energies

Review

Analysis of the Potential Management of the Low-Carbon Energy Transformation by 2050

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Abstract: Establishing conditions that meet climate requirements should be one of the most important goals of the whole world in order to protect against the negative effects of climate change. Without cooperation and considerable commitment from everyone, it is possible that these negative effects will worsen. The implementation of the Energy Policy from now until 2050 should facilitate the transformation of the coal-based power system toward a more sustainable and diversified mix of energy sources. Financial investments in the countries analyzed in this paper create real opportunities and changes for the transition toward renewable energy sources (RES), but there is criticism concerning the insufficient speed of change and the costs of the transformation for society. The dominant emphasis on the optimum selection of energy sources creates conflicts, especially in democratic decision-making. Resource management is both incremental and participatory, and while decisions are strongly based on science, the decision-making process is rarely rational or comprehensive. It is difficult to estimate environmental costs, especially because there is no method for comparing the many criteria between the different energy sources since there are differences in the energy efficiency results obtained in different areas. Public opinion is of great importance and it has a huge influence on the development of the development strategies and policies that are undertaken. Therefore, as part of our analysis, we conducted research using a questionnaire to obtain opinions on fundamental issues regarding the climate and energy strategies that have been adopted in the EU. This was important for achieving the main goal of this article, which is a multidimensional analysis of activities aimed at adapting the national economy to the EU strategies that are responsible for reaching the energy and climate goals by 2050. The low-emission energy transformation is aimed at introducing significant changes for the entire economy while at the same time ensuring the implementation of the so-called European triad of goals (energy security, energy competitiveness and climate protection), which often contradict each other in practice.

Keywords: analysis; management; energy transformation; energy pillars; energy policy

Citation: Jałowiec, T.; Wojtaszek, H.; Miciuła, I. Analysis of the Potential Management of the Low-Carbon Energy Transformation by 2050. *Energies* **2022**, *15*, 2351. https://doi.org/10.3390/en15072351

Academic Editor: T. M. Indra Mahlia

Received: 1 February 2022
Accepted: 10 March 2022
Published: 23 March 2022

1. Introduction

This paper identifies the scope of the energy transformation in Poland and involves strategic prejudices toward a type of technology that is aimed at creating a low-carbon energy system [1,2]. The appropriate management of the low-emission energy transformation strategy in Poland is one of the key elements that may affect the success of this project. Poland is committed to the development of renewable energy sources in accordance with the applicable requirements set out in the energy policy of the European Union. Individual countries adopt various mechanisms to support the development of renewable energy sources in order to meet the requirements of the energy directive efficiency [2].

The feasibility of the assumed goals for the energy transformation is related to the financial strategy, for which EUR 200 billion has been allocated in the energy sector and

EUR 167 billion in other industrial sectors [3]. The financial strategy until 2030 estimates the need for EU and national funds for climate policies (EUR 58.4 billion), including funds from: the EU Cohesion Policy; the Repair and Resilience Facility; the Just Transition Fund; REACT-EU; and other national and EU funds and new national instruments that support the energy transformation [4,5].

All assumptions are based on an action plan that ensures synergy through a significant reduction in emissions and the improvement of air quality. The literature on this subject contains information on the implementation of the transformation as a determinant [6]. The energy transformation in Poland demonstrates important elements and is related to making decisions in energy policy, as well as analyses, decisions, management, control and knowledge [7].

Consistency in meeting climate expectations should be one of the most important aspects of the resulting role of each country, along with meaningful and mutual cooperation. Striving to meet the demands of the energy policy between now and 2050 defines the actions necessary for a more sustainable and diversified mix of energy sources. Financial investments in the countries analyzed in this paper create real opportunities and changes for the transition toward renewable energy sources. The dominant emphasis on the optimal selection of energy sources causes inevitable conflicts in decision-making. It is worth emphasizing that public opinion is of great importance and has a huge impact on the development of the strategies and development policies that are undertaken.

2. Literature Review

Climate and Energy Policy

Poland's Energy Policy until 2040 (PEP2040) [8] emphasizes a fair and inclusive energy transition toward a carbon-free system that is based on innovation, sustainable economic growth, increased efficiency and competition. The last key factor is improving air quality, which would solve a major nationwide problem [9–11].

PEP2040 concerns the implementation of the Paris Agreement, which was developed for the purpose of mitigating climate change through transformations in compliance with all of the principles of correctness. PEP2040 concerns national action toward the implementation of the EU climate and energy policy, in which significant increases have been recorded during the current period [12].

The policy takes into account activities that are aimed at adapting the national economy to the requirements of the EU that are responsible for reaching the climate and energy goals by 2030.

The European Green Deal [13] has become desirable because it hopes for the unification of the implementation of climate neutrality with the possibility of consistency with all agreements. The low-emission energy transformation envisaged in PEP2040 aims to implement major changes for the entire economy that would ensure energy security, point to the principles of cost allocation and secure vulnerable social groups [14,15].

PEP2040 includes an explanation of the form and conditions of the energy sector. Three pillars of PEP2040 have been distinguished, in which the objectives, along with the activities necessary for their implementation, and key projects have been indicated [16].

The three pillars of the energy transformation are based on the goals and functions of the low-emission energy transformation presented in PEP2040 [17], along with an independent mission of the end user and the involvement of local industry, thereby providing an impulse for the economy whilst ensuring energy security, in an innovative and socially acceptable way that also respects the environment and climate [18].

The energy transformation in Poland will follow the principles set out in the figures below (Figures 1 and 2).

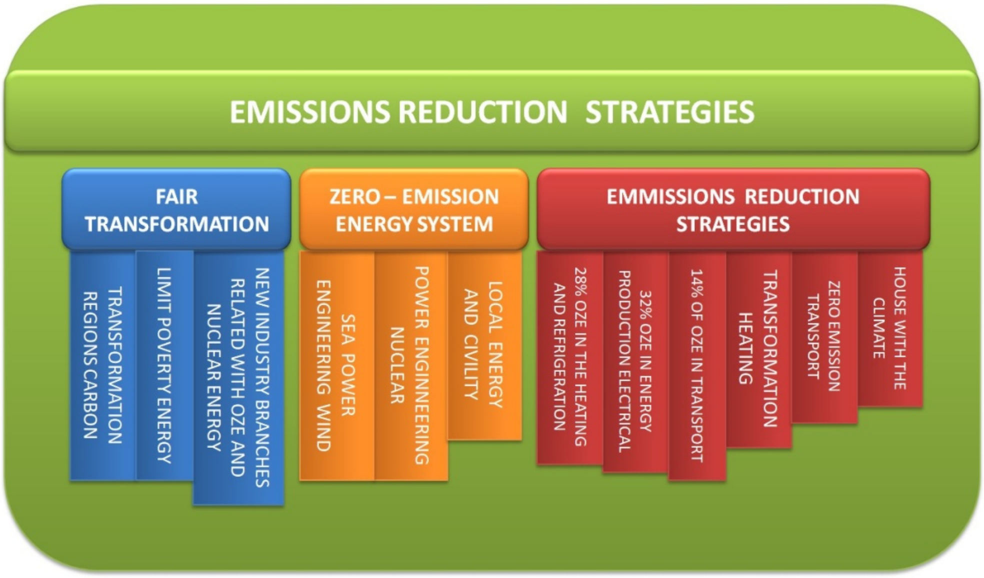

Figure 1. Emission reduction strategies for between now and 2040 [19].

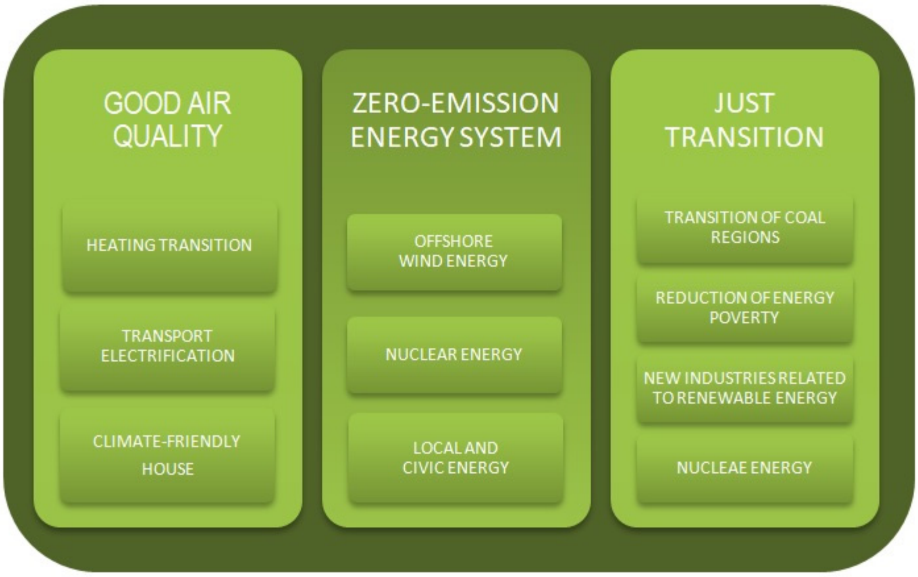

Figure 2. The pillars of Poland's Energy Policy until 2040 [20].

The three pillars indicated above are intended to be assessed as fair, participatory, innovative, forward-looking, developmental and competitive. Accessibility for all, especially those who are aggrieved, is also of key importance so that everyone can benefit from the transformation. It is focused on new technologies with forward-looking plans and, at the same time, it is effective in the development of the economy. The 2040 energy policy presents a vision of Poland's path toward the energy transformation [21].

This policy consists of creating strategic investment decisions that are aimed at the rational management of the national economic, raw material, technological and human resource capacities and creating a flourishing economy within the energy sector, which would encourage a fair transformation [22].

Based on the above description, the following list of strategies was produced (Figure 3).

Figure 3. A list of Poland's strategies until 2040 [23].

By 2040, more than half of the installed capacity will be zero-emission sources. It is important to implement offshore wind energy in the Polish power system and commission a nuclear power plant [24]. These are two new strategic areas and industries that will be built in Poland. It is an opportunity for the development of the domestic industry, specialized personnel competences, new jobs and added value for the national economy. Parallel to the large-scale energy sector, distributed and civic energy will also develop based on local capital.

The transformation also requires the increased use of renewable energy technologies in heat generation and the increased use of alternative fuels in transport through the development of electromobility and hydro-mobility [25,26].

Collaboration between stakeholders in the automotive sector is key to developing the customer base and maximizing utilization and profit. Car sharing can deliver tangible results, with an emphasis on balancing the support provided for mobility [27] services in order to achieve success. There is also the opportunity to use car sharing (rented or shared use of a car by both individuals and companies) to demonstrate benefits in the form of saving time, reductions in traffic and a focus on combining operational knowledge to develop advanced technologies that can create mobility services with social, economic, environmental and social advantages [28]. In many ways, this is true of today's car sharing, which has been transformed by advances that have increased stakeholder collaboration and integration, new automotive ventures and a renewed focus on electric vehicles (EVs), such as P2P services and technologies. It is now a growing low-carbon idea [29].

Excessive energy consumption was the reason for the analysis of the actual consumption based on the factors that influence it, mainly for car sharing vehicles. Methods for system management that can reduce the energy consumption of electric vehicles are becoming essential. There are many possibilities, but very often it turns out that it is enough simply to use EVs correctly, i.e., (charging the battery properly) [30].

The strategic goals are contained within eight detailed action concepts, where each action plan identifies a multitude of behaviors that are defined as strategic projects. The detailed concepts of operation are presented in the figure below (Figure 4) [31].

The predicted domestic demand for primary energy is presented on the left-hand side of the chart. On the right-hand side, the predictions for electricity generation sources are presented (Figure 5).

The Polish economy is still undergoing a process of transformation and making progress in terms of managing the governance of Europe. The implementation of the reform of the manufacturing sector is necessary, i.e., repairing electricity supplies in Poland that are ineffective and uncertain. Coal is a fundamental fuel and represents over 80% of the mix of energy sources. The current mix of energy sources needs to be questioned. The implementation of Poland's Energy Policy until 2050 should facilitate the transformation of the coal-based power system into a more sustainable and diversified mix of energy sources (Figure 5).

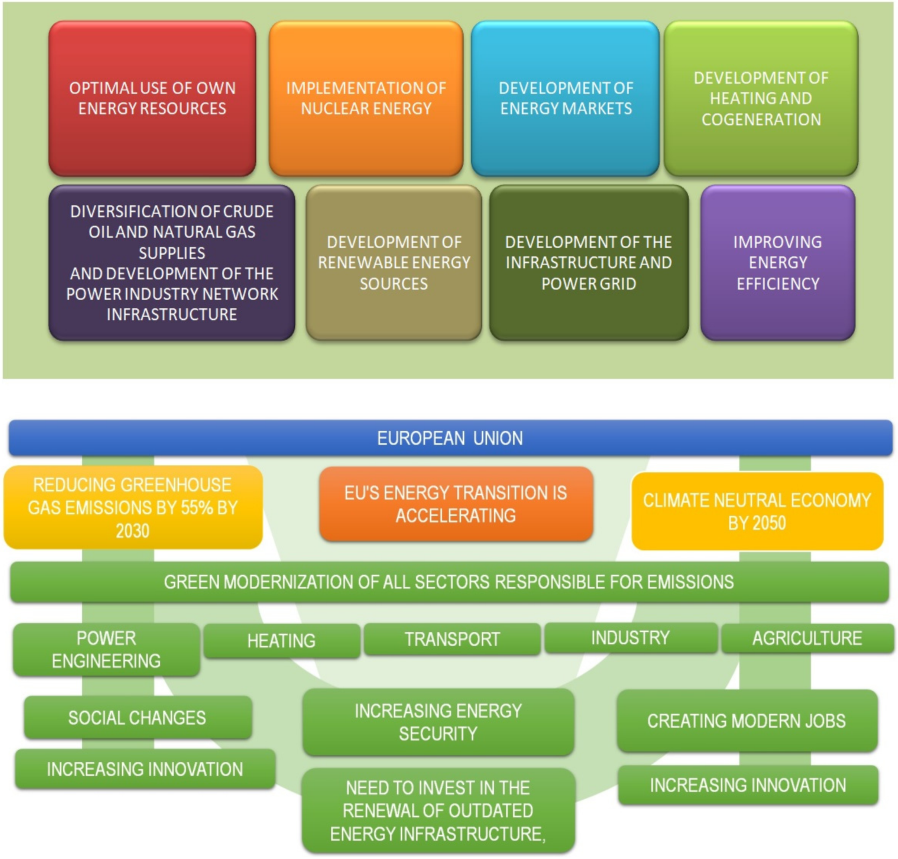

Figure 4. A draft of the Poland's Energy Policy until 2050.

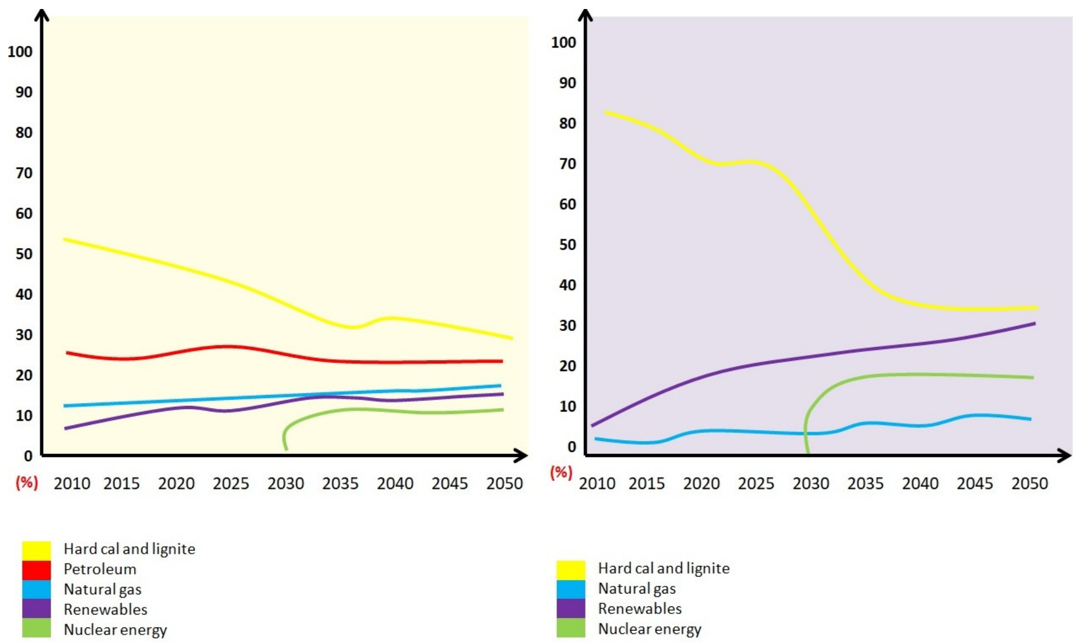

Figure 5. The predicted domestic demand for primary energy and the predicted sources of electricity generation [32].

3. Context Policy Analysis

3.1. Realization of Possibilities

The analysis of the feasibility of meeting the policy requirements was used to develop the analysis of the results of the context policies. The Ministry of Climate and Environment's policies until 2040 and 2050 and other studies that have analyzed the role of renewable, alternative and nuclear energy in reducing carbon dioxide emissions in the CPTPP countries were also used, as well as the Progress in Energy journal that was used in 2021. They also studied the technological and economic optimization of a system that would be entirely based on renewable energy by 2050.

The transformation of coal regions [33], support from European funds of around PLN 60 billion and a reduction in energy poverty would lead to a reduction of 30% in emissions by 2030 and the new industries related to renewable energy and nuclear energy [34] would lead to 300,000 new jobs. The zero-emission energy system [35] is the second pillar of the energy policy, in which offshore wind energy aims to produce about 8–11 GW by 2040 and the capital expenditure is approximately PLN 130 billion. Nuclear energy aims to produce approximately 6–9 GW and the capital expenditure is around PLN 150 billion. Local and civic energy would see an increase in the number of recipients actively participating in the market to 300 sustainable energy areas and 1 million prosumers by 2030. Good air quality is the third pillar. The aims of this pillar include the transformation of heating through the withdrawal of coal from use in individual heating [36] in cities by 2030 and in rural areas by 2040, along with the development of district heating in cities to enable an increase of 1.5 million households that are connected to the heating network by 2030 [37]. The policy also aims to increase the number of zero-energy buildings using 3 million of the above-mentioned heat sources in houses by 2030 and building 1000 low-emission public buildings by 2030. Zero-emission transport will rely on the development of electromobility [38] in cities with more than 100,000 residents, all new public transport vehicles being zero-emission [39] from 2025 and all public transport vehicles being zero-emission by 2030 [40]. The expected and, at the same time, key action is the global growth of the use of renewable energy in all possible components [41]. It is planned to obtain at least 23% of the final gross energy [42] consumption from renewable energy by 2030. A minimum of 32% renewable energy in electricity production is planned through the use of offshore wind energy (approx. 5, 9 GW), photovoltaics (approx. 5–7 GW) and onshore wind energy (approx. 8–10 GW), along with 28% renewable energy in heating and cooling using biomass, heat pumps, biogas and geothermal energy. A minimum of 14% renewable energy in transport is planned through the use of biofuels and electromobility [43–45].

3.2. Sources of Funding

Actions taken toward the innovation of energy that is based on renewable energy sources should lead to more radical and decisive decisions. There are obvious solutions that are based on the development of research and various types of projects that are based on significant progress in energy and climate policy. Government spending on research and development (R&D that is based on innovation) should be increased and its implementation should be the focus of attention. Currently, the areas that require activity in the development of low-emission technologies to improve electricity and energy efficiency receive only one third of budgetary financing. Support for implementation projects that are aimed at reducing individual costs may be of key importance. The mobilization of support for public funds is now possible until 2030 thanks to the development of new technologies that are based on industrial innovations. New opportunities for cooperation would guarantee jobs and an increase in commercial activities [46,47]

Figure 6 below presents the Draft Energy Policy of Poland until 2050.

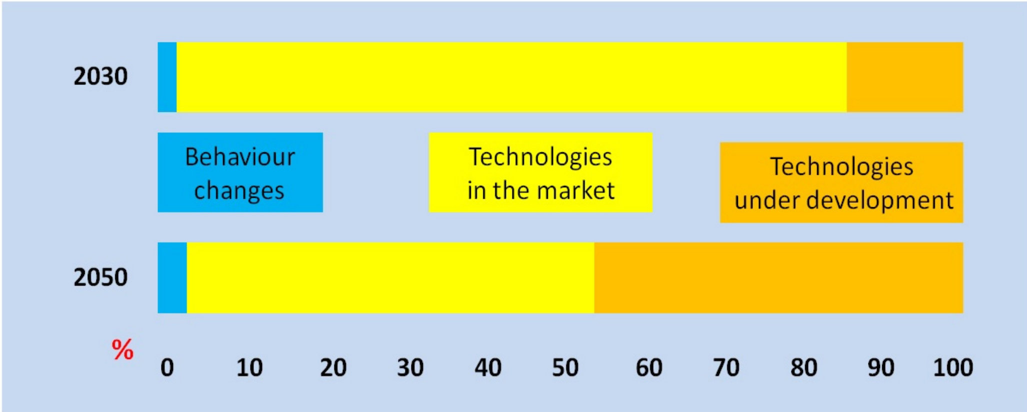

Figure 6. A draft of the Poland's Energy Policy until 2050 [48].

Achieving zero emissions of harmful substances into the air is possible with clearly defined procedures and the consistent commitment of all citizens.

The introduced changes allow for the creation of various areas that are responsible for the efficient functioning of the strategies. The possibilities also relate to obtaining new jobs and increasing the efficiency of the rational use of energy in terms of transport development. A majority of the potential reduction in carbon dioxide emissions is related to consumer choices. In many cases, emission reduction concerns people-dependent situations. People can give up combustion cars and buy electric cars (this applies to households with the financial resources available for this, i.e., those in developed countries). People can also use collective transport or devices that generate a much lower load of energy and pollute the atmosphere less. Actions that are based on reducing emissions should be implemented and aimed toward rational access to energy for all by 2030. Decisions should be rational, transparent, appropriate and focused on key actions, which may not be easy to implement.

It is advisable to create an appropriate energy price that will enable everyone to use low-emission solutions, regardless of the financial situation of potential users [49].

The Figure 7 below presents the sources of financing in Poland (in billions).

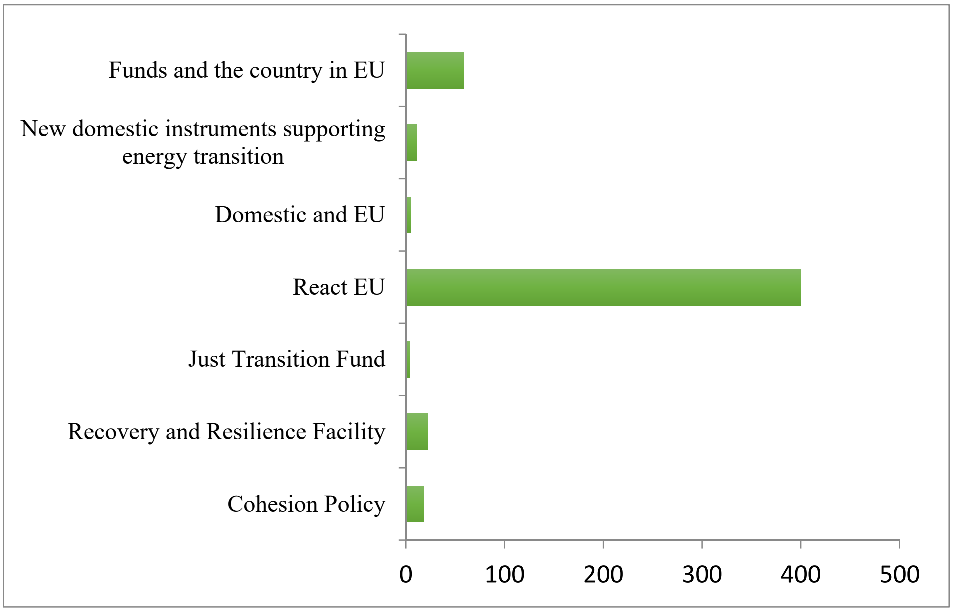

Figure 7. Funding sources in Poland (in billions) [**50**].

PEP2040 provides information on funding sources [51,52]. Many of the estimates and criteria relate to current proceedings, such as the NextGenerationEU fund [53] or the

Just Transition fund [54,55], for the analysis and receipt of applications [56]. By 2030, the Ministry of Climate and Environment estimates that EUR 58.4 billion for climate policies will come from EU and national funds [57], the details of which are presented in the chart below (Figure 7).

Most of the resources will come from REACT-EU, then the Recovery and Resilience Facility in the form of grants and loans, then the Cohesion Policy, national instruments supporting the energy transition, national and EU funds and the Just Transition fund [58,59].

The charts present the investments in renewable energy sources both between 2016–2020 and in 2020 separately (Figure 8). When analyzing the transactions of funds and comparing the year 2020 to the period 2016–2020, we noted that investments were proportional and aligned with the predictions that were based on the previous history of financial investments in RESs in terms of the scale of change (total).

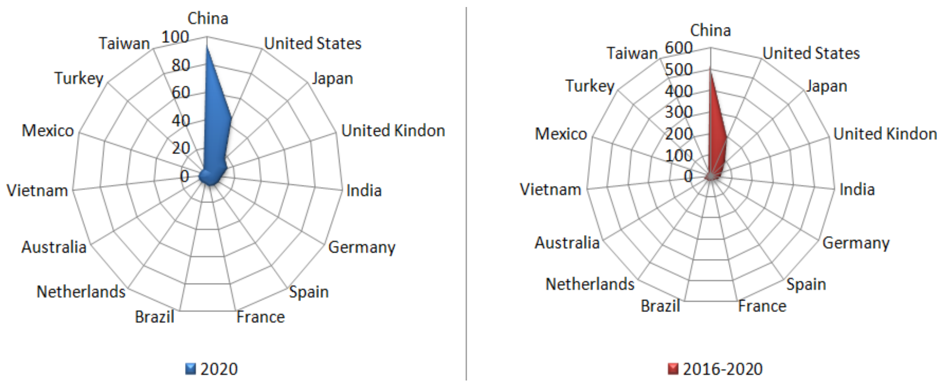

Figure 8. An analysis of investments in renewable energy sources over the period of 2016–2020 (USD billions) [60].

Figure 8 below presents an analysis of investments in renewable energy sources in 2016-2020 (USD billion).

Figure 9 shows the scale of investments in individual market renewable energy sources.

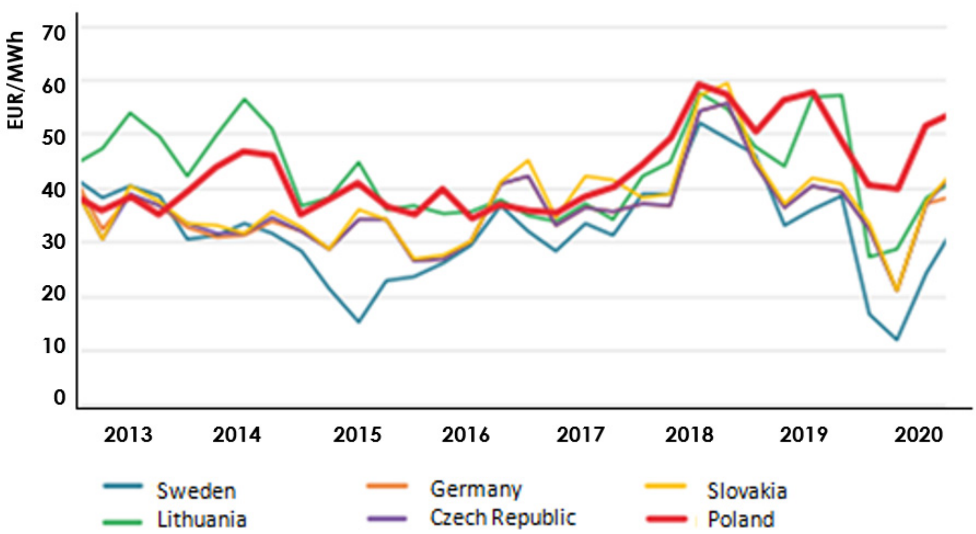

Figure 9. An electricity price comparison [61].

Electricity prices in Poland are much higher compared to the countries presented (2020), followed very closely by Lithuania and Slovakia. According to this list, the lowest prices are in Sweden.

3.3. Technological Changes

Renewable energy sources are obtaining innovative statures in geothermal energy, in which growth is estimated to reach up to 70% by 2050, while coal production is steadily declining.

Figure 10 shows the scale of investments in individual market renewable energy sources.

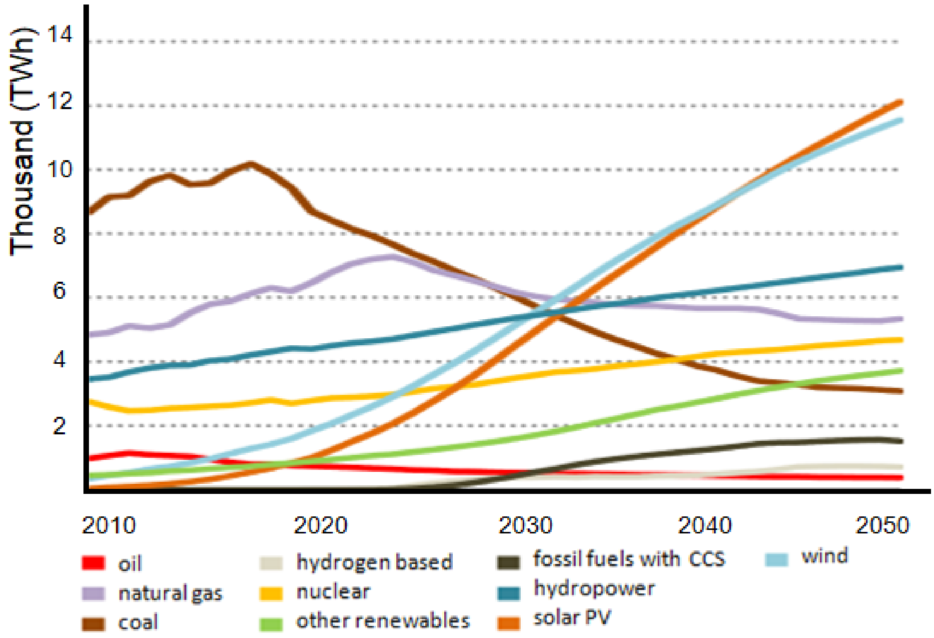

Figure 10. Global electricity generation by source in the APC [62].

Global electricity production is estimated to almost double from about 30,000 to more than 50,000 TWh, which will become obvious in the next three decades assuming that the analysis of 2050 compared to 2020 is correct. Thanks to low-emission energy sources, we can see progressive growth. It is worth noting that the use of renewable energy sources in electricity generation may increase up to 70% by 2050. In Figure 10, we can note that photovoltaics and wind (50% of the electricity supply) compete with various other production sources. There is a noticeable increase in hydropower, which is estimated to become one of the leading electricity resources by 2050. Nuclear energy continues to grow due to China. Natural gas consumption appears to increase slightly while the contribution of coal to electricity production drops significantly by 2050. By around 2030, hydrogen and ammonia could be being used as fuel for generating electricity, along with natural gas in gas engines and coal.

The realization of these predictions would extend the mobilization of existing assets, contribute to the progress of the power system and lower the global cost of transforming power components, as demonstrated by total battery capacities potentially increasing significantly (even up to 70%) by 2050.

Figure 11 shows GHG emissions by energy source (grams per kWh).

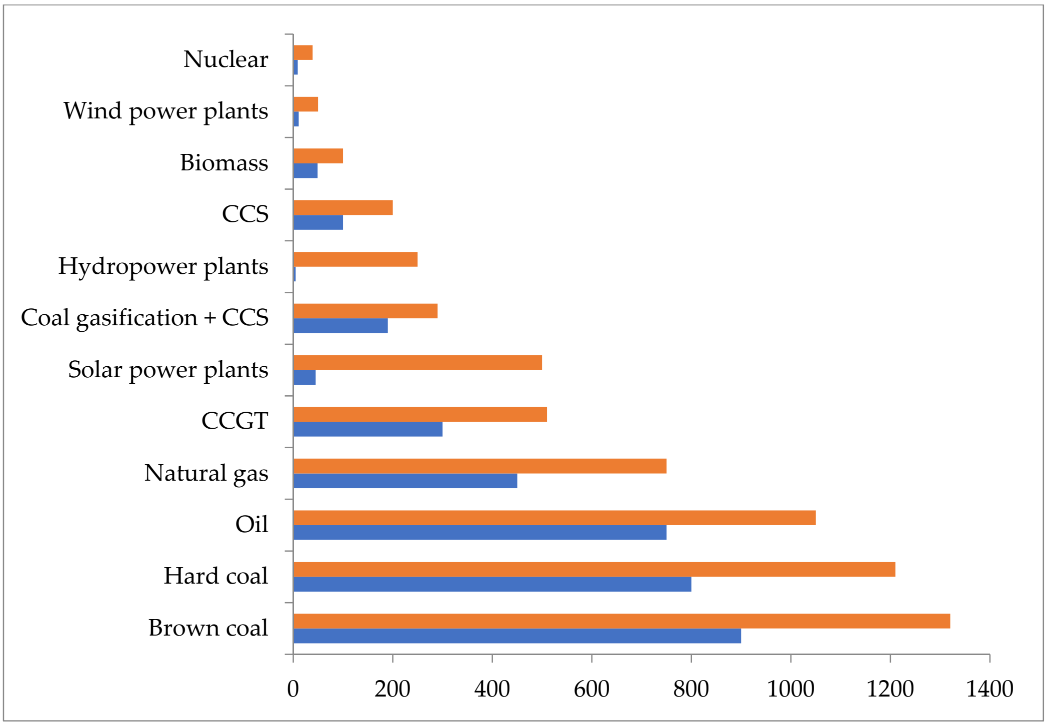

Figure 11. Greenhouse gas emissions by energy source (grams per kWh) [63].

In Figure 11, two bars show the range that could be achieved with different conditions and/or slight technological changes for each technology. Therefore, this corresponds to the actual range for these technologies, from the minimum value (first bar) to the maximum value (second bar) [64–67].

The Figure 12 shows the average annual efficiency of electricity generation.

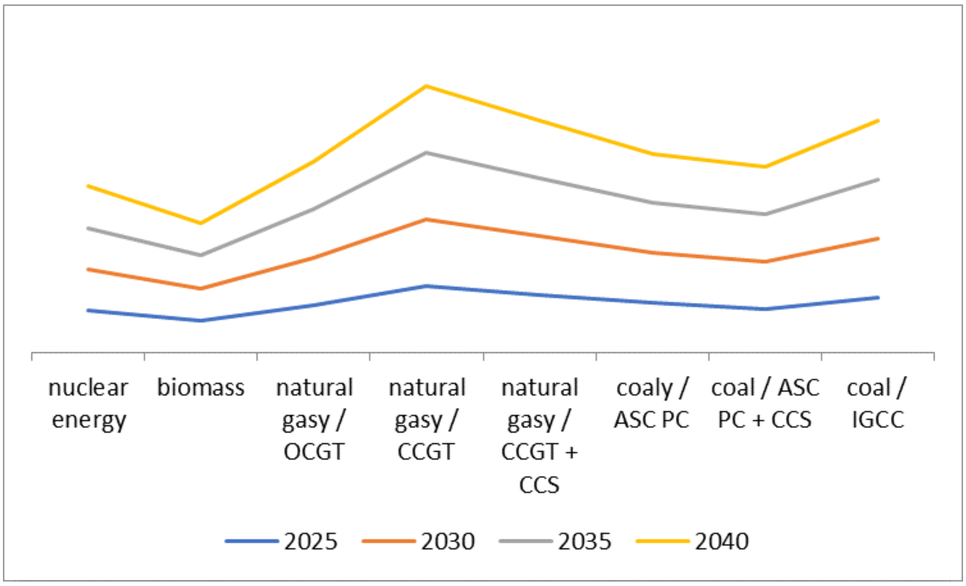

Figure 12. A forecast of the average annual efficiency of electricity generation (%) [68].

The average annual efficiency of electricity generation by 2040 is estimated to maintain a uniform level of 32.6%, as well as a level of 25.3% for biomass and a level of 45.5% for natural gas (CCGT + CCS), with a slight increase of 0.10% by 2030. Energy from open-cycle gas turbines (OCGT), on the other hand, is projected to increase by 0.3% in 2030 compared to 2035 and 2040. Levels of energy from combined-cycle gas turbines (CCGT) are predicted to stay uniform, with a slight increase in 2030, and average at 52%, as are levels from pulverized coal with advanced supercritical steam conditions (ASC-PC) at almost 40%. On the other hand, the use of coal from integrated gasification combined cycles (IGCC) shows an upward trend of 3.1% from 2025 to 2030 and is estimated to be at 45.8% in 2035 and 2040.

The unit investment outlays are presented in Figure 13.

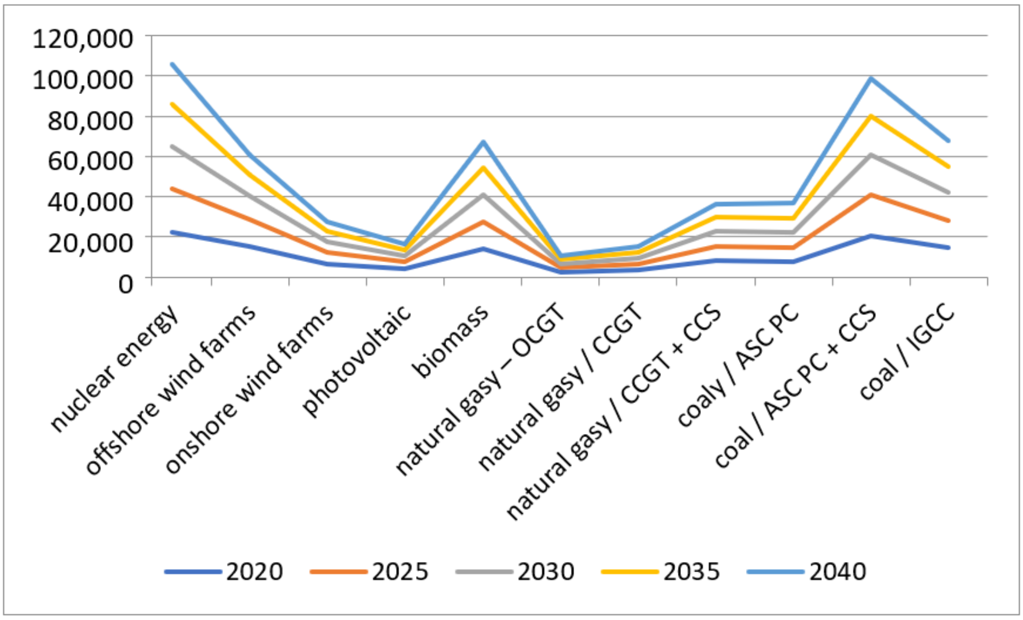

Figure 13. Unit investment, contract expenditures and overnight cost (OVN) (PLN million/GW net) [69].

The largest investments show a successive proportional increase from 2020 to 2040, according to Figure 13. With photovoltaics, we see a collapse of the index for biomass of over 60,000 and another decline for energy from open-cycle gas turbines (OCGT). We can successive growth for energy from combined-cycle gas turbines with carbon capture storage (CCGT + CCS) and pulverized coal with advanced supercritical steam conditions (ASC-PC). There is a significant increase in the use of pulverized coal with advanced supercritical steam conditions and carbon capture and storage (ASC-PC + CCS) and a drop in the use of coal from integrated gasification combined cycles (IGCC). It is worth emphasizing that most of the factors are proportional, excluding 2020.

The following Figure 14 shows the investment outlays for the expansion of production capacity (PLN billion).

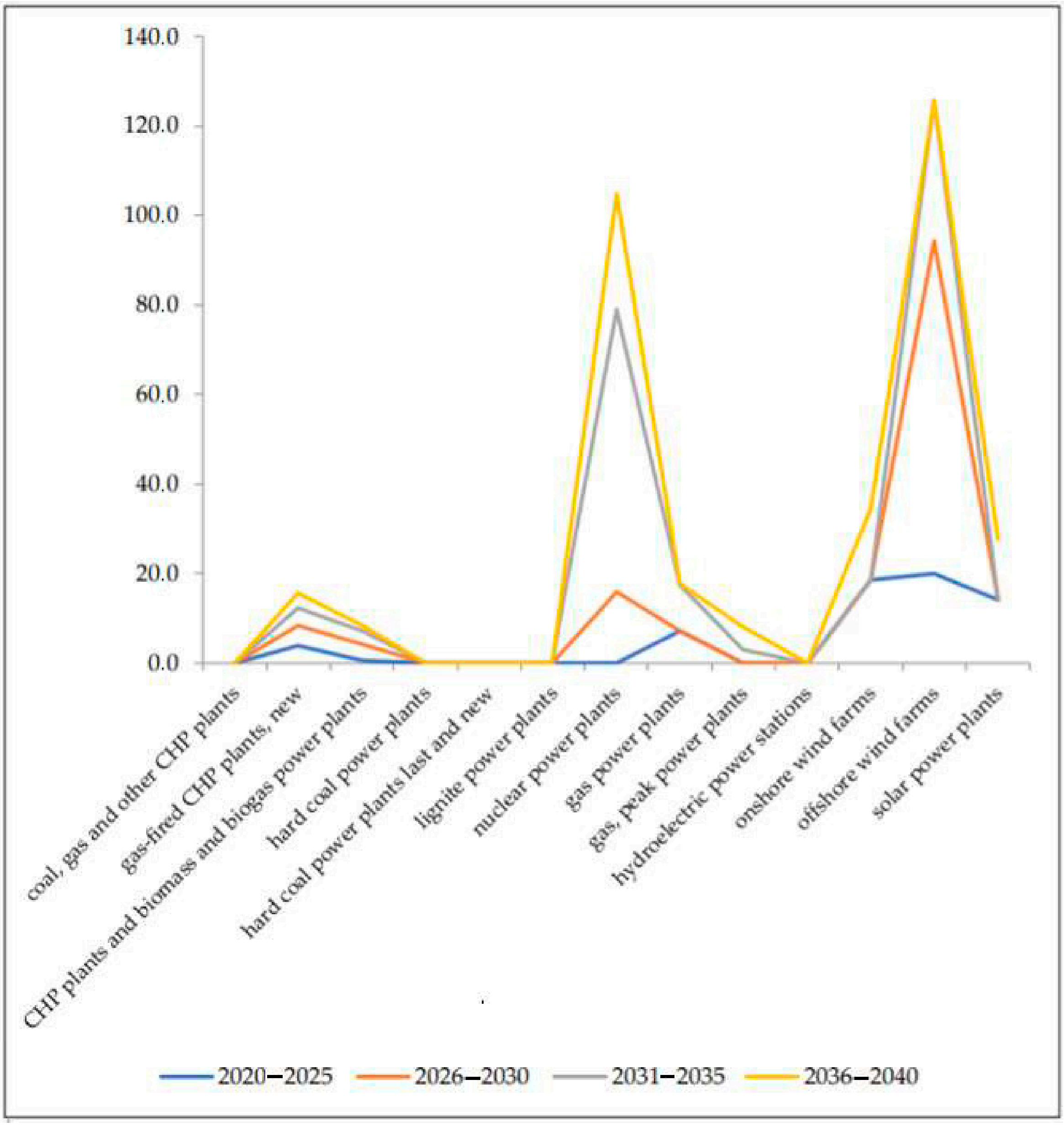

Figure 14. Capital expenditure on the expansion of generation capacity (PLN billions) [70].

Figure 14 shows the necessary investment outlays for the expansion of the National Power System, which would allow Poland to obtain the mix of energy sources resulting from the optimization model. According to the model results, the highest annual investment expenditures will fall in the period 2026–2030 and will be related to investments in offshore wind energy [71]. In the years 2031–2040, most of the necessary investment outlays will be required to implement nuclear power. The cumulative capital expenditure in the years 2021–2040, including the costs of construction (capital interest is included in the initial value of fixed assets), will exceed PLN 340 billion. This scale of costs is a huge challenge for the entire economy and requires the combination of private and public capital [72].

The investment outlays for the expansion of electricity generating capacity will be highest in the years 2026–2030, when the costs for offshore wind farms are estimated to amount to PLN 74.3 [billion], and then again in the years 2031–2035, when the costs for nuclear power plants are estimated to reach PLN 63 [billion]. These are among the highest predicted expenditures [73].

Figure 15 shows the investment outlays for the expansion of production capacity (PLN billion).

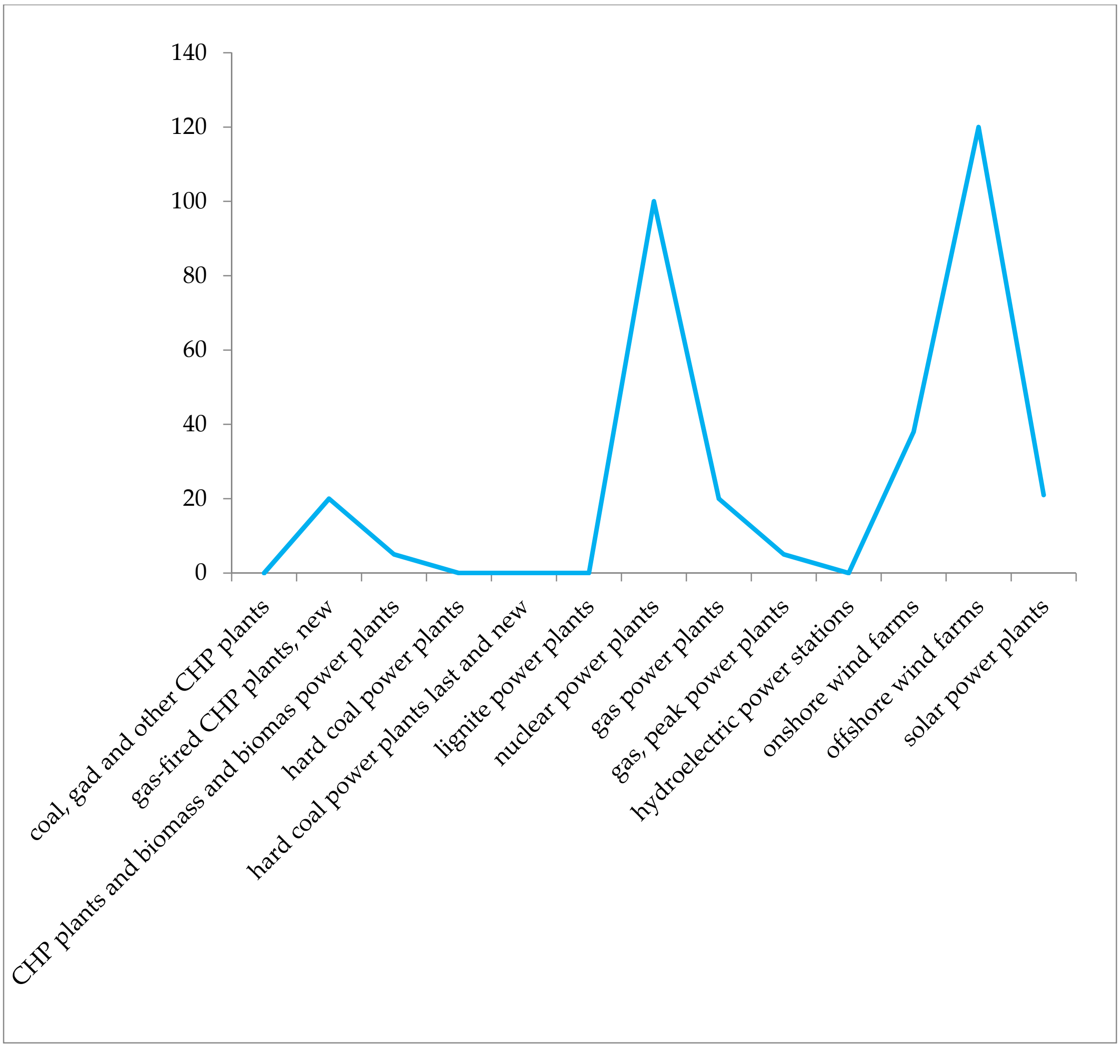

Figure 15. Capital expenditure on the expansion of generation capacities (PLN billions) [74].

The largest capital expenditures for the expansion of production capacities relate to lignite power plants (PLN 125.8 billion) and hard coal power plants (PLN 104.8 billion). The next largest are for onshore wind farms (PLN 34.4 billion) and solar power plants (PLN 27.6 billion). Two more values of below 20% are visible for gas power plants and gas-fired CHP plants [75].

Figure 16 presents the forecast of investment outlays for the expansion of production capacity (PLN billion) for the years 2020-2040.

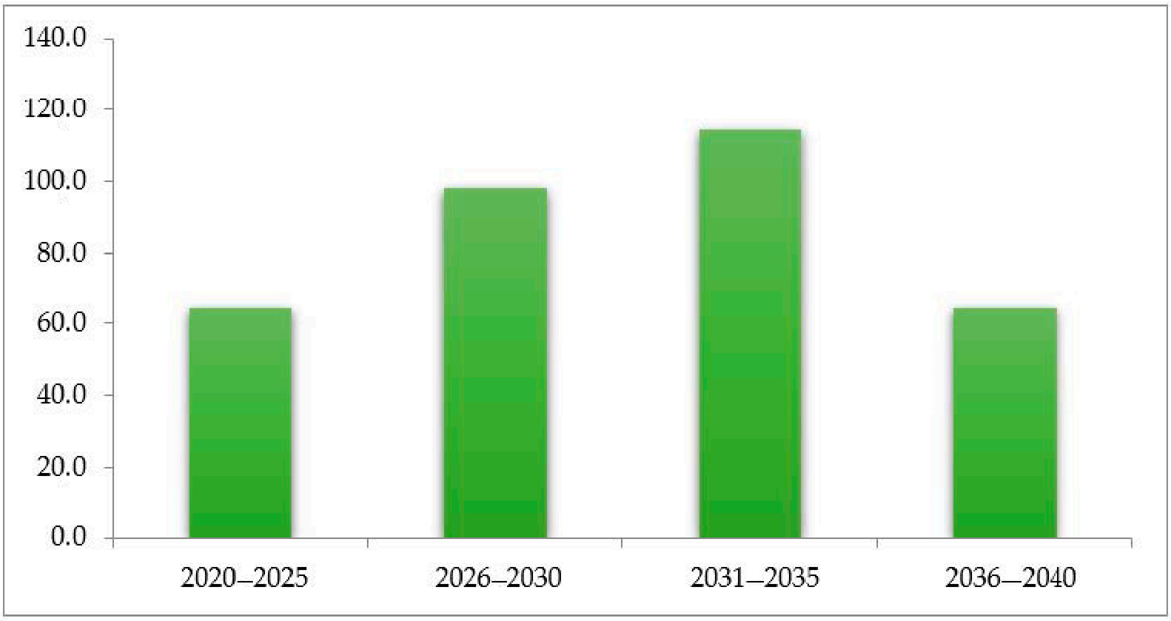

Figure 16. A forecast of investment outlays for the expansion of generation capacity (PLN billions) for 2020–2040 [76].

The forecast of investment outlays for the expansion of production capacities indicates almost the same predicted allocation in the years 2020–2025 and 2036–2040, during which it is PLN 64.5 million and around PLN 64.1 million, respectively. In turn, in the years 2026–2030, it is forecasted to be PLN 98.3 million and PLN 16.2 million more in 2031–2035. The outlays are predicted to be the largest in the years 2031–2035 and the lowest in 2020–2025 [77].

3.4. Social Performance Results

During national public consultations, proposed changes were presented along with both positive and negative opinions, as presented in Table 1.

Table 1. The positive and negative comments identified during national public consultations.

<table>
<tr><th colspan="2">Consequences</th></tr>
<tr><th>Positive</th><th>Negative</th></tr>
<tr><td>• Fair transformation
• Low-emission energy system
• The desired air quality
• Ambitious low-carbon solutions
• Radical low-emission solutions
• Current key energy and economic challenges
• Change of the deadline for the implementation of short-term actions due to the pandemic
• Reduction of greenhouse gases at EU level
• Greater protection of the energy consumer
• Greater share in the energy market by building a low-emission energy system [78]
• Use of energy transformation to develop new industrial sectors and stimulate economic growth
• The need to support fair transformation not only in mining regions, but also in regions that are dependent on coal [79,80]</td><td>• Fast pace of low-emission energy transformation in PEP2040
• Big financial challenges
• Big organizational challenges
• Big technical challenges
• Burden on the domestic economy
• Negative socioeconomic effects
• The timing of activities and the goals of long-term forecasts have not been adjusted
• Higher prices of CO_2 emission allowances
• Increase in the target scope of a 21–23% share of renewable energy sources in gross final energy consumption by 2030 (the target was increased by at least 23%)</td></tr>
</table>

Table 1. *Cont.*

Consequences	
Positive	**Negative**
• Fair transition will mean providing new development opportunities for the regions and communities that are most negatively affected by the low-carbon energy transition • Providing new jobs • Construction of new branches of industry to participate in the transformation of the energy sector [80] • The energy transition will be conducted in a way that is fair for everyone • Energy efficiency is a priority in the EU policy, which will increase the base of programs and instruments that financially support better energy management • More lenient rules for locating onshore wind farms, which would secure the quality of life for local communities within the vicinity of wind turbines • The time horizon of the support will be adjusted to the market needs • Significant advantages and versatility of using hydrogen as a fuel in the power industry [26], the fuel and energy sectors, the world of science and EU institutions • The potential of hydrogen as a fuel and energy carrier [81]	• Entities participating in the consultations indicated that the energy efficiency target is very ambitious and will be a big problem for the economy, particularly for entrepreneurs • Divergent on nuclear, technical or editorial acceleration of the construction schedule of the first unit and attention was drawn to the need to reconsider the validity of implementing this type of technology in the second unit [82] • the need to highlight future limitations related to financing gas investments, which will impede the transformation process • Comments on the fuel subsector, mainly related to alleged responsibilities for the implementation of certain measures • Reservations regarding the possibility of the rapid development of electromobility in Poland in the short term

The benefits relate to a fair transition using low-carbon solutions. The transformation is prepared for all (from single person farms to entrepreneurs) so that the regions that are most affected by the negative effects of the transformation can also develop. By stimulating the industry for economic growth, the mining and energy regions that are impacted by the change will be supported [83].

4. Materials and Methods

4.1. Research Background

The decision to carry out an analysis of the opinions of entrepreneurs was due to the complexity of the climate system and the social, economic, ethical and political challenges. Limiting climate change requires efforts on a global scale, from all countries. Driving the development of new technologies to deal with climate change will bring about significant economic benefits [84].

Actions taken to reduce the use of fossil fuels can also bring about significant benefits to social health (by reducing the emissions of conventional air pollutants) and national security (by reducing dependence on imported energy sources) [85].

The costs of the action required to reduce the risks of climate change are immediate and many of the benefits will emerge elsewhere and affect future generations. The costs are to be covered largely by EU funds. Experts are divided in the assessment of this strategy. Positive feedback points to a positive direction. on the other hand, there are criticisms concerning the insufficient speed of change and the costs of the transformation for society [86–89].

4.2. Research Methodology

The following methods of statistical analysis were used to develop the research results: descriptive statistical measures and statistical tests; sample randomness test; and the Chi-squared test of independence.

we used a sample randomness test called the series test to verify the null hypothesis [90]:

Hypothesis 0 (H0). *the sample is random*

against the alternative hypothesis;

Hypothesis 1 (H1). *the sample is not random.*

The hypothesis verification procedure was as follows:

1. Determine the median *Me* from the trial;
2. Map each sample item x_i according to the order in which the items for testing were taken, using symbol *a* when x_i < *Me*, *b* when x_i > *Me* and results of x_i = *Me* could be omitted;
3. Determine the total number of series *k*, where the series was each substring of a complex sequence of the elements *a* and *b* and all consecutive elements of the substring were of the same type [91];
4. Assuming the null hypothesis was true, the number of the *k* series had a known and stable distribution;
5. The rejection area was two-sided. From the distribution arrays of the number of series that were fixed in advance of the materiality levels α, n_1 and n_2 (numbers *a* and *b*), we read critical values for k_1 and k_2 such that relationships $P(k \leq k_1) = \frac{\alpha}{2}$ and $P(k \leq k_2) = 1 - \frac{\alpha}{2}$ took place;
6. When $k \leq k_1$ or $k \geq k_2$, we rejected the hypothesis about the randomness of the sample; however, when $k_1 < k < k_2$, there was no reason to reject the sample randomness hypothesis [92].

From the normal distribution tables $N(0,1)$, the critical value was determined as u_α, so that for a predetermined significance level α, the following relationship existed: $P(|Z| \geq u_\alpha)$.

When the value of the statistic *U* of the sample fits $|Z| \geq u_\alpha$, that results in a hypothesis H_o

We rejected when $|Z| < u_\alpha$ as this had no basis for rejecting the hypothesis H_0.

The Chi-squared test of independence verified the null hypothesis:

Hypothesis 0 (H0). *two variables are independent*
against the alternative hypothesis;

Hypothesis 1 (H1). *the variables are dependent.*

The checking statistics were:

$$\chi^2 = \sum_{i=1}^{l} \sum_{j=1}^{k} \frac{\left(n_{ij} - \hat{n}_{ij}\right)^2}{\hat{n}_{ij}}$$

where

- n_{ij} are the real values and
- $\hat{n}_{ij}$ are the theoretical values calculated according to the formula $\hat{n}_{ij} = \frac{n_i n_j}{n}$.

Assuming the null hypothesis was true, the test statistic had a distribution of χ^2 o $(k-1)(l-1)$ degrees of freedom, where *k* is the number of columns (number of variants of the first feature) of the analyzed cross table and *l* is the number of rows (number of variants of the second feature). The critical area for this test was the right-hand area $\left[\chi^2_\alpha; \infty\right]$, where χ^2_α was the critical value read from the distribution tables χ^2 for a predetermined materiality level α.

The group of respondents comprised the general public and entrepreneurs. The research area covered the Mazowieckie Voivodeship. The research period was from March 2020 to May 2021. The completion of the research was estimated to be in 2020; however, due to the COVID-19 pandemic, the research period was extended. During this time, a total of 584 people were interviewed, with 62 questionnaires being rejected due to incorrect completion. The number of correctly completed questionnaires was 522. The errors consisted of entering data in the wrong boxes or the failure to fill in the form. The questionnaire was deliberately designed in such a way so as to capture the respondents' ability to select answers consciously. The mistakes were not due to a lack of understanding, but from too little time spent on filling in the questionnaire. The main limitations often resulted from the lack of physical contact between the researchers and the respondents. Perhaps if the research had been conducted in person, it would have been possible to avoid returning so many incorrect questionnaires. Initial doubts about the correct implementation of the planned research assumptions quickly turned into success in a new dimension. The COVID-19 pandemic forced many people (including all of us) to improve or fully start using the Internet, mostly with very advanced programs.

The pandemic had a significant impact on the transport situation. The restrictive measures implemented in response to the COVID-19 pandemic triggered sudden and massive changes around the world. High disruptions were noticed for both commuter and non-commuter journeys, highlighting a significant reduction in the frequency of all types of travel and the use of all modes of transport. It seems natural to reduce the frequency of travel in order to reduce the potential spread of the virus [93]. Airplanes [94] and buses are considered to be the most risky means of transport during the pandemic, during which avoiding public transport has been consistently encountered in all countries. Socioeconomic inequalities and morbidity are related to actual risks and their perception in terms of expected health. There has been a direct global impact of the COVID-19 crisis and guidance is being established for transport [95] practitioners to help to develop future strategies to mitigate issues caused by similar situations [96].

5. Results

In the city of Warsaw, entrepreneurs had the financial resources to provide their employees with intuitive programs that could be mastered by even the most resistant users; however, barriers could still result from the lack of practical skills and internal conviction about the use of advanced programs.

The following two charts show the data obtained from the research, which was conducted using a questionnaire that was completed by the general public and entrepreneurs.

Figure 17 shows the gender structure of employees by age.

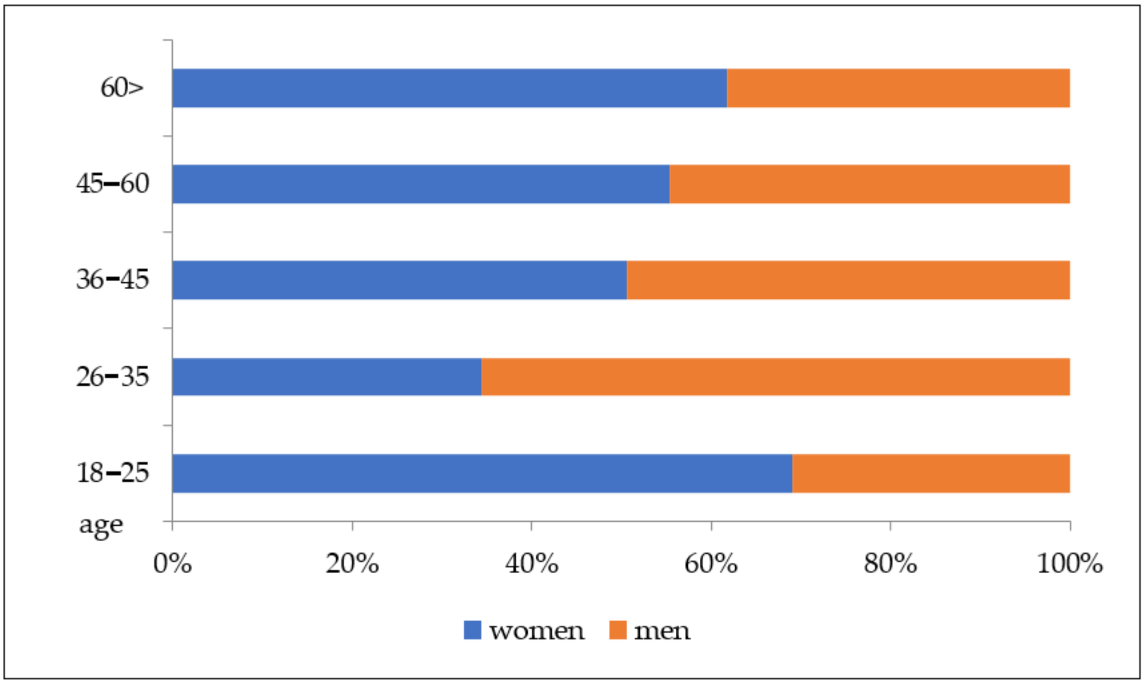

Figure 17. Structure of employees by age.

The largest proportion of surveyed employees comprised women (48% of responses) and men (2% less than women) in the age range of 36 to 45 years old. Next was women in the age ranges of 18 to 25 and 26 to 35 years old. With men, the number of employees in the age range of 18 to 25 was almost 3.5 times smaller than that in the age group of 26 to 35 years old.

Figure 18 shows the gender structure of by gender.

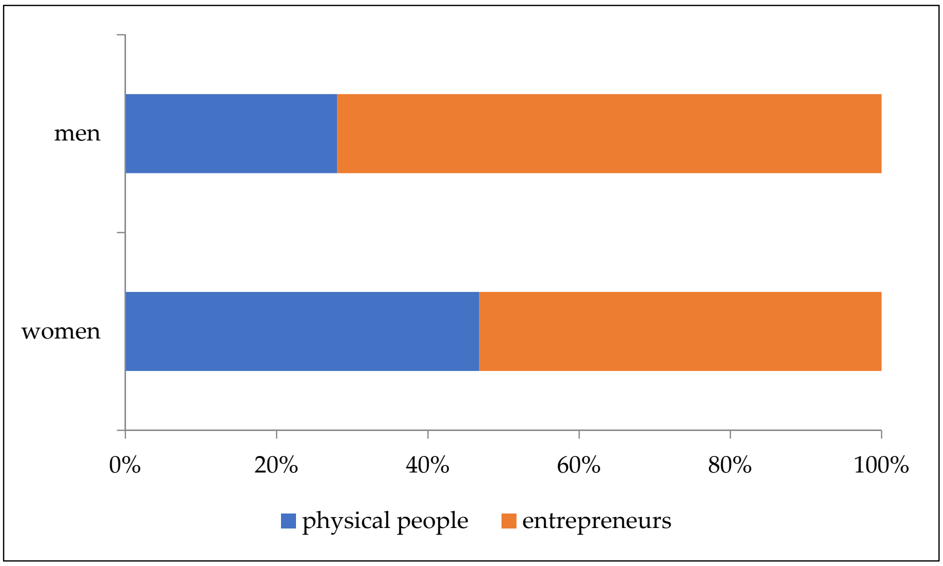

Figure 18. Employee structure by gender.

The research sample consisted of both the general public and entrepreneurs and included women and men. There was almost 20% more women than men among the sample from the general public, but there were 25% more male entrepreneurs than female entrepreneurs.

Figure 19 shows the education structure of the surveyed respondents.

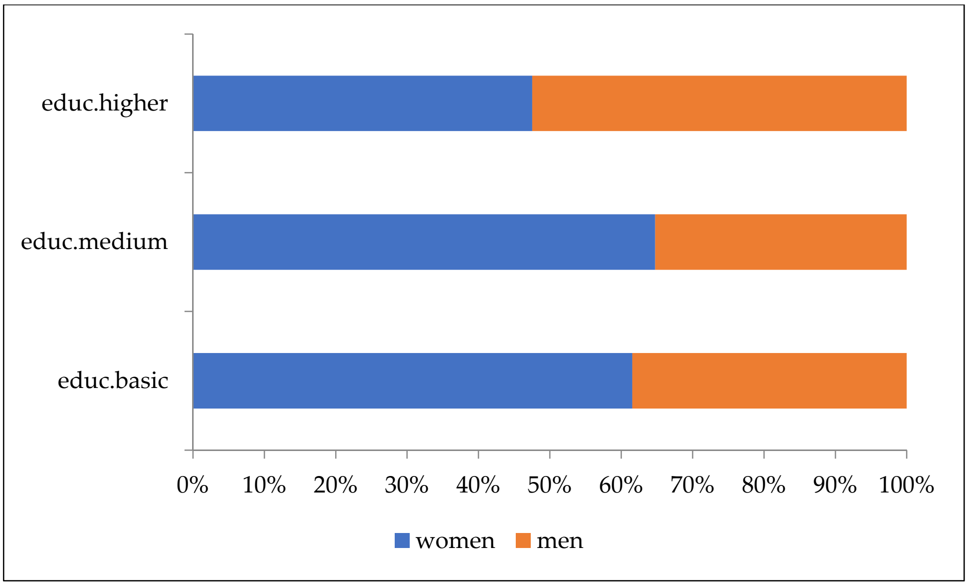

Figure 19. Education of the surveyed respondents.

The education of the surveyed respondents was mostly higher education, then the results were slightly more than two times lower for secondary education in the case of women and almost four times lower in the case of men. On the other hand, the primary education of both women and men was, to a small extent, indicative of a small coefficient of influence on the entire study population.

In Figure 19, we can notice that women in the age group of 36 to 45 years old had received higher education. Almost 2.5 times fewer women only had secondary education and very few had only primary education. There was no significant correlation between the education of women and their age.

Figure 20 shows the structure of education by age of women.

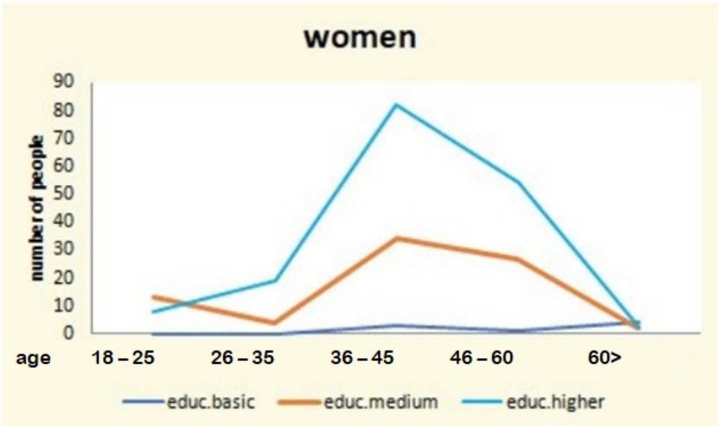

Figure 20. Education structure by age of women.

In Figure 20, we can notice that the greatest proportion of men with higher education was in the age range of 36 to 45 years old and more than half of that number only had secondary education. A very small number of men only had primary education. There was no significant correlation between the education of men and their age. A summary of all of the variables that significantly shaped the individual parameters included in the specification shows that the results were similar and without any significant statistical differences.

Figure 21 shows the structure of education by age of men and Figure 22 presents opinions on the development of renewable energy sources.

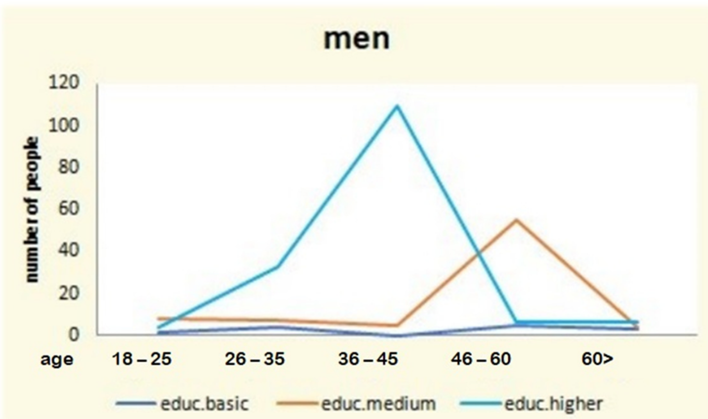

Figure 21. Education structure by age of men.

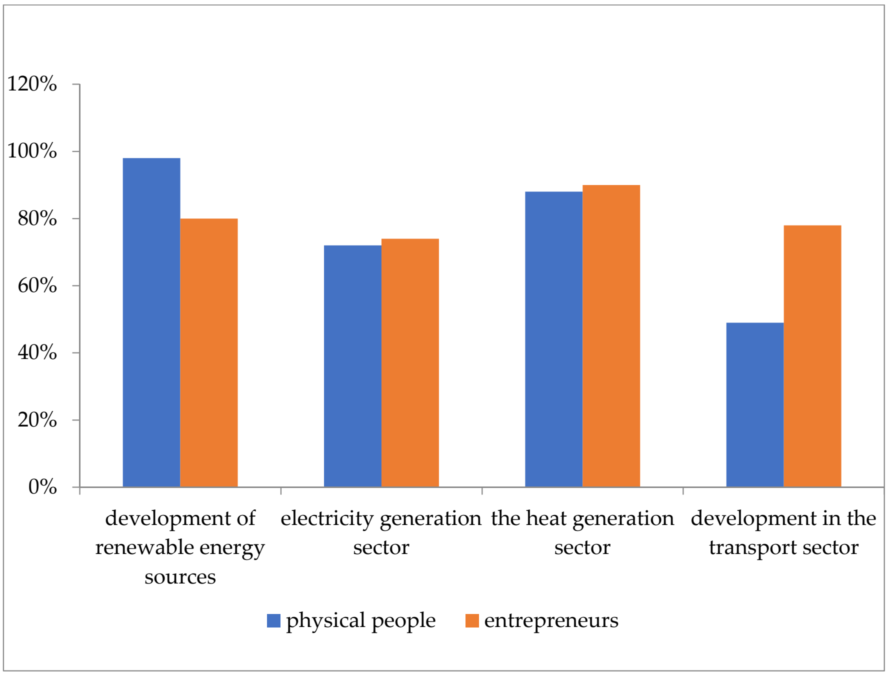

Figure 22. Opinions on the development of renewable energy sources.

Opinions on renewable energy sources were more optimistic when assessed by the general public than by entrepreneurs. On the other hand, in terms of development in the transport sector, it was more positively assessed and viewed as feasible by entrepreneurs than the others. Opinions concerning the heat generation sector and the energy generation sector were very optimistic and were similar among all respondents. The relationship between the general public and entrepreneurs was not statistically significant for $p = 0.0057$, where p was not < 0.005.

Figure 23 presents opinions on the possibilities of developing renewable energy sources.

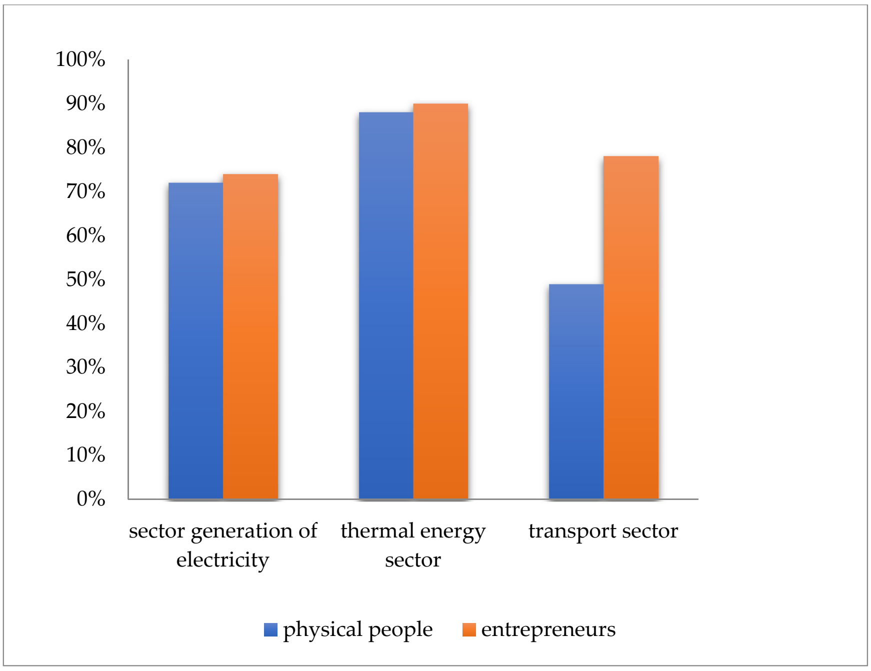

Figure 23. Opinions on the possibilities of the development of renewable energy sources.

Opinions on the development of renewable energy sources were at a high level and 98% of the general public believed that it was achievable, while entrepreneurs expressed opinions that were 18% lower. The opinions of all respondents were similar regarding the electricity generation sector, with over 70% positive feedback. The heat generation sector received 90% positive feedback from entrepreneurs, with 2% less from the general public. The development in the transport sector scored 78% from entrepreneurs but only 49% from the general public. Therefore, entrepreneurs perceived greater development potential.

Figure 24 presents opinions on the stability of supplies.

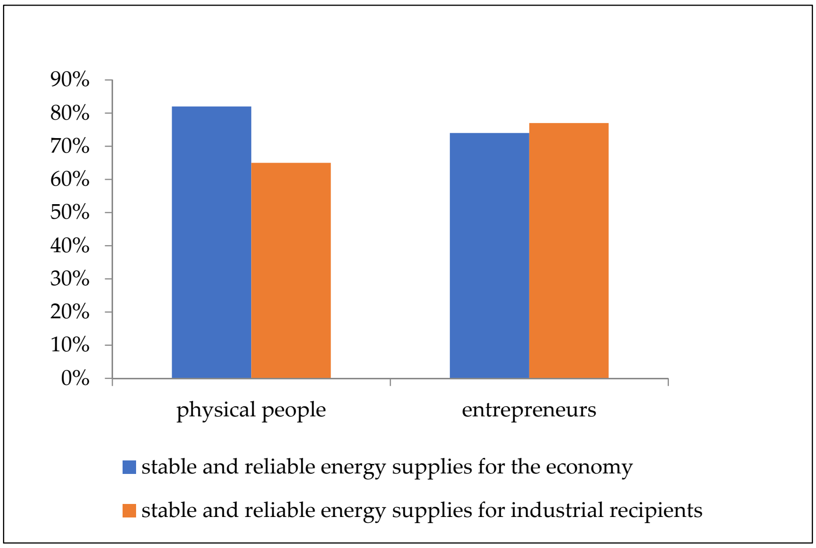

Figure 24. Opinions on the stability of supplies.

Both the general public (82%) and entrepreneurs (74%) expressed a positive opinion about the stability of supplies for the economy. Stable and reliable energy supplies for industrial recipients were valued mostly by entrepreneurs (77% of responses), with only 65% of the general public expressing a positive opinion.

Figure 25 presents opinions on the factors determining the effectiveness of project implementation.

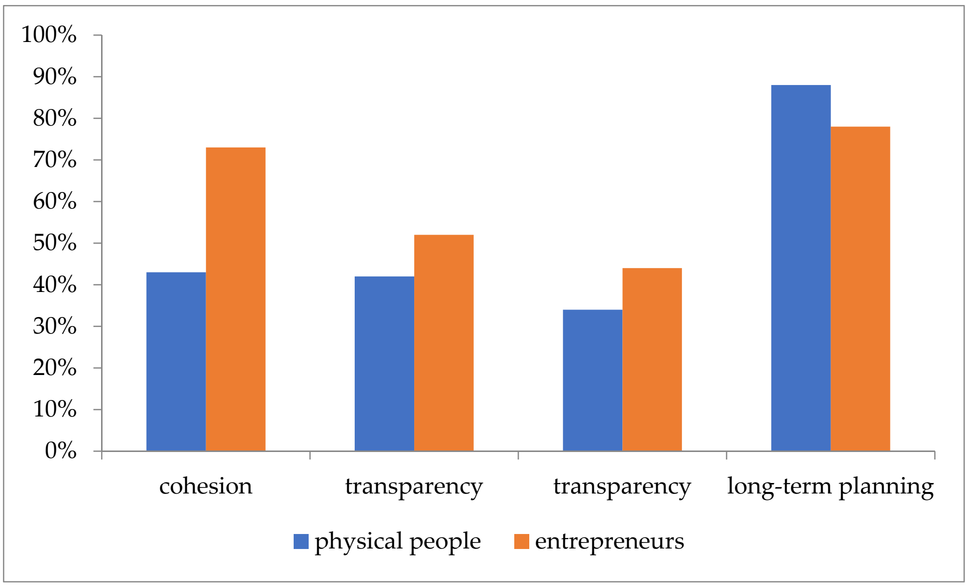

Figure 25. Opinions on the factors determining the effectiveness of project implementation.

Factors determining the effectiveness of the assumed goals, in the opinion of the majority of respondents, require long-term planning (88% of the general public and 10% fewer entrepreneurs). The entrepreneurs also appreciated consistency (73%) and transparency (50%). The comprehensiveness factor was rated the lowest in the opinion of the general public (34%) and in the opinion of entrepreneurs (44%). The general public also rated consistency (43%) and transparency (42%) poorly.

Figure 26 presents opinions on management functions that increase efficiency.

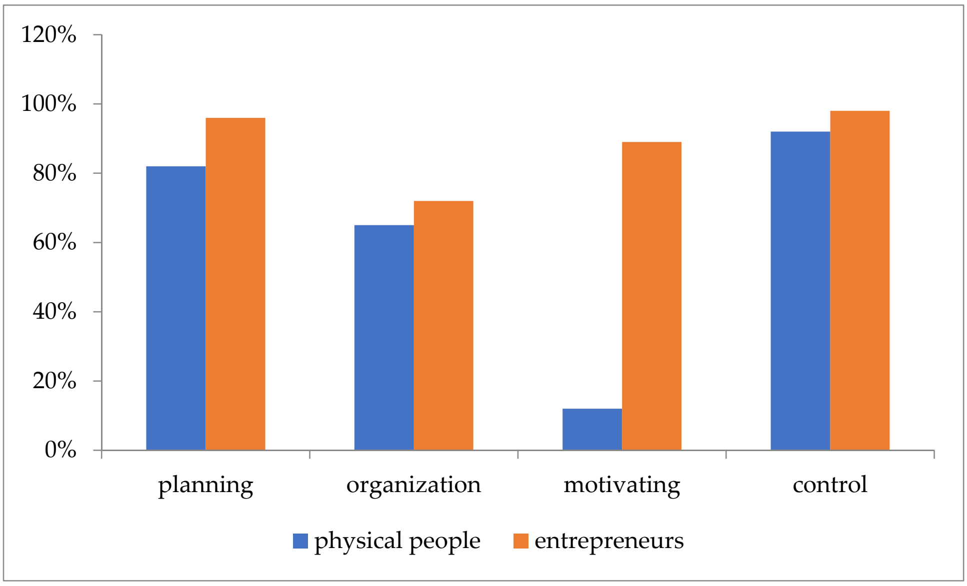

Figure 26. Opinions on management functions that increase efficiency.

Assumptions regarding the basic functions of management were highly rated as necessary by entrepreneurs, within which they most strongly indicated the need for control (98%), planning (96%), motivation (89%) and organization (72%). The general public also recognized the need for control (as much as 92% of responses), then planning (82%) and organization (65%). Motivation only received 12% of responses, which proves that there is no need to motivate in this respect. Motivation was defined as incentives in the form of educational programs, with admission tickets to the place being provided and education being combined with fun for children, thanks to which the children could pass knowledge on to their parents. There was no financial incentive.

Figure 27 presents opinions on the achievable results.

Referring to the opinions on the possible results of fair transformation, most of the general public (92% of responses) indicated the possibility of increasing the results, whereas this was true for only 76% of entrepreneurs. A very optimistic opinion was also observed regarding the key energy and economic challenges as well as good air quality with a rating of almost 90% from entrepreneurs 65% from the general public.

The opinions expressed about the factors that may contribute to the failure to achieve the assumed goals were similar for both the general public not conducting business activities and entrepreneurs. Respondents were concerned that the low-emission energy transformation of PEP2040 and large organizational challenges could be at too fast a pace, demonstrated by a uniform level exceeding 80%, which meant that respondents had high concerns in this regard and had the same opinion. The opinions regarding the negative socioeconomic effects, especially in mining regions, also exceeded the previously indicated percentage, but entrepreneurs responded to a greater extent by 6%. The same situation arose concerning the burden on the national economy and major technical challenges, with 7% more entrepreneurs reporting financial challenges as a threat. The fast pace of the low-emission energy transformation was indicated by the general public as more of a risk, while 16% fewer entrepreneurs reported this concern.

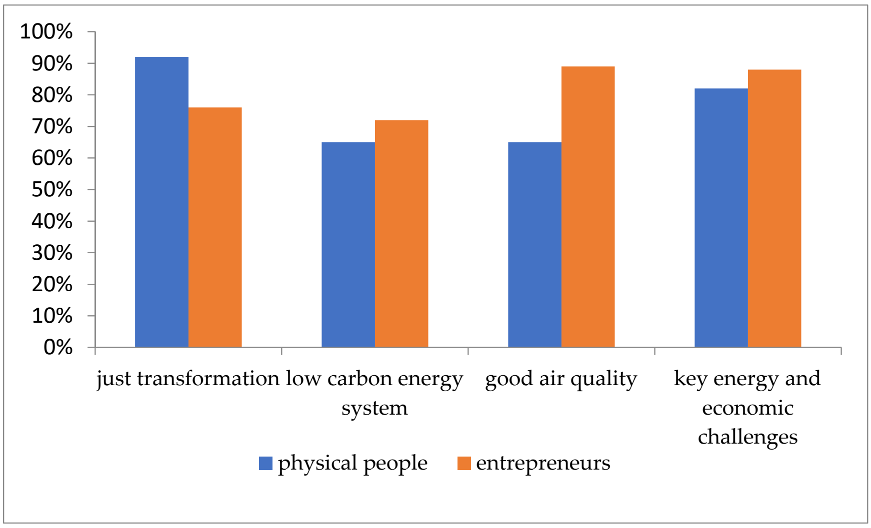

Figure 27. Opinions on achievable results.

Figure 28 presents opinions on the factors that may contribute to the failure to achieve the assumed goals.

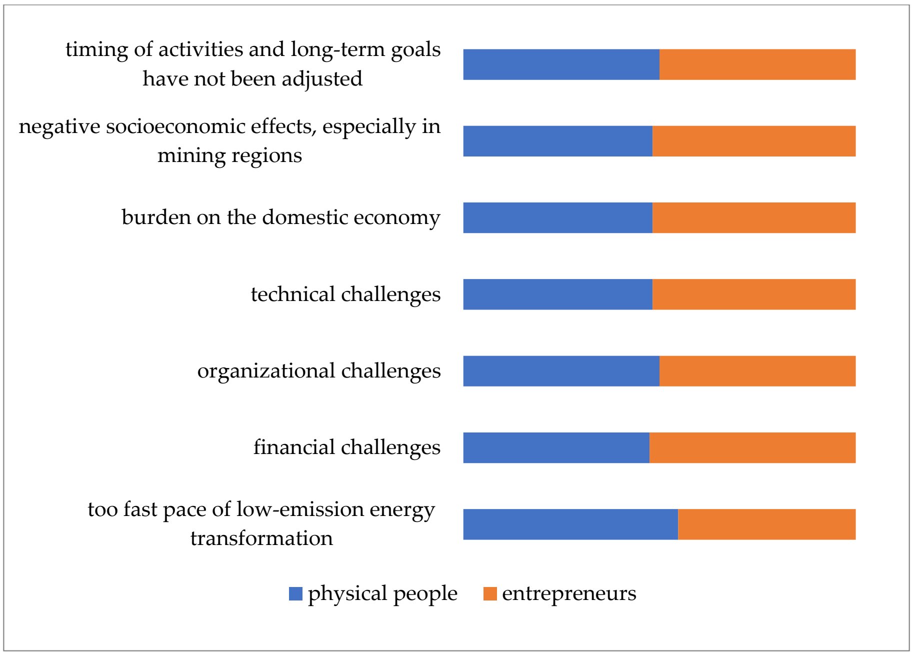

Figure 28. Opinions on the factors that may contribute to the failure to achieve the assumed goals.

6. Discussion and Conclusions

The dominant emphasis on the optimal selection of energy sources creates conflicts, especially in democratic decision-making [97]. Resource management is both incremental and participatory, and while decisions are strongly based on science, the decision-making process is rarely rational or comprehensive [98]. New branches of industry will emerge, resulting in new jobs. The obtained funds could help with the purchase of new innovative programs and technologies to facilitate the efficient financial and economic management of energy. The rules for obtaining land sites for wind energy have been made easier, along with the possibility of increasing the time horizon adapted to market needs. The design of the regulations is aimed at a greater reduction in greenhouse gases, an increase in the shares of the energy market and ensuring greater protection for consumers. These changes support the strategy for the development of renewable energy sources. On the other hand, the compromise is such that the legal and financial support that applies to all technologies in various energy sources will support the increase in environmental protection, i.e., cleaner coal technologies.

Hydrogen has a wide range of applications as a fuel in the energy sector, transport, industry and in the world of science and business.

There is a risk that the imposed pace of the low-emission energy transformation of PEP2040 is too fast and that the undertaken high organizational, technical and financial challenges are too big, which puts a strain on the national economy and could cause negative socioeconomic effects. Achieving the energy efficiency target for companies may turn out to be difficult due to increasing the target proportion of renewable energy sources from 21–23% by at least 23%.

Doubts relate to the different timings of the long-term goals and the possibilities of the rapid development of electromobility in Poland in the short term.

There is also a high risk of reporting inaccuracies in future gas investment restrictions.

The use of renewable energy sources is growing and coal is being withdrawn from the energy production system; therefore, there may be insufficient energy for industrial enterprises, for which there is the need for steady and strong supplies. Gas development is a substitute for coal and provides a low-carbon energy and beneficial nuclear energy activities [78].

PEP2040 is a stable post-COVID-19 pandemic strategy for economic growth. It is important to control the strategy in order to quickly address any irregularities and to achieve the goals of Poland's Energy Policy until 2040.

The Just Transition fund is available for all farms and industrial enterprises. Support will be provided not only for mining regions, but also for all those affected by this change. The participants of the RES policy have the chance to use innovative solutions to facilitate energy management. New branches of industry will create new jobs.

The implementation of the low-emission energy transformation should strive for innovative solutions to its objectives and functions that maintain respect for the environment and climate, which is clearly visible in the three pillars. All activities are focused on the development of the economy. The goal of zero-emission transport relies on zero-emission public transport being available from 2030: the target for all public transport vehicles to be zero-emission. The key is the integration of offshore wind energy into the Polish power system and the commissioning of a nuclear power plant. This would also create new jobs, which would help to reduce unemployment.

It is worth emphasizing that everyone will receive help as a part of the energy transformation, and not only in places where major changes have taken place. A lot of funds have been allocated for this purpose and many specialists and practitioners have been involved. There is a noticeable focus on increasing the use of renewable energy technologies in heat generation and increasing the use of alternative fuels in transport through the development of electromobility. Public consultations that aimed to summarize opinions on the strategy clearly indicated the need to maintain current activities along with an orientation toward the process of evolution, which seems to be a natural way of operating within this sector. A very good way to improve the entire structure of planned activities within the field of energy transformation would be to make all decisions work toward a low-emission energy system and adequate air quality by drastically reducing the emissions of all harmful factors and establishing appropriate measures to limit climate change, thereby ultimately eliminating negative actions in this area. Air quality refers to the levels of emissions of all harmful factors: smog, dust, acid rain, pollution and greenhouse gases.

The authors emphasize the features that allow the definition of activities that are largely focused on minimizing risks. These features include ambitiousness, fairness, radicalness, topicality, innovation and punctuality. A positive attitude toward striving for innovative activities may result in using the energy transformation development new industrial sectors.

Skills at the management level, in terms of changing the processes into innovative success, play an important role here.

New branches of industry that are created as a result of the transformation of the energy sector may significantly affect the creation of new jobs, which would have a significant impact on economic growth. Creating technological innovation [79,80] may also bring about tangible benefits through the creation of new programs and instruments that increase the basis for R&D projects. The combination of these actions may turn out to be feasible, if only because energy efficiency is a priority in the European Union's policy. The priority solution of a fuel and energy carrier and significant advantages and versatility can be realized through hydrogen. The authors analyzed the risk and possible negative consequences of not meeting the requirements for a low-emission economy. The key aspects included: the rapid imposed pace of changes along with a high scale of organizational challenges; large financial and technical expenditure; the lack of the full and timely correction of all activities in accordance with the schedule and long-term forecasts. Concerns are arising in enterprises, as companies that may not necessarily be prepared to implement certain changes, particularly traditional companies. It may turn out to be a lack of facilities for implementing changes (effective change management). Some comments from individuals seem inconsistent with the rest of the postulates, and there is no clear and rational allocation of responsibilities to all stakeholders within the fuel sub-sector.

Planning the results based on the average efficiency of energy production until 2040 assumes maintaining a uniform level. It seems that the strategy should take into account preparations for the threat of dangerous infectious diseases (COVID-19, etc.) to the world to a greater extent. Many financial resources are required, which requires the involvement of the entire economy and the combination of private and public capital. The authors positively assessed the increase in investment outlays during the years 2031–2035. This is probably a safer option, within which it is possible to achieve better preparation in terms of fulfilling the energy "mission" and rational spending. The authors do not assume a lack of rationality, but we are focused on increasing opportunities to maintain an appropriate level of spending. Opinions on renewable energy sources were more optimistic when assessed by the general public than by entrepreneurs. On the other hand, in terms of development in the transport sector, it was more positively assessed and viewed as feasible by entrepreneurs than the general public. Identical opinions were assessed as invoking high optimism concerning the heat generation sector and the energy generation sector. The stability of energy delivery was assessed very positively by all participants in the study.

The expressed opinions on the factors responsible for the effectiveness of the project implementation indicated the need for long-term planning (more by the general public than entrepreneurs, with a difference of 10% from 88%). Additionally, entrepreneurs emphasized consistency in action. The key functions of management were of key importance in meeting the requirements for all participants. Entrepreneurs appreciated all basic management functions, including the controlling, planning and motivation, more than the general public.

The general public assessed management functions very similarly, but to a lesser extent, apart from the controlling function. Increasing the results was more feasible for the general public than for the entrepreneurs. It is worth pointing out that the outcome of the key energy and economic challenge of raising air quality was viewed very optimistically by all respondents. The factors that may contribute to the failure to achieve the assumed goals were very similar both in the case of people not conducting business activities and entrepreneurs. The indicated opinions were confirmed with theoretical statements, which were presented in the previous discussion.

The implementation of Poland's Energy Policy until 2040 is possible thanks to rational functioning, the application of fairness, innovation and a forward-looking approach and the principles of competitiveness. The predominance of positive comments from national public consultations in the field support the energy transformation and national funds.

Managing the low-emission energy transformation in Poland consists of improving the activities that are aimed at implementing specific changes in this area. It turns out that it is very important to take care of the basic management functions (planning, organizing, motivation and control). It is also important to react quickly to and control any irregularities and be motivated to fulfill your mission.

The authors note that COVID-19 had a limited negative impact on environmental pollution only to a small extent and for a short period of time. in summary, it can be seen that the pursuit of innovation by industrial enterprises may be of key importance for the achievement of the energy policy goals.

All activities that are aimed at the innovation of industrial enterprises indicate the importance of achieving the goals of Poland's Energy Policy until 2040. It seems that the direction of the transformation until 2050 policy is more decisive and realistic, although it still requires a lot of accurate and consistent decisions and expected actions to be made.

Author Contributions: Conceptualization, H.W.; methodology, T.J., H.W. and I.M.; software, T.J., H.W. and I.M.; validation, T.J., H.W. and I.M.; formal analysis, T.J., H.W. and I.M.; investigation, T.J., H.W. and I.M.; resources, H.W. and I.M.; data curation, T.J., H.W. and I.M.; writing—original draft preparation, T.J., H.W. and I.M.; writing—review and editing, H.W. and I.M.; visualization, H.W. and I.M.; supervision, T.J., H.W. and I.M.; project administration, H.W. and I.M.; funding acquisition, T.J., H.W. and I.M. All authors have read and agreed to the published version of the manuscript.

Funding: Funding for the implementation of this research activity and the publication of this article was obtained from the Academy of Martial Arts in Warsaw and the University of Szczecin in Szczecin. The project was financed within the framework of the program of the Minister of Science and Higher Education in Poland under the name "Regional Excellence Initiative" in the years 2019–2022, project number 001/RID/2018/19. The amount of financing was PLN 10,684,000.00.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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