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Evaluation of Energy Transition Scenarios in Poland

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Abstract: Long-term energy scenarios form the basis of energy policy-making. In practice, the use of energy scenarios for the effective creation of energy policy differs in each country. Therefore, the aim of this study is to present two possible scenarios for the development of the Polish energy sector, resulting from the current national policy and international commitments of Poland. The study examined the development of the energy mix in Poland in the 2040 perspective, in accordance with the strategic document Energy Policy of Poland (PEP 2040). The analysis took into account four diagnostic features: electricity production, electricity price, the share of renewable energy sources (RES) in final energy consumption, and CO_2 emission reduction. In addition, the analysis allowed for the presentation of the implications for the Polish economy and society after the application of the diversified variant with nuclear energy and the diversified variant with natural gas. Both scenarios assume too slow development of RES, and the ambivalent attitude of the Polish political elite towards zero-emission energy sources significantly hinders the development of some of its forms (e.g., onshore wind energy). Unfortunately, both the first and second variants entail a large increase in electricity prices, which will affect the entire economy and increase the level of energy poverty among Poles. The study provides strategic insights on the consequences of Poland's choice of a specific energy transformation scenario. The results may serve as a starting point for understanding Poland's restraint towards achieving zero emissions and contribute to the discussion of the direction of development of the Polish energy sector.

Keywords: energy transition; energy scenarios; energy policy; polish energy transformation

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1. Introduction

Climate protection issues have now moved to the top of the political agenda. The popularization of transformational actions in the energy sector started after the adoption of the Climate Change Agreement at the Paris Climate Conference (COP21) in 2015. Almost 190 countries, signatories to the agreement there, committed themselves to the climate target of keeping the temperature increase below 2 °C and preferably at 1.5 2 °C [1]. As a result, the countries of the European Union (EU), have begun to look for solutions that would significantly reduce greenhouse gas emissions by 2030 and achieve climate neutrality by 2050. The European Green Deal is a new growth strategy proposed and adopted by the European Commission in December 2019. Its aim is for the European Community to achieve climate neutrality, i.e., zero net greenhouse gas emissions, by 2050. It is worth adding that by 2030 gas emissions are to be reduced by 50–55% compared to 1990 [2].

Despite an uneasy starting point, Poland has begun the transformation of its energy system. Decarbonizing the Polish economy is a huge challenge. The country does not have many rivers on which hydroelectric power plants could be built, and the number of hours of sunshine is 1300–1900 per year, which is fifty percent less than in southern Europe [3]. Natural gas resources are low and geopolitical factors make importing this raw material on an appropriate scale a challenge. The Baltic Sea allows the development of offshore wind energy in the north of the country, but it is in the south where the most energy-consuming areas are found. Poland also does not have a nuclear power plant, unlike other EU countries from the former Eastern bloc, such as Bulgaria, the Czech Republic, Hungary, Romania, or Slovakia. Energy is largely based on coal [4].

The purpose of this article is to assess the scenarios for the development of the Polish energy sector resulting from the current national policy and Poland's international commitments. The analysis will present the economic and social implications for Poland of the implementation of each of the discussed energy transformation scenarios. The following research questions are aimed at achieving the assumed objective:

1. What are the real scenarios for the development of the energy mix for Poland in the 2040 perspective?
2. How will the energy mix develop in the described scenarios?
3. What will be the impact of each of the proposed energy transformation scenarios on the Polish economy and society?

The article consists of five parts. After the introduction, the theoretical background of creating scenarios for energy sector development is presented. The third section presents the methods used in writing the article and a description of the scenarios. The fourth section contains an analysis of the energy transformation scenarios in Poland. A summary of the results of the analysis, as well as recommendations and possible policy implications, are presented in the fifth section.

The study provides strategic insights on the consequences of Poland's choice of a specific energy transformation scenario. The results may serve as a starting point for understanding Poland's restraint towards achieving zero emissions, as well as contribute to the discussion of the direction of development of the Polish energy sector.

2. Literature Review

Each country creates its own scenarios for the development of the energy sector, which aim to identify different directions of development, which are feasible, and moreover, which support the formulated policy objectives [5,6]. Unfortunately, the future is becoming more uncertain and forecasts are more difficult to prepare [7]. Therefore, the creation of several scenarios, having the same conditions but different enough to capture a realistic range of possibilities for future development paths, including the speed of transformation, should be used to construct a vision for energy policy in a given country [8]. Several factors need to be considered in these projections: economic in nature (economic growth and income growth) and social in nature (population growth rate and life expectancy), as they play a significant role in transforming the energy system [9]. It is worth emphasizing that the transformation towards sustainable development is the result of both technological changes and comprehensive changes in the behavior of society at various levels of activity, which is a stimulus for the implementation of the energy transformation. Social innovations refer to fundamental changes in attitudes, strategies, and policies. Social innovation plays an important role in transforming society into a community where people look for ways to meet their own needs and thus reduce dependence on standardized offers for market economy products and energy sector organizations [10]. In the transition to sustainable development, technical and social innovation co-evolve and interact positively [11]. Transforming Social Innovation (TIS) views the emergence and development of technology as a global process that transcends sectoral and geographic boundaries [12].

Scenarios illustrate the long-term consequences of policy decisions and provide perspectives for policy debate. It is worth mentioning that sustainable scenarios, in contrast to the stringent ones, which include stringent climate targets and high energy demand, are characterized by a lower rate of development of green technologies, as they have to meet overall energy needs, building on existing generation technologies, without the tension of rapid expansion of renewable energy sources (RES) and the issue of their financing [13]. This is because states tend to achieve some stability and resist any fundamental change. Very often, states have institutionalized power and incumbent organizational structures that prevent them from seeing new development alternatives open up and keep supporting the old system. Moreover, infrastructure, production technologies, and domestic raw material resources also influence the state's restraint towards systemic change [11]. As a result, unblocking the energy system requires sufficient time to implement policy measures to stimulate the development of sustainable technologies. Political intervention is most effective in the early stages of transformation. When old technology is fully developed and there are several niche markets, state actions may turn out to be negligible, but their effect may increase by increasing niche markets and slowing the development of the existing energy system [14].

Experience shows that energy transitions take time, typically half a century from initial entry to the majority market share. Previous energy transitions have been driven by technological change, economic factors, access to resources, or the offer of higher levels of energy services to consumers. Therefore, business opportunities, the economic benefits of the transition, or state self-determination have been at the heart of the change [15]. Energy transition relies on an energy policy framework designed by the government that can accelerate the process and determine its direction. A well-designed transition policy takes into account the characteristics of the energy system and includes energy demand and supply. It is therefore necessary to use policy instruments that evolve over time to meet the needs that exist on both the demand and supply side [16].

When creating energy scenarios, it is important to consider new technologies that will help create an Intelligent Energy Management System (IEMS). One of the solutions that will help to meet the Paris requirements is the concept of a virtual power plant (VPP), which will facilitate cooperation between individual market participants, ensuring monitoring and energy efficiency through a two-way energy flow. This concept helps consumers to trade excess electricity on the market at the desired price without third-party interference [17,18].

The energy transition process is characterized by the interplay of old and new technologies as well as a structural link with other sectors such as information and communication technology (ICT) [19]. Blockchain-based technologies can play an important role in the energy transformation, offering profitable local energy trading, accelerating renewable energy production, and providing grids with new demand-response resources to increase grid stability [20].

The energy system is indifferent as a result of the deep-rooted dependence of energy infrastructure on development pathways. According to the shock theory applied to Poland in the 1990s by the then Minister of Finance L. Balcerowicz to switch the Polish economy, struggling with numerous economic problems, to a free-market economy, it is unlikely that the gradual introduction of any policy—in this case, climate policy based on renewable energy sources—has transformed the system on the necessary scale [21,22]. What is needed is a systemic shock that throws the system out of balance, creating incentives for new business models and technologies [23,24]. In other words, new technologies enabling a cost-effective share of 100% renewable energy will be developed only if the right premises are created. The rapid development of green energy sources, in particular in the electricity sector, in several countries around the world has resulted in a surplus of energy coming onto the market that has accelerated a shift in thinking about new models and coalitions of market participants [25,26]. In this way, critical points can move the energy system towards new technological offers. In a simple, gradual change, the current fossil fuel-based energy system is more likely to adapt and return to the old equilibrium [27]. The system shock is also intended to signal to market participants that the transition goes beyond gradual change. Actors must therefore quickly familiarize themselves with the coming changes in order to generate new ideas and business models as quickly as possible [28,29].

As can be seen, energy transitions contribute not only to changes in the energy system itself but also touch the social sphere, hence viewing the process of creating a low-carbon or zero-carbon economy only through the prism of fuel and technology is hardly diagnostic for energy transition. A change in the social-energy order can occur when large numbers of consumers become producers [30].

So, scenarios are tools used to create space for thinking about what is possible. They make it possible to create a simulation in relation to a specific decision or strategy that cannot be easily tested in real conditions, e.g., due to costs and/or social problems [31]. Comparing the similarities and differences that have emerged in scenarios allows a better understanding of the factors that influence the pace of change [32].

Summing up, creating scenarios allows selecting an action plan, without which it is difficult to maintain energy security, develop domestic business, create new jobs, or improve the innovativeness of the economy.

3. Methodology

The methodological approach in this research is mainly based on a review of the literature, descriptions of the most realistic scenarios of the Polish energy transformation, quantification of the scenarios, and their comparison. The main step of the research is the description of the scenario where each scenario has been defined on the basis of verified information. The time frame of the study was set for the period from 2030 to 2040, as the current energy policy of Poland (PEP 2040), which was adopted by the government in January 2021, is envisaged until then. It shows that the energy transition in Poland will be carried out based on three pillars:

- I equitable transition (providing new development opportunities for regions and communities most negatively affected by the energy transition);
- II zero-emission energy system (achieving zero-emission in the energy sector will be possible through the construction of a nuclear power plant, implementation of offshore energy, development of prosumer energy while increasing the share of gas in the electricity generation sector);
- III good air quality (moving away from fossil fuels not only in the energy sector but also in transport and construction) [33].

After a long wait of more than ten years for this document, the ruling elite did not find it necessary to extend the time horizon of this document to 2050. The PEP would then be in line with the timeframe set by the European Union in the European Green Deal Strategy. The PEP 2040 is another attempt to find a consensus between the EU requirements contained in the European Green Deal and the expectations of mining communities. Extending the period of coal mining in Poland seems unjustified, especially in the context of rising coal prices and increasingly difficult access to deposits. Referring to PEP 2040, there is only one scenario—diversified with nuclear energy. It is based on diversified energy sources with nuclear energy, which allows replacing coal-based production with nuclear energy. In order to prevent the loss of continuity of energy supply, some existing coal power plants are being modernized to significantly extend their lifetime. Other important energy sources in this scenario are natural gas and energy from renewable sources.

Despite the absence of the second scenario in PEP 2040, many researchers and market observers consider it appropriate to distinguish a diversified scenario with natural gas. This scenario is similar to the first one, except that it is based on energy carriers that currently exist in Poland, without the nuclear energy subsector. In this variant there is increased energy production from natural gas and RES. In both scenarios, apart from the leading source, green energy plays an important role. The development of energy production from renewable sources, supported by cogeneration units, is therefore assumed. It is worth mentioning that the coal-based scenario, which relied on coal-burning generating units to produce electricity, has been strongly promoted until recently [34], but Poland's adoption of the Paris Agreement and the European Green Deal completely precludes the implementation of this very scenario, hence the transformation plans contained in the Polish energy strategy do not envisage the use of coal in a perspective longer than 2049.

Many countries are considering one more energy transformation scenario—the RES scenario, which is entirely based on renewable energy and assumes a gradual withdrawal from coal, without modernizing coal blocks to extend their lifetime. This scenario has not been analyzed because the Polish government did not even take it into account when preparing Poland's energy strategy until 2040, hence its entry into force is not realistic.

The study consisted in a separate analysis of two variants of the Polish energy transition, during which four diagnostic features were identified and used: electricity production, electricity price, share of RES in final energy consumption, and reduction of CO_2 emissions. Both scenarios are based on a separate key energy carrier to drive change in the Polish energy sector. The study indicates the consequences of the pace of transformation, the shape of the resulting energy landscape, and the effects of climate change mitigation during the implementation of each scenario. Various research methods were used in the study. The analysis and criticism of the literature allowed for deepening the knowledge in the area of the assumed research issues. The formulation of research problems was possible thanks to synthesis. The institutional and legal method analysis was used to present the applicable legal provisions related to the analyzed phenomenon. The forecasting method was used to determine the changes in the Polish economy that will occur as a result of selecting each of the presented scenarios of energy transformation. The inductive inference has been used to refine general conclusions.

4. Polish Energy Transformation Scenarios

4.1. Diversified Scenario with Nuclear Energy

The scenario included in the PEP 2040 allows for the replacement, initially in a small and then in a larger part of the electricity production generated from coal, by energy from the atom. This scenario plays a leading role in countries with nuclear power plants and a high proportion of their electricity generation from coal. Hence, it can be seen in the energy strategies of the Czech Republic, Romania, Slovakia, and France, among others [35]. Other important energy sources in this scenario are natural gas and energy from renewable sources. Such a scenario is also forecast for Poland, but there is one major barrier that makes it difficult to implement—there is no nuclear power plant in Poland. For over a decade, the ruling elites have been discussing a return to the idea of building such a unit but apparently without success. Poland's first experience with a nuclear power plant was still under communist rule, with the construction of the Żarnowiec Nuclear Power Plant commencing in 1982 [36]. However, in 1990 the government of T. Mazowiecki suspended the construction of this investment due to financial difficulties and lack of public acceptance [37]. The first attempt to reactivate the nuclear program in the Polish energy sector took place in 2009–2012. However, at that time, the nuclear energy landscape looked very different. In Europe alone, two nuclear power plants were being built, one in France and one in Finland. The situation changed after the disaster at Japan's Fukushima Dai Ichi power plant, after which Germany announced the decommissioning of its nuclear units by 2022. This led to a global freeze of nuclear projects, including in Poland [38]. Recently, the discourse of nuclear revival is visible in official documents issued by the Polish government [39]. According to the assumptions of the Polish Nuclear Power Program of 2020, two power plants with three nuclear reactors III and III + generation each with a total capacity of 6 to 9 GWe are to be built in Poland. In 2022 a final decision will be taken on the location of the nuclear power plant, and four years later construction of the first power plant will begin, with commissioning scheduled for 2034. Ten years later, the second nuclear power plant is to be commissioned [40]. Poland's ruling elite believes that if Poland is to remain competitive in the global market for goods and services it must introduce the atom into its energy sector, especially in view of the withdrawal of coal from the energy mix. The emphasis on the competitiveness of the economy is signaled by reasoning based on market rationality [41].

There are number of factors that could affect the described scenario. The first of these is capital expenditures which, as history shows, are usually higher than estimated and are caused by delays in the timing of investments [42]. The second risk factor is the already mentioned delay in the implementation of the investment, even a delay of several months is particularly undesirable in this scenario, as it will significantly hinder the process of reducing greenhouse gas emissions. The times when a nuclear power plant could be commissioned within a decade are gone forever. For example, Finland has been building its power plant for 17 years, the Slovaks, after 12 years of construction, have just commissioned the 3rd unit at the Mochovce power plant [43], and the only known example of an investment only slightly delayed is the Barakah power plant in the United Arab Emirates (2012–2020), obviously thanks to the UAE's huge financial resources [44]. It is worth adding that replacing a 1000 MW coal power plant with a nuclear power plant allows for the reduction of annual CO_2 emissions three times in comparison with replacing a gas power plant [45].

The recovering Polish economy after the COVID-19 pandemic will need increased amounts of energy; this will be associated with a shift in demand for final energy from fossil fuels towards electricity, resulting from the increasing mechanization of industry and services, the spread of electric vehicles (plug-in hybrids), and the electrification of the process of heating water and producing heat in many households so far using coal or gas for this purpose. It is forecasted that the increase in demand for power at its peak in 2020–2040 will be about 27.8%, which means that after 2040 it will reach a value of 31 GW [46].

In the diversified scenario with nuclear energy, the share of coal in domestic energy production by 2030 will still be high and will reach 56%, gas power plants and gas heating plants will be another source of energy generation (10.5%), while renewable sources will constitute 32%. The nuclear power plant, to be commissioned only in 2034, will initially provide 8% of the electricity, and the energy shortage will be made up by imports. The inclusion of a nuclear power plant in the system will reduce the amount of pollution from the energy sector by phasing out generating units with low efficiency. Increased demand for energy necessitates the expansion of transmission infrastructure, which will improve power supply reliability and increase cross-border exchange opportunities. To improve efficiency, smart electricity grids will be implemented, which will facilitate the integration of the activities of connected grid users. By 2040, a virtually new electricity system will be built in Poland. Based on the analysis of effects and impact on GDP and savings potential, Poland declares a national target of 23% energy efficiency improvement by 2030. At the same time, according to the Energy Efficiency Directive, in each year of the 2021–2030 period, Poland will achieve new savings of at least 0.8% of annual final energy consumption. In 2040, in the scenario with nuclear energy, the share of RES will increase to 40%, the share of nuclear energy will increase to ca. 14% and of gas to 17%, while the share of coal will decrease to 28% (Figure 1) [33].

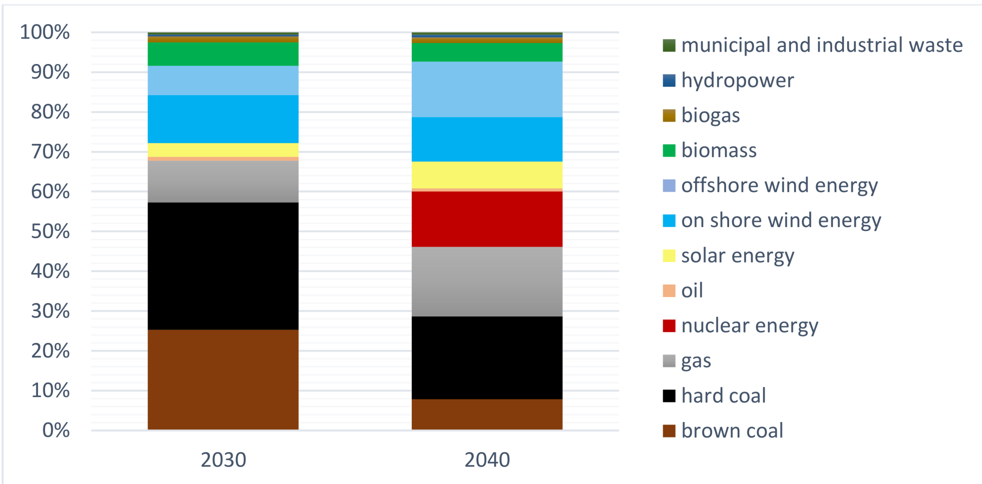

Figure 1. Gross electricity generation forecast by fuel, in %. Source: Own elaboration based on: [46].

An important element of the transition that directly affects society is the price of energy. For several years, one can observe an increase in wholesale electricity prices in Poland, which at the same time are among the highest in the EU [47]. It is worth adding here that the wholesale price is a derivative of fuel prices and CO_2 costs, hence the wholesale price of energy in Poland is coupled to the price of hard coal, which accounts for 50% of energy produced in the country. The increase in prices results firstly from the growing value of coal extracted from domestic deposits, which has become more expensive than imported coal [48] and secondly from increased actions of the Union in favor of climate, resulting in increased prices of greenhouse gas emission allowances. The Union plans to deepen the reduction of CO_2 emissions by 2030 in relation to 1990 by 55%, instead of the previously approved 40% [49]. Lower electricity prices in other EU member states are due to, among other things, switching the electricity generation subsector from coal to gas or having nuclear power plants. Electricity prices in Poland are only expected to stabilize between 2030 and 2035, mainly as a result of coal units being switched off and the price of greenhouse gas emission allowances falling as demand for them decreases (Figure 2).

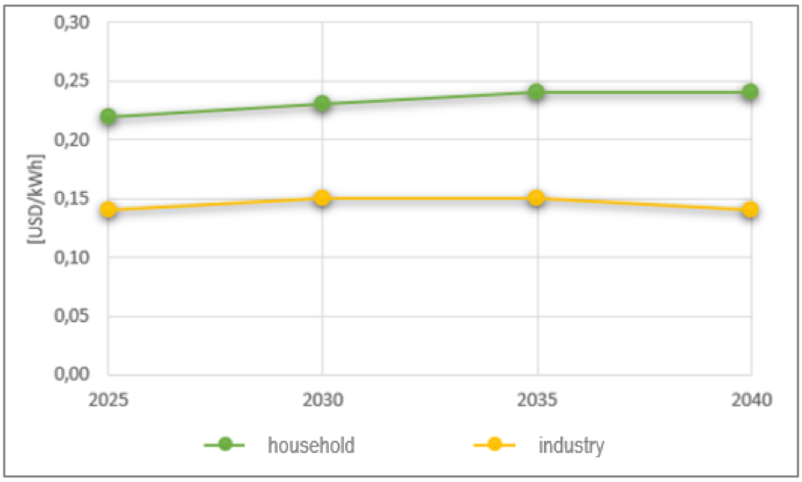

Figure 2. Electricity prices in Poland by customer. In USD/kWh. Source: Own elaboration based on: [46].

The growing prices of energy in Poland and energy raw materials in the world will increase the operating costs of individual sectors and industries generating gross value added, which in turn will increase energy poverty in this country.

Another important element of the diversified nuclear-based scenario is to ensure energy security. For many years, the most important domestic energy source in Poland was coal; it gave Poland a comparative advantage, placing it in the forefront of Community countries not dependent on electricity imports. However, as a result of the already known decarbonization prospects, coal production will be phased out in Poland by 2049. Coal mining will not maintain its competitive advantage in the domestic market, even assuming an increase in its productivity. In the case of the discussed scenario, there will be a balancing of domestic coal supply with power sector demand, due to the diversification of the generation mix and the growing share of nuclear and RES. By utilizing the domestic renewable energy potential, 65.6 TWh of electricity will be produced in 2030, i.e., about 23% in final energy consumption, while ten years later it will already be 92 TWh, which is only 28.5% (Figure 3).

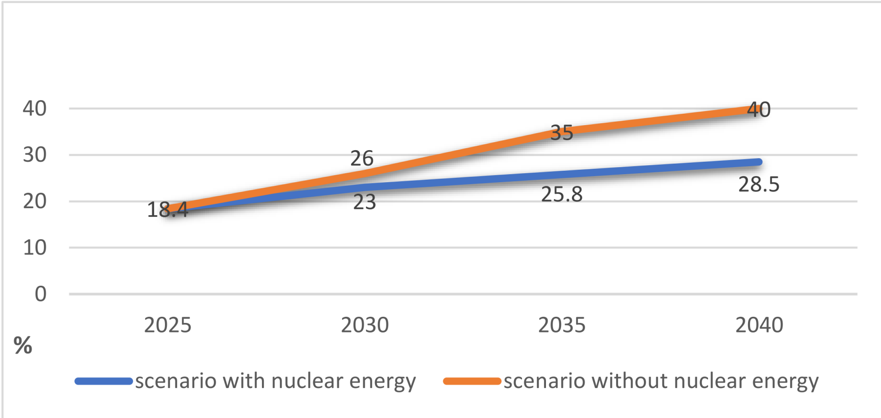

Figure 3. Projection of RES share in gross final energy consumption, by scenario. Source: Own elaboration based on: [46,50].

As the energy transition is aimed at reversing unfavorable global climate change, a very important element of the energy transition scenarios is the reduction of the energy sector's impact on climate and the environment. In the analyzed scenario, the situation with the reduction of CO_2 emissions will start to improve after the nuclear power plant becomes operational, i.e., after 2034. The CO_2 emission intensity for electricity and heat production in 2030 will be 268 million tonnes, hence the reduction will be 29% in relation to 1990, while ten years later it will be 209 million tonnes, i.e., there will be a decrease of 45% in relation to 1990 [46].

To sum up, the lack of profitability of investing in new coal-based generation capacity will result in a dynamic process of reducing the number of coal power plants after 2030, which at the same time will force a faster development of non-coal energy sources and will affect the reduction of CO_2 emissions.

4.2. Diversified Scenario with Natural Gas

The transition towards climate neutrality will be based on a wide share of natural gas, which in this scenario is treated simultaneously as the main and transition fuel before RES reach higher technological viability. It is worth noting that transitional fuel in this scenario means a low-carbon fuel that is intended to be an alternative to fossil fuels in order to reduce greenhouse gasses emissions [51]. The role of natural gas in the energy transition is time-limited. The European Commission has decided to change the rules for providing financial support to projects belonging to the Trans-European Energy Networks (TEN-E), in order to mobilize member states to redirect their investment efforts towards the energy infrastructure of the future. The end of funding for the construction of oil and gas infrastructure has thus been announced. The aftermath of this decision is the withdrawal of financing for new gas projects by a number of banks, including the European Investment Bank, which will not be granting loans for gas investments from 2022 [52].

For several years, the demand for gas in Poland has been constantly growing. It is used not only in the energy sector but also in the industry: for the production of fertilizers, in metallurgy (steel and glass) and for heating in households [53].

Over the last decade, Poland has developed its gas infrastructure to such an extent that it is able to cut itself off from supplies from the East and thus diversify its sources of gas supply. Of strategic importance for the energy security of the country is the LNG terminal in Świnoujście, thanks to which Poland has the possibility to import gas from any direction. This will be complemented by the Baltic Pipe pipeline which will enable the transmission of gas from Norway to Poland and Denmark, as well as to final customers in neighboring countries. Thanks to the reverse flow it will also be possible to transport gas from Poland to Denmark. Deliveries will start in October 2022. Another important investment that will affect the expansion of the Polish gas portfolio will be the construction of a floating regasification terminal (FSRU) in the port of Gdansk. The unit is to commence operation in 2024 or 2025. [24,54]. In addition, the expanding technical infrastructural capabilities increase the chances of achieving energy self-sufficiency in the supply of gaseous fuel [55].

In the diversified scenario with natural gas, as in the scenario with nuclear energy, a high share of coal in domestic energy production equal to 56% will persist for the next decade, but there is no structural coal supply gap. Although significant amounts of the raw material will be imported, in the long run, convergent dynamics of demand and supply of domestic coal will be established [50].

The emerging production gap after the closure of coal power plants will be filled in large part by gas sources. Poland is planning the largest increase in gas consumption in electricity generation in the entire EU from 14.5 TWh achieved in 2019 to 53 TWh in the next 10 years [46]. This will place it third among the Community countries in the ranking of electricity production from gas. It is worth mentioning that over the next three years, the gasification level in the country will increase to approximately 76%, which will contribute to the elimination of places without access to the raw material [33]. By 2030, new gas units will be built in as many as eight locations [56].

Activities undertaken within the framework of the scenario outlined in PEP 2040, which takes into account the development of the nuclear subsector, do not differ too much from those contained in the alternative scenario, assumed by most researchers and observers of the energy market in Poland. This is a result of the time horizon included in the Polish energy strategy, with 2040 as the cut-off year and the date of nuclear power plant commissioning (2034). In view of the above, in both scenarios until the mid-2030s the forecast of the energy mix, electricity prices, and greenhouse gas emissions will look similar. The situation will become much more complicated when the political elite delays or withdraws from the nuclear power plant construction. Then, there will be a need for further development of the import infrastructure guaranteeing diversification of sources of supply, such as: Baltic Pipe 2, further LNG import capacities, or in the worst-case scenario, gas supplies from Germany, namely Nord Stream and Nord Stream 2 (if the Russians manage to complete the investment). Furthermore, an additional 6.4 GW of new CCGT capacity and 2.8 GW of new gas-fired reserve capacity will have to be built to make up for the production from the missing nuclear units. Investment activities in RES units will also be intensified (e.g., offshore installations, hydrogen, photovoltaics, which can reduce the demand for energy in the summer season and improve the economic efficiency of the system) (Figure 3) [50].

As far as the EU strives for climate neutrality, the development of energy hybrid systems based on intersectoral cooperation between gas systems and electricity systems could prove very beneficial. This cooperation should include allowing the TSO to own and provide services in the power to gas facility for the conversion of electricity into hydrogen or the use of underground gas storage facilities as energy storage facilities injected, inter alia, with hydrogen, which can secure the needs of both the gas system and the electricity system [57].

Gas consumption is highest in the diversified scenario with gas, in which this fuel is used not only for the purposes of reserving variable RES but also for producing electricity, which will translate into an increase in wholesale energy prices and an increase in its import, which will be much higher (ca. 70 TWh) than in the case of the scenario with nuclear energy and will amount to 449 TWh [46,50]. The problem of greenhouse gas emissions, which according to the European Green Deal should be decreasing, is inextricably linked with the increase in gas consumption. Thanks to the transition of the system from coal to gas, its emissivity will start to decrease and in 2030 it will amount to 268 million tonnes, hence the reduction will be 29% in relation to 1990 [46]. Due to the increase in gas capacity in 2040, the emissivity will be higher than in the PEP 2040 scenario and will be around 220 million tonnes [50].

To sum up, in the coming decades low-emission gas generation technologies may play a significant role in the Polish energy transformation process. Thus, gas as a transition fuel will play a regulating and balancing role in generation or cogeneration [56]. The gas scenario forces the growth of RES, because only in this way Poland will be able to effectively reduce CO_2 emissions and thus reduce the risk resulting from climate policy and potential costs at the European and pan-European levels.

5. Conclusions

The Polish Energy Strategy PEP 2040 announced in 2021 is a strategic document whose implementation will determine the shape of the Polish economy for the coming decades. Unfortunately, it only covers the period until 2040 and thus is not correlated with the EU climate neutrality goal planned until 2050. In many aspects it is based on surreal assumptions, for example, with regard to the most important issue, such as the forecast price of CO_2 emissions. To make matters worse, the Polish energy strategy does not provide for another variant of the energy transition in the event that the proposed solutions are delayed. Thus, this scenario is characterized by high investment uncertainty, which will discourage investors from taking action [58]. In both scenarios, the role of RES in the transformation process has been diminished, thus more emphasis has been put on the security of supply than on solving the problem of balancing the electricity system. The greatest hopes are placed in the development of offshore wind energy. It is also incomprehensible that the development of this form of onshore energy generation, which has been blocked since 2016 since the entry into force of the so-called Distance Law, has been blocked. It prevents windmills from being built within a radius of less than 10 times the total height of the windmill from residential buildings and forms of nature protection [59]. The nuclear scenario pushed by the Polish government does not take into account the potential of photovoltaics in electricity generation—it does not foresee any increase in installed capacity between 2025 and 2035.

Gas capacity in many countries is intended to serve as a supplement in a system of unstable RES. In the case of both analyzed scenarios, gas capacity will operate not only in the situation of a decline in green energy production but, what is unusual in the basis of the system, analogously to coal capacity which is currently in operation. Based on PEP 2040 assumptions, the wholesale price of electricity will exceed 72 Euro/MWh, i.e., there will be a 40% increase compared to 2020. In practice, this means that neighboring countries intensively developing RES will have much lower energy prices than Poland [60].

Decision-makers in Poland should be aware that in 15 years, the gas boom of today will be replaced by a recession in the gas market. Therefore, investment decisions taken today should take into account the risk of decarbonization of the gas sector by 2050. The Polish economy has no other choice but to develop the gas market, even under the assumption that it is a transitional fuel and will replace coal. For in this way, the energy security of the country will be maintained at an optimum level. On the other hand, the energy transition without introducing the atom into the Polish energy system will increase Poland's dependence on natural gas, thereby increasing the country's dependence on imports of this fuel. In the mid-2030s, there may be further increases in gas prices due to the move away from less carbon-intensive fossil fuels in the world. However, critics of the rationale for using natural gas in the energy transformation process fail to see the important role it will play in the process of controlling energy systems, ensuring the stability of system operation [61].

Emissions in Poland arise mainly in five sectors of the economy: industry, energy, transport, construction, and agriculture. The analysis shows that the reduction of CO_2 emissions will be slightly higher (about 3.5%) in the diversified scenario with a nuclear power plant and will amount to 45% in 2040 compared to 1990. Therefore, in the next decade, Poland must reduce further 55% in order to achieve emission neutrality assumed by the EU in 2050. Actions are necessary for all emission areas, mainly consisting of resignation from fossil fuels in favor of emission-free energy sources (RES, hydrogen, ammonia, fuel cells, electrification of the heat generation process and technologies of capturing, using, and storing CO_2).

An important element of the transformation having a direct impact on society is the price of energy carriers. Both scenarios assume an increase in energy prices, and in addition, in the diversified scenario with natural gas, one should take into account a large increase in natural gas prices, which has recently started to grow rapidly due to the high demand for this raw material and investments of producers limiting new production capacities for climatic reasons. There is no doubt that the cost of energy carriers has an impact on the prices of products purchased by consumers. On the other hand, at the level of enterprises or local governments, energy is an important component of the costs incurred, and an increase in its price may reduce the competitiveness of some industries. Ultimately, this can lead to instability in livelihoods and affect social and political stability. Another important social effect resulting from the transformation of the energy system is the depopulation of Silesia—the largest mining region in Poland. Both scenarios assume a move away from coal, hence the situation of the population living in this region, who are massively employed in the mining and extractive industries, will depend on the methods of transforming the region and the number of funds allocated for this purpose.

The diversified scenario with nuclear energy proposed in PEP 2040, as well as the unwritten one based on gas, is in fact only an announcement of a reduction in greenhouse gas emissions and not a turn towards low and zero emission energy systems. Both options for the development of Poland's energy mix are a continuation of the current policy based on a centralized energy management system. Projects promoting the development of local and regional electro power are treated as competitive to the projects of energy concerns. The concept of distribution of financial resources obtained from the Just Transition Fund basically assumes their transfer to the investments of state energy companies. This will allow them to maintain their monopolistic position in the market and will hinder the development of electro power for the next decade [62]. Furthermore, most importantly, despite a significant decline in share, coal power plants will remain a significant producer of electricity until 2049.

Poland has chosen the path of energy transformation through the balanced scenario, which is characterized by a lower rate of RES development. It allows Poland to meet its overall energy needs based on its existing generation technologies, without the tension associated with the rapid expansion of green technologies and the issue of their financing.

Polish decision-makers should take into account the alternative diversified scenario with natural gas analyzed in the study, in case the implementation of nuclear energy cannot be implemented on time, as the history of nuclear projects in Poland does not encourage optimism, especially with the current poor level of advancement of works. The most effective measure leading to independence from imports is the construction of renewable energy sources, thanks to which the Polish energy mix will also catch up with the European one and the wholesale energy prices will be equalized.

Slowing down the energy transformation by Poland will certainly have a negative impact on its development. The energy transition has become an economic development plan, an engine of innovation, and a tool to create jobs. Poland's lack of climate neutrality in 2050 will mean that it will not fully participate in the global technological revolution, and its membership in the EU, which is shaken in the context of other political events in recent years, may be called into question. In addition, the economic backlogs that have made up for the last decade will increase again.

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