

TOWARDS A GREEN FUTURE: THE POLISH ENERGY MARKET AND THE POTENTIAL OF RENEWABLE ENERGY SOURCES

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Purpose: The purpose of the article is to present the current situation in the energy sector in Poland, with particular emphasis on the role of renewable energy sources (RES), and to assess the impact of these investments on the future of the energy sector in Poland.

Design/methodology/approach: Secondary research was conducted to characterize the energy market in Poland. Documents from four leading electric power producers in Poland were examined.

Findings: Despite the fact that Polish energy sector still heavily relies on coal, the future of the Polish energy sector appears to be closely linked to the development of RES. Leading companies operating in the Polish energy sector have adopted strategies involving significant investments in RES.

Research limitations/implications: This study focuses on the power sector and does not take into account investments in RES made by households. Therefore, future research could focus on the energy transition of households in particular, identifying the determinants and constraints of this transition.

Practical implications: This paper shows how legal regulations, including CO2 emission restrictions and international commitments, affect the current situation of the Polish energy market and shape its development. These regulations also point out the need to accelerate the country's energy transition in order to increase energy security through diversification of energy sources.

Social implications: Large-scale investments in renewable energy sources will contribute to reduction of greenhouse gas emissions, thus, they will have positive effect on the environment.

Originality/value: The issue of energy transition is addressed from both a practical and social point of view. The analysis conducted uses the most recent data, thereby providing up-to-date knowledge.

Keywords: renewable energy sources, energy transition, electricity generation, energy market, electricity.

Category of the paper: research paper.

1. Introduction

In the era of global pursuit of sustainable development, the importance of renewable energy sources (RES) in shaping the future of energy is undeniable. Poland, at the current stage of energy transformation, serves as a unique research subject due to its historical dependence on fossil fuels. The energy policy of Poland is conditioned by international commitments, including existing legal regulations established by the European Union (EU). Poland, as a member of the EU since 2004, is obligated to diversify its energy sources, including increasing the use of RES in the energy mix (Chodkowska-Miszczyk, Szymańska, 2012).

This issue becomes particularly significant in the context of the established air quality norms in Polish cities, that have been, for many years, exceeded. trend results in Poland being positioned at the bottom of the ranking of EU countries in terms of atmospheric quality, which underscores the urgent need for intervention in environmental and energy policy (Adamczyk, Graczyk, 2019). Increasing the share of RES does not only contribute to the improvement of the environment by reducing pollution, but also enhances the efficiency of use and conservation of energy resources, along with the reduction of waste production (Pultowicz, 2009). Furthermore, the increase in the use of RES contributes to the improvement of energy security (Sobolewski, 2010).

Energy security can be defined as "the ability to satisfy the market conditions demand for energy in terms of quantity and quality, at a price resulting from the equilibrium of demand and supply, while maintaining environmental protection conditions" (Borgosz-Koczwara, Herlender, 2008). Therefore, the inclusion of RES into the fuel and energy base contributes to increasing energy security, as it reduces the dependence degree of the availability of these resources on the market and it includes the possibility of them being imported.

Energy transition actions undertaken in the modern world are observable in both the social, economic, environmental and political spheres (Seroka, 2022). The policy of continuous tightening of emission standards is a result of processes occurring in the global economy and those of climate and technology (Kielierz, 2018). Plans to modernize Poland's electricity generation structure must take into account increasing the share of RES (Skoczkowski et al., 2016). Energy transition and ensuring energy security, especially in a coal-dependent economy such as the one in Poland, are activities with a long-term perspective. Yet, the energy transition process in Poland is progressing in an inefficient manner (Kubiczek et al., 2023).

Coal remains the most important resource when it comes to electricity generation in Poland (Ministerstwo Aktywów Państwowych, 2022, p. 14). Operating an energy market based largely on the use of a single energy source is risky. As recently as 2021, it was noted that Poland's continued reliance on coal threatens energy security (Pietrzak et al., 2021). This risk was materialized when, in 2022, Russia began its invasion of Ukraine, and the price of energy carriers and coal imports increased as a result. The war in Ukraine, according to experts,

may in the short term affect the pace of decarbonization of the energy sector (PKO, 2022), however, in the slightly longer term, it may significantly accelerate the energy transition (Polska Akademia Nauk, 2022). Nevertheless, the war resulted in the need to update Poland's Energy Policy to 2040 (PEP2040), noting the need to develop RES in Poland with an increased focus on coal (Ministerstwo Klimatu i Środowiska, 2022, pp. 1-3).

Increasing global energy demand further accelerates the depletion not only of fossil fuel (Sowa, 2018), but also energy security. It is worth noting that Poland, due to its geographical location, is a country with high RES potential (Seroka, 2022). Together with the possibility of obtaining subsidies for projects related to increasing the share of RES in the energy mix, especially infrastructure construction, it effectively encourages large companies to invest (Gouardères, 2023). This is reflected in the development strategies of leading Polish energy companies (Enea, 2024; Tauron, 2022a). Reports from these companies reveal investment strategies focused on the development of RES projects, with the aim of not only increasing the share of green energy in their portfolios, but also contributing to national and EU climate goals (Tomaszewski, Sekściński, 2020).

The purpose of the article is to present the current situation in the energy sector in Poland, with particular emphasis on the role of RES, and to assess the impact of these investments on the future of the energy sector in Poland. The article is structured as follows. The first part compares the use of RES in Poland and Europe, analyzing the share of RES in electricity generation and the structure of the market, including key power generation companies. This part focuses on discussing the main factors shaping the energy market in Poland, including historical conditions, the impact of CO₂ emission allowances and their prices, as well as aspects related to energy security. The second part presents the energy mixes of Poland's leading energy producers, with particular emphasis on the share of RES. In the third part, taking into account the regulations governing the development of the electricity market, a comparison of past and planned investments in RES by leading companies is presented, allowing one to understand the adaptation strategies and development directions of the RES sector in Poland.

2. Main factors shaping the situation of the electricity market

For decades, Poland's energy mix has been based on coal. Scenarios for shifting away from this energy carrier adopted by the Ministry of State Assets show a significant decline in coal's share of electricity generation between 2018 and 2050 (Figure 1). This suggests that the power sector is moving away from fossil fuels such as coal, toward more sustainable energy sources. Two scenarios show that CO₂ allowance prices have a significant impact on the rate of coal decline. In the high CO₂ allowance price scenario, the decline is much faster, proving that pricing policies can be an effective tool in accelerating the transition to cleaner energy.

In 2050, even in the scenario of a balanced increase in the price of CO₂ allowances, the share of coal drops to 28% from 77% in 2018. In the high price scenario, it drops to just 11%. As a result, it can be assumed that in the future, coal will have a much smaller role in electricity generation in Poland (Ministerstwo Aktywów Państwowych, 2022, p. 42; Ministerstwo Klimatu i Środowiska, 2021, pp. 99-100).

RES are the natural direction to move away from coal. According to Eurostat, in 2021, Poland had more than 17% share of RES for electricity generation, with the EU average at 37.5%. According to Eurostat (2023) in Europe, Scandinavian countries lead the way (especially Norway with 114% and Iceland 99%); among EU members, Austria has the most RES in the energy mix with 76%.

In less than a decade from 2012 to 2021, the share of renewable energy in Poland's electricity generation has steadily increased. This suggests that Poland is successfully increasing its use of RES. The most significant increase in the share of RES occurred between 2018 and 2021. It was an increase from 13% to 17%. In these 3 years, it was greater than in the 7 previous years (2012-2018 period), where there was a pattern of only 2.5 pp (Eurostat, 2023).

There is an increase in the penetration of RES in all sectors and technologies. According to the National Energy and Climate Plan for Poland, the share of RES in gross final energy consumption is expected to reach 21-23% by 2030 (Komisja Europejska, 2020, p. 2). In the electricity sector, the share of RES is to be no less than 32%, with wind and photovoltaic energy dominating (Ministerstwo Klimatu i Środowiska, 2021, p. 77). Nevertheless, Poland significantly lags behind most EU countries, highlighting the need to intensify efforts to increase RES use.

2.1. Energy market in Poland

In 2022, an increase was observed in the volume of gross domestic electricity generation to 175,157 GWh. This represented an increase of 0.9% compared to 2021. At the same time, gross domestic electricity consumption amounted to 173,479 GWh, a decrease of 0.5% compared to the previous year.

Polska Grupa Energetyczna (hereinafter: PGE) dominated the electricity market in 2022, as in previous years, both in terms of generation and sales to end users. In the same period, there was an increase in the importance of the PKN Orlen Group (hereinafter: Orlen) in terms of the amount of energy injected into the National Power System (NPS).

The market share ratio of the three largest producers, measured on the basis of the amount of energy put into the network (taking into account the amount of energy supplied by producers directly to end users), fell slightly to 66% in 2022 (down 1 pp compared to 2021). The ratio of the three largest producers' share of installed capacity continued a clear downward trend, declining by 6.2 pp. In 2022, the three largest groups, namely PGE, Enea and Tauron Polska Energia (hereinafter: Tauron), still had almost half of the installed capacity. However, in terms of the amount of energy put into the network, Tauron was replaced by Orlen in the group of the

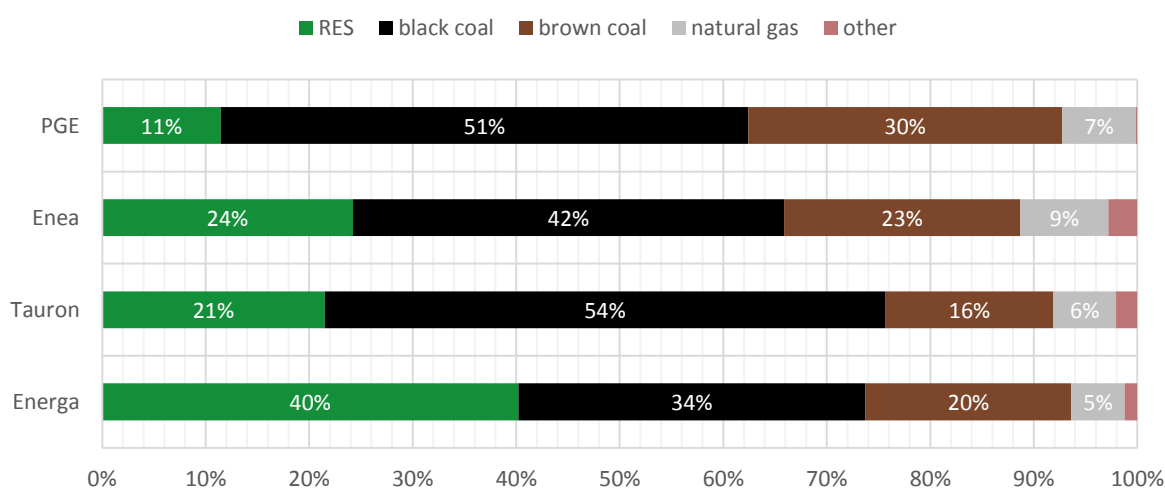
three largest producers. It is worth noting that these three companies account for more than two-thirds of Poland's electricity generation. In 2022, producers from Orlen significantly strengthened their position in the electricity generation market and a significant factor contributing to this was the acquisition of producers from the PGNiG into their structure (Urząd Regulacji Energetyki, 2023).

In 2022, total electricity consumption amounted to 163.5 TWh, not including direct consumption for heating and lighting in entities included in Section D (generation and supply of electricity, gas, steam, hot water and air for air conditioning systems). This represents a decrease of 0.3% compared to 2021. The highest consumption of electricity was recorded in the Mazowieckie (17% of the country's total consumption) and Silesian (16%) voivodeships, while the lowest consumption was recorded in the Podlaskie, Warmińsko-Mazurskie and Lubuskie voivodships. Electricity consumption in the industrial and construction sectors accounted for 42% of total consumption, while consumption by small consumers amounted to 46% of total consumption (Główny Urząd Statystyczny, 2023, p. 20).

2.2. Share of energy sources of power generation companies

In 2022, an increase was observed in the volume of gross domestic electricity generation to 175,157 GWh. This represented an increase of 0.9% compared to 2021. At the same time, gross domestic electricity consumption amounted to 173,479 GWh, a decrease of 0.5% compared to the previous year.

Conventional fuels, i.e. black coal (43% share in 2023) and brown coal (21%), continue to play a dominant role in electricity generation (Energy.intrastat.pl, 2024). However, a noticeable change is the increase in the share of electricity generation from RES. In wind sources, the share of electricity generation increased from 8% to 10%, and in other RES it increased from 3% to 5% compared to 2021 (Urząd Regulacji Energetyki, 2023). Figure 1 presents the energy mixes of the leading electricity producers.



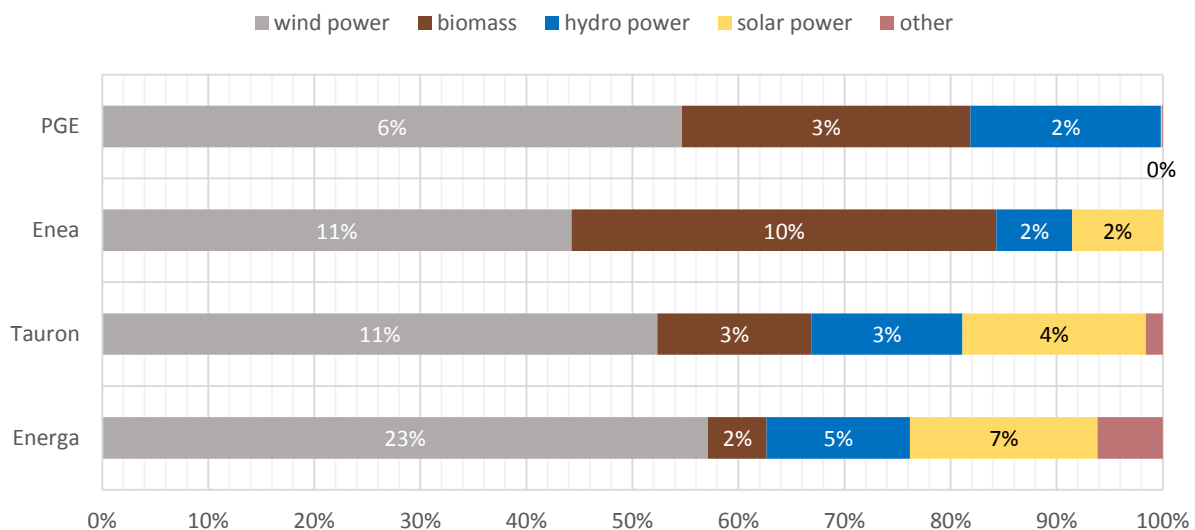
Note. None of companies use nuclear power.

Figure 1. Structure of fuels and other primary energy carriers used to generate electricity sold in 2022.

Source: own study based on (Enea, 2023a; Energa, 2023; PGE, 2022; Tauron, 2024b).

Energa stands out as having the highest use of RES, accounting for 40% of the company's energy mix. This is significantly higher than the other companies, demonstrating Energa's commitment to promoting sustainability. Tauron, on the other hand, relies heavily on black coal, which accounts for 54% of the company's energy mix. This is the largest share of this coal among all companies, which may indicate the need for further diversification of energy sources. PGE shows a balanced use of black coal (51%) and brown coal (30%), showing that the company is trying to maintain a balance between different energy carriers. Finally, Enea uses black coal (42%) as its main energy source, but it also uses RES, which accounts for 24% of the company's energy mix.

Analyzing Figure 2, which shows the structure of RES used by Poland's four major power companies (PGE, Enea, Tauron and Energa) in 2022, it can be seen that the wind power leads the way, accounting on average for half of the RES mix (from 44% at Enea, to 57% at Energa).



Note. Other includes biogas, geothermal.

Figure 2. Structure of RES used to generate electricity sold in 2022.

Source: own study based on (Enea, 2023a; Energa, 2023; PGE, 2022; Tauron, 2024b).

For PGE, wind power accounts for 55% of its RES mix and this is yielding 6% of its energy mix. The share of other RES in PGE's energy mix is relatively low. Enea shows a balanced use of various RES. Wind power and biomass account for 11% (44% of the RES mix) and 10% (40% of the RES mix) of the company's energy mix, respectively. Tauron also shows a balanced use of various RES, with wind power accounting for the largest share at 11% of the company's energy mix. Energa stands out with a significant share of wind power, which accounts for almost 23% of the company's energy mix. Energa also shows significant involvement in solar power, which accounts for more than 7% of the company's energy mix. None of the companies use geothermal energy.

These differences in energy strategies show that Polish energy companies are following different paths toward sustainability. However, attention should be paid to the need for further development and investment in RES to accelerate Poland's energy transition.

2.3. Regulations conditioning the development of the electricity market

In order to harmonize and liberalize the internal energy market, the EU has applied a series of measures to create an energy market that is competitive, customer-focused, adaptable and non-discriminatory, with supply prices based on market mechanisms. These measures include aspects such as market access, transparency and regulation, consumer protection, interconnection and security of supply. They have strengthened the rights of individual consumers, energy communities and vulnerable customers, while clarifying the roles and responsibilities of market participants and regulators, as well as promoting the development of trans-European energy networks. Against the context of the Russian invasion of Ukraine, the EU energy market is undergoing profound structural changes (Ciucci, 2023).

The invasion of Ukraine and the ensuing energy market situation, including the need to move away from fossil fuels imported from Russia, prompted the Council of Ministers to adopt, on March 29, 2022, the assumptions for updating PEP2040. The update aims to minimize or mitigate the risks of potential crises at home and abroad, while pursuing the main goal of the energy policy, namely "ensuring energy security while ensuring the competitiveness of the economy and reducing the environmental impact of the energy sector." A fourth pillar - energy sovereignty – has been added to the three pillars of PEP2040 which include a just transition, building a zero-emission system and improving air quality (Ministerstwo Klimatu i Środowiska, 2022, p. 1).

Therefore, Poland plans to increase technological diversification and expand capacity based on domestic sources. This could mean investing in new technologies and infrastructure to tap domestic energy sources. By 2040, about half of power generation is expected to come from renewable sources. Plans call for further development of wind and solar power capacity, while intensifying the use of weather-independent RES (hydropower, biomass, biogas, ground heat). Poland also plans to improve energy efficiency. This may involve investing in technologies that allow more efficient use of energy, such as smart grids and energy-saving technologies. Furthermore, diversifying energy supplies and providing alternatives to hydrocarbons will mean investing in new energy sources, such as nuclear power or natural gas, which can provide alternatives to coal. This shows that Poland is planning ambitious changes in its energy strategy to increase the share of RES, improve energy efficiency and diversify its energy supply. Still, a threat to the development of RES may be posed by the agreement to periodically increase the use of black coal, maintaining the readiness of coal units (Ministerstwo Klimatu i Środowiska, 2022, pp. 1-4). Nevertheless, studies have shown that the price of CO₂ emission allowances will have a significant impact on the rate of transition away from coal in Poland.

2.4. RES investment plans of the electricity market in Poland

Poland's leading electricity producers are committed to the country's energy transition. Table 1 shows both the current status and future plans of Poland's four major power companies - PGE, Enea, Energa and Tauron - with regard to the use of RES.

Table 1.

Selected RES investment of Poland's four major power companies

	Current	In the future
PGE	20 wind farms, 29 hydropower plants, 4 hydro-pumped power plants and 24 photovoltaic farms	23 photovoltaic installations, the company has about 3000 hectares of land secured for investment purposes. Target solar farms with a capacity of more than 2 GW
ENEA	26 RES installations including more than 20 hydropower plants, as well as wind farms	The Development Strategy envisions a "Green Change for Enea". It is a sustainable transformation of the Group building value growth, with the assumption of achieving climate neutrality by 2050. Plans for offshore wind farms, photovoltaic farms, onshore wind farms and energy storage facilities
ENERGA	The country's largest run-of-river hydroelectric power plant in Wloclawek, 44 small hydroelectric power plants, a hydropower pumped storage plant, 6 wind farms and 6 photovoltaic power plants	By the end of 2030, the corporation will reach an installed renewable capacity of more than 2.5 GW. Baltic Power's offshore wind farm of up to 1.2 GW with a completion date of the end of 2026
TAURON	11 wind farms, 2 photovoltaic farms and a microgrid in Bytom	The Group is building three photovoltaic farms with a total capacity of 200 MW and five wind farms with a capacity of over 160 MW. The strategy "TAURON's Green Turnaround. Energy Around the Clock" indicates the Group's priorities, the most important of which is to achieve climate neutrality by 2050

Source: (Enea, 2020, 2023b, 2024; Energa, 2022, 2024; PGE, 2023a, 2023b; Tauron, 2022b, 2024c, 2024a).

An investigation of the investment strategies of various energy companies in Poland, such as PGE, Energa, Enea and Tauron, shows a diverse approach to the use of RES. All of these entities are definitely committed to RES development, but at different levels and with different technologies.

PGE and Energa appear to be the most committed to a variety of RES technologies, which shows their desire to diversify their energy portfolios. On the other hand, Enea and Tauron seem to be focusing their efforts mainly on wind power, which may be due to their strategic approach to using available wind resources.

Nonetheless, all of these companies still have a long way to go, especially in terms of future plans for photovoltaics and other renewable technologies. The increased interest in these technologies indicates the need for further development and investment in these areas to meet the growing demands for sustainable electricity generation. In this context, the future strategies of these companies will be key to shaping the RES landscape in Poland.

3. Conclusions

Poland's geographic location creates many opportunities for RES exploitation. Furthermore, Poland, by becoming a member of the EU, received a number of funding and support opportunities for RES projects, which could significantly accelerate the process of decarbonization and modernization of the energy sector. Despite this potential, however, the Polish energy sector still relies heavily on coal. Although this situation is historically conditioned, the lack of decisive action within the energy transition has resulted in a threat to energy security.

The future of the Polish energy sector appears to be closely linked to the development of RES. Leading companies operating in the Polish energy sector have adopted strategies involving significant investments in RES. These investments are key to lowering the cost of electricity generation in the long term. By diversifying energy sources, it will be possible to achieve greater stability of energy prices in the domestic market. In addition, the development of RES is fundamental to increasing Poland's energy security. In the context of global geopolitical instability, especially in the face of Russia's invasion of Ukraine and the risks associated with fossil fuel supplies, having a diversified fuel and energy base is crucial. Furthermore, investment in RES contributes to Poland's environmental goals and international commitments, such as reducing greenhouse gas emissions. In the long term, the energy transition makes it possible to effectively pursue sustainable development in the face of growing demand for electricity.

The presented findings have numerous practical implications. They show how legal regulations, including CO₂ emission restrictions and international commitments, affect the current situation of the Polish energy market and shape its development. They also point to the need to accelerate the country's energy transition, in order to increase energy security through diversification of energy sources.

The analyses presented in this study have some limitations, as they mainly focus on the power sector and do not take into account investments in RES made by households, that are nowadays increasingly becoming prosumers of electricity. Therefore, future research could focus on the energy transition of households in particular, identifying the determinants and constraints of this transition.

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