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Offshore Energy Development in Poland—Social and Economic Dimensions

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Abstract: The development of green technology in the world is progressing extremely rapidly. New possibilities for obtaining energy from renewable sources are constantly being sought and existing solutions are being improved. The multifaceted potential of the seas and oceans is an important aspect being taken into account in the development of the energy systems of a number of economies. One dimension of action in this area is the orientation towards offshore wind energy and the construction of offshore wind farms for this purpose. The purpose of this article is to analyse the importance of offshore wind farms in Poland's energy system and to assess public perception of the changes taking place in this dimension. The article is based on research and critical analysis of the available literature, legal regulations and industry reports, as well as on the results of our own surveys, the scientific findings of which were developed with the application of statistical instruments using PQstat software, ensuring the expected quality of results. The findings of the article indicate the significant importance of offshore wind farms in the creation of Poland's energy mix, with differing public attitudes towards their construction. Furthermore, the results of the research indicate a differentiated attitude of society towards the construction of offshore wind farms. The main motivation for majority support of the measure in question are economic reasons, which are connected with the expectation of a real price reduction per 1 kW of energy, as well as increased attractiveness of the region due to investments in this area. The main concern with the measure relates to environmental aspects, with concerns about the functioning of ecosystems in light of the construction and subsequent operation of wind farms. Negative public opinion is also signalled in relation to the potential risk of landscape change in a direction that is undesirable for the studied developed coastal tourist region in Poland.

Keywords: wind energy; climate change; RES technologies; renewable energy management; Baltic Sea wind potential; economics of RES solutions

Citation: Chomać-Pierzecka, E. Offshore Energy Development in Poland—Social and Economic Dimensions. *Energies* **2024**, *17*, 2068. https://doi.org/10.3390/en17092068

Academic Editor: Hua Li

Received: 31 December 2023
Revised: 14 April 2024
Accepted: 24 April 2024
Published: 26 April 2024

1. Introduction

Energy demand in the world is increasing. The post-pandemic period, as well as the outbreak of war in Ukraine, has complicated the energy market situation. Economies are struggling with the availability of energy raw materials, which, in the case of natural energy-bearing raw materials, are an increasingly scarce commodity, contributing to an increase in their prices and, consequently, in the price of energy produced from such sources. This problem particularly affects countries whose energy system is based on conventional production, which is additionally burdened with charges for the emission of environmentally destructive compounds [1].

The increase in energy prices is an extremely debilitating factor for national economies that rely heavily on traditional energy production. Poland is an example of such an economy. Hence, the search for generation alternatives in this area is fully justified. This is motivated by formal and legal regulations forcing economies to take steps to transform outdated generation systems into environmentally safe ones based on renewable sources. There is also strong pressure on the need to model energy systems in line with environmental policy from growing public awareness of the changes required in this area.

The expectation of access to energy from green sources goes hand in hand with the expectation of a lower cost of energy, which further motivates the challenges in this sphere.

The green energy market is extremely broad. It draws on natural sources such as sun, wind, earth or biomass energy. An important aspect of this development is the orientation towards the energy potential of the seas and oceans, which includes wave energy, currents, tides, as well as wind in marine and ocean areas. This last strand inspires the deeper analysis, in the context of the prospects for strengthening Poland's energy mix, which is the reference subject of this article.

The viability of building wind installations is determined by a number of factors. According to existing studies, a key determinant of the effectiveness of wind farms is their appropriate location [2]. This aspect is linked to the availability of adequate wind resources, which reach higher speeds in the open sea than onshore winds and are generally a better source of green energy [3,4]. The quality of the wind resource [5] is considered in terms of its strength, intensity and direction, which are to an important extent determined by the conditions of the sea [6]. Overall atmospheric stability is important [7]. Another important determinant is the appropriate structure of the seabed or the appropriately low depth of the seawater. In terms of the attractiveness of offshore reservoirs, the North Sea is in the lead, with 80% of Europe's offshore installations located there. The Irish Sea and the Bay of Biscay are also important in this area, each with 10% of offshore wind farms installed in Europe. According to the researchers, the conditions of these reservoirs meet the conditions for the erection of efficient installations. The Baltic Sea appears to be particularly attractive in this respect, with a proper water surface at a distance of 26 km from land and an average installation depth of 42 m, with water depth determining the investment availability of the reservoir bottom [8]. An analysis of the wind potential of the Baltic Sea (level of approx. 8–10 m/s [8]) provides the basis for forecasts of reasonable development of this energy segment. A number of countries bordering this basin, including Poland, are interested in offshore energy from the Baltic Sea. The above justifies the interest of theoreticians and practitioners of economic life in exploring this issue, which justifies the choice of the research topic adopted in this article.

The need for research in this area stems from the insufficient number of available studies exploring the potential of offshore wind as a source of power for the Polish energy system. The research gap noted relates particularly to the aspect of analysing and assessing the public's position on planned and ongoing changes in this area. Hence, an analysis of the importance of offshore wind farms in the creation of Poland's energy system was considered as the main objective of this article. At a detailed level, this study refers to the thread of assessing social support for the implemented actions.

This study was prepared in order to strengthen knowledge in the field of offshore wind energy as well as to draw attention to the social position on the development of this dimension of energy supply in Poland, in response to the diagnosed gap. The results of the findings are to serve the development of the concept of offshore wind energy development in Poland and may serve as inspiration and basis for the definition of educational programmes and promotion of this dimension of activities among the Polish community, hence the topic was deemed important.

The layout of this article is intended to ensure the completeness of the findings in terms of the stated objective.

The structure of the article is built of the following:

(a) Introduction;
(b) Literature review related to renewable energy issues including offshore wind energy;
(c) Analysis of the RES market in Poland, with particular emphasis on the potential of offshore wind energy;
(d) Analysis and evaluation of social support for the ongoing offshore wind energy development in Poland;
(e) Discussion;
(f) Summary and conclusions.

2. The Market for Renewable Energy Sources Including Offshore Wind Energy as a Direction for the Transformation of the Energy Systems of the World's Economies—Literature Review

The progressive development of economies entails an unabated demand for energy [9]. The increase in electricity consumption increases its market price, which is created by the expensive energy-bearing raw material—in the case of production based on classic generation formulas—and the associated system of emission production charges. The above motivates the search for solutions that will enable reliable production of green electricity, low-emission production (mainly the CO_2 problem) or energy security. The orientation towards production stability through diversification of sources, as well as towards lowering the market price by drawing on renewable sources, is nowadays the main direction of the transformation of energy systems towards RES, realising sustainable development [10–12]. The justification for this is to respect is the increasing greening of life, stemming from increased public awareness, growing out of concern for the future of the planet and quality of life in the decades to come. Consumer preferences against this background are undergoing intense changes. Environmental pressures are increasing, creating a key condition for the development of the energy systems of the world's economies. In line with the above, the demand for clean energy is on an upward trend, creating serious challenges for economies whose energy systems are based on traditional production formulas. Hence, the subject of interest in this article is directed towards exploring the issue of renewable energy in Poland [13], which is heavily dependent on coal. A special dimension of interest in this area is created by the potential of offshore wind and the role of offshore wind farms in the process of strengthening renewable energy sources in this country. Wind, like the sun, is a widely available source of renewable energy. Its particular potential is created by the area of seas and oceans [14,15]. Here, geographic location and economic considerations in relation to project implementation are the main constraints on tapping this source of renewable energy.

Offshore wind energy is recognised worldwide as an important source of energy supply [16], the availability of which is determined by natural conditions, including those related to wind power [17,18], as well as formal and legal challenges shaped by the impact of wind installations on the environment [15]. In this context, attention is drawn to the fact that wind power increases with increasing distance from the coastline into the seas and oceans [19], indicating that the wind potential in this area is unrivalled compared to conditions on land [20]. Thus, this draws attention to the aspect of lower turbulence, enabling relatively uniform energy generation over vast areas of sea and ocean, which are suitable for wind farm installations [21]. The wind potential of offshore ocean areas for wind farms is explored in numerous studies [22,23]. Drawing attention to the conditions indicated, it is highlighted as pointless to overlook existing energy resources, particularly in countries directly adjacent to offshore or ocean basins [24], promoting the natural need to develop offshore wind energy, and this development is noted worldwide. Offshore wind energy technologies are constantly being improved [3,25,26], increasing the investment justification in the direction in question. In 2021, 93 GW of wind energy was produced, where 21 GW was created by offshore wind [12], confirming the strong development of this dimension of the world's energy transition.

For years, Europe has been recognised as a leader in offshore wind energy. Among existing offshore areas, a strong position is held by the Baltic Sea, whose wind is a significant carrier of clean energy as a result of the shape of this relatively small inland body of water. Due to its small size while being located in a fairly large area among the surrounding land, this sea is subject to a strong temperature gradient, triggering wind [27]. The conditioning of the Baltic Sea wind considered as an energy carrier has been subjected to a multifaceted analysis for years, using numerous techniques [28] (wind speed, wind resources). In the opinion of researchers, the energy potential of the Baltic Sea—like that of the Black Sea or the Caspian Sea—is of good quality and suitable for the application of wind technologies whose effectiveness in closed or semi-open sea basins is proven [29]. Importantly, the first

successfully operating wind farm ('Vindeby', 400 MW) was installed in 1991, precisely in the Baltic Sea in Denmark. Subsequent installations have been successfully installed in succession. Along the coastline of this sea there are still a number of locations suitable for the installation of further offshore wind farms. Therefore, the discussion of the energy potential of the Baltic Sea in the perspective of the development of the RES dimension in Poland was taken as the main objective of this study. Furthermore, the existing studies do not sufficiently address the thread of public opinion research on the subject of planned and ongoing changes oriented towards the strengthening of RES sources in Poland towards wind energy. In response to the gap identified above, the research on the characteristics of the Baltic Sea potential was expanded to include a diagnostic survey, which provides a basis for determining the level of public awareness and public sentiment expressed by the level of acceptance or lack thereof of the changes taking place. The main aspect of this dimension of the diagnosis is the impact of offshore wind farms on the wider coastal environment, captured in the socio-economic dimension.

3. Materials and Methods

The stated purpose of this article influenced the layout of the study. Considerations of a conceptual nature were captured in the introduction. A literature review consolidated the background to the research, justifying the direction taken. The literature reference took into account the analysis of research studies, industry reports and statistical data and summaries.

The in-depth analysis (the empirical–analytical part) was conducted in the direction of diagnosing the state in terms of the explored themes, systematising the conditions shaping the studied area and the results obtained in its area. The process of decomposition and study of the phenomena and then synthesis of the findings was carried out taking into account the rules of economic analysis, which ensured the flow of substantive findings.

The research process was oriented towards the verification of the hypotheses stating the following:

1. Investments in offshore wind power constitute the right, socially supported direction of Poland's energy system transformation (H_1);
2. The socially supported development of offshore wind power plants will significantly strengthen the RES dimension in Poland's energy mix (H_2);
3. The development of offshore wind energy will significantly strengthen the socially expected progress of Poland's energy system transformation (H_3).

The link between public opinion and activities in the sphere of energy system transformation in Poland is obvious. Public consultations and agreements are part of the right of every citizen of a democratic state [30], in which the community defines its diverse needs, expresses opinions and makes suggestions or proposals for solutions on the topic being explored. In Poland, this dimension is regulated by the Act of 6 May 1987 on Public Consultation and Referendum, as amended [31], providing a tool for involving the Polish community in the decision-making process. The stance and involvement of citizens has a real impact on the shape of the established solutions. Investigating the public's position on the issue of Poland's energy system transformation, with a particular focus on offshore wind energy development, is therefore justified.

This article is based on a literature survey with reference to selected formal and legal regulations and industry reports, and on the results of our own questionnaire survey, carried out between 1 and 3 May 2023 in a coastal urban agglomeration in northern Poland (Ustka, Pomeranian Voivodeship), bordering the shore of a body of water into which offshore wind farms are planned in this location [32].

The design of the questionnaire was oriented towards a broad spectrum of research: the analysis and evaluation of tourism services, the analysis and evaluation of consumer preferences in the market for tourism services, as well as the evaluation of the directions of (tourism) development of the coastal region in Poland, including investments in offshore energy. Hence, the layout of the questionnaire dedicated to the issues explored in this article

adopted a narrow layout—six questions, including four closed and two multiple-choice, open-ended questions, limiting the research spectrum to the key aspects of the study. The content of the survey questions is presented in detail in the research part, in the area of the analysis of the actual picture of the opinion of the surveyed community in the surveyed area. In order to ensure a proper survey of public opinion, a contrasting sample street survey technique was adopted, allowing a broad spectrum of opinions to be captured.

The sample of respondents was made up of Polish tourists who stayed in Ustka in the period 1-3.05.2023; therefore, the findings obtained in the research are only relevant for this sample and may not be transferable to the general population. The sample of respondents was formed by the following groups:

- Respondents aged up to 30 years (54.6%);
- Respondents aged 31–60 (37.3%);
- Respondents aged 61 and over (8.1%).

The Pomeranian Voivodeship was represented by 23.7% of the survey population, with the remaining 76.3% of respondents representing the other voivodeships of Poland. In this study, the characteristics of the population did not constitute differentiating variables.

The choice of instrumentation was determined by the characteristics of the data and the research assumptions made. Participation in the survey was open and anonymous. A total of 287 people took part in the survey, with 273 correctly completed questionnaires accepted for further processing.

Simple methods were used in the area of inference. The cause-and-effect dimension of the analysis of the research threads ensured the quality of the inference. In-depth research was carried out using statistical methods.

4. Results

4.1. Results from Literature Research and Industry Reports

4.1.1. Offshore Wind Energy in the Transformation of the Energy System of the World, Europe and Poland—Overview of Trends

The intensive growth of wind power globally, both onshore and offshore [33], is confirmed by an analysis of the growth of connected capacity over time. The results of the analysis show year-on-year increases in 2021 carved out a 12% increase in installed capacity (with an overall global result of 824.874 GW) [5], in 2022 this was +9% (906 GW) and 2023 is assumed to be +15% and to exceed the global level of 1000 GW [34].

Unchanged over the years, the main producers of wind energy are China (with the Gansu wind farm with a target capacity of 20 GW) with over 46.42% share of global wind energy production in 2021 and the United States of America (with the Alta Wind Energy Centre with a target capacity of 3 GW) with about 16% of world production [35]. The year 2022 also counted Brazil, Germany and Sweden among the largest markets for wind installations, which together with China and the USA generated 71% of new installations globally [34].

On the European continent, 2023 closed at 272 GW of wind power installed capacity, with onshore farms accounting for 87% of this result and offshore farms for 13%. The increase in installed capacity this year was for onshore +14.5 GW, while for offshore it was +3.8 GW [36], setting a historical record for capacity growth in this sphere [37]. The projections for further growth in this dimension of the power source should be highlighted, with an estimated increase in the offshore dimension to 21 GW in 2024 [36]. For years, Germany has been the leading European wind power producer with an installed capacity of 70 GW, followed by Spain (30.6 GW) and England (29.6 GW). A detailed breakdown of the leading wind power producers is presented in Figure 1.

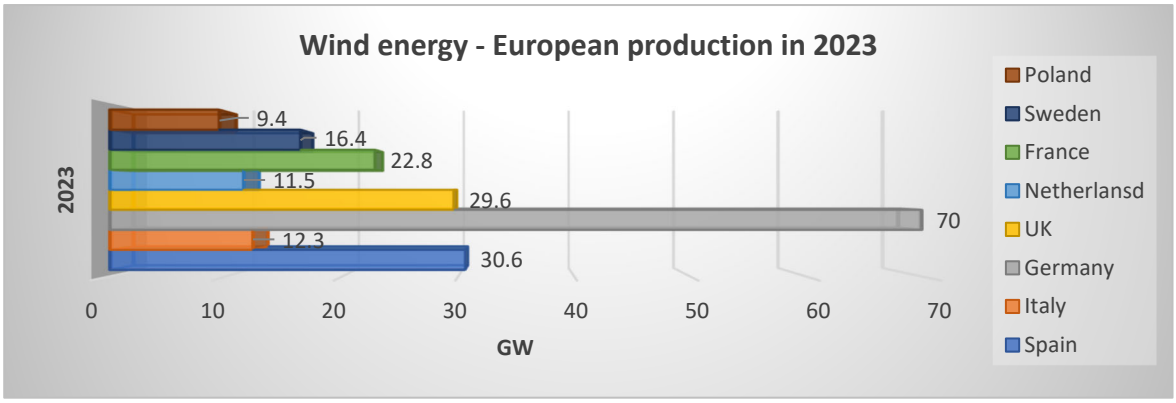

Figure 1. Wind energy—European production in 2023 [36].

In the offshore sphere, the leaders include England (15 GW) and Germany (9 GW). A detailed breakdown of the leading wind power producers is presented in Figure 2 [36].

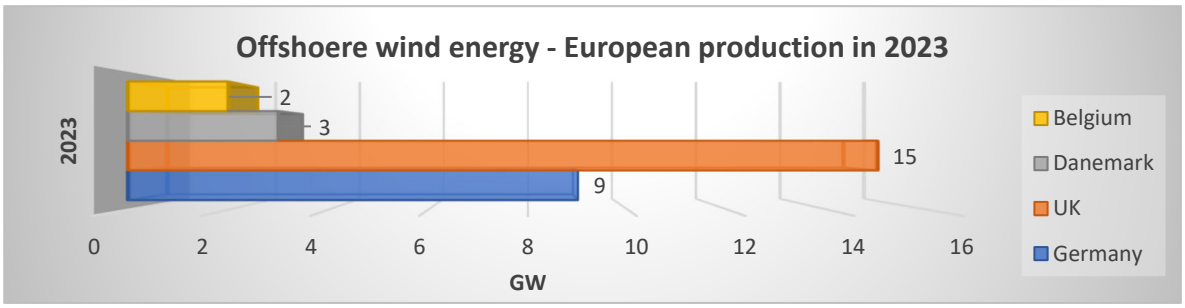

Figure 2. Offshore wind energy—European production [36].

Harvesting energy from offshore wind is an important pillar of wind energy. Poland's participation in this field is expected in the near future [12]. Poland's potential in this field is estimated at a level of 12 GW of connection capacity, which is expected to generate energy production of over 43.2 TWh net. In relation to the above, Poland's offshore wind energy potential is ranked fourth in the countries interested in wind energy in the Baltic Sea, after Sweden, Denmark and Latvia [37,38].

The development of offshore wind power in Europe is making a strong showing. There is a significant increase in the commissioning of offshore wind installations, confirming an upward trend [39]. According to the Polish energy policy, offshore wind installations are to constitute 13% of Poland's energy mix by 2030, and by 2040 this relation is to increase to 19% [32]. Numerous studies have been pointing to the legitimacy of such a development for years, anchoring the development of this dimension of energy on the European continent [40,41]. In terms of the geographical distribution of offshore wind power plants on the world map (257), 140 of them are located in Asia, there are 115 in Europe and 2 in the United States of America [42].

According to analysis by BloombergNEF in its Global Offshore Wind Report, a significant increase in connection capacity in the offshore wind field will be created by the 26 offshore wind installations under construction, with a capacity of 12.41 Mw. It is also assumed that the average capacity of future installations of this type will reach an average of 45.6 GW, with offshore energy growth expected to progressively reach four times the level recorded in 2022 in 2035 [42]. What is important here is the capacity and capability of the supply chain to respond effectively to the expectations of the environment, correlated with maximum low-cost levels. This is to ensure that the objectives of the transformation of the energy systems of the individual countries of the world are met in a manner that safeguards security (of energy, production processes or the environment), in correlation with

an affordable (cost) dimension of its acquisition. Indeed, the financial side adopts a key criterion for offshore energy development, creating the basis for market price determinations that shape the demand side in this market segment.

4.1.2. Offshore Potential Versus Wind Power in Light of Energy Price Formation

The market price of energy is an extremely important aspect today. Due to the outbreak of war in Ukraine and the energy crisis caused by the disruption or breakage of energy commodity supply chains, electricity prices in Europe and worldwide have become volatile. In addition, this was compounded by unfavourable macroeconomic conditions, e.g., due to the increase in interest rates by the Central Bank, and consequently by financial institutions at the level of the economies, in order to combat inflation [43].

The very significant increase in electricity prices in Poland necessitated state intervention and the freezing of electricity prices. The above was regulated in Poland in the Act of 27 October 2022 on emergency measures to limit the level of electricity prices and support certain consumers in 2023 (the "Emergency Measures Act"). The intervention covered the following [44]:

1. Households, setting the maximum price for this group of consumers in 2023 at 154 EUR/MWh (693 PLN/MWh);
2. The micro-, small- and medium-sized enterprise sector, setting for this group of recipients in 2023 174 EUR/MWh or 785 PLN/MWh (excluding VAT or excise duty).

The risk of an increase in electricity prices in 2024 reinforces the public's orientation towards RES sources and public support for undertaking and intensifying such activities. It is worth pointing out that the current price level for electricity in the European Union averages around 97 EUR/MWh, while in Poland it is 124 EUR/MWh (quoted in April 2023) [45].

The lack of stability in the energy market motivates the intensification of efforts to accelerate the energy transition. In Poland, a special role for power generation from RES sources is seen in wind power [15], which as the results of the analyses show, is the cheapest source of energy, whose increase in the country's energy mix contributes to adjustments in electricity prices. It has been estimated that an increase of 1 GW of installed capacity contributes to a reduction in the cost of generating 1 MWh by approximately EUR 6 [46]. In addition, at the peak of wind generation (when the weather is windy), generation from wind farms provides up to 40% of the country's electricity needs in the afternoons. This conditioning contributes to significant adjustments in market energy prices (even by several tens of percent) [47]. For example, in October 2022, average wholesale electricity prices were among the lowest in Europe, at just under 103 EUR/MWh [46]. Hence, the offshore dimension appears to be particularly attractive, with greater potential and relatively fewer restrictions in terms of available locations than onshore, the development of which is still restricted in Poland by the distance law, which was slightly liberalised in 2023. At the same time, it should be emphasised that the process of producing energy from offshore wind is more expensive than onshore production, hence the estimated annual percentage decrease in the cost of offshore wind energy production for Poland in the 2020–2021 period was at the level of −13% and was lower by 2% than the price change indicator for onshore production in the same period [46].

In general, the energy price formation process is also influenced by the reduction of environmental charges for emission reductions. In this regard, it is worth noting that the increase in global installed capacity due to wind power development reduces carbon dioxide emissions by approximately 1.1 billion tonnes globally [48]. This is another empowering argument for offshore reinforcement activities. It is an important aspect of stabilising energy systems oriented towards optimising energy prices and building a sustainable energy future [49], oriented towards the supply of safe and cheap green energy. The overriding value of this measure is the reduction of progressive climate change, directly affecting the environment.

4.1.3. Offshore Wind Energy in Light of the Transformation Needs of the Polish Energy Market

As already signalled, the Baltic Sea fulfils the conditions for the development of wind farms drawing on its wind resources. Poland's geographical location therefore offers the possibility to take this energy supply potential into account when modelling changes to the existing energy system. Hence, in addition to the onshore dimension with a share of more than 10% of the power generation structure, Poland is orienting its activities towards obtaining energy from offshore sources [35]. The distribution of sources in the production of electricity in Poland in 2022 is presented in Figure 3.

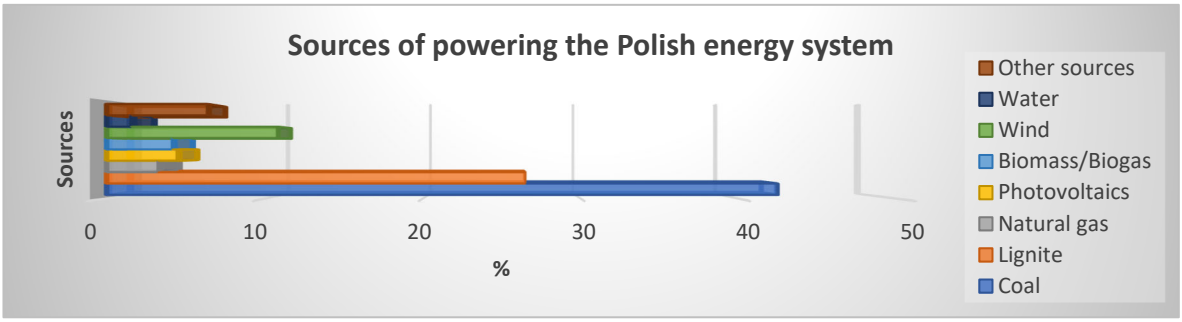

Figure 3. Sources of powering the Polish energy system in 2022 [37].

Analysis of the structure of Poland's power supply sources in the period January 2023–April 2023 indicates a strengthening of the wind power dimension to 15.1% (an increase of 39.81% compared to the annual average for 2022) [8]. According to estimates, the share of solar and wind energy in the country's energy mix increased the most in 2023 compared to 2022. In the same period, there was a slight increase in the share of water as a source of energy supply for Poland, the share of biogas remained unchanged and the share of biomass was adjusted [50].

The development of wind energy in Poland is progressing. The regulations of the Act of 9 March 2023 amending the Act on investments in wind power plants and certain other Acts (the Wind Energy, Distance Act) have been revised. Moreover, the offshore dimension is being strongly promoted, which is expected to strengthen the result of the share of wind energy (in total) in the Polish energy system in the near future, making this source of renewable power unrivalled in Poland. It is worth noting that it is the offshore dimension that is seen as an opportunity to reduce the power deficit in the Polish power system [51]. It is estimated that offshore wind potential for Poland oscillates around 33 GW of energy [52]. According to the report 'Offshore wind energy potential in Poland', prepared by the Polish Wind Energy Association, full utilisation of offshore wind energy potential could meet up to 57% of the country's electricity demand [53]. Efforts to maximise the potential of Baltic Sea wind energy integrate the interests of the countries concerned. In this regard, Poland, Germany, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania and the EU signed the Baltic Sea Declaration on Offshore Wind Energy to accelerate and coordinate activity in this area [54,55]. This should be seen as an important step towards making the development of offshore sources in the region a reality.

In Poland, like, e.g., Lithuania, Spain and Ireland, formal and legal regulations providing a basis for offshore activities have been or are being established. Romania, Turkey and Greece are working on this dimension of challenges. The National Energy and Climate Plan/PEP 2040 is a key regulation indicating that Poland's renewable energy sector is to reach 50 GW of installed capacity by 2030, and by 2040 it is to reach 88 GW. According to these assumptions, renewable energy sources will create energy at the level of 47% of energy demand by 2030 (approximately 93 TWh), and by 2040 this indicator is to increase to 51% (124 TWh) [49]. According to Poland's Energy Policy, the installed capacity of offshore wind farms is expected to reach 5.9 GW by 2030 and then 11 GW by 2040, although other

sources indicate an expected level of offshore capacity of 18 GW by 2040 [56]. Work in this area is ongoing. The location of further offshore wind farms is being decided, key purchase decisions are being made and construction permit processes are being prepared and launched. At the same time, there are indications of measures aimed at amending the law and improving the conditions in the sphere of investment in offshore wind installations (e.g., the Act of 15 December 2022 on special protection for certain consumers of gaseous fuels in 2023 valorising the level of financial support established), which will make the implementation plans in this area a reality [56]. It is assumed that the first plug-ins to the Polish power grid—as planned—will take place at the end of 2025. Offshore is an important step in the transformation of the energy system of Poland, Europe and the world.

4.2. Analysis and Assessment of Public Support for Offshore Wind Energy Development in Poland—Results of a Diagnostic Survey

The direction of Poland's energy system transformation is subject to public consultation. Activities in this area involve soliciting opinions and assessments of the proposed solutions, as well as noting the proposals of actions enabling the creation of responses to diverse social needs.

The social stance determines the scope and pace of making arrangements, hence an analysis of the general approach in a given area allows one to estimate the level of complication of the arrangement's procedure, determining, inter alia, its scope, duration and quality of final decisions. In the light of the pre-consultation on the concept of updating the national strategic assumptions in the field of energy, including the National Energy and Climate Plan for 2021–2030 (NERP) and the Energy Policy of Poland until 2040 (PEP2040), it was considered important to find out the public opinion on the changes taking place in the direction of offshore wind energy development in Poland. To this end, a survey was conducted in a coastal town in Poland (Ustka) between 1 and 3.05.2023 to investigate the general attitude of the public towards the ongoing offshore wind farm investment process in the immediate vicinity. The open and anonymous nature of the survey was intended to ensure the objectivity of the findings contained in the 273 correctly completed questionnaires, which in general revealed the following:

1. In response to the question about support for ongoing investment in offshore wind energy in Poland, 63% of the respondents answered positively, 32% stated that they did not have an opinion on the subject and 5% answered that they did not support such action (Figure 4);
2. In response to the question about support for further development of offshore wind energy in Poland, 61% of respondents answered positively, 34% said they had no opinion on the subject and 5% replied that they did not support such action (Figure 5);
3. In response to the survey question, "can the development of offshore wind power significantly affect the strengthening of the energy system in Poland", 41% of respondents confirmed this direction, 36% did not take a position on the issue and as many as 23% gave a negative answer (Figure 6);
4. With regard to the research question, "will investments in offshore wind power plants strengthen the process of transformation of the Polish energy system in the direction socially expected", 59% of respondents answered that they would, 34% stated that they did not have an opinion on the subject and 7% indicated that such a possibility of significance was not present (Figure 7);
5. From the findings related to the request to give (max. 3) positives of the construction of offshore wind farms in Poland, the respondents indicated:
    (a) Potential for lowering electricity prices (61%);
    (b) Green energy source (57%);
    (c) Direction of modernisation of the Polish energy system (76%);
    (d) Development of the Pomerania region-increase in investment potential (48%);
    (e) Development of the labour market—new jobs (54%).

6. When asked to list (max. 3) negatives of the construction of offshore wind farms in Poland, respondents indicated:
   (a) Risk of destruction of onshore and offshore ecosystems due to construction and operation of offshore wind farms (46%);
   (b) Risk of landscape disturbance in connection with offshore wind installations (71%);
   (c) Risk of disruption to the tourist character of coastal towns in connection with the construction and operation of offshore wind farms (65%);
   (d) Risk of negative impact of offshore wind farms on human health (68%).

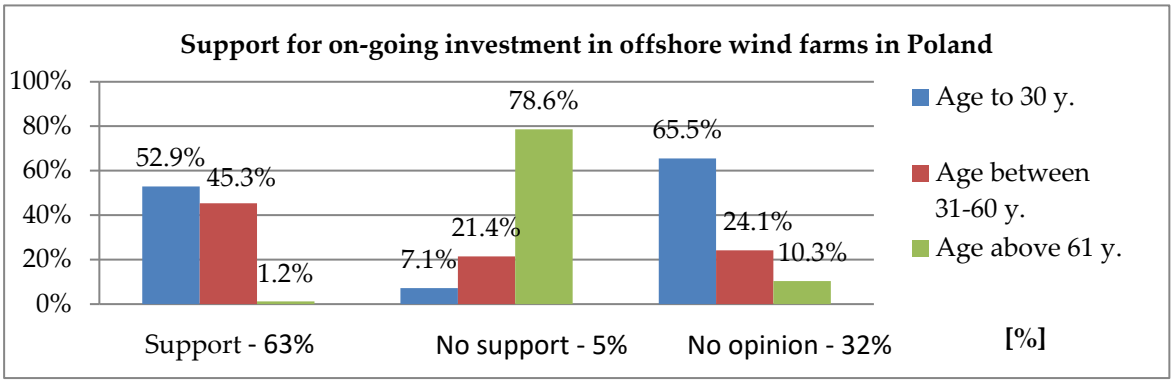

Figure 4. Support for on-going investment in offshore wind farms in Poland—results of a study.

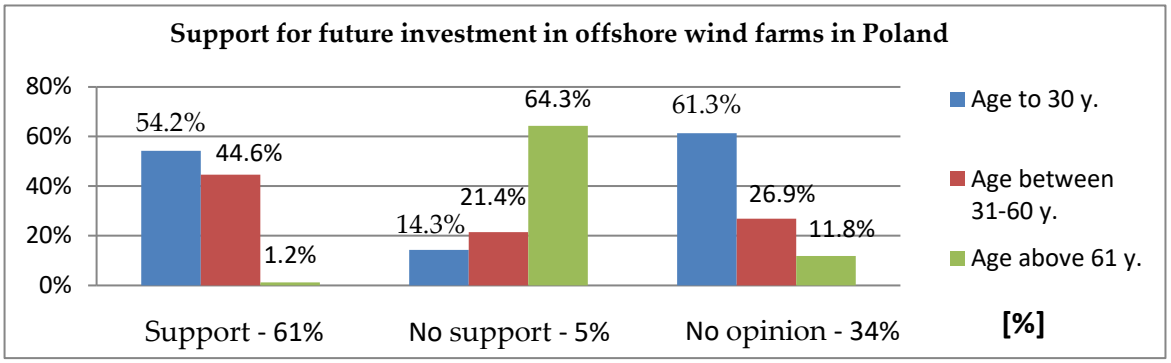

Figure 5. Support for future investment in offshore wind farms in Poland—survey results.

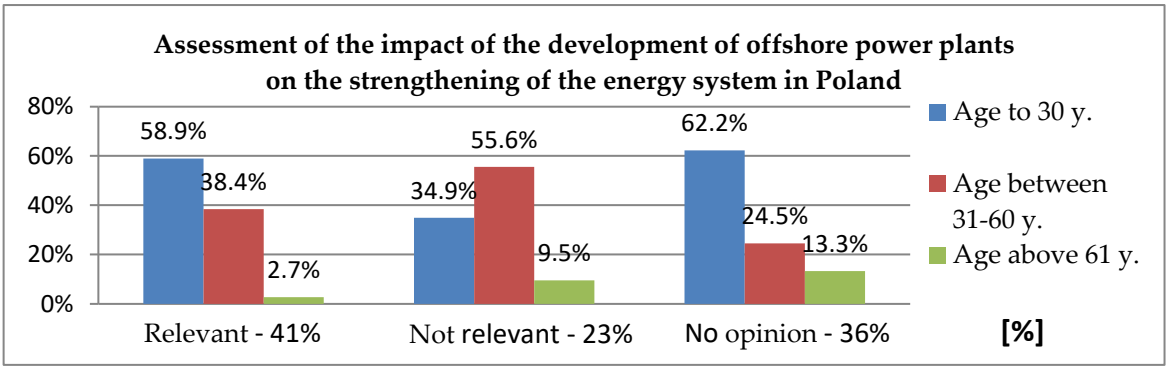

Figure 6. Assessment of the impact of the development of offshore power plants on the strengthening of the energy system in Poland—results of studies.

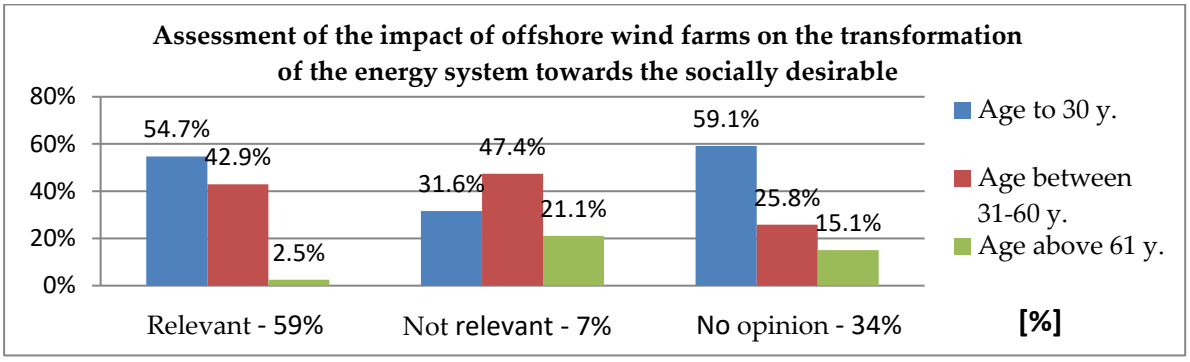

Figure 7. Assessment of the impact of offshore wind farms on the transformation of the energy system towards the socially desirable—results of studies.

A qualitative analysis of the results reveals that young respondents—aged up to 30—are the most supportive of offshore wind energy development activities. This age group also sees offshore wind energy as a development and stabilisation opportunity for the country's energy economy. The group of respondents aged over 61 is least supportive of the measures in question. Representation of this group was the smallest in the surveyed population (8.1%).

A detailed analysis of the findings in question creates grounds for searching for answers in relation to the established theses. The results of the findings developed in relation to the in-depth study of the indications of the diagnostic survey constitute the input data for statistical analysis using a logistic regression model, in order to verify the hypotheses established for this study. For the in-depth study, explanatory and explanatory variables were adopted.

The variables explained are the determinants of energy system transformation in Poland, in relation to the explored aspect of offshore wind farm development in Poland. They were determined strictly in relation to the results of the survey discussed above, which revealed that investments in offshore wind farms are driving the energy system transformation process in Poland, hence their importance in the Polish energy system is significant. Three main explanatory variables were identified in relation to the above:

1. The development of investments in offshore wind farms;
2. The increasing importance of offshore wind farms in the Polish energy system;
3. Progress of the energy system transformation process in Poland.

The explanatory variables were isolated from the area of public support on a 1–3 scale, where 1 means full support, 2 means no opinion on support and 3 means no support. A summary of variables with their characteristics is included in Table 1.

Table 1. Summary of variables with their characteristics.

Variable Number	Description Variable	Variable Designation	Type of Attribution
1	development of investment in offshore wind power plants	X_1	Dichotomic
2	increasing importance of offshore wind farms in the Polish energy system	X_2	Dichotomic
3	progress in the transformation of the energy system in Poland	X_3	Dichotomic
4	full support	Y_1	Numerical (scale 1–3)
5	no opinion in favour	Y_2	Numerical (scale 1–3)
6	no support	Y_3	Numerical (scale 1–3)

Noting as a result of the findings that support for offshore wind energy development in Poland assumes a significant character, the following part of the study will present results related to the explanatory variable Y_1, denoting full support for the explored activities.

The results from the area of descriptive variable statistics are presented in Table 2.

Table 2. Results from the area of descriptive statistics.

	śr.	SE	SD	SD^2	Min.	Max.
Y_1	0.5494	0.030	0.498	0.248	0	1
X_1	0.6117	0.060	0.488	0.238	0	1
X_2	0.4102	0.059	0.492	0.242	0	1
X_3	0.5897	0.058	0.492	0.242	0	1

The impact of the explanatory variables (X_1—the development of offshore wind investment, X_2—the increase in the importance of offshore wind farms in the Polish energy system, X_3—the progress of the energy system transformation process in Poland) and the explanatory variable (Y_1—full support) was determined using a logit regression model, according to the formula [57]:

$$ln\frac{\mathrm{p_i}}{1-\mathrm{p_i}} = Z_\mathrm{i} = x^J\beta = \beta_0 + \beta^1 + \beta^2 X^1{}_\mathrm{i} + \beta^2 X^2{}_\mathrm{i} + \cdots + \beta_\mathrm{k} X_\mathrm{ki} \quad (1)$$

where:

$$ln\frac{p_\mathrm{i}}{1-p_\mathrm{i}} = logit\ (p_\mathrm{i})$$

The estimated parameters in this approach are $\beta_0 \ldots \beta_\mathrm{k}$, being the components of the vector β. For the purpose of analysing the estimation findings, the odds ratio (OR) was used; to determine whether the odds ratio determined for a variable (X_{mi}) increased per unit (one unit) and the odds ratio excluding such an increase would be equal [57]:

$$\exp(\beta_m) = \frac{\Omega({x_\mathrm{i}}^m, X_{mi}+1)}{\Omega({x_\mathrm{i}}^m, X_{mi})} \quad (2)$$

where

${x_\mathrm{i}}^m$ is the vector of the variable $\mathrm{x_i}$ variable is a vector without the X_{mi} variable, whereby chance is expressed by the notation:

$$ln\frac{\mathrm{p_i}}{1-\mathrm{p_i}} = \exp\left({x_\mathrm{i}}^J\beta\right) = \exp(\beta_0 + \beta_1 X_{1\mathrm{i}} + \beta_2 X_{2\mathrm{i}} + \cdots + \beta_\mathrm{k} X_\mathrm{ki}) = \Omega(x_\mathrm{i}) \quad (3)$$

With reference to the above, a unit increase in the value of the variable X_{mi} (with the other parameters held constant) is created by a change in the odds ratio of $exp(\beta_m)$-multiples. Consequently, if:

1. $exp(\beta_m) > 0$, then the odds ratio increases;
2. $exp(\beta_m) < 0$, then the odds ratio decreases.

That is, the OR change times for the binary variable X_m, $exp(\beta_m)$ at "$\mathrm{Y_i} = 1$" for category "1" and variable x_m, relative to the OR for category "0" and variable x_m. Importantly, the results for the logit model $\hat{\beta}_j$ (in terms of the OR change room), express the odds ratio values $\exp(\hat{\beta}_j)$, where the average change in the OR odds ratio is shaped by a unit increase in the variable [57].

Bearing the above in mind, the probability of the transformation of the energy system of Poland including offshore wind energy, with the participation of particular conditions, can be captured in the range <0.1>. Then, the probability at the level of $\leq$0.5 expresses the transformation of the Polish energy system including offshore wind energy as independent from indications of social opinion, while the results with prediction values > 0.5 represent the transformation of the Polish energy system dependent on social opinion. The

classification of the results in juxtaposition with the indications in the area of the odds ratio >1 provides the basis for assessing the identification of random measures and enables the determination of the predicted values within the adopted model [57].

The findings for the logit regression models were developed using PQstat software version 1.8.4.164.

The first activity in the area of data analysis is the study of correlation in terms of the parameters adopted for the study—the components of the research model. The correlation matrix of these variables is included in Table 3.

Table 3. Correlation matrix of the variables.

Variable	Y_1	X_1	X_2	X_3
Y_1	1.000			
X_1	1.635	1.000		
X_2	2.438	1.491	1.000	
X_3	1.696	1.037	0.696	1.000

The results in the area of interdependence of variables are homogeneous. The observed indications take on a positive character with regard to the strength of the linear relationship. The strongest result in the area of interdependence reached 2.438 (Y_1–X_2), representing a strength of correlation in which collinearity is not significant (indications < 0.5).

The results of the findings in the area of logistic regression for category Y_1 are presented in Table 4. Included are the findings of vector β, error scale b, confidence interval CI, the results of the Wald statistic, and the odds ratio OR.

Table 4. Logistic regression model for category Y1 (full public support).

	β	Error b	−95% CI	+95% CI	Wald Stat.	OR Odds Ratio
X_1	0.585	0.289	0.018	1.152	4.098	1.796
X_2	1.191	0.298	0.606	1.776	15.953	3.291
X_3	1.267	0.268	0.741	1.794	22.281	3.552
Pseudo R2	0.103					

The unit distribution of the change in the odds ratio is included in Figure 8.

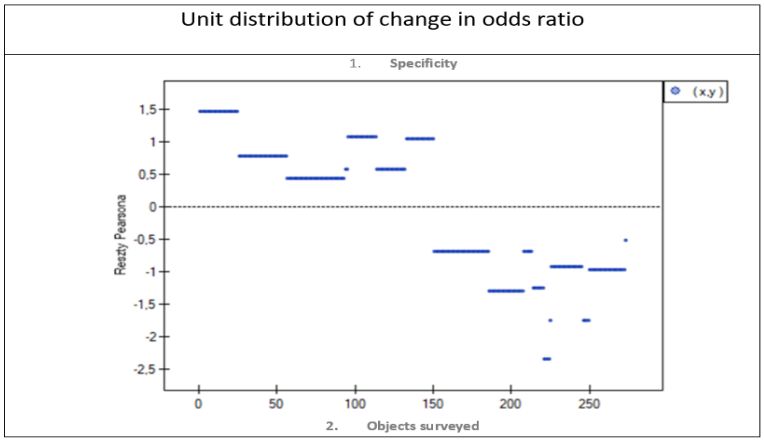

Figure 8. Unit distribution of change in odds ratio.

The findings of the research indicate that the increase in social support positively influences the growing importance of offshore wind farms in the Polish energy system. The

above is determined by socially supported development of offshore wind farm investments, creating progress in the energy system transformation process in Poland. This means that the public perception of actions in the sphere of RES development with particular emphasis on offshore wind farms positively influences the pattern of actions taken in the explored research area.

5. Discussion

Public opinion takes on a critical role from the perspective of matters of key importance for the development of the economy, which determines the conditions of social existence [31]. Any available form of soliciting comments, remarks, proposals for solutions or analysis is considered valuable in this regard. The main forms include the written form (traditional paper form, or in a digital record using electronic communication means), as well as surveys, interviews, obtaining oral opinions or findings from meetings, thematic workshops or study visits [58]. All of them are to contribute to the substantive enrichment of the created solutions, in order to strengthen the scope, quality and degree of public alignment of the solutions, which is to benefit the economy and society. In the light of the currently ongoing public consultation process on the update of strategic documents, the National Energy and Climate Plan 2021–2030 and the Energy Policy of Poland until 2040, aiming to establish a vision for the development of Poland's energy system towards increasing the capacity of the energy system and enhancing its security, as well as strengthening the dimension of low-carbon energy production and related arrangements concerning the EU climate and energy targets until 2030 [58], the survey of public opinion on the role and importance of offshore wind energy in the presented set of challenges seems to be fully justified. The identification of challenges or opportunities in the process of designing development scenarios—in accordance with the needs and public perception—is a leading determinant of the effectiveness of action [22], hence the conclusions developed in this study constitute their usefulness.

The findings of this study unequivocally indicate public support for the implemented challenges in the sphere of sustainable development of the Polish energy system in the studied area, with particular emphasis on investments in offshore wind farms. This support can be considered as a determinant of the transformation process of the Polish energy system, which is confirmed by research in the area of the adopted variables. The significant importance of the social stance in the implementation of actions is indicated by the legal regulations discussed above. This theme is furthermore strongly emphasised in the literature. Among others, M. Wójcik-Jurkiewicz and others reach similar conclusions in general terms, including social opinion among the elements determining the decarbonisation process in Poland, pointing to the risk of social acceptance for low-carbon solutions in a country whose energy system is strongly based on conventional energy production. These authors point to the necessity of taking action to implement a policy protecting the environment (low-carbon) and citizens (cost-effective) in a socially acceptable formula, which is to be ensured by education in this field [59]. Also, H. Lucas et al. strongly emphasise the importance of public opinion polling and educational challenges in the sphere of improving social convictions towards gaining acceptance for the changes taking place in the energy transition of economies. In this regard, attention is drawn to the need to select the most appropriate communication practices and actions oriented towards increasing public support for the development of renewable energy [60]. I. Čábelková et al. point to the importance of public uncertainty when it comes to assessing the desirability of implementing energy solutions. In this respect, these authors emphasise that opinions on renewable energy sources are formed in relation to individual concerns about the use of low-carbon sources, as well as environmental aspects [61]. P. Biniek draws attention to the risk of social conflicts against this background [62]. J. Kádár et al. complement the theme of social opinion on RES with the aspect of personal stance towards climate change, or limited trust of citizens in relation to decisions in the sphere of energy transition, which are direct reasons for limitations of public involvement in actions for RES-based energy development [63]. L. H. Broska

et al. also draw attention to the role of a social approach to the energy transition process through the prism of citizen participation, through the creation of energy communities. These authors signal the fact that these solutions can play an important role in the state's energy system in the future [64], which can be considered as a result of long-term public education. In this regard, H. Lucas et al. point to the need to empower consumers to actively participate in the creation and co-creation of the state's energy system [60]. The outlined theme is elaborated by H. Friman et al. highlighting the problem of the need to communicate the different possibilities of energy generation in order to optimise the costs of its acquisition and consumption. In this regard, the role of a well-chosen public education programme is also accentuated in order to develop the right social attitude, open to a transformation towards distributed energy systems and renewable energy [65]. Not insignificant in this respect is the aspect of offshore wind energy, which has not been strongly emphasised in energy policy and, as a result, not developed at a sufficient level in the public debate [66]. This is a very important aspect of the direction of the transition, as offshore wind energy has for years been seen as having significant energy supply potential and continually improving in terms of technology and efficiency [67,68]. This is particularly important as this direction enjoys relatively high public support, although there are still a number of issues (e.g., environmental) that need to be explored and improved in this area.

The detailed dimensions of the research provided useful findings on the causal relationship between the age of the surveyed social units and the stance towards the changes taking place. The population of respondents strongly represented the territory of the Pomeranian Voivodeship. The results indicate significant support for measures to transform Poland's energy system towards RES—with particular emphasis on offshore wind energy development. The impact of place of residence on the strength of support for offshore wind energy development is clear. Inhabitants of the Pomeranian oivodeship are the most interested in offshore wind energy development activities among the surveyed population (representation of different parts of the country in a tourist destination). The level of this support was at 63%. They see the main opportunities in the development of the region (57%), the strengthening of the attractiveness of the labour market (55%), as well as (above all) the potential for lowering the purchase price of electricity on a market strengthened by cheap, green electricity from offshore wind farms (84%). This group of respondents also indicated a set of concerns about the construction and development of offshore wind energy in the study region. Predominantly, respondents who were negatively in favour of offshore wind development (83%) or indicated that they had no opinion on the subject (36%), and to a generally lower extent those in favour of offshore wind development (14%), indicated concerns about the risks of the following:

1. Destruction or disturbance of marine and terrestrial ecosystems due to the construction and operation of offshore wind farms (58%);
2. Disturbance of the landscape in connection with offshore wind energy installations (41%);
3. Disturbance of the tourist character of coastal towns in connection with wind energy installations and energy business development (40%);
4. Negative impact of offshore wind farms on human health (22%).

The results of the survey indicate a set of chances, articulated by the respondents, for improvement of the functioning of the community (mainly coastal) in connection with investments in offshore wind farms, which should be read very positively. The arrangement of the articulated risks is due to incomplete knowledge about the investments in offshore wind farms, which indicates the need for more education in this regard. The lack of widespread knowledge about the location of wind farms at a minimum distance of 22 km from the coastline renders the concerns raised with regard to the disturbance of the landscape and the character of coastal towns, as well as the negative impact of offshore wind installations on human health, pointless [32]. The selection of locations for wind farm installations has furthermore taken into account the fishing areas at national level, to eliminate potential disturbance to marine life in their core areas due to the construction

and operation of the farms. Moreover, the fact that efforts were focused on environmental, economic and energy issues creating conditions for the development of the energy system is additionally noteworthy. Other observations concern the issue of the region's development, its industrialisation entailing an intensive development of the labour market, which is a consequence of investments in offshore wind farms (the investment phase is expected to create around 34,000 full-time jobs [32]. Promotion of this knowledge, supported by information on the environmental protection measures taken in relation to the construction and further operation of offshore wind farms, should gain momentum in order to eliminate misperceptions about the investment, reduce public fears and strengthen support for activities that are important for the sustainable development of the energy sector in Poland and the improvement of social well-being. The above should inspire decision-makers to take appropriate action in this regard. Similar conclusions have been reached in the field of alternative research, e.g., W. Drożdż et al. point to the need for education in the field of energy, emphasising that it is investments in offshore wind farms that have the potential of modelling social and economic benefits at the site of their construction [69], and public awareness and activity in co-creating solutions in the sphere of the development of the Polish energy system may bring a number of benefits [15] considered both from the perspective of the economy and the social unit—the individual energy consumer.

6. Conclusions

The results of the findings of this article create grounds for verification of the theses established for this study. The assumption within the H_1 hypothesis that investments in offshore wind power plants constitute the right, socially supported direction of Poland's energy system transformation has been confirmed. Public opinion in support of the undertaken direction of action, and the positive social stance positively influences the development of offshore wind power plants in Poland. The above provides a basis for the evaluation of the ongoing process of offshore wind farm investment in Poland, under the criterion of social acceptance for the adopted direction of action, in the sphere of Poland's energy system transformation and determines positive verification of hypothesis H_2 that socially supported development of offshore wind farms significantly influences the increase of RES share in Poland's energy mix. Similarly, hypothesis H_3, that the development of offshore wind power plants will significantly enhance the socially expected progress of the energy system transformation in Poland, was positively verified.

The process of findings revealed that the place of residence of a social unit positively influences the favourable evaluation of offshore wind investments in Poland. The above makes it possible to assess the perception of the system of opportunities and threats from the point of view of the social group living in the immediate vicinity of the offshore wind farm investment area. The above makes it possible to assess the background of the social approach to offshore wind farm development activities, which is particularly important in this region of Poland. The assessment of interest and social approach in the area of offshore wind energy also enables the assessment of the potential for fluidity of actions in the sphere of updating the formal and legal framework, determining the scope, pace and quality of future works in the area of strengthening the RES dimension in the energy mix of Poland, in connection with the construction of offshore wind farms.

The main focus of the presented research was to determine the importance of offshore wind energy in the transformation of the Polish energy system and to assess public support for the changes taking place. In relation to the above, an analysis and assessment of the current situation related to offshore wind energy in Poland was made.

The findings of the research lead to the conclusion that social support positively affects the increase in the importance of offshore wind farms in the Polish energy system. The results of the qualitative findings indicated that the strongest support for the implemented changes is expressed by young people (age category up to 30 years). The results of the odds ratio findings in terms of the increase of the significance of offshore wind farms in the Polish power system confirmed the above trend at the insignificant level (3.552),

while the odds ratio result at the similar level was recorded in the area of progress in the transformation of the Polish power system (3.291). However, it is necessary to emphasise the research limitations created by the adopted sample, hence with certain reservations only generalisations can be made regarding the nationwide position in this respect.

Undoubtedly, socially supported development of investments in offshore wind power plants creates progress in the process of transformation of the energy system in Poland. Therefore, the development of offshore wind energy can be considered as the direction of development of the Polish energy system in line with the expectations of the citizens of this country, justifying the ongoing process of investing in wind installations. Social justification goes hand in hand with economic justification, which is supported by argumentation drawn from numerous studies cited in this study.

The findings from the considerations presented in this article also indicate the need to strengthen education in the field of sustainable energy development in Poland, with particular emphasis on offshore wind energy. Educational needs in this area are generally created by age groups aged 31 and over, indicating a strong trend of 'no opinion' or lack of support for urgently needed measures. In this regard, it would be justified to implement a social campaign on the subject of energy policy with an indication of the role of offshore wind farms in the Polish energy system, expanded with the potential of benefits expected in connection with the launch of wind farms, as well as the exposure of actions taken to reduce the risk in connection with their construction and operation. The above is necessary to strengthen social awareness shaping civic attitudes towards the implemented activities, which is the main recommendation of this study. In addition, the results of the findings of this report can be used in the process of implementing programs to promote the greening of life as the right direction of social development determining the common responsibility for the future of the planet, determining the practical usefulness of the findings.

Funding: This research received no external funding.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The author declares no conflicts of interest.

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