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The Innovative Nature of Selected Polish Companies in the Energy Sector Compared to the Use of Renewable Energy Sources from a Financial and an Investor's Perspective

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Abstract: Analysis of the energy sector from the micro perspective that relates to individual companies is much rarer than a macroeconomic analysis that concerns the power industry as a whole and its impact on the functioning of the economy. However, energy companies directly implement the government's energy policies and innovation strategies. Thus, this article attempts to answer the question concerning the relationships in three large energy companies operating in Poland (1) between the use of renewable resources for production and the innovative nature of a company, (2) between the use of renewable energy sources and the standing on the stock exchange and profitability. This study used multiple case studies, financial analysis indicators, a time series analysis, and an interdependence analysis. This study covers 2011–2022 and allows consideration of long-term changes in domestic energy policy. Our findings suggest that there is a relationship between a company's investment activity and the use of renewable energy sources. Unfortunately, the scope of the use of RESs in these companies is small (from ca. 1% to 15%, which demonstrates the low progress of green transformation) and has negative correlations with the investors' assessment and profitability. In relation to innovation, the ratio of intangible assets to total assets was the highest for Tauron SA, increasing from 1.96% to 5.16%. Its material commitment to innovation is distinguishable from the other two companies. This is also the company with the highest share of RESs in energy production. The second place belongs to Enea SA with its ratio of intangible assets to total assets that increased from 0.72% to 1.69%. The ratio was lowest for PGE SA, increasing from 0.37% to 1.47%. The results and standing of the analyzed energy companies are strongly affected by energy policy amendments, including the improved status of coal and the re-oriented use of RESs (prioritizing solar energy over wind). As a result, these companies, despite the twelve-year period of the implementation of green transformation in the European Union, have achieved little on the path to sustainable energy. Therefore, achieving the goal of a zero-emission economy seems unlikely, since the renewable energy mix is still very slight and not diversified. Changes in energy policy are also not conducive to sectoral and economic innovation.

Keywords: renewable energy sources; intangible assets as a financial innovation dimension; innovative nature of energy sector; assessment of investment in innovative assets and renewable energy sources

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1. Introduction

Non-renewable fuel resources have been depleting gradually and their use results in increasing changes to the climate [1,2]. In these circumstances, energy transformation seems unavoidable [3–6]. Certainly, it will not solve all environmental and social problems and will not take place by the assumed deadline and in the anticipated scope [7–9]. Nonetheless, it will be necessary to make the future of coming generations more certain.

However, striving to improve quality of life results in a growing demand for electricity [10–13]. It is a very difficult task for companies in the energy sector to meet that demand in the current economic circumstances.

Improved innovation in the energy industry is one of the contemporary ways to simultaneously meet social and climatic expectations. Improvements in innovation can be achieved by the development and implementation of energy-efficient technology. Another way is to make energy production more eco-friendly and to use renewable sources of energy [14–19]. In this context, much attention is also paid to decisions about the direction of investment in renewable energy, which is highlighted in the research of, among others, Izanloo et al. (2022) [20].

Nonetheless, understanding the need for change and creating appropriate capital, organizational, and legal conditions in each of the above-mentioned cases is indispensable. This means that companies in the energy sector, which are usually state-owned, need a pan-economic incentive to trigger innovation and to initiate energy transformation [21–24].

However, the implementation of a transformation in energy and of innovative policies is conditional on the operations of the energy companies [25–27]. The scope of those operations shapes the efficiency of the transformation of energy systems and, indirectly, societies' quality of life.

Emerging and developing economies face many problems relating to innovation and to energy transformation. These problems stem from income inequalities and from no access to cutting-edge technology [28–31]. Furthermore, the problems are further intensified by a low level of social acceptance of changes and the remnants of imperfect political systems [32–34].

In the overall economy of Poland, non-renewable resources have only been used recently and to a small extent. In the initial period of energy transformation, the use of wind energy was postulated. In 2015, after the political options for power generation changed, it was decided to develop solar energy. As a result, neither wind energy nor solar energy have reached their full development potential [35–37]. Poland's renewable energy mix is still slight and undiversified. As a result, the overall energy balance remains unsustainable and monolithic, dominated by traditional energy sources—primarily by hard coal [38,39].

Given these circumstances, this article attempts to answer questions concerning the relationships in three large energy companies (1) between the use of renewable resources for production and the innovative nature of a company, (2) between the use of renewable energy sources and the standing on the stock exchange and profitability.

These studies in this area are initiated because of the need to fill in the research gap relating to determining the energy companies' contribution to energy transformation in developing economies in the context of their innovation. There have been no studies so far from the perspective of individual energy companies and the triple relationship of innovation, renewable resources, and financial/investors' results, and our findings may be a valuable resource that can be used to shape both innovation and energy policies.

The contribution of these studies to policy development in the energy industry stems from:

- Identification of the relationship between innovation and the level of use of renewable resources and the assessments of investors in a developing economy;
- In-depth empirical studies of the use of RESs and the scope of innovation, carried out from the individual companies' perspectives;
- Assessment of the scale of innovation in the context of the companies' financial reports;
- Analysis of the impact of changes in national resource policies on innovation and the use of RESs in energy companies in the developing economy.

The structure of this paper has been subordinated to these goals. First, studies of the literature that consider two key study threads are presented. The first, Section 1, refers to innovation in the energy industry analyzed in the context of the entire economy. The second, Section 2, considers the innovative nature of energy companies. Next, Section 3,

this study's assumptions and tools are presented, including financial analysis indicators, a time series statistical analysis, and an interdependence analysis. Subsequently, Section 4, the authors describe the findings from a financial perspective, based on reports of the analyzed companies, and from the investors' perspectives, considering stock exchange information, general profitability (ROA), and owners' profitability (ROE). In our discussion, Section 5, the results are brought together with the findings of previous studies and used to develop recommendations to improve innovation in the analyzed sector. The final Section 6 includes the key conclusions, this study's limitations, and possible directions for further study.

2. Studies of the Literature

Studies of the literature are presented from two perspectives. The first, which is more often analyzed in academic publications, refers to the impact that is exerted by the innovation level of the energy sector on the economy and the environment (a macro perspective). The second refers to the innovation of companies in the context of energy transformation, decarbonation, and the promotion of renewable energy sources (a micro perspective).

2.1. Innovation in the Energy Sector from a Macro Perspective

At present, innovation relating to energy technology is closely connected to sustainable economic development and the use of renewable energy sources. The studies of Li and Ge (2023) [40] reveal that the development of new energy technologies may help to diversify the energy structure, to increase energy supply, to reduce risk caused by fluctuations in international fossil fuel prices, to maintain geopolitical stability, to ensure national energy security, and to reduce carbon dioxide emissions.

Nonetheless, when sustainable development is considered in this way, its benefits are not equal in all economies. The studies by Drago and Gatto (2022) [41] show that the major beneficiaries of green transformation are well-developed states, including the United Kingdom, the United Arab Emirates, Australia, Belgium, Finland, France, Germany, and the U.S. The countries with lower national incomes do not have any policy and regulation to support energy saving in the energy industry and to implement the innovative use of RES technology.

Similar conclusions were proposed by Napolitano et al. (2022) [42]. According to their studies, the income inequalities of individual states are significantly and strongly correlated negatively with the ability to initiate green innovation. An unequal income distribution is important particularly for countries with low and medium incomes, where it is perceived as an obstacle to green innovation. The authors note too that innovation may trigger new inequalities, which may reduce the ability to develop new technology as the ability to innovate goes hand in hand with a long-term national development path.

In this line of studies, Alemayehu et al. (2022) [43], when analyzing energy innovation in Ethiopia, identify the key determinants of innovation in emerging economies. They include the availability of private funds and public aid, the availability of R&D, and the possession of relevant professional skills. This last aspect is of particular importance as the absence of knowledge concerning technology innovation and its benefits strengthens unfriendly attitudes to the decision to implement it.

These conclusions on energy innovation in developing economies are complemented in an interesting way by Michalak and Wolniak (2023) [44]. They claim that there is an inversely proportional relationship between indicators of innovation in the economy and the share of coal in the energy mix. Highly innovative countries that invest both in traditional and in open innovations accelerate their energy transformation significantly and increase the share of RESs in their resource policy.

Countries that are rich in valuable nonrenewable resources also decide to use renewable energy sources. An example of such an approach may be Iran, as described by Khazaee

et al. (2022) [45]. This oil-rich country is also trying to develop green innovations using solar, wind, and geothermal energy.

From a macroeconomic perspective, the demand policy of any state is one of the key determinants of innovation in the energy sector. According to Lee et al. (2022) [46], it drives the fast spread of mature technology. Moreover, it promotes newer technology and reduces the risk connected with technological lock-in.

In this line, Stevens et al. (2023) [47] claim that the development of RES policy itself does not directly contribute to the level of innovation in the economy. However, it may stimulate innovation when developing smart power grids and energy storage technology. This is an important direction of investment in energy innovation as it ensures the supply–demand balance and energy transmission capacities.

Unfortunately, according to Norouzi et al. (2023) [48], this aspect is frequently considered marginal, and innovation in smart grids is not deemed to be a mainstream technology in energy transformation. Furthermore, the development of network technology innovations may be slowed down by conflicts between stakeholders connected with the grid, including the state, local authorities, energy companies, the business environment, and energy end users.

Similar conclusions are reached by Temmes et al. (2021) [49], who claim that increased investment in renewable energy production is conditional on increased investment in electrification and energy production discontinuity management. They state as well that energy transformation has changed the investment structure profoundly from large, centralized projects into a multitude of small ones, which is a challenge both for the energy sector and for the financial sector. Investments in renewable energy sources do not have a suitable legal background, including an effective and efficient public procurement system.

On the other hand, innovation in the area of renewable energy sources as an aspect of general innovation exerts a positive impact on the pace of energy transformation. Such a finding is confirmed, inter alia, by the studies of Solarin et al. (2022) [50]. According to Aldieri et al. (2022) [51], environmental innovations may play a crucial role in energy efficiency improvements, which contribute directly to reduced greenhouse gas emissions and foster climate protection.

The environmental impact of innovation is evaluated differently in the reference works. For example, the studies of Fang (2023) [52] show that investment in renewable energy and in green technology exerts a negative influence on carbon dioxide emissions in China. This is why the author recommends increasing the government's investment budget for R&D projects and more efficient stimulation of investments in clean energy and low-emission technologies.

Raghutla and Chittedi (2023) [53] confirm the conclusions drawn from these studies. Moreover, the authors identify the causes of the adverse environmental impact of innovation. One of them is a low share of eco-innovation in the total innovation mix. The other is connected with the delayed impact of innovation on the reduction of carbon footprints and greenhouse gas emissions.

On the other hand, Zhang et al. (2023) indicate [54] that technology innovation has a long-term favorable impact on electricity consumption, while the introduction of new, more effective technologies may result in the reduction of total electricity consumption, thus decreasing the adverse impact of the power sector on the climate.

As these studies were carried out for the Polish economy, it is worth referring to innovation in the Polish energy sector. In this context, the studies by Dzikuć et al. (2021) [55] prove that Poland is left behind when it comes to implementing innovation in company operations, including but not limited to the energy sector and, more specifically, the development of renewable energy. This results, for example, from insufficient state aid, a relatively low GDP per capita, and an insufficient commitment to the R&D sector. According to the authors, the development of renewable energy sources in Poland may be more feasible with favorable legal solutions, the growing cost of energy production for traditional sources, and an increasing social acceptance of energy transformation.

Most studies devoted to the macroeconomic significance of innovation in the energy sector emphasize the government's role in effective energy transformation. For example, Heard et al. (2022) [56] indicate that Germany could take higher risks in their R&D portfolio, could include all state institutions in the energy transformation process, or could consider energy innovations in the context of social transformation. Understanding social responses, human needs, and human preferences and managing those aspects will be of key importance for effective planning and obtaining positive results in the economy's decarbonation process.

2.2. Innovation in the Energy Sector from a Micro Perspective

The pan-economic view of energy innovations is a result of the operations in the entire sector, which, in turn, are conditional on decisions made by individual companies. For this reason, the analysis of individual players in the energy market becomes important.

The studies by Lyu and Liu (2021) [57] indicate that today's energy companies usually implement innovations based on artificial intelligence and robots. Those solutions allow productivity improvements and higher salaries for employees. Artificial intelligence may contribute to more effective risk management in energy companies, as described by Quest et al. (2022) [58]. Moreover, according to Shabalov et al. (2021) [59], it may also reduce the risk of accidents and increase environmental safety.

Andoni et al. (2019) [60] note the growing role of blockchain technology in the energy sector as well. Nonetheless, because of the existing legal, organizational, and competitive obstacles, its current implementation is more difficult. In this thread of studies, Polas et al. (2022) [61] add that blockchain technology may be an attractive link between an orientation towards sustainable development and the perception and acceptance of green innovations by society.

This approach is based largely on the Industry 4.0 idea as exposed in discussions, e.g., by Pandey et al. (2023) [62]. The authors emphasize as well that the future use of renewable resources by energy companies will be conditional on the development of the concept of Industry 5.0 and Society 5.0. It is impossible to think of energy transformation without the commitment and acceptance of citizens. This aspect appears in the studies of social innovations in the energy sector carried out by Wittmayer et al. (2022) [63], Slee (2020) [64], Matschoss et al. (2022) [65], and Dall-Orsoletta et al. (2022) [66].

On the other hand, Dudnik et al. (2021) [67] add that the digitization of energy companies by means of artificial intelligence will not be possible without their employees' acceptance and commitment. Based on Russian companies, the researchers claim that there is resistance to innovations at various levels of the organizational structure. It is rooted primarily in the mental states of employees, i.e., their fear that artificial intelligence will contribute to job reductions in the company and the absence of mental readiness for changes, combined with an unwillingness to learn. The authors stress as well that innovations in the energy sector develop more slowly in emerging and developing economies than in more developed countries.

Innovation not only brings profits and an improved image to the companies but also contributes to improving their long-term financial stability. This phenomenon is identified and described by Duong et al. (2023) [68], based on the example of Vietnamese companies. Furthermore, the researchers find that the favorable impact of innovation efficiency on financial stability takes place in larger energy companies, whereas a concentration of ownership improves sustainable development in smaller ones.

These conclusions are confirmed by the findings of the studies of Xu et al. (2020) [69]. Nonetheless, the authors stress that investments in innovative operations require appropriate financial outlays and are encumbered with significant risk. This delays the favorable impact of innovative operations on the stability of energy companies.

As both state-owned and private companies operate in the energy sector, the publications devoted to innovations developed from the micro economic perspective often compare the two groups. For example, Häggmark and Elofsson (2022) [70] note that re-

search and development (R&D) in the energy industry has become a priority both for the private and the public sector. Nonetheless, the public sector is more effective than the private sector when it comes to increasing the number of patent applications when compared to R&D expenses. Innovation efficiency in the private sector decreases, which may result from the fact that the analyzed technologies have already been implemented and research into new ones has become more and more advanced, meaning more expensive and time-consuming. Moreover, the private sector displays a shift of research priorities towards technology that guarantees higher profits.

Comparative analyses have also been carried out in the context of the size of energy companies. Thus, a study by Meijer et al. (2019) [71] proves that important obstacles to innovation development in small- and medium-sized companies in the sustainable energy sector include high market competition, limited financial resources, an unwillingness to take risks, no know-how, and the technological complexity. On the other hand, large companies find it much easier thanks to the availability of internal funds, although they also have more paperwork, which may hamper innovation.

It is also worth paying attention to the close and multi-threaded relationship between energy and sustainable development. For example, Seraji et al. (2023) [72] describe the quadruple nexus of water, the environment, food, and energy, emphasizing that this nexus is of key importance in the quality of contemporary urban life.

Palmié et al. (2020) [73] claim, however, that there are no significant differences between mature energy companies and start-ups in the sector when it comes to the process of business models that foster the development of innovation. Companies adapt them to their operations. The authors suggest that green transformation may be supported by foreign companies thanks to knowledge exchange and technology transfer. Similar conclusions are drawn from the findings of the studies of Nawrocki and Jonek-Kowalska (2023), carried out in Poland [74], and of Hoicka et al. (2022) [75]. Zhang and Fu (2022) [76] add, however, that foreign innovations improve the innovative nature of the energy sector solely when they are unique and do not duplicate or imitate solutions implemented in other countries.

In the context of Polish energy companies, it is worth paying attention to the studies of Cader et al. (2022) [77], which indicate that the environmental aspects, i.e., safety and energy efficiency, the share of renewable energy in electricity production, and the implementation of new technology relating to environmental protection are highly important for the energy companies that were analyzed by the authors. The researchers stress, however, that it will be necessary to ensure consistency between the strategies applied by Polish energy companies and the societal expectations relating to energy transformation on the way to effective implementation of corporate social responsibility.

Based on this study of the literature, it can be claimed that the innovation of energy companies is usually discussed in the context of the employed technology and its impact on financial results. Here, the publications devoted to individual and network innovation determinants can be found as well. However, it is difficult to find any threads devoted to the analysis of the triple relationship between innovation, renewable resource use, and the perception of the companies by investors and owners. Nevertheless, this thread is particularly crucial in developing economies, where energy transformation is relatively slow and entails many problems. The authors of this paper try to fill in this gap by analyzing three case studies of Polish energy companies.

3. Materials and Methods

As already mentioned, this study was conducted based on three energy companies operating in Poland and listed on the Warsaw Stock Exchange. They include the following companies, in each of which the Treasury has a majority share:

1. Tauron SA is one of the leading energy corporations in Poland, covering 18% of the territory of Poland. It is the largest distributor in the country and the second-largest electricity seller and producer. The basic areas of the group's activities that create the

energy value chain are hard coal mining, and the production, distribution, and sale of electricity and heat. The majority share of the Treasury is 30.06% [78].

2. PGE SA is a vertically integrated entity, participating in the entire electricity value chain. It is one of the biggest electricity sector companies in Poland. The Group is involved in lignite extraction, the production of electric energy out of fossil fuels (lignite, hard coal, and natural gas) and from renewable energy sources (waterpower plants, wind farms, and biomass), and the distribution and sale of electric energy to end customers. The majority share of the Treasury is 60.86% [79].
3. Enea SA is a vertically integrated structure that covers five basic areas of the energy market with its activity: electricity and heat energy production (e.g., Kozienice Power Station and Połaniec Power Station), trade in electricity, the distribution of electricity, the distribution of heat, and the mining and enriching of hard coal (Lubelski Węgiel Bogdanka). The group provides energy for 2.5 million customers, and the distribution grid covers 1/5 of the area of Poland. The majority share of the Treasury is 52.29%. [80].

The above description demonstrates that these are large energy companies controlled by the state and integrated vertically with hard coal mining [81]. In these companies, mines are suppliers of energy, which largely determines their production structure.

This study's sample contains companies listed on the Warsaw Stock Exchange, since they make their financial statements public. Furthermore, listed companies must also publish information on the share of renewable energy sources in their production. Both these conditions were met by the above-mentioned companies.

The research period covers the implementation of the provisions of the 2009 Climate Package. Before its introduction, renewable energy sources were used sporadically in Poland and the energy mix had practically not changed for many years. The authors' intention was to obtain an answer to the question whether anything has changed in the real, measurable (not the declarative) approach of Polish enterprises to sustainable development and green transformation.

Because of the low number, this study's samples were analyzed as a multiple (triple) case study. This method has high analytical accuracy, but it does not allow us to verify results or test hypotheses statistically [82]. This is why the following research question was asked during the studies: Are there any relationships in three large energy companies operating in Poland (1) between the use of renewable resources for production and the innovative nature of a company, (2) between the use of renewable energy sources and the standing on the stock exchange and profitability?

During this research, the stages that are presented in Table 1 were distinguished.

Table 1. The research stages and methods.

Stage	Description	Methods	Justification
Studies of the literature	Studies devoted to works dealing with energy innovations from the perspective of the whole sector and of the individual energy companies using international publication databases.	Studies of the literature based on international scientific databases.	This stage identified the research gap and existing study findings in the analyzed area.
Innovations and RESs: a financial perspective	(A) the analysis of the production structure of the studied companies;	$S_{RES} = \frac{RES\ production}{total\ production}$ [%] (1)	Identifying the scope of using renewable energy sources and joining the green transformation.
	(B) the share and changes in the ratio of intangible assets to total assets in those companies;	$S_{IA} = \frac{intangible\ assets}{total\ assets}$ [%] (2) total assets—the representation of the worth of everything a company owns; intangible assets—rights suitable for economic exploitation (patents, copyright, franchises, goodwill, trademarks, trade names, etc.)	Identification of the effects of innovative activities.

Table 1. *Cont.*

Stage	Description	Methods	Justification
	(C) identification of the correlation between the use of renewable energy sources and innovation expressed as the share of intangible assets in total assets	Pearson's linear correlation coefficient: $r_{xy} = \frac{cov(x,y)}{s_x \times s_y}$ (3) *cov (x,y)*—x and y covariance; and s_x, s_y—x and y standard deviations. The assumed significance level is $p = 0.05$.	Determining the relationship between the use of renewable energy sources and the innovativeness of the surveyed enterprises.
	The sources of data were financial statements.		
Innovations and RESs: an investor's perspective	Studies of the ties between innovation and RES energy production with an appraisal of the analyzed companies by stock exchange investors and the owners and general profitability.	At that stage, the following financial analysis indicators were used: $PBV = \frac{price}{book\ value}$ (4) documenting the overvaluation (P/BV > 1) or undervaluation (P/BV < 1) of the company. $ROE = \frac{net\ financial\ result}{equity}$ (5) illustrating the rate of return for the company owners:. $ROA = \frac{net\ financial\ result}{total\ assets}$ (6) illustrating the assets' ability to generate financial profit. Pearson's correlation coefficient was used to identify the correlation between the above indices and the share of RESs in production (the significance level was adopted as $p = 0.05$): $r_{xy} = \frac{cov(x,y)}{s_x \times s_y}$ (7) *cov (x,y)*—x and y covariance; and s_x, s_y—x and y standard deviations.	Assessment of the impact of the use of renewable energy in production on the perception of enterprises by investors. Assessment of the impact of the use of renewable energy in production on the rate of return for owners. Assessment of the impact of the use of renewable energy in production on the efficiency of the company.
	The source of data for this stage was stock exchange listings and information included in the Profit and Loss Account and stock quotes.		

Source: own elaboration.

Further in the study, the findings of empirical studies comprising stages 2 and 3 are presented. They are a starting point for further discussion and a summary of the findings.

4. Findings

This chapter presents the findings in two parts. The first part refers to the financial perspective based on information included in financial statements. The second refers to the investors' perspective, reflecting the perception of the company by the stock exchange stakeholders.

4.1. Innovative Nature of Selected Polish Companies in the Energy Sector Compared to the Use of Renewable Energy Sources from a Financial Perspective

At the first stage of our studies, the innovative nature of the analyzed companies was assessed in a financial context based on items included in financial statements referring to the share of renewable resources in the total energy production and the immaterial assets reflecting the material innovative potential.

Thus, Figure 1 depicts the share of renewable resources in energy production in the analyzed energy companies in 2011–2022.

According to this diagram, the most green energy is generated by Tauron SA (an increase in the share of RESs in production from 4.63% to 15.52%). A relatively high share of RESs was also recorded in Enea SA, increasing from 1.88% to 10.64%. This parameter is the lowest for PGE SA, increasing from 1.61% to 4.98%. It is worth stressing, however, that the share of green energy in total production has been growing steadily in all the analyzed companies and changes in the shares of RESs are correlated in time.

In 2017–2019, there was a clear decrease in the share of RESs in production in all the studied companies. This resulted from unfavorable amendments to the regulations concerning wind farms, the government's departure from prioritizing wind energy production, and the reorientation of the green transformation to solar energy. The proposed changes caused uncertainty and regression, as well as temporary withdrawal of the energy

companies from investments in RESs. However, after 2019 there has been a strong growth tendency of the share of RESs in production in all the analyzed entities.

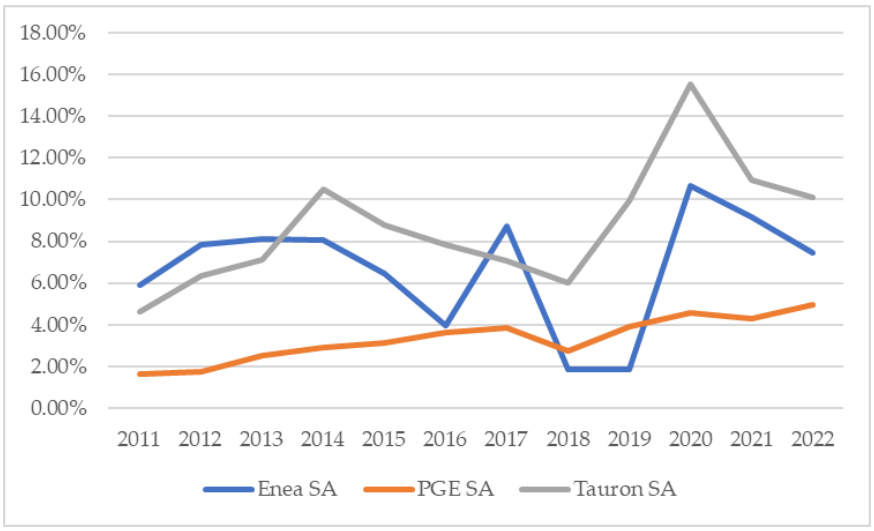

Figure 1. Share of renewable energy sources in the analyzed energy companies in 2011–2022.

Here, it is worth explaining that Polish energy policy has long rested on hard coal. This energy source is still predominant in the Polish energy balance [83,84]. Low decarbonation rates result largely from the Polish government's policy of maintaining energy security. Another contributing factor is the low social acceptance of the use of RESs, stemming from an unwillingness to change and the need to cover the energy transformation costs by a society with a relatively low income level when compared to developed European countries.

In the above conditions, the energy companies, including but not limited to the state-owned ones, find it difficult to implement the EU recommendations requiring a departure from fossil fuels and discontinuing mining in the economy, even more so that all of them have hard coal or lignite mines in their structures and are obliged to produce energy in cooperation with those vendors. In this context, the observed share of RESs is a response to the political changes that clearly document the strong dependency of the energy sector on the socio-political conditions.

During the second stage of our studies, the analyzed aspects included the share of intangible assets in total assets, illustrating the analyzed companies' involvement in innovative activities (Figure 2) by individual categories (Table 2).

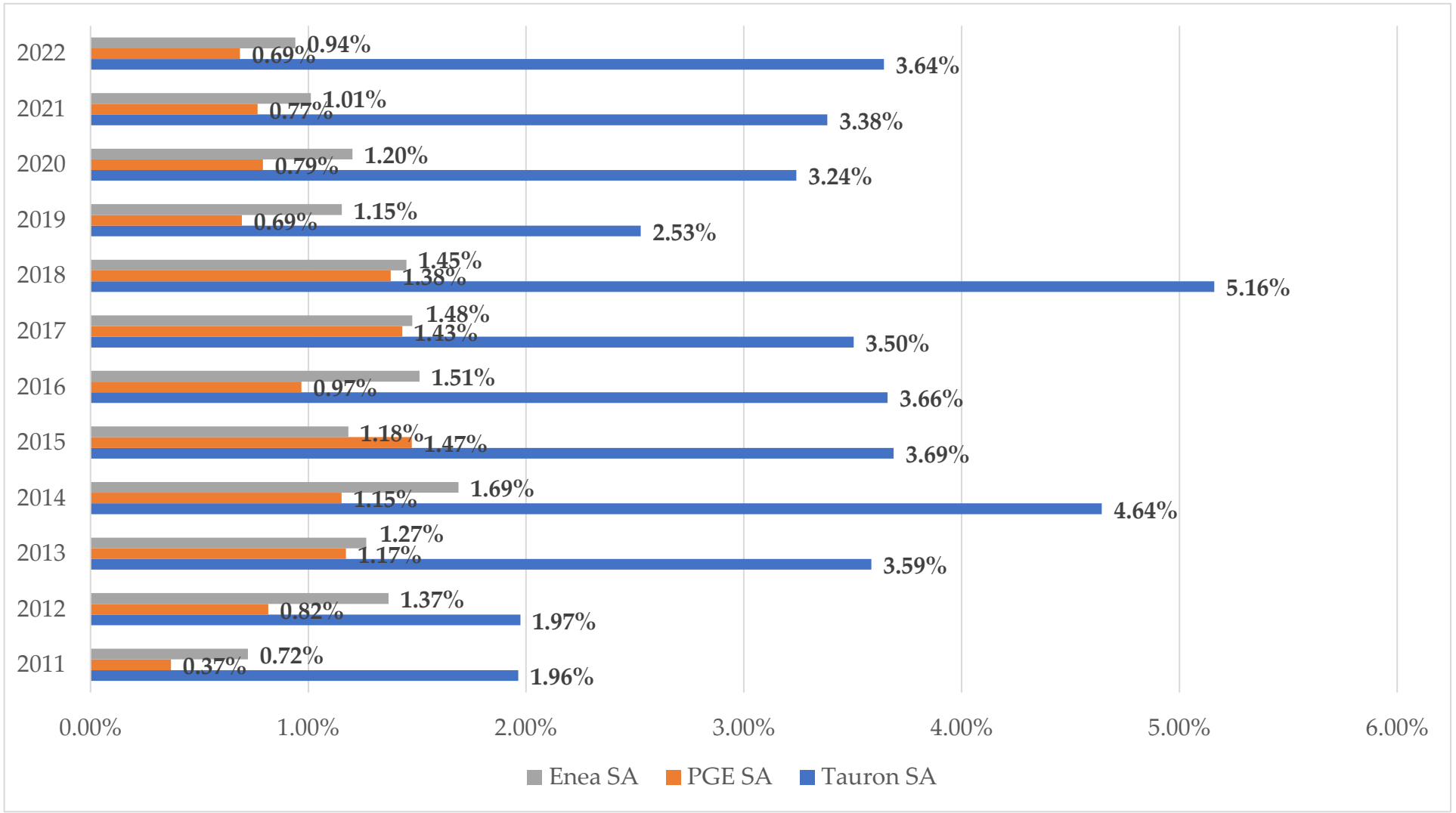

Figure 2. Share of intangible assets in total assets in the analyzed companies in 2011–2022.

Table 2. The intangible assets structure in the analyzed companies in 2011–2022.

Components	Enea SA Years											
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
R&D expenses	0.12%	0.87%	0.83%	0.65%	0.55%	0.55%	0.69%	0.70%	1.16%	1.12%	1.77%	1.68%
Goodwill	18.72%	38.76%	36.97%	44.40%	32.23%	27.42%	24.92%	24.48%	25.35%	24.34%	23.61%	22.42%
Computer software, licenses, and patents	71.93%	52.72%	54.29%	47.42%	58.49%	59.74%	61.54%	62.83%	68.98%	70.20%	70.48%	71.96%
Easement title	0.00%	1.59%	3.01%	4.43%	4.62%	5.50%	6.67%	7.62%	0.00%	0.00%	0.00%	0.00%
Perpetual usufruct title to land	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Relations with customers	6.31%	4.14%	3.95%	3.10%	2.25%	1.91%	1.74%	0.00%	0.00%	0.00%	0.00%	0.00%
Geological information	0.00%	0.00%	0.00%	0.00%	1.86%	4.88%	4.44%	4.36%	4.52%	4.34%	4.15%	3.94%
Certificate exchange agreements	1.54%	1.01%	0.96%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coal supply agreements	1.39%	0.91%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guarantees of energy origin	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rights to CO_2 emissions	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Components	PGE SA Years											
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
R&D expenses	2.53%	1.77%	1.58%	1.52%	1.29%	1.36%	1.13%	1.05%	1.35%	1.20%	1.11%	0.94%
Goodwill	1.74%	22.46%	25.37%	22.90%	19.43%	0.68%	11.80%	10.93%	13.14%	13.61%	17.61%	16.27%
Computer software, licenses, and patents	67.24%	49.79%	41.26%	42.51%	44.36%	54.49%	43.30%	45.53%	60.64%	61.31%	58.65%	57.84%
Easement title	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Perpetual usufruct title to land	0.00%	0.00%	5.53%	5.12%	4.82%	5.58%	21.59%	20.20%	0.00%	0.00%	0.00%	0.00%
Relations with customers	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Geological information	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Certificate exchange agreements	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coal supply agreements	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guarantees of energy origin	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rights to CO_2 emissions	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	28.49%	25.98%	26.25%	27.94%	30.10%	37.89%	22.18%	22.30%	24.87%	23.88%	22.62%	24.94%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Components	Tauron SA Years											
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
R&D expenses	0.61%	0.47%	0.28%	0.24%	0.36%	0.32%	0.35%	0.33%	0.78%	0.83%	1.25%	1.09%
Goodwill	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Computer software, licenses, and patents	38.10%	41.97%	26.27%	24.38%	34.80%	35.76%	35.62%	40.56%	71.81%	72.71%	77.06%	73.11%
Easement title	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Perpetual usufruct title to land	34.12%	30.04%	56.17%	40.51%	49.69%	46.06%	42.74%	40.47%	1.36%	1.22%	0.00%	0.00%
Relations with customers	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Geological information	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Certificate exchange agreements	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coal supply agreements	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Guarantees of energy origin	0.00%	0.00%	1.40%	10.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rights to CO_2 emissions	13.46%	11.66%	2.39%	13.60%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other	13.71%	15.86%	13.48%	10.63%	15.15%	17.86%	21.28%	18.64%	26.05%	25.24%	21.68%	25.80%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

According to Figure 2, the ratio of intangible assets to total assets was the highest for Tauron SA, increasing from 1.96% to 5.16%. Its material commitment towards innovation is distinguishable from the other two companies. This is also a company with the highest share of RESs in energy production. The second place belongs to Enea SA with its ratio of intangible assets to total assets that increased from 0.72% to 1.69%. The ratio was lowest for PGE SA, increasing from 0.37% to 1.47%. For these two companies, the share of RESs corresponds to the ratio of intangible assets to total assets, suggesting that there is a relationship between the companies' commitment to innovation and energy production from

renewable energy sources. The higher the energy production from RESs, the greater the companies' commitment to green transformation. The use of renewable energy resources promotes innovation.

It is worth noting, however, that the share of the measurable effects of innovation in the assets of the surveyed enterprises is very small (even in Tauron). It constitutes only a fraction of the infrastructure. In this context, it is difficult to consider intangible assets as sufficient to strengthen green innovation in the future, especially since their share in assets fluctuated over time without a constant upward trend.

Additionally, the structure of intangible assets is dominated by the effects of innovative activities—patents, licenses, and computer software. Furthermore, a negligible part is represented by research and development, which seems to be a necessary condition for carrying out green transformation.

Furthermore, Figure 3 depicts changes in the intangible assets of the analyzed companies in 2011–2022. They indicate that there was an intense period of innovation in 2011–2014. However, starting from 2015, the pace of those changes has been much slower, whereas from 2018 we can observe the reduced potential of the intangible assets. Changes in intangible assets are correlated positively with the share of renewable resources in energy production. At 0.05, those are not statistically significant correlations, due to the low observation number. Nonetheless, for Tauron SA and Enea SA they indicate an average correlation (Tauron SA = 0.4895 and Enea SA = 0.5448) and suggest that there is a relationship between a commitment to innovation and the energy production of RESs.

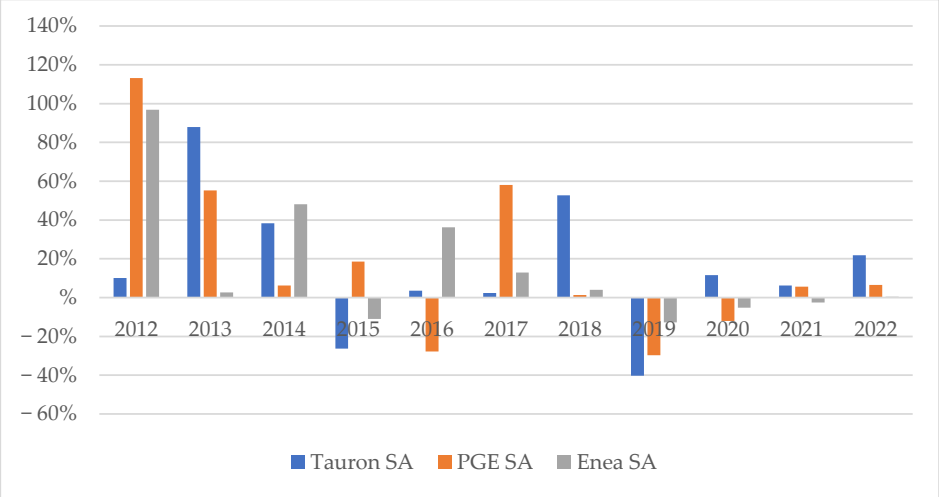

Figure 3. Changes of the intangible assets in the analyzed companies in 2011–2022.

Further analysis refers to the structure of intangible assets. In Tauron SA, they include mostly computer software, patents, licenses, and the perpetual usufruct title to land. There are also some R&D expenses. In Enea SA, this is also mostly software, patents, and licenses. This company also discloses a significant share of goodwill relating to the acquisition of smaller energy companies. A similar structure of intangible assets is shared by PGE SA. Nonetheless, in that company contrary to the two previous ones, the share of software, patents, and licenses in the structure of total intangible assets has been decreasing, which may indicate reduced resultant innovation. Moreover, in PGE SA there is also a reduced share of R&D expenses, while in Tauron SA and Enea SA this share has been growing steadily, meaning that potential innovation decreases as well.

4.2. Innovative Nature of Selected Polish Companies in the Energy Sector Compared to the Useof Renewable Energy Sources from an Investment Perspective

The second part of the analysis looked for answers to the question of how the investors perceive the energy companies' commitment to green energy generation and if the related

activities are reflected in the financial results of the analyzed companies. Considering the above, Table 3 presents such indicators as P/BV, ROA, and ROE for the analyzed energy companies.

Table 3. P/BV, ROA, and ROE for the analyzed companies in 2011–2022.

Enterprise	Years											
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
						P/BV						
Tauron SA	0.56	0.49	0.48	0.45	0.29	0.35	0.25	0.19	0.10	0.28	0.32	0.20
PGE SA	0.88	0.77	0.79	0.81	0.64	0.53	0.42	0.42	0.16	0.28	0.37	0.25
Enea SA	0.73	0.60	0.67	0.58	0.42	0.40	0.31	0.28	0.18	0.21	0.27	0.21
						ROA						
Tauron SA	5.31%	5.77%	4.94%	4.46%	−5.01%	1.80%	4.12%	0.90%	0.56%	−2.02%	1.32%	1.97%
PGE SA	5.97%	5.84%	6.58%	6.37%	−4.74%	4.32%	4.28%	2.33%	−4.38%	0.84%	4.90%	3.62%
Enea SA	5.08%	4.73%	4.43%	5.46%	−0.76%	3.77%	4.53%	2.96%	3.62%	−4.68%	5.27%	0.68%
						ROE						
Tauron SA	8.02%	9.27%	7.69%	6.60%	−10.03%	2.26%	7.80%	1.11%	−0.06%	−13.60%	2.24%	−7.80%
PGE SA	12.57%	8.80%	9.26%	8.24%	−7.37%	6.20%	5.93%	3.15%	−8.26%	0.34%	8.50%	6.27%
Enea SA	7.71%	5.67%	6.61%	7.62%	−3.23%	6.69%	8.55%	4.84%	2.47%	−15.02%	12.50%	0.72%

The data in Table 3 indicate that all the analyzed companies were undervalued in the entire period. This means that their investors consider them to be relatively unattractive public companies with a traditional profile of operations. In 2015 (a period of regular growth of the companies' commitment to RESs), the undervaluation level is average. After 2015, the value of all analyzed energy companies falls significantly, which corresponds both with the reduced share of RESs in production and with the deteriorating financial results of the analyzed companies.

The most undervalued company is Tauron SA, and the least undervalued is PGE SA. This tendency suggests that there was no response of investors to the analyzed companies' commitment to the green transformation process and the use of RESs. This is also confirmed by the very high, statistically significant negative correlation coefficient for PGE SA (−0.8547), indicating that the increased share of RESs in production leads to a reduced P/BV indicator. A similar though less intense relationship can be found in Enea SA (−0.3728) in this respect. These relationships may stem from the high commitment of the analyzed companies to the use of RESs. They may also result from the fact that investors do not consider green transformation important, or even that they deny its reasonableness. Eventually, they may stem from other determinants of results and the image of the analyzed companies, including changing energy policy, the COVID-19 pandemic, or the conflict between Russia and the Ukraine.

The ROE also has negative correlations with the share of RESs in energy production. The correlation is the highest in Tauron SA where the RESs are used to the highest degree (the statistically important correlation of −0.6953). Negative correlations are found for Enea SA (−0.1913) and PGE SA (−0.3932) as well. They are lower and with no statistical significance, but they still illustrate the possible direction of interdependency.

The holistic profitability of the analyzed companies (ROA) was positive and very good by 2015. In subsequent years, it deteriorated significantly. The analyzed companies disclosed losses in certain periods. The observed changes may result from political changes (in 2015, a new right-wing party seized power) and resultant amendments to energy policy, including the decision to use RESs. Unfortunately, in 2015–2022, the analyzed companies did not manage to rebuild their potential relating to the use of RESs. Their financial results did not improve as well.

5. Discussion

The analyses presented in this paper indicate that innovation and the use of RESs by energy companies display positive correlations. This tendency is particularly visible in the initial development period of RESs in Poland, i.e., from 2011 to 2014. In this period, the Polish activities of green transformation were developed most intensely. Our conclusions reinforce the pan-economic observations of Stevens et al. (2023) [35] and Temmes et al. (2021) [37], who stipulate that the national resource policy may drive energy innovation effectively.

Unfortunately, the reduced use of RESs in the analyzed companies and the reduced scope of innovative activities following 2015, which is reflected in the intangible assets of the analyzed companies, correspond to the conclusions of Dzikuć et al. (2021) [43] concerning the significant arrears of Polish energy companies relating to innovation and the use of RESs. This is also an indirect reference to the analysis of Michalak and Wolniak (2023) [33], which indicated that both the innovation levels and the energy transformation rates are low in the coal-based energy sector. All the analyzed companies are integrated vertically with coal mines, which, certainly, makes it more difficult to produce energy from RESs. Therefore, a rather pessimistic conclusion can be drawn that Poland stands little chance of efficiently responding to climate change, because there is no RES development without innovation, which is clearly highlighted by Solarin et al. (2022) [38] and Aldieri et al. (2022) [39].

We can also conclude that neither innovation nor the increased use of RESs are encouraged by the negative correlation between the share of RESs in energy production and the companies' perception by stock exchange investors. The investors seem to deem the green production aspect unimportant, meaning that it does not translate to the market value of the companies. All the studied companies are permanently undervalued, and the increased use of RESs aggravates that undervaluation further in two of them.

The share of RESs displays a negative correlation with the owners' profitability. The identified relationships may be, certainly, accidental and stem from other circumstances, but they clearly point to an absence of the expected ties between an increased use of RESs and the companies' image as perceived by investors and the profit for the owners. The absence of such an impact may result in the discontinuation of innovative activities for energy transformation in the context of the use of RESs. This means that these findings do not confirm the conclusions drawn by Duong et al. (2023) [56] and Xu et al. (2020) [57] concerning the favorable impact of innovation and RESs on the financial standing of energy companies even from a long-term perspective.

It is also worth drawing in the qualitative findings of the studies of Cader et al. (2022) [64] among Polish energy companies. The authors concluded that the analyzed companies were interested in the environmental aspects of energy production and the increased share of RESs. Therefore, there is a discrepancy between managers' declarations and their actual outcomes, at least in the three companies analyzed in this paper (which have a significant share in and impact on energy sector operations in Poland).

This may stem from the public nature of the studied companies and the majority share of the state in their capital structure causing significant subordination of the companies' operations to the national resource policy. Companies' commitment to innovation and RESs has decreased significantly after the policy was amended in 2015. The growing tendency relating to RESs appears only three years later and is not reflected permanently in improved profitability. This confirms the conclusions reached earlier by Lee et al. (2022) [34], namely that there is a significant role for the state in creating innovation and supporting green transformation.

The worst period in terms of commitment to innovation and the use of RESs is 2015–2018 when there were amendments to energy policy and a reorientation of instructions relating to the use of RESs. The share of RESs in energy production displays negative correlations with the stock exchange value, which suggests no interest of investors in the scope of green transformation or perhaps even their aversion to such innovation. Political

changes and related changes of the energy policy (such as a departure from decarbonation and a reorientation from wind to solar energy) seem to be the strongest factors affecting both perception of the energy companies and their holistic profitability (ROA) and owners' profitability (ROE).

In the circumstances described above, it may be expected that the standard problems of transformation, identified in the Polish economy by, inter alia, Drago and Gatto (2022) [30] and by Napolitano et al. (2022) [31] and Alemayehu et al. (2022) [32] in other emerging and developing economies, will be intensified.

In connection with the above, our recommendations for the resource policy in Poland and other countries facing similar problems may be phrased as follows:

- Ensuring unchanging (stable in time) resource policy in the energy sector, paying particular attention to the need to increase the share of RESs in energy production;
- Implementing the adopted strategy of the use of RESs, including the financial aid instruments for private investors and institutions consistently;
- Commitment of all government institutions to the green transformation process, as highlighted by, inter alia, Heard et al. (2022) [44];
- Education with respect to the benefits of innovation and the use of RESs targeted to increase acceptance of energy transformation, which will make effective transformation feasible [51–54];
- Monitoring and supporting energy companies in their innovative activities and the use of RESs, including making their strategies more consistent with the national resource policy;
- Creating a legal and organizational framework to ensure the increased use of RESs [37].

6. Conclusions

The following final conclusions can be drawn from the discussed analyses:

- The share of RESs in the total energy production in the analyzed companies increased from ca. 1% to more than 15% in the analyzed period, which indicates slow progress of the green transformation. Nonetheless, a tendency for the growth of the share of RESs in total energy production was observed in the analyzed companies.
- Changes of the share of RESs in energy production were strongly affected by political decisions, which reduced the value of RESs and hampered the growth rate. When faced with changing energy policy and the prioritization of energy security at the expense of decarbonation, state-owned energy companies find it difficult to increase the share of RESs in total energy production.
- The highest capital commitment to innovation, expressed by the share of intangible assets in the total assets, was found for Tauron SA. This is also a company with the highest share of RESs in energy production.
- In Enea SA and PGE SA, the share of intangible assets was lower than in Tauron SA, similar to the share of RESs in production, which indicates the interdependency of a capital commitment to innovation with the green transformation scope.
- Changes in intangible assets reflecting a commitment to innovation display positive correlations with the use of RESs in energy production, meaning that innovation and energy transformation go hand in hand.
- The predominant factor in the intangible assets of the analyzed companies was the resultant innovation dimension in the form of software, patents, and licenses.

The surveyed enterprises do not participate in the benefits of green transformation. It seems that they are not interested in the sustainable development of the Polish energy sector. Their priority is the political guidelines that determine Polish energy policy. The above conclusions highlight the role of government decisions in the energy transformation process. Without a consistent and pro-ecological attitude of the state authorities, effective changes in the Polish energy mix will not be possible. This will expose the Polish economy to exclusion and increase the distance from developed countries.

The major limitation of these studies is the defects of the case study as a research method. The conclusions cannot be verified statistically and, consequently, generalized for the whole population. Financial reports do not provide any data characterized by a high frequency of measurement, which makes an accurate analysis of cause and effect more difficult. Nonetheless, these studies, in the assumed scope, provide new information about the energy sector in developing economies from a micro perspective and may become grounds for improving the strategies of these companies and national energy policies.

The main direction for improving these strategies should be to increase the share of renewable energy sources in energy production. Without such actions at the enterprise level, green transformation will not be effective. Diversification of renewable energy sources is also important, as it favors substitution and maintaining continuity of energy supplies. The individual strategies of energy companies should be consistent with the assumptions of the national energy policy, which should correspond to the assumptions of the European Union's climate policy. A prospective path for the development of a Polish zero-emission energy system may also be the use of nuclear energy. However, the development of this source requires significant capital expenditure and is associated with a long investment period.

Another limitation of the research may also be the analyzed period of 12 years, which may be insufficient to assess the effects of changes in energy policy. Nevertheless, this is the period in which the Climate Package has been in force, and it is difficult to consider it as a short-term research perspective, especially in the context of the weak effects of the changes.

Further studies may comprise inter-economic comparative analyses. They may also refer to the perception of the green economy by stock exchange investors and the impact of these perceptions on stock exchange decisions.

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References

1. Anghelache, C.; Anghel, M.G.; Iacob, Ș.V.; Pârțachi, I.; Rădulescu, I.G.; Brezoi, A.G. Analysis of the Situation of Renewable and Non-Renewable Energy Consumption in the European Union. *Energies* **2023**, *16*, 1338. [CrossRef]
2. Martins, F.; Felgueiras, C.; Smitkova, M.; Caetano, N. Analysis of Fossil Fuel Energy Consumption and Environmental Impacts in European Countries. *Energies* **2019**, *12*, 964. [CrossRef]
3. Marinina, O.; Kirsanova, N.; Nevskaya, M. Circular Economy Models in Industry: Developing a Conceptual Framework. *Energies* **2022**, *15*, 9376. [CrossRef]
4. Ponomarenko, T.; Marinina, O.; Nevskaya, M.; Kuryakova, K. Developing Corporate Sustainability Assessment Methods for Oil and Gas Companies. *Economies* **2021**, *9*, 58. [CrossRef]
5. Thompson, S. Strategic Analysis of the Renewable Electricity Transition: Power to the World without Carbon Emissions? *Energies* **2023**, *16*, 6183. [CrossRef]
6. Siontorou, C.G. Fair Development Transition of Lignite Areas: Key Challenges and Sustainability Prospects. *Sustainability* **2023**, *15*, 12323. [CrossRef]
7. Cotta, B.; Domorenok, E. Catching up with the European Union's recovery and resilience agenda: Green transition reforms in the Italian National Recovery and Resilience Plan. *Contemp. Ital. Politics* **2022**, *14*, 424–440. [CrossRef]
8. White, D. Just Transitions/Design for Transitions: Preliminary Notes on a Design Politics for a Green New Deal. *Capital. Nat. Social.* **2020**, *31*, 20–39. [CrossRef]
9. Wells, P.; Abouarghoub, W.; Pettit, S.; Beresford, A. A socio-technical transitions perspective for assessing future sustainability following the COVID-19 pandemic. *Sustain. Sci. Pract. Policy* **2020**, *16*, 29–36. [CrossRef]
10. Pasten, C.; Santamarina, J.C. Energy and quality of life. *Energy Policy* **2012**, *49*, 468–476. [CrossRef]

11. Brugger, H.; Eichhammer, W.; Mikova, N.; Dönitz, E. Energy Efficiency Vision 2050: How will new societal trends influence future energy demand in the European countries? *Energy Policy* **2012**, *152*, 112216. [CrossRef]
12. Liu, L.; Chen, T.; Yin, Y. Energy Consumption and Quality of Life: Energy Efficiency Index. *Energy Procedia* **2016**, *88*, 224–229. [CrossRef]
13. Kowalska-Styczeń, A.; Owczarek, T.; Siwy, J.; Sojda, A.; Wolny, M. Analysis of Business Customers' Energy Consumption Data Registered by Trading Companies in Poland. *Energies* **2022**, *15*, 5129. [CrossRef]
14. Wolniak, R.; Saniuk, S.; Grabowska, S.; Gajdzik, B. Identification of Energy Efficiency Trends in the Context of the Development of Industry 4.0 Using the Polish Steel Sector as an Example. *Energies* **2020**, *13*, 2867. [CrossRef]
15. Wolniak, R.; Skotnicka-Zasadzień, B. Development of Photovoltaic Energy in EU Countries as an Alternative to Fossil Fuels. *Energies* **2022**, *15*, 662. [CrossRef]
16. Iancu, I.A.; Hendrick, P.; Micu, D.D.; Cirstea, S.D. The Demand for Energy Imports from Non-Renewable Resources in EU-27 Economy. *Energies* **2023**, *16*, 5177. [CrossRef]
17. Kristia, K.; Rabbi, M.F. Exploring the Synergy of Renewable Energy in the Circular Economy Framework: A Bibliometric Study. *Sustainability* **2023**, *15*, 13165. [CrossRef]
18. Zahedi, R. Feasibility study for designing and building a zero-energy house in new cities. *Sol. Energy* **2022**, *240*, 168–175. [CrossRef]
19. Zahedi, R. Development of a New Simulation Model for the Reservoir Hydropower Generation. *Water Resour. Manag.* **2022**, *36*, 2241–2256. [CrossRef]
20. Izanloo, M.; Aslani, A.; Zahedi, R. Development of a Machine learning assessment method for renewable energy investment decision making. *Appl. Energy* **2022**, *327*, 120096. [CrossRef]
21. Konopelko, A.; Kostecka-Tomaszewska, L.; Czerewacz-Filipowicz, K. Rethinking EU Countries' Energy Security Policy Resulting from the Ongoing Energy Crisis: Polish and German Standpoints. *Energies* **2023**, *16*, 5132. [CrossRef]
22. Strojny, J.; Krakowiak-Bal, A.; Knaga, J.; Kacorzyk, P. Energy Security: A Conceptual Overview. *Energies* **2023**, *16*, 5042. [CrossRef]
23. Zdonek, I.; Tokarski, S.; Mularczyk, A.; Turek, M. Evaluation of the Program Subsidizing Prosumer Photovoltaic Sources in Poland. *Energies* **2022**, *15*, 846. [CrossRef]
24. Dat, M.N.; Trung, K.D.; Minh, P.V.; Van, C.D.; Tran, Q.T.; Ngoc, T.N. Assessment of Energy Efficiency Using an Energy Monitoring System: A Case Study of a Major Energy-Consuming Enterprise in Vietnam. *Energies* **2023**, *16*, 5214. [CrossRef]
25. Lorenc, S.; Leśniak, T.; Kustra, A.; Sierpińska, M. Evolution of Business Models of Mining and Energy Sector Companies according to Current Market Trends. *Energies* **2023**, *16*, 5212. [CrossRef]
26. Bigioi, A.D.; Bigioi, C.E. Governance and Performance in Romanian Energy Companies. *Energies* **2023**, *16*, 5041. [CrossRef]
27. Cherepovitsyn, A.; Kazanin, A.; Rutenko, E. Strategic Priorities for Green Diversification of Oil and Gas Companies. *Energies* **2023**, *16*, 4985. [CrossRef]
28. Alghassab, M. A Computational Case Study on Sustainable Energy Transition in the Kingdom of Saudi Arabia. *Energies* **2023**, *16*, 5133. [CrossRef]
29. Arler, F.; Sperling, K.; Borch, K. Landscape Democracy and the Implementation of Renewable Energy Facilities. *Energies* **2023**, *16*, 4997. [CrossRef]
30. Zhakiyev, N.; Khamzina, A.; Zhakiyeva, S.; De Miglio, R.; Bakdolotov, A.; Cosmi, C. Optimization Modelling of the Decarbonization Scenario of the Total Energy System of Kazakhstan until 2060. *Energies* **2023**, *16*, 5142. [CrossRef]
31. Bublyk, M.; Kowalska-Styczeń, A.; Lytvyn, V.; Vysotska, V. The Ukrainian Economy Transformation into the Circular Based on Fuzzy-Logic Cluster Analysis. *Energies* **2021**, *14*, 5951. [CrossRef]
32. Nevskaya, M.A.; Raikhlin, S.M.; Vinogradova, V.V.; Belyaev, V.V.; Khaikin, M.M. A Study of Factors Affecting National Energy Efficiency. *Energies* **2023**, *16*, 5170. [CrossRef]
33. Mularczyk, A.; Zdonek, I.; Turek, M.; Tokarski, S. Intentions to Use Prosumer Photovoltaic Technology in Poland. *Energies* **2022**, *15*, 6300. [CrossRef]
34. Zdonek, I.; Mularczyk, A.; Turek, M.; Tokarski, S. Perception of Prosumer Photovoltaic Technology in Poland: Usability, Ease of Use, Attitudes, and Purchase Intentions. *Energies* **2023**, *16*, 4674. [CrossRef]
35. Lorenc, S.; Kustra, A. Distributing Enterprise Value to Stakeholders in the Range of Sustainable Development on the Basis of the Energy Industry in Poland. *Sustainability* **2021**, *13*, 2130. [CrossRef]
36. Kustra, A.; Lorenc, S. Financial Balance Analysis of Geothermal Companies in Poland Based on Managerial Cash Flows. *Energies* **2021**, *14*, 7885. [CrossRef]
37. Styk, K.; Bogacz, P. A Method for Stakeholder Mapping in Connection with the Implementation of a Development Project. *Energies* **2022**, *15*, 1592. [CrossRef]
38. Kęsek, M.; Bogacz, P.; Migza, M. Study on the Usefulness of Lean Management Tools and Techniques in Coal Mines in Poland. *Energies* **2023**, *16*, 7240. [CrossRef]
39. Bogacz, P.; Cieślik, Ł.; Osowski, D.; Kochaj, P. Analysis of the Scope for Reducing the Level of Energy Consumption of Crew Transport in an Underground Mining Plant Using a Conveyor Belt System Mining Plant. *Energies* **2022**, *15*, 7691. [CrossRef]
40. Li, D.; Ge, A. New energy technology innovation and sustainable economic development in the complex scientific environment. *Energy Rep.* **2023**, *9*, 4214–4223. [CrossRef]

41. Drago, C.; Gatto, A. Policy, regulation effectiveness, and sustainability in the energy sector: A worldwide interval-based composite indicator. *Energy Policy* **2022**, *167*, 112889. [CrossRef]
42. Napolitano, L.; Sbardella, A.; Consoli, D.; Barbieri, N.; Perruchas, F. Green innovation and income inequality: A complex system analysis. *Structual Chang. Econ. Dyn.* **2022**, *63*, 224–240. [CrossRef] [PubMed]
43. Alemayehu, A.G.; Gebreeyesus, A.; Palladino, G.; Setti, M. Behavioral precursors in the innovation-decision process: The case of bioenergy in Ethiopia. *Energy Strategy Rev.* **2020**, *30*, 100499. [CrossRef]
44. Michalak, A.; Wolniak, R. The innovativeness of the country and the renewables and non-renewables in the Energy mix on the example of European Union. *J. Open Innov. Technol. Mark. Complex.* **2023**, *9*, 100061. [CrossRef]
45. Khazaee, M.; Zahedi, R.; Faryadras, R.; Ahmadi, A. Potential assessment of renewable energy resources and their power plant capacities in Iran. *Glob. J. Ecol.* **2022**, *7*, 60–71. [CrossRef]
46. Lee, J.; Jun, S.-P.; Lee, C. Does demand-side innovation policy drive lock-in? Global evidence from solar energy in 155 countries. *Energy Res. Soc. Sci.* **2022**, *89*, 102539. [CrossRef]
47. Stevens, K.A.; Tang, T.; Hittinger, E. Innovation in complementary energy technologies from renewable energy policies. *Renew. Energy* **2023**, *209*, 431–441. [CrossRef]
48. Norouzi, F.; Hoppe, T.; Kamp, L.M.; Manktelow, C.; Bauer, P. Diagnosis of the implementation of smart grid innovation in The Netherlands and corrective actions. *Renew. Sustain. Energy Rev.* **2023**, *175*, 113185. [CrossRef]
49. Temmes, A.; Heiskanen, E.; Matschoss, K.; Lovio, R. Mobilising mainstream finance for a future clean energy transition: The case of Finland. *J. Clean. Prod.* **2021**, *319*, 128797. [CrossRef]
50. Solarin, S.A.; Bello, M.O.; Tiwari, A.K. The impact of technological innovation on renewable energy production: Accounting for the roles of economic and environmental factors using a method of moments quantile regression. *Heliyon* **2022**, *8*, e09913. [CrossRef]
51. Aldieri, L.; Gatto, A.; Vinci, C.P. Is there any room for renewable energy innovation in developing and transition economies? Data envelopment analysis of energy behaviour and resilience data. *Resour. Conserv. Recycl.* **2022**, *186*, 106587. [CrossRef]
52. Fang, Z. Assessing the impact of renewable energy investment, green technology innovation, and industrialization on sustainable development: A case study of China. *Renew. Energy* **2023**, *205*, 772–782. [CrossRef]
53. Raghutla, C.; Chittedi, K.R. The effect of technological innovation and clean energy consumption on carbon neutrality in top clean energy-consuming countries: A panel estimation. *Energy Strategy Rev.* **2023**, *47*, 101091. [CrossRef]
54. Zhang, L.; Abbasi, K.R.; Hussain, K.; Abuhussain, M.A.; Aldersoni, A.; Alvarado, R. Importance of institutional quality and technological innovation to achieve sustainable energy goal: Fresh policy insights. *J. Innov. Knowl.* **2023**, *8*, 100325. [CrossRef]
55. Dzikuć, M.; Gorączkowska, J.; Piwowar, A.; Dzikuć, M.; Smoleński, R.; Kułyk, P. The analysis of the innovative potential of the energy sector and low-carbon development: A case study for Poland. *Energy Strategy Rev.* **2021**, *38*, 100769. [CrossRef]
56. Heard, B.R.; Kerxhalli-KleinField, M.; Holmes, K.J. Beyond A single stimulus: How to leverage the federal government to advance clean energy innovation? *iScience* **2022**, *25*, 104366. [CrossRef]
57. Lyu, W.; Liu, J. Artificial Intelligence and emerging digital technologies in the energy sector. *Appl. Energy* **2021**, *303*, 117615. [CrossRef]
58. Quest, H.; Cauz, M.; Heymann, F.; Rod, C.; Perret, L.; Ballif, C.; Virtuani, A.; Wyrsch, N. A 3D indicator for guiding AI applications in the energy sector. *Energy AI* **2022**, *9*, 100167. [CrossRef]
59. Shabalov, M.Y.; Zhukovskiy, Y.L.; Buldysko, A.D.; Gil, B.; Starshaia, V.V. The influence of technological changes in energy efficiency on the infrastructure deterioration in the energy sector. *Energy Rep.* **2021**, *7*, 2664–2680. [CrossRef]
60. Andoni, M.; Robu, V.; Flynn, D.; Abram, S.; Geach, D.; Jenkins, D.; McCallum, P.; Peacock, A. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174. [CrossRef]
61. Polas, M.R.H.; Kabir, A.I.; Sohel-Uz-Zaman, A.S.M.; Karim, R.; Tabash, M.I. Blockchain Technology as a Game Changer for Green Innovation: Green Entrepreneurship as a Roadmap to Green Economic Sustainability in Peru. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 62. [CrossRef]
62. Pandey, V.; Sircar, A.; Bist, N.; Solanki, K.; Yadav, K. Accelerating the renewable energy sector through Industry 4.0: Optimization opportunities in the digital revolution. *Int. J. Innov. Stud.* **2023**, *7*, 171–188. [CrossRef]
63. Wittmayer, J.M.; Hielscher, S.; Fraaije, M.; Avelino, F.; Rogge, K. A typology for unpacking the diversity of social innovation in energy transitions. *Energy Res. Soc. Sci.* **2022**, *88*, 102513. [CrossRef]
64. Slee, B. Social innovation in community energy in Scotland: Institutional form and sustainability outcomes. *Glob. Transit.* **2020**, *2*, 157–166. [CrossRef]
65. Matschoss, K.; Mikkonen, I.; Gynther, L.; Koukoufikis, G.; Uihlein, A.; Murauskaite-Bull, I. Drawing policy insights from social innovation cases in the energy field. *Energy Policy* **2022**, *161*, 112728. [CrossRef]
66. Dall-Orsoletta, A.; Romero, F.; Ferreira, P. Open and collaborative innovation for the energy transition: An exploratory study. *Technol. Soc.* **2022**, *69*, 101955. [CrossRef]
67. Dudnik, O.; Vasiljeva, M.; Kuznetsov, N.; Podzorova, M.; Nikolaeva, I.; Vatutina, L.; Khomenko, E.; Ivleva, M. Trends, Impacts, and Prospects for Implementing Artificial Intelligence Technologies in the Energy Industry: The Implication of Open Innovation. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 155. [CrossRef]
68. Duong, K.D.; Huynh, T.N.; Nguyen, D.V.; Le, H.T.P. How innovation and ownership concentration affect the financial sustainability of energy enterprises: Evidence from a transition economy. *Heliyon* **2022**, *8*, e10474. [CrossRef]

69. Xu, X.L.; Shen, T.; Zhang, X.; Chen, H.H. The role of innovation investment and executive incentive on financial sustainability in tech-capital-labor intensive energy company: Moderate effect. *Energy Rep.* **2020**, *6*, 2667–2675. [CrossRef]
70. Häggmark, T.; Elofsson, K. The drivers of private and public eco-innovations in six large countries. *J. Clean. Prod.* **2022**, *364*, 132628. [CrossRef]
71. Meijer, L.L.J.; Huijben, J.C.C.M.; Boxstael, A.; Romme, A.G.L. Barriers and drivers for technology commercialization by SMEs in the Dutch sustainable energy sector. *Renew. Sustain. Energy Rev.* **2019**, *112*, 114–126. [CrossRef]
72. Seraji, M.A.N.; Ranjbar, Z.; Keshavarzzadeh, M.; Mousavi, S.; Zahedi, R. Biomass and solar energy in buildings, energetic dark greenhouse, an economic approach analysis. *Therm. Sci. Eng.* **2023**, *6*, 2136. [CrossRef]
73. Palmié, M.; Boehm, J.; Friedrich, J.; Parida, V.; Wincent, J.; Kahlert, J.; Gassmann, O.; Sjödin, D. Startups versus incumbents in 'green' industry transformations: A comparative study of business model archetypes in the electrical power sector. *Ind. Mark. Manag.* **2021**, *96*, 35–49. [CrossRef]
74. Nawrocki, T.L.; Jonek-Kowalska, I. Innovativeness in energy companies in developing economies: Determinants, evaluation and comparative analysis using the example of Poland. *J. Open Innov. Technol. Mark. Complex.* **2023**, *9*, 100030. [CrossRef]
75. Hoicka, C.E.; Zhao, Y.; McMaster, M.-L.; Das, R.R. Diffusion of demand-side low-carbon innovations and socio-technical energy system change. *Renew. Sustain. Energy Transit.* **2022**, *2*, 100034.
76. Zhang, R.; Fu, Y. Technological progress effects on energy efficiency from the perspective of technological innovation and technology introduction: An empirical study of Guangdong, China. *Energy Rep.* **2022**, *8*, 425–437. [CrossRef]
77. Cader, J.; Koneczna, R.; Smol, M. Corporate social responsibility as a significant factor of competitive advantage—A case study of energy companies in Poland. *Energy Rep.* **2022**, *8*, 7989–8001. [CrossRef]
78. Available online: https://www.money.pl/gielda/spolki-gpw/pltaurn00011,o_firmie.html (accessed on 30 July 2023).
79. Available online: https://www.money.pl/gielda/spolki-gpw/plpger000010,o_firmie.html (accessed on 30 July 2023).
80. Available online: https://www.money.pl/gielda/spolki-gpw/plenea000013,o_firmie.html (accessed on 30 July 2023).
81. Jonek-Kowalska, I. Consolidation as a risk management method in the lifecycle of a mining company: A novel methodological approach and evidence from the coal industry in Poland. *Resour. Policy* **2018**, *60*, 169–177. [CrossRef]
82. Stake, R.; Visse, M. *Case Study Research. International Encyclopedia of Education*, 4th ed.; Elsevier: Amsterdam, The Netherlands, 2023; pp. 85–91. [CrossRef]
83. Jonek-Kowalska, I. Multi-criteria evaluation of the effectiveness of energy policy in Central and Eastern European countries in a long-term perspective. *Energy Strategy Rev.* **2022**, *44*, 100973. [CrossRef]
84. Jonek-Kowalska, I.; Nawrocki, T.L. Holistic fuzzy evaluation of operational risk in polish mining enterprises in a long-term and sectoral research perspective. *Resour. Policy* **2019**, *63*, 101464. [CrossRef]