observed and compared across the years to assess overall financial performance. This quantitative analysis enabled an in-depth understanding of financial trends within different-sized firms in the energy sector.

4.2.2. Input–Output (I–O) Analysis

To understand the broader economic context and the interdependencies within the energy sector, an input–output (I–O) analysis was conducted. This analysis examined the evolution of the technical coefficients for both suppliers and buyers in the energy sector from 2005 to 2016, using data from national I–O tables.

- Suppliers: The analysis focused on the contribution of various industries to the energy sector's supply chain. Changes in the relative importance of these sectors over time were analyzed, revealing shifts in the economic dynamics.
- Buyers: The demand side of the energy sector was also examined, highlighting how various industries have increasingly relied on energy inputs. The evolution of energy consumption patterns was tracked, showing significant increases in energy demand across industrial sectors.

Data for the I–O analysis was sourced from national economic tables, and the coefficients were compared for both suppliers and buyers to identify key shifts in the energy sector's economic dynamics over the study period. This quantitative methodology provided insight into the complex relationships within the energy sector and its influence on broader economic trends.

4.2.3. Comparative Analysis

The financial performance of the companies was compared across the four key ratios, and the findings were interpreted to provide insights into the financial health and stability of large, medium, and small companies in the energy sector. Additionally, the I–O analysis revealed broader economic trends, highlighting the growing importance of energy in industrial production and the increasing complexity of energy supply and demand in the sector. By integrating financial data with I–O analysis, this study provides a comprehensive view of the economic and financial factors driving sustainability in the energy sector. The combined application of financial performance analysis and I–O methodology offers unique insights into the challenges and opportunities faced by companies of varying sizes. This integration ensures a multi-faceted understanding of sector dynamics, which would not be achievable through a single analytical method alone. The use of mixed methodologies enables the triangulation of data, ensuring more robust conclusions.

4.2.4. Employment and Gender Disparities

The study also investigates employment trends and gender disparities within the sector, specifically focusing on the gender pay gap (GPG). By comparing male and female workers' base salaries and total earnings, the study evaluates gender equity in the renewable energy workforce and contributes to broader discussions on diversity and inclusion in energy policy. Qualitative insights are used in conjunction with the quantitative analysis of employment data, ensuring a nuanced understanding of gender dynamics in the energy sector.

5. Results

5.1. Financial Indicators

Tables 1–3 present the financial performance of the three companies—EDP, E-redes, and Logical Gravity—offering insights into their financial health and how this correlates with their renewable energy investments and transitions.

EDP (Large Company)
Return on Equity (ROE)

- EDP's ROE ranged from 8.07% to 13.67%, peaking at 13.09% in 2015. This suggests solid returns on equity, though the decline in recent years reflects the large capital base and the significant financial investments in renewable energy projects. EDP's ongoing shift towards green energy sources requires substantial upfront capital, which could impact short-term profitability.

Profit Margin

- EDP's profit margin fluctuated between 6.57% and 11.35%, with the highest margin recorded in 2020 (11.35%). This indicates strong operational efficiency, particularly in the years when renewable energy projects began contributing more significantly to the revenue stream. The decline in 2022 (7.51%) could reflect the increasing costs related to renewable infrastructure development.

Current Ratio

- The current ratio varied from 0.72 to 1.19, indicating that EDP has generally maintained adequate liquidity, despite its sizable investments in renewable energy. The decrease to 0.88 in 2022 could be linked to higher capital expenditures and the financial pressures associated with these energy transitions.

Solvency Ratio

- EDP's solvency ratio ranged from 23.52% in 2022 to 30.45% in 2020, signaling strong financial health, which is essential for supporting long-term renewable energy projects. The company's ability to meet long-term obligations remains robust, but it is clear that the capital-intensive nature of renewable energy projects could strain solvency in the short term.

E-redes (Medium-Sized Company)
Return on Equity (ROE)

- E-redes' ROE ranged from 17.94% to 54.77%, with a notable decline in recent years. Despite the high returns in earlier years, the drop could be due to significant investments in green energy infrastructure, which may not yet yield optimal returns. E-redes is investing heavily in renewable energy grid integration, which is capital-intensive and impacts short-term profitability.

Profit Margin

- E-redes demonstrated strong profit margins between 7.25% and 16.01%, with the highest margin in 2021 (16.01%). This reflects the company's strong financial performance, particularly during years when renewable energy uptake and energy distribution networks were growing, though margin reductions in later years might signal the increasing cost pressures associated with transitioning to a greener grid.

Current Ratio

- The current ratio ranged from 1.34 to 2.36, indicating a strong liquidity position, which is crucial as E-redes invests in energy transition technologies, such as smart grids and renewable energy infrastructure. The rise in liquidity in 2020 could be linked to financial efficiency during a period of less capital expenditure.

Solvency Ratio

- E-redes' solvency ratio ranged from 19.57% in 2016 to 30.12% in 2022, reflecting strong solvency despite increasing debt due to renewable energy investments. The higher solvency ratio in 2022 indicates an improved financial position, which could be attributed to the company's focus on improving debt management and strategic investments in sustainable energy.

Logical Gravity (Small Company)
Return on Equity (ROE)

- Logical Gravity's ROE showed extreme volatility, ranging from negative values to an extraordinary high of 142.11% in 2021. This volatility is a red flag, as it underscores the financial instability typical of small companies, especially when transitioning to renewable energy sources. Their challenges in managing these transitions are reflected in the instability of their returns on equity.

Profit Margin

- The profit margin varied greatly, from a low of −32.99% in 2022 to a high of 53.15% in 2020. This fluctuation indicates poor financial stability, which is exacerbated by the small company's difficulty in financing and integrating renewable energy projects. The sharp drop in profitability in 2022 points to financial struggles, likely linked to the high capital costs and unpredictable revenue streams associated with green energy investments.

Current Ratio

- Logical Gravity's current ratio ranged from 1.1 to 1.7, which suggests moderate liquidity. However, the relatively weak liquidity position compared to E-redes and EDP makes it harder for the company to absorb the financial burdens associated with renewable energy transitions.

Solvency Ratio

- The solvency ratio was typically negative, indicating the company's inability to meet long-term obligations in most years. This reflects the small scale of the company and its financial instability, exacerbated by large, capital-intensive investments in renewable energy infrastructure.

Comparison of Financial Performance

Table 1. Financial indicators for EDP 2014–2022.

Year	Turnover [1]	Gross Profit [1]	Net Profit [1]	Cash-Flow [1]	Total Assets [1]	Shareholder Funds [1]	Current Ratio	Profit Margin (%)	ROE (%)	Solvency Ratio (%)	Capital [1]
2022	23,015.31	1727.65	724.22	2835.03	62,733.55	14,755.99	0.88	7.51	11.71	23.52	27,237.83
2021	18,129.42	1608.12	743.8	2705.18	57,755.99	15,830.99	1.19	8.87	10.16	27.41	25,037.57
2020	16,597.62	1884.11	982.53	2969.19	52,699.97	16,048.51	1.06	11.35	11.74	30.45	26,006.42
2019	16,878.96	1341.01	574,9	2558.40	47,589.07	14,190.80	0.95	7.95	9.45	29.82	23,035.01
2018	18,137.68	1192.05	594.47	2248.78	47,662.89	14,770.88	0.79	6.57	8.07	30.99	26,000.11
2017	20,127.83	1824.12	1335.02	3344.64	50,460.59	16,166.87	1.13	9.06	11.28	32.04	27,260.82
2016	15,763.64	1423.60	1012.53	2604.54	46,468.66	14,479.50	0.86	9.03	9.83	31.16	25,502.61
2015	17,817.21	1727.73	993.66	2588.09	46,309.99	13,196.67	0.72	9.7	13.09	28.5	24,793.74
2014	20,270.82	1986.58	1263.21	2959.60	52,052.16	14,531.74	0.94	9.8	13.67	27.92	24,917.11

[1] Values in thousand Euros.

Table 2. Financial indicators for E-redes 2014–2022.

Year	Turnover [1]	Gross Profit [1]	Net Profit [1]	Cash-Flow [1]	Total Assets [1]	Shareholder Funds [1]	Current Ratio	Profit Margin (%)	ROE (%)	Solvency Ratio (%)	Capital [1]
2022	1540.20	224.3	138.58	461.65	4152.47	1250.59	1.4	14.56	17.94	30.12	75.34
2021	1607.39	257.28	164.14	494.72	4638.08	1159.55	1.62	16.01	22.19	25	87.37
2020	1671.84	221.4	114.17	442.1	5098.46	1355.87	2.36	13.24	16.33	26.59	104.65
2019	1440.67	189.72	88.05	382.59	4938.97	1282.88	1.61	13.17	14.79	25.98	97.25
2018	2548.90	184.85	141.29	428.15	6117.53	1352.44	1.34	7.25	13.67	22.11	70.76
2017	2962.22	372.75	281.74	579.52	5760.18	1386.90	1.43	12.58	26.88	24.08	163.49
2016	2694.70	354.87	319.4	576.45	5014.55	981.14	1.46	13.17	36.17	19.57	114.07
2015	2936.49	343.28	271.69	533.15	5730.96	831.7	1.45	11.69	41.28	14.51	103.21
2014	3880.91	428.67	274.05	565.57	6658.73	782.65	1.66	11.05	54.77	11.75	90.78

[1] Values in thousand Euros.

Table 3. Financial indicators for Logical Gravity, 2014–2022.

Year	Turnover [1]	Gross Profit [1]	Net Profit [1]	Cash-Flow [1]	Total Assets [1]	Shareholder Funds [1]	Current Ratio	Profit Margin (%)	ROE (%)	Solvency Ratio (%)	Capital [1]
2022	0.9316	−0.307	−0.307	−0.268	0.894	−0.306	1.27	−32.99	.	−34.24	0.14
2021	0.8896	0.0308	0.0207	0.0629	0.809	0.0216	1.22	3.46	142.11	2.68	0.12
2020	0.4914	0.0077	0.0006	0.0245	0.462	0.0144	1.1	1.56	53.15	3.13	0.61
2019	0.3982	0.0229	0.0158	0.0272	0.251	0.0153	1.31	5.75	149.85	6.1	0.33
2018	0.0426	−0.0048	−0.0049	−0.0046	0.0355	−0.0044	1.7	−11.34	.	−12.44	-
2017	-	−0.0007	−0.0007	−0.0004	0.0029	−0.0007	0.68		.	−22.02	-
2016	-	-	-	-	-	-	-	-	-	-	-
2015	-	-	-	-	-	-	-	-	-	-	-
2014	-	-	-	-	-	-	-	-	-	-	-

[1] Values in thousand Euros.

Profit Margin • EDP: Profit margins remained stable, but slightly lower compared to E-redes, likely due to its larger, more diversified operations and the need for greater capital to finance its renewable energy transition. • E-redes: Demonstrated higher profit margins, particularly in 2021, reflecting strong operational performance, but these were impacted by the company's increased expenditure on renewable energy projects. • Logical Gravity: Profit margins were highly volatile, indicating significant challenges in profitability, particularly as the company struggled to finance and stabilize its renewable energy investments.

Return on Equity (ROE) • EDP: ROE remained stable but showed a slight decline, which could be attributed to the growing capital base and the impact of renewable energy investments on short-term returns. • E-redes: ROE was very high in the earlier years but declined over time, suggesting that while the company initially benefitted from efficient renewable energy integration, recent investments have not yet produced the expected returns. • Logical Gravity: ROE was highly volatile, reflecting the instability in managing renewable energy transition costs with limited resources.

Liquidity and Solvency • EDP: Despite the declining current ratio, EDP's strong solvency ratio reflects its ability to finance large renewable energy projects and manage long-term obligations. • E-redes: A solid liquidity position and improving solvency ratio suggest that E-redes is managing its renewable energy investments effectively, despite the challenges of transitioning. • Logical Gravity: The company's weak liquidity and negative solvency ratio signal significant challenges in financing and managing its energy transition, which hampers its long-term sustainability.

In summary, EDP, E-redes, and Logical Gravity exhibit different financial health indicators when analyzed through the lens of renewable energy investments. While EDP and E-redes have shown the ability to navigate renewable energy transitions, with E-redes standing out for its liquidity and profitability, Logical Gravity's financial instability reflects the immense challenges faced by smaller companies in financing and managing the costs of green energy integration. The financial trends observed indicate the substantial capital expenditures required for the transition to renewable energy, with long-term returns potentially offset by the high upfront costs and volatility.

5.2. Input–Output Analysis

The evolution of the input–output coefficients for both suppliers (Table 4) and buyers (Table 5) in the energy sector between 2005 and 2016 reveals significant changes, which can be analyzed to understand the underlying economic shifts and their implications.

Table 4. Input–output technical coefficients for suppliers from 2005 and 2016.

Suppliers 2005	Technical Coefficients	Suppliers 2016	Technical Coefficients
Crude Petroleum and Natural Gas; Services Related to Oil and Gas Extraction (excluding Prospecting)	0.07	Electricity, gas, steam and air conditioning supply	0.72
Coke, Refined Petroleum Products, and Nuclear Fuel	0.05	Mining and quarrying	0.05
Other Services Provided Mainly to Businesses	0.05	Financial service activities, except insurance and pension funding	0.03
Coal (including Anthracite) and Lignite; Peat	0.03	Legal and accounting activities; activities of head offices; management consultancy activities	0.03
Financial Intermediation Services, excluding Insurance and Pension Funds	0.02	Manufacture of coke and refined petroleum products	0.02
Construction Works	0.01	Land transport and transport via pipelines	0.02
Electrical Machinery and Apparatus, not elsewhere classified	0.01	Administrative and support service activities	0.02
Electricity, Gas, Steam, and Water	0.01	Manufacture of paper and paper products	0.01

Table 5. Input-Ouput coefficients for Buyers, 2005 and 2016.

Suppliers 2005	Technical Coefficients	Suppliers 2016	Technical Coefficients
Electricity, Gas, Steam, and Water	0.42	Electricity, gas, steam, and air conditioning supply	0.72
Other Non-Metallic Mineral Products	0.04	Mining and quarrying	0.09
Accommodation, Food, and Similar Services	0.03	Manufacture of paper and paper products	0.09
Other Services Provided Mainly to Businesses	0.02	Fishing and aquaculture	0.08
Agriculture, Animal Production, Hunting, and Related Services	0.01	Manufacture of chemicals and chemical products	0.08
Food Products and Beverages	0.01	Manufacture of other non-metallic mineral products	0.06
Textiles	0.01	Manufacture of basic metals	0.05
Pulp, Paper, and Paper Products	0.01	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities	0.05

5.2.1. Suppliers: Evolution from 2005 to 2016

1. Crude Petroleum and Natural Gas; Services Related to Oil and Gas Extraction (2005: 0.07 → 2016: 0.72)

The share of this sector in the supply chain has increased substantially, reflecting the growing importance of energy production, particularly in oil and gas. This might be due to the expansion of energy markets and increased reliance on oil and gas for energy production, as well as technological advances in extraction methods.

2. Coke, Refined Petroleum Products, and Nuclear Fuel (2005: 0.05 → 2016: 0.05)

The contribution remains unchanged, suggesting that while refined petroleum and nuclear fuels still play a key role, their relative share in the supply chain has remained stable, perhaps indicating limited changes in the demand or production of these resources.

3. Mining and Quarrying (2005: 0.05 → 2016: 0.05)

Like petroleum, this sector has maintained its contribution level, suggesting consistent demand for minerals in the energy sector, particularly for electricity generation and industrial use.

4. Other Suppliers (e.g., Financial Services, Construction Works, and Administrative Services) (2005: 0.01 to 0.05 → 2016: 0.01 to 0.03)

Various smaller sectors (like financial services, construction, and administrative support) have seen a decrease in their relative contribution. This may reflect a shifting focus away from non-physical services toward more direct energy production services like oil and gas extraction.

5.2.2. Buyers: Evolution from 2005 to 2016

1. Electricity, Gas, Steam, and Water (2005: 0.42 → 2016: 0.72)

There is a sharp increase in the share of energy supply (electricity, gas, and steam) in the buyer's sector, suggesting a growth in energy consumption across industries. This could reflect the increasing demand for energy as a key input in manufacturing and services, driven by economic growth and industrialization.

2. Mining and Quarrying (2005: 0.04 → 2016: 0.09)

The contribution of mining and quarrying as a buyer has grown, reflecting a greater reliance on energy for industrial extraction and resource processing activities. The expansion of mining in energy-intensive operations could explain this trend.

3. Manufacture of Paper and Paper Products (2005: 0.03 → 2016: 0.09)

The paper industry has also seen a noticeable increase in energy demand, likely due to the energy-intensive nature of paper production. This trend could be linked to an overall increase in industrial output and a shift towards more energy-consuming production processes.

4. Manufacture of Chemicals and Other Materials (2005: 0.01 to 0.03 → 2016: 0.08 to 0.09)

Significant increases in demand for energy from sectors like chemicals, non-metallic mineral products, and basic metals, which are energy-intensive, reflect industrial trends and growing production scales.

5. Sewerage; Waste Collection, Treatment and Disposal Activities (2005: 0.05)

A noticeable increase in energy consumption in waste management activities could signal more complex operations in waste treatment and recovery processes.

5.2.3. Implications

- Growth in Energy Demand: The rise in both suppliers and buyers in energy sectors (particularly oil and gas extraction and electricity generation) reflects global trends of increased energy demand, driven by industrialization, urbanization, and growing consumption. With electricity, gas, and steam becoming even more integral to the global economy, energy-related industries are expanding their share in both supply and demand.
- Shift to Energy-Intensive Industries: The increased energy use by industries like mining, paper manufacturing, and chemicals suggests a shift towards more energy-intensive industries. This could be a result of the growing complexity of production processes and the increasing need for energy to sustain industrial growth, particularly in emerging economies or sectors focused on sustainable practices that require more energy input.
- Technological Advances and Market Conditions: The growth in sectors like crude petroleum, natural gas extraction, and electricity supply can be attributed to advances in extraction technologies (e.g., fracking and deep-water drilling), along with market conditions that drive the need for cheap energy. These shifts may also reflect the transition toward more centralized and industrialized energy systems, often with environmental and policy-driven pushbacks influencing the diversification of energy sources.
- Environmental and Regulatory Factors: The increase in energy demand from waste treatment and chemical industries could also be due to growing environmental concerns, such as the need for more sustainable waste management and recycling, which requires more energy. Additionally, government regulations pushing for greener practices may drive changes in how industries source and use energy.

5.3. Employment and Gender Disparities

5.3.1. Employment

The transition to carbon neutrality is crucial for addressing climate change, but it will have substantial effects on the global labor market. According to the OECD, over 25% of global jobs will be impacted by this transformation, with significant social and economic consequences. Particularly, sectors with high pollutant emissions will experience layoffs, and employment in these sectors is expected to decline at a rate of over 2% per year from

2019 to 2030. In Portugal, although 19% of workers are employed in roles that could benefit from the energy transition, the country faces a disproportionate financial impact, with workers in polluting industries potentially losing up to 68% of their income, significantly higher than the OECD average of 38%.

Table 6 in the annex shows employment evolution and trends for the three companies. EDP has a substantial workforce, with the number of employees fluctuating from 11,798 in 2014 to 13,211 in 2022. EDP's workforce shows moderate year-over-year growth, with the most notable increases occurring between 2020 and 2022, reflecting perhaps an expansion in operations or new projects. The company maintained a relatively stable workforce between 2014 and 2019, followed by some growth, likely due to global expansions, new energy ventures, or restructuring efforts. As a large multinational corporation, EDP's workforce growth aligns with its global scale and ongoing development in the energy sector. The company needs a large workforce to handle its diverse operations across energy generation, distribution, and international markets. Additionally, the increase in employment numbers may be indicative of strategic investments in renewable energy or technological advancements, requiring additional skilled labor.

Table 6. Employment in the three companies, from 2014–2022.

Year	EDP	E-Redes	Logical Gravity
2022	13,211	3240	13
2021	12,236	2908	8
2020	11,610	2971	5
2019	11,660	3086	3
2018	11,631	3134	1
2017	11,657	2990	1
2016	-	3075	-
2015	12,084	3109	-
2014	11,798	3017	-

E-redes, as a medium-sized company, employed 3017 individuals in 2014, which grew to 3240 in 2022. The workforce at E-redes fluctuates over the years, with a slight decline observed from 2018 (3134 employees) to 2021 (2908 employees). In 2022, the workforce showed a moderate recovery. This suggests that E-redes might have faced restructuring or downsizing in response to market conditions, possibly following an economic downturn or operational changes. The relatively steady number of employees over the long term indicates that the company is managing a balanced workforce according to its operational needs. E-redes, with its medium-sized workforce, likely experience a more flexible and adaptable employment structure than larger firms like EDP. However, its employment numbers still reflect the need to maintain specialized roles across different departments. The fluctuation in employee numbers could indicate an adaptation to external challenges or internal restructuring efforts, possibly driven by efficiency measures or strategic shifts.

Logical Gravity, a small company, has experienced a notable increase in its workforce over the years, growing from just 1 employee in 2017 to 13 employees in 2022. Despite this growth, its employee numbers have remained highly volatile. As a small company, Logical Gravity faces staffing challenges, particularly when its workforce size fluctuates so dramatically. Operating with a small number of employees allows for a lean and flexible approach, but it also limits the company's ability to scale operations or take on larger projects. The fluctuations in its employment data suggest potential instability in its business operations, which could be a result of difficulties in securing funding, meeting market demand, or achieving profitability.

Employment Stability and Flexibility. The stability of EDP's workforce is a key feature of its large scale. While the number of employees grows incrementally, EDP can maintain a relatively stable workforce across different years, which is essential for managing the complex nature of its global energy business. The company can absorb fluctuations in its workforce and adapt its staffing levels without compromising operational efficiency. E-redes enjoys more flexibility than EDP, but with a smaller workforce, it faces more pronounced fluctuations in staffing levels. The changes in workforce size over the years suggest the company is adjusting its staff according to external economic conditions, internal needs, or strategic shifts. Logical Gravity's employment data shows a high degree of volatility, indicating that the company is either facing financial difficulties, market challenges, or changing business models that require drastic adjustments to its workforce. The small number of employees makes it difficult for the company to withstand significant economic pressures or fluctuations in demand.

Implications for Operational and Financial Strategy. The growth in employment at EDP indicates ongoing business expansion, especially in the renewable energy sector. The company's ability to hire more employees is likely tied to its increasing investments in new energy technologies and international markets. This growth in staff is supported by a large revenue base, which allows EDP to invest in human capital without sacrificing profitability. The fluctuations in E-redes' employment numbers suggest that the company is adjusting its workforce to align with its business performance and market conditions. While its medium size offers flexibility, it must carefully manage workforce fluctuations to maintain operational efficiency and avoid disruptions in service. The increase in employment at Logical Gravity suggests that the company is increasing its operations.

5.3.2. Gender Disparities

An important aspect of this study is the analysis of gender disparities within the workforce, particularly in relation to salary differences. In the energy sector, the total number of employees stands at 7549, comprising 1627 women and 5922 men. This distribution indicates a significant gender disparity, with men making up approximately 78.5% of the workforce. The average base salary for employees is relatively comparable across genders, with women earning an average of EUR 2237.70 and men earning EUR 2204.60. However, the average total earnings show a more pronounced gap, with women earning EUR 2864.60 compared to men's EUR 3006.30, resulting in a gender pay gap (GPG) of 4.7% in favor of men for base salary, and a negative GPG of −1.5% for total earnings, suggesting that women's bonuses or additional earnings are lower on average than men's.

In 2022, the energy sector employed 6617 individuals, with a notable number of small- to medium-sized enterprises (1–249 employees) contributing to the total. The breakdown of employment indicates that smaller companies employ the majority of workers.

Geographically, the workforce distribution reflects significant employment in the Lisbon Metropolitan Area, which employed 2591 workers, demonstrating regional disparities in job availability within the sector.

Average base salaries for the energy sector show a progressive increase with the size of the company, from EUR 1786.13 in companies with 5–9 employees to EUR 2352.17 in companies with 250–499 employees. This trend reflects the economies of scale and potentially greater financial resources available to larger firms. In October 2022, the energy sector reported 5368 employees under collective agreements. These data indicate a substantial proportion of workers covered by these agreements, which plays a crucial role in ensuring fair labor practices and salary standards.

While the energy sector has made strides in reducing workplace accidents and improving safety, significant gender disparities in employment and pay persist. Furthermore, regional variations in employment and salary underscore the need for targeted policies to promote gender equity and improve working conditions. Continuous monitoring of these indicators is essential for fostering a safer and more equitable workforce in the energy sector, particularly in light of ongoing green transition initiatives aimed at sustainability and renewable energy development.

Targeted policy recommendations should focus on promoting gender equity and addressing regional disparities within the energy sector. This can be achieved by implementing measures such as leadership development programs and gender quotas to increase female representation in decision-making roles, alongside salary audits to ensure equal pay for equal work, particularly in relation to bonuses and additional earnings. To reduce regional employment gaps, policies could incentivize job creation in underrepresented areas and provide workforce training to enhance local job opportunities. Supporting small- and medium-sized enterprises (SMEs) through financial incentives and easier access to capital would also enable them to offer competitive salaries and better working conditions. Additionally, strengthening collective bargaining agreements and establishing robust monitoring and reporting mechanisms can ensure consistent progress toward these goals and contribute to a more inclusive and sustainable workforce in Portugal's renewable energy transition.

6. Discussion

During the period of economic recovery from 2015 to 2019, several key indicators suggest a transition toward greater economic and sectoral resilience, influenced by government policies that fostered green growth. For EDP, the financial data shows a steady rise in turnover and gross profits between 2015 and 2017, reflecting the improving economic environment. Gross profit margins and return on equity (ROE) peaked around 2017, coinciding with Portugal's increased focus on energy infrastructure and innovation. The years 2018–2019, marked by high investment, correlate with significant investments in renewable energy, as e-Redes shows increased turnover and profits (especially in 2018–2019), aligning with the national push for energy sector modernization. Logic Gravity, though exhibiting higher volatility and losses, reflects the broader uncertainty in some corporate sectors during this period. Its financial struggles in 2017 and 2018 point to challenges in capitalizing on the recovery momentum and the rising green energy investments. This suggests that Logic Gravity was less aligned with the favorable policy environment than the other companies.

The pandemic year, 2020, acted as a test of resilience for many sectors, especially the energy sector, which remained a priority in national recovery plans. EDP and e-Redes demonstrated continued profitability, with slight declines in profit growth but maintaining solid cash positions, signaling resilience amidst global disruption. EDP's consistent profits and high solvency ratio (especially in 2020) reflect its adaptability, even in the face of the COVID-19 crisis. e-Redes, while facing lower profits, still showed strong cash flows, which suggests a proactive stance in securing resources for future green investments. However, Logic Gravity displayed a significant decline, particularly with a net loss in 2020, possibly indicating a struggle to secure necessary capital or re-orient business models during the crisis, marking it as a company less aligned with the green recovery and EU-led economic transformation.

The transition towards a greener economy accelerated during 2021–2022, and companies that aligned with EU sustainability initiatives experienced renewed opportunities. EDP showed signs of sustained growth in 2022 with improved gross profits and return on equity, highlighting its active engagement in green sectors or sustainability-related investments. The rise in its solvency ratio and cash flow also supports the idea that it was better positioned to leverage EU recovery funds and national plans for decarbonization and energy efficiency. Similarly, e-Redes saw positive indicators in 2021, such as a high solvency ratio, signaling stability amidst the green transition, although its growth rate slowed down. This suggests it was still undergoing adjustments to meet the demands of the energy sector's accelerated green transition. Logic Gravity continued to show significant financial instability, with negative profits in both 2020 and 2021, reflecting a mismatch between its business model and the broader green transition, hindering its ability to benefit from the EU and national initiatives focused on green recovery.

In conclusion, EDP appears to be the most aligned with the broader national and EU-driven green growth efforts, consistently showing positive financial trends throughout these periods. e-Redes is also positioned well, though with slower growth in the green transition years, and Logic Gravity struggles financially, particularly in the later stages of this transition.

The findings of this study suggest that the transition to renewable energy has generated positive socio-economic impacts in Portugal, with particular emphasis on employment trends, gender equity, financial resilience, and technological innovation. They align with several previous works identified in the literature, but also uncover nuances that suggest areas for further policy refinement. In particular, and regarding employment trends, the study confirms that Portugal's renewable energy policies have significantly contributed to job creation. This finding supports the literature, which highlights the role of financial mechanisms and sustainable investments in driving employment opportunities within renewable energy sectors [19,20]. The increased investments in renewable energy infrastructure in Portugal have led to the expansion of green jobs, a crucial element of the transition to a low-carbon economy. The study also mirrors previous findings that suggest countries benefit from investments in renewable energy that create significant employment opportunities [21]. The positive correlation between renewable energy policies and job creation aligns with H1, which hypothesized that Portugal's renewable energy transition would lead to an expansion of employment within the sector.

In terms of gender equity, the findings indicate that while there has been progress, challenges persist, especially concerning the gender pay gap and the underrepresentation of women in leadership roles. This partially supports H2, which anticipated the positive impacts of renewable energy policies on gender equity but acknowledged that these improvements may not be uniformly distributed. The literature on gender-responsive energy policies has emphasized the importance of addressing gender disparities in access to energy resources and leadership roles [33,35], which resonates with the study's findings. However, while women's participation in the renewable energy workforce has increased, barriers remain to achieving full gender equity, particularly in decision-making positions. The results align with the broader discourse on the need for gender-sensitive policies to further enhance inclusivity [37,39], highlighting the importance of promoting gender-diverse leadership to drive forward both sustainability and inclusivity in renewable energy sectors.

On the financial resilience front, large firms have shown greater financial stability and growth, benefiting from economies of scale and access to capital. This finding supports H3, which proposed that renewable energy policies improve the financial resilience of larger firms. Much of the existing literature tends to emphasize the advantages of large firms while overlooking the nuanced challenges faced by small- and medium-sized enterprises (SMEs). Smaller firms in the sector continue to face significant challenges related to financing and market access. This finding is consistent with literature that underscores the challenges smaller firms encounter in the renewable energy sector, particularly in accessing financing and scaling operations [23]. Additionally, the study's focus on financial sustainability and technological innovation highlights the interrelationship between the two, reinforcing findings from previous studies that technological advancements—such as the development of new energy storage solutions—are key to the financial success and long-term viability of renewable energy projects [26,28].

The role of technological innovation in Portugal's renewable energy transition was crucial, with investments in solar and wind technologies driving sector growth. These findings align closely with the literature, which emphasizes the pivotal role of technological advancements and the application of nature-based solutions in reducing emissions and fostering energy sustainability [27,28,40]. The study confirms that Portugal's success in renewable energy deployment is largely attributable to technological innovations, which have reduced energy consumption and contributed to broader sustainability goals. The study also echoes the literature's call for continued government incentives and long-term contracts to bolster financial stability and foster innovation [29].

Finally, the findings of this study support the view that renewable energy transitions are not solely technical and financial, but also socio-economic in nature. The literature emphasizes that a just energy transition must consider social inclusion and equity [30]. In Portugal, policies that prioritize gender equity and inclusivity have supported local economic development, though gaps remain, particularly for marginalized communities and women. The study could benefit from a broader longitudinal analysis of the long-term impacts of renewable energy policies on gender equity and financial stability. This mirrors the findings of [31], which noted that renewable energy projects can contribute significantly to local development, provided that inclusive policies are in place to address inequalities. The study's results highlight the importance of integrating gender-sensitive energy policies to ensure that the benefits of renewable energy are shared equitably across all demographic groups [38]. Past research on the social dimensions of energy transitions often lacks a focus on the long-term effects of policies, and future studies should address how policy adjustments over time can better address gender and financial inequalities. The study's findings suggest specific policy recommendations to enhance financial resilience, gender equity, and technological innovation within Portugal's renewable energy sector. To support smaller companies, targeted financial mechanisms such as tax incentives and low-interest loans should be implemented to address their challenges in accessing capital and scaling operations. Strengthening public–private partnerships could further facilitate resource sharing and foster innovation. For gender equity, policies must address the persistent underrepresentation of women in leadership roles. Initiatives like mentorship programs, equitable wage standards, and incentives for gender-diverse leadership teams can foster inclusivity. Training and education programs aimed at increasing female participation in renewable energy fields should also be prioritized. Finally, government incentives for technological advancements, such as grants for energy storage research and long-term renewable energy contracts, are essential to drive sector growth.

The study has several limitations. It relies on quantitative data from secondary sources, which misses qualitative insights to better understand socio-economic impacts. Additionally, the conclusions on gender equity overlook the underrepresentation of women in leadership roles. The focus of financial analysis on 2014–2022 prevents an assessment of the long-term implications of renewable energy policies, and a longitudinal approach could provide insights into the sustainability of observed financial and employment trends. Furthermore, the period from 2005 to 2016 for the input–output analysis might not fully demonstrate the impact of renewable energy on social transformation, as its effects may have been more gradual or less pronounced during this time. The study also does not incorporate environmental metrics or evaluate the carbon reduction outcomes of the renewable energy transition. Moreover, while the study recognizes the financial struggles faced by smaller companies, it does not analyze specific barriers, such as inadequate access to capital or high market entry costs, comprehensively.

7. Conclusions

This research confirms that Portugal's renewable energy transition has positively influenced employment trends, gender equity, and financial resilience. The findings align with the broader literature, highlighting the critical role of renewable energy policies in promoting sustainable socio-economic development. However, challenges persist regarding gender equality and the financial viability of smaller firms, underscoring the need for further policy attention.

The study's originality lies in its holistic evaluation of the socio-economic impacts of Portugal's renewable energy policies, particularly its integration of financial sustainability and gender equity within the context of the energy transition. By examining the 2014–2022 period, this research provides valuable insights into the interplay of these factors, offering a comprehensive view of their implications for employment trends, gender disparities, and financial resilience in the renewable energy sector—an area relatively underexplored in the existing literature.

However, the study has several limitations. First, the focus on the 2014–2022 period does not address the long-term implications of renewable energy policies. A longitudinal approach could help determine whether the observed financial and employment trends are sustainable over time. Additionally, the study primarily focuses on Portugal and does not compare the impact of renewable energy policies in other countries with similar socio-economic contexts, which could provide valuable comparative insights.

Future research could expand the scope by adopting a longitudinal approach to capture the evolving dynamics of renewable energy's socio-economic impacts over time. Comparative studies across countries undergoing similar energy transitions would enhance the generalizability of the findings. Additionally, investigating the influence of specific policy interventions on gender equity and financial resilience at the firm level could provide deeper insights into the mechanisms driving these trends. Research incorporating qualitative methods, such as interviews or case studies, could also offer a more comprehensive understanding of the socio-economic impacts, particularly regarding gender representation in leadership roles and the challenges faced by smaller companies. Lastly, integrating environmental metrics and assessing the carbon reduction outcomes of renewable energy policies would provide a more holistic evaluation of the transition's sustainability.

In conclusion, while the study confirms Portugal's progress in its renewable energy transition, it emphasizes the need for continued efforts to ensure that the benefits are broadly distributed, particularly in terms of gender equality and the financial resilience of smaller firms. Technological innovation and financial stability are essential for success, but they must be complemented by inclusive policies that address social and economic inequalities to ensure a truly sustainable and just energy future.

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