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The Challenges of Poland's Energy Transition

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Abstract: The ongoing climate changes necessitate an effective climate policy. The energy transition is now an important topic and problem, especially in Poland. (1) The undertaken analysis of the problem of energy transition is important for political, social and technological reasons. Political, because it shows the weakness of the implementation of Polish energy policy in regards to climate change. Social, because energy transition will bring about significant social changes in the largest industrial region of Poland. Technological, as the departure from fossil fuels requires the introduction of other sources of energy on a massive scale, for which Poland is not prepared. The aim of the study was to critically analyse the activities to date in the field of energy transition in Poland. The second goal of the analysis was an attempt to answer the question of whether the process of energy transition and achieving the goals set in the EU's European Green Deal are possible at all until 2050. (2) To achieve the goals, the system method and the decision-making method were primarily used. These methods allowed for an examination of the main determinants of the Polish energy transformation. (3) The main results include the confirmation, contrary to the announcements of the Polish government, that despite the adoption in Poland of the strategy "Poland's energy policy until 2040", the effective implementation of the energy transition before 2050 is not only very difficult, but may even be impossible to implement in the assumed time. This is due to political, economic, social and technological conditions. Coal energy is outdated, expensive and ineffective. Due to natural conditions, wind energy is not able to meet the energy demand of the industry. The development of nuclear energy is only in the planning phase. (4) To sum up, in the next thirty years, Poland will not be able to achieve the assumed effects of the energy transition, which is in contradiction with the official declaration of the government.

Keywords: energy transition; climate change; climate policy; European Union

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1. Introduction

Over the past thirty years, the transition to low-carbon, energy-secure Europe has increasingly gained importance in the policies and strategies of the European Union [1]. Its exemplification is the European Green Deal—an ambitious package of measures for a sustainable economy, covering, among others, a substantial reduction of greenhouse gas emissions, investment in cutting-edge research and innovation, and protection of the environment in Europe [2]. The Green Deal is an integral part of the strategy—the aim of which is to implement the United Nations 2030 Agenda and the sustainable development goals [3]—and is a tool that is to help the EU to secure the position of the world leader in counteracting climate change [4]. The achievement of the EU's ambitious energy and climate goals by 2050 will entail the acceleration of energy transition and changes in energy culture in many member states [5]. The transition towards a low-carbon economy and energy system entails extensive changes that require broad social and political support. According to the European Commission's data, in 2018, almost 34 million Europeans could

not afford to heat their homes properly. These figures confirm that energy poverty remains a considerable challenge in the EU. The share of total European household expenditure on energy (excluding transport) varies depending on the income level and country. There was a downward trend in the proportion of household expenditure on energy in 2012–2018, with the exception of 2017, when this indicator increased slightly, and then fell again in 2018, reaching values similar to or lower than those before the economic recession in 2009–2012. [6]. The collapse of the Soviet Union in the late 1980s and early 1990s led to a drastic economic crisis in this area. The situation improved between the mid and late 1990s and before 2000, which was reflected in the high rate of economic growth, and after the accession of CEE countries to the EU (2004; 2007; 2013), which resulted in new opportunities for modernisation and gradual bridging of the development gap. Despite significant progress, research into the energy cultures of the European Union has shown that this group of countries still contains more energy-intensive energy cultures than the countries of Western and Southern Europe [7] and energy infrastructure is an artefact of the Cold War division [8]. Taking into account the purchasing power, political framework, industrial capacity and infrastructure, the CEE region is described as lagging in terms of adopting modern environmental standards, energy generation and mobility [9].

The example of Poland, compared to other EU countries in Central and Eastern Europe, is special because the vision of transforming energy policy involves the necessity to convert the culture of coal energy into a sustainable culture [10]. This means the need for a radical transformation of the coal sector, consisting of closing it down and, inter alia, choosing a course towards the development of two "new" energy sectors: offshore and nuclear. The complexity and scale of the planned energy transformation raise questions about the chances of its success [11,12]. On the one hand, the political elite and society are favourable to the transformation. On the other hand, the transformation entails high socio-economic costs, necessitates changes in Poland's energy mix and requires large financial outlays for the restructuring of the energy sector [13,14] and the introduction of forms of support for scattered civil power industry. Energy clusters and energy cooperatives in Poland are considered potential tools for building local energy communities. Research has shown that such a solution can be profitable [15]. These issues are extremely complex and require further studies in the socio-political, economic and technological areas. This article primarily deals with research in the socio-political area [12].

Assuming that, on the one hand, not all types of energy have the same quality and environmental costs and that there is a correlation between well-being and different energy sources, as well as between energy sources and the environment, the task was to check whether, in the case of the proposed energy transformation of Poland, the energy–environment–well-being triad, which is understood as 1. meeting energy needs (energy), 2. transitioning to a clean power industry (environment) and 3. satisfying citizens (understood as contentment with environmental protection and energy prices (well-being)), is possible in the case of the implementation of the PEP2040.

The main aim of the research was to check whether Poland will be able to successfully complete the energy transformation [15,16]. Moreover, answers to the following research goals were sought: (1) What role does coal energy culture play in Poland's energy transformation and what barriers to its transformation can be identified? (2) What is the current energy situation in Poland in the context of transformation challenges related to the goals of the PEP2040? (3) How does satisfying Poland's energy needs through the implementation of the PEP2040 fulfil the conditions of clean and environmentally friendly energy? (4) Can the proposed energy transformation proceed in line with well-being criteria? The main hypothesis of our research was that the implementation of the assumptions of the European Green Deal, and, consequently, the real energy transformation in Poland is not very realistic, or is even impossible, until 2050. This hypothesis allows us to look at the problems of the energy transformation in an innovative way. Many analyses undertaken in this area indicate that Poland has real chances for the timely implementation of the assumptions of the energy transformation.

In order to verify this hypothesis, we focused on the analysis of three main pillars of the new strategy aimed at accelerating Poland's energy transformation: the transformation of coal regions, the development of an offshore wind power industry and the nuclear power industry. In each case, an attempt was made to identify social, economic and political factors of influence. For this purpose, and for the research hypothesis put forward in this way, an article structure was selected to include a review section and a research section, which best allowed us to present the research results existing in the literature, an analysis of their findings and verification of the research hypothesis.

2. Materials and Methods

2.1. Backgrounds and Research Scheme

Energy transformations are unpredictable, complex and very diverse social engineering endeavours [17,18]. In the case of the current energy transformation of Poland, they are affected not only by technical aspects (new technologies) and economic factors (costs), but also by political decisions (PEP2040) and social reaction (attitudes to nuclear and offshore energy). When looking for an answer to the question of whether, in this particular case, it is possible to achieve the energy–environment–well-being balance, the conceptual framework of socio-technical changes developed by Geels [19] was used, which is appropriate for studying the transformation of the coal sector in Poland. Industries suitable for this framework are reluctant to change, have great political influence, are characterised by large scale and have many inadequate investments [20].

Energy culture is presented in various ways in social sciences, the dominant approaches focus on the functions of energy in society, studying the impact of energy use on social institutions, the importance of energy for society [21], patterns of energy use practices and ways of thinking about energy or analysing energy as an object of discourse [22].

Barriers to transition from coal to sustainable culture are related to the mechanisms of the perpetuation of coal technologies, despite the existence of rational economic and environmental premises as to the possibility of choosing a different development path. Unruh [23] pointed to the fact that industrial economies have been trapped in energy systems based on fossil fuels through a process of technological and institutional co-evolution driven by path-dependent increasing returns to scale, presented mechanisms for breaking dependence on this path [24] and described the conditions, opportunities and strategies that are conducive to the transition between the pathways of carbon dependency and low-emission paths [25]. In the case of carbon technology path dependency, the impact of interconnected technological, institutional and social forces has been pointed out. It has been stressed that for political entities, making decisions that are too radical and have a direct impact on the life of voters, the consequences of which, due to political costs, are unpredictable, seems to be one of the factors strengthening the dependence on a specific technological path.

In order to achieve the set goals, which were a critical analysis of the activities to date in the field of energy transformation in Poland and an attempt to answer the question whether the process of energy transformation and the achievement of the goals set out in the EU's Green Deal are possible at all by 2050, the following research procedure was adopted: (1) conducting a query and analysis of the literature on the title issue; (2) selecting research methods allowing for a critical analysis of the energy transformation process; (3) collecting scattered material documenting the problems and successes of energy transformation in Poland compared to selected EU countries; (4) presenting the share, changes, potential, problems and development policy of individual energy sources in the country's energy balance; (5) to achieve the first goal of the study—use of the collected material for a critical analysis of the effects of the energy transformation to date; (6) for the realization of the second goal of the work—a critical analysis of the material presenting the potential and problems of the energy transformation broken down into individual sources, including the assessment of the possibility of achieving the goals set in the European Green Deal; (7) conducting a discussion to enable the verification of the research hypothesis, in which

we assumed that the current energy transformation policy in Poland will not allow the achievement of the assumed goals in the planned time perspective.

2.2. Methods and Objectives

Our research was conducted on the basis of the analysis of existing data, decision-making processes and literature analyses. In order to achieve our research goals, we used a comprehensive methodological set of instruments [26,27]. Firstly, the system method was used, which made it possible to look at the process of energy transformation in Poland in a broad way, taking into account the external environment (in particular from the European perspective) [28] and national conditions (social, political, economic and technological ones) [29]. Secondly, the decision-making method was complementary. It enabled us to analyse how rational actors could behave in the conditions of risk and uncertainty accompanying the energy transformation [27]. Thirdly, a multi-paradigmatic approach that is typical of transformation processes was adopted. A multifactorial approach was used to verify the main hypothesis as well as to attain the research goals set out in the work and to answer the questions put forward, as it allowed for the analysis of complex political, social and economic phenomena with insufficient explanation power of individual factors [30]. In order to capture social opinions, we also used the CATI method. The respondents' attitudes towards various aspects of the energy transformation were examined. As a result of using of a wide sample, it was possible to objectify the conclusions. In the field of legislation, the institutional and legal method was applied. In the part devoted to economic conditions, simple methods of statistical analysis were employed with the use of statistical data from Poland and EU countries.

2.3. Scope of the Research

The article identified the selected determinants of energy transformation of Poland, a CEE country, from the perspective of the social sciences [5]. Since most energy policies are adopted and implemented by governments, the state is the main entity of political perspective analysis [31]. The framework for the study was the resolution on "Poland's Energy Policy until 2040" adopted by the Polish government on 2 February 2021, defined as the development strategy for the fuel and energy sector, which determines the scope of Poland's energy transformation [32] and is a contribution to the implementation of the Paris Agreement and the EU climate and energy policy. The provisions of the document stress the fact that it heeds the scale of challenges connected with the adaptation of the national economy to the EU regulatory conditions, including the European Green Deal, climate and energy goals for 2030, the COVID pandemic recovery plan and regulations related to the pursuit of climate neutrality. The thematic scope of the article covered three out of eight specific objectives of the strategy: optimal use of own energy resources (objective 1), the Polish nuclear power programme (objective 5) and the development of renewable energy sources (objective 6). In the article, we refer to the political, economic and social conditions of the transformation of coal regions, the wind power industry in Poland and the implementation of the Polish nuclear energy programme.

3. Results

3.1. Progress of the Processes of Energy Transition in Poland and EU Members of CEE

The European Union's energy transition is intended to combine social expectations (concern for the environment and climate protection) with a strategy of economic growth (GDP growth) and industrial development (reindustrialisation and employment) based on innovative technologies. Its effects are to ensure the security of supply, maintain competitiveness and global environmental sustainability [33]. The European Commission, assuming that the success of energy transformation in the European Union can be achieved thanks to financial support for the energy transformations of the member states and regions to a large extent dependent on fossil fuels and high-emission industries, established the

Just Transition Mechanism to help mobilise at least €150 billion over the period 2021–2027 in the most affected regions to alleviate the socio-economic impact of the transition [34].

Due to its demographic and economic potential and the amount of greenhouse gas emissions, Poland is probably the best example showing the problems of transformation in the CEE countries. The process of Poland's energy transformation is related to historical consequences and its operation for several decades in the sphere of the Soviet Union's influence. During this period, especially in the years 1970–1990, a number of negative phenomena occurred in the Polish energy sector, such as high energy intensity of the economy, much higher than in Western Europe; excessive dependence on carbon, with low consumption of hydrocarbon fuels; high environmental degradation, largely due to the energy sector; an improper system of fuel and energy prices (these prices differed from the economically justified costs of obtaining fuels and energy, which led to, among other thing, wastefulness) [35]. At the time of Poland's accession to the European Union, apart from systemic and functional differences, the Polish energy system also showed many significant disparities in fixed asset characteristics. In 2004, the Polish energy sector covered a wider area of the economy than in most EU countries, because apart from electricity and gas, heating played an important role in it. In comparison with the old EU countries, Poland had significant resources of solid fuels (hard coal and lignite) and more modest resources of hydrocarbon fuels (natural gas and crude oil). Despite changes in the structure of obtaining and consuming primary energy, coal was still the basic energy carrier in the Polish economy. As the degree of diversification increased, the country's energy self-sufficiency dropped. Moreover, most of the power was located in thermal power plants. Polish electricity supplying infrastructure was technically worn out. The structure of energy consumption was disadvantageous in comparison with the EU. Industry was the most important consumer of electricity. Taking into account the structure of entities, the Polish energy sector was more fragmented than in the old EU countries [36].

Even though energy policies implemented in 2004–2020 in Poland, prepared by changing governments, had similar general goals, they did not take into account the progress of previous policies. As a result of the political risk related to the lack of predictability, among other consequences, investment processes and modernisation of this sector slowed down in Poland [37,38]. In comparison to the CEE countries [39,40], although several reforms of the energy sector were partially implemented in Poland, it was not possible to reduce greenhouse gas emissions, including CO_2, especially in the energy sector in 2009–2018 (Table 1).

Table 1. Changes in greenhouse gas emissions in selected EU countries in 2009–2018 [41].

Country	Emission all Gases		Gases from Energy		CO_2 from Energy	
	2018 Kt.	2018/2009 %	2018 Kt.	2018/2009 %	2018 Kt.	2018/2009 %
Austria	81,501	99.3	54,693	96.4	53,482	96.3
Bulgaria	58,595	100.0	41,197	93.1	39,383	92.7
Czechia	129,388	92.7	96,876	87.3	92,006	88.5
Estonia	20,184	121.4	17,590	123.1	17,301	123.4
Germany	888,719	95.1	720,284	94.3	704,109	94.3
Hungary	64,068	98.2	45,519	94.3	43,974	94.3
Latvia	12,120	105.2	7697	99.6	7206	100.3
Lithuania	20,648	102.3	11,907	98.0	11,242	97.2
Poland	415,858	105.2	342,088	105.4	316,466	105.5
Romania	116,531	90.7	77,010	85.6	65,976	87.6
Slovakia	43,534	95.1	29,309	90.3	27,294	90.5

Despite the efforts made and arrangements within the EU, in the same period, in the post-Soviet countries and in Poland, the emission of all greenhouse gases increased in each sector of their emission, as indicated by the data for Estonia, Latvia, Lithuania and Poland. The aforementioned countries, compared to other countries in the CEE region (e.g., Czechia, Romania and Slovakia) recorded a significant increase in emissions, similar to the "old" EU countries, such as Austria or Germany. It should also be emphasised that while the three Baltic countries, due to their area, size of the economy and number of inhabitants, are relatively small emitters of CO_2 in the overall increase in greenhouse gas emissions, Poland is the second largest producer of greenhouse gases in the described region.

The period from joining the EU (2004) to 2020 was characterised by many different political initiatives, such as the creation of economic solutions, legal regulations and mustering social support, undertaken in order to reform and increase the innovativeness of the sector. In the years 2004–2020, the energy policy of Poland was largely focused on the introduction and implementation of the EU's energy policy, followed by the enactment of the climate and energy policy of the European Union after it was formulated [42].

After twenty years of Poland's membership in the European Union, the energy situation is still not considered good. Electricity production decreased in 2019. However, the share of coal in its production amounted to 73.6%, only 4.8 percentage points less than in 2018. The import of electricity to Poland almost doubled and reached 10.6 TWh. The largest amount of electricity produced from RES in history was generated—over 25 TWh. However, this result is still too low to meet the EU obligations [14].

As shown by the data (Table 1), the period of 2009–2018 was not utilised by some CEE countries. In Bulgaria, Estonia, Latvia, Lithuania and Poland, the energy transformation was not achieved to the extent that would reduce greenhouse gas emissions. In Lithuania and Latvia [43], there was a slight decrease in CO_2 emissions in the energy production process, which resulted in lower CO_2 emissions in this sector, but in Estonia and Poland, in terms of energy production, in 2018 compared to 2009, CO_2 emissions increased significantly.

In 2018, households in the lowest 10 percent income bracket spent 8.3 percent of their outlays on energy (Figure 1). Households with lower middle and middle incomes spent 7.4 percent and 6.7 percent, respectively, of their expenditure on energy. In terms of regions, the inhabitants of Central and Eastern Europe with average incomes spent 10–15%, while Northern and Western European households with the same income expended 3–8%. In individual countries, the poorest households spent from 5% in Luxembourg, Finland and Sweden to just over 20% in Slovakia and the Czech Republic. In absolute terms, the poorest households in the EU laid out on average a total of € 945 for energy products [44].

Until 2018, the average share of European households that declared problems with keeping their home warm and paying utility bills dropped from 11% to 8% and from 10% to 7%. Despite this change, there are still substantial differences between member states.

While the above data show that problems with citizens' access to energy are diminishing, the issue of energy poverty in the European Union remains serious [45]. It is particularly significant in the context of energy transformation in Poland and in other countries of the CEE region. The increase in the costs of energy production from renewable sources may translate into an increase in energy prices, which may result in a negative attitude of citizens towards the energy transformation. Therefore, introducing changes in the energy sector requires a high level of commitment of states and governments to counteracting social problems [46].

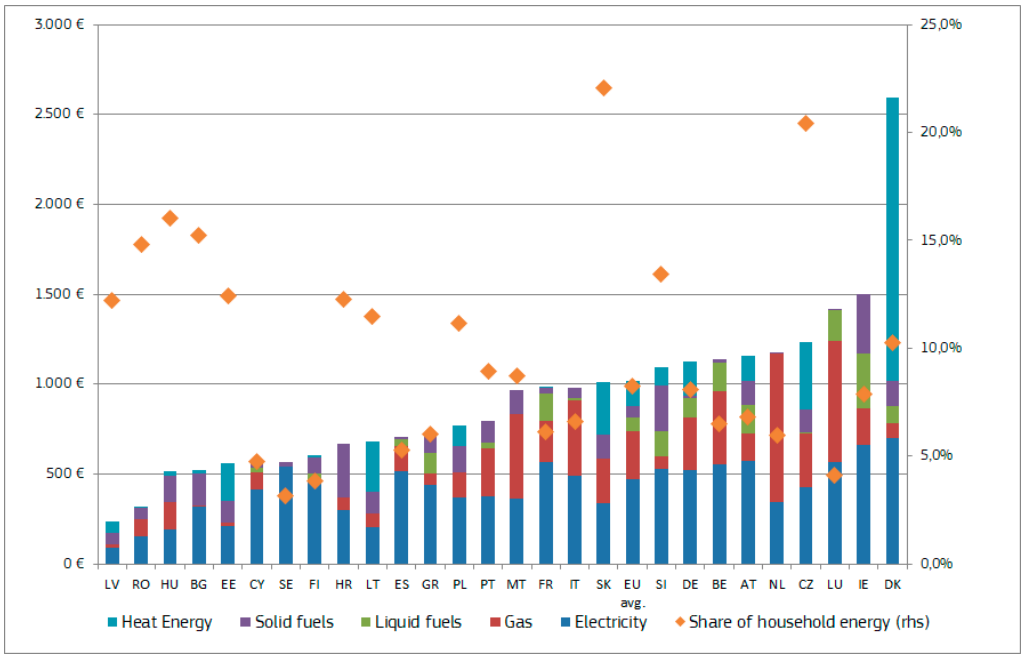

Figure 1. Poorest households' energy expenditures (excl. transport) by fuel and energy share in their total expenditure (2018) [44].

3.2. The Energy Policy of Poland until 2040 (PEP2040)

The PEP2040 sets the framework for transformation in Poland. The document contains a description of the status and conditions of the energy sector, the pillars on which the specific objectives were based, together with the actions necessary for their implementation and strategic projects. The PEP2040 defines specific objective 1 as the optimal use of the country's own energy resources, defining the transformation of coal regions as a strategic project in this area. The provisions of the PEP2040 indicate that (1) demand for lignite will be met by domestic resources; (2) research and development activities should be geared towards fostering innovations that reduce the environmental burden of coal mining and towards new solutions that contribute to the low-carbon, efficient and flexible use of the raw material (e.g., gasification, liquid fuels); (3) for social, economic and environmental reasons, the restructuring of coal regions will be pursued in order to ensure that a fair energy transition leads to economic empowerment, leaves no one behind and serves future generations. This process will be supported by the financial instruments of the EU Just Transition Mechanism.

Domestic coal resources are to remain an important element of Poland's energy security, but an increase in demand is to be met by sources other than conventional coal capacity. The strategy assumes that the share of coal in the energy consumption structure will reach no more than 56% in 2030, and with increased prices of CO2 emission allowances, it may even fall to the level of 37.5%. An increasingly important role is to be played by renewable energy sources (RES)—their level in the structure of national net electricity consumption is to be no less than 32% in 2030, through the development of photovoltaics and offshore wind farms.

The first nuclear power unit with a capacity of 1–1.6 GW is to be commissioned in 2033, with subsequent units to be launched every 2–3 years—the entire nuclear programme assumes the construction of six units by 2043. The deadlines are due to anticipated capacity losses in the NPS, which is also related to an increase in electricity demand. The strategy also foresees the development of distributed energy based on RES energy generation, sale, storage or participation in DSR programmes by individual entities (e.g., active consumers, renewable energy prosumers and others) and energy communities (e.g., energy clusters, energy cooperatives).

The rich literature on energy transformation in Poland most often addresses issues and problems related to mining and energy industry based on hard coal [47–50], the problems of nuclear energy [51] and of energy based on RES [52] and matters of political challenges posed by energy transformation for Poland, both in the internal dimension [53] and Poland's obligations as a member of the European Union [54,55]. The input factors include historical conditions, the current structure of energy produced (dominance of fossil resources) and alternative visions of transformation (RES, nuclear energy and offshore wind energy). Additionally, the directions of transformation are influenced by a negative attitude to the necessary changes, especially in the traditional mining regions, shared by the largest trade union in the country [56].

3.3. Transformation of Coal Mining Regions

The transformation of coal mining regions is considered extremely difficult and complicated. The European Commission already indicated two decades ago that the restructuring of this sector would have serious social consequences [57], but it was not until 2010 that it took measures directly aimed at regions heavily dependent on coal, including Silesia [58], which is responsible for approximately 90% of registered domestic emissions of gaseous pollutants [59].

In Poland, coal has been a key factor in ensuring energy security and, despite its declining role, it still accounts for the majority of the energy mix. For many years, successive stages of restructuring the hard coal mining sector have not brought the expected results [60], on the one hand, due to the traditional understanding of the role and significance of hard coal mining for the security of the country, and, on the other hand, as a result of the strength of the mining trade unions, whose opinions have been and still is taken into account by every Polish government [61]. Poland is also an exporter and importer of hard coal. In 2011–2018, Polish hard coal exports decreased significantly and Poland became a net importer of hard coal (except for 2013). Energy coal dominated in coal imports (68–85% in 2011–2018) [62] (p. 14).

The economic downturn associated with the COVID-19 pandemic changed the structure of electricity production. There was an increase in the share of hydro power plants, wind farms and RES in the structure of electricity production, which was influenced by a 4.1% decrease in total production in Poland, to the level of 152.3 TWh (Table 2). There was a decrease (from 2019 to 2020) by 8.5% in the share of energy derived from hard coal and lignite. An increase in the share was recorded by hydro (10%), gas (15%), wind (2%) and renewable energy (500%) power plants. However, the latter account for only 1.44% of the total production.

Table 2. Changes and participation in electricity production (TWh) by energy sources in 2019/2020 (in power plants based on different sources) [63].

Year	Total	Hard Coal	Lignite	Gas	Hydro	Wind	RES	Others
2019	158.77	78.19	41.50	12.10	2.45	13.90	0.44	10.19
(%)	100.00	49.25	26.14	7.62	1.54	8.75	0.28	6.42
2020	152.31	71.55	37.97	13.92	2.70	14.17	2.20	9.80
(%)	100.00	46.98	24.93	9.14	1.77	9.30	1.44	6.44
2020/2019 (%)	95.91	91.51	91.49	115.04	110.20	101.94	500.00	124.48

In December 2020, as much as 80% of electricity in Poland was produced from fossil raw materials—hard coal, lignite and gas. Regardless of the more or less ambitious plans of the government, energy conversion, changing this structure, reducing the share of fossil resources and increasing RES in electricity production requires significant costs (Figure 2).

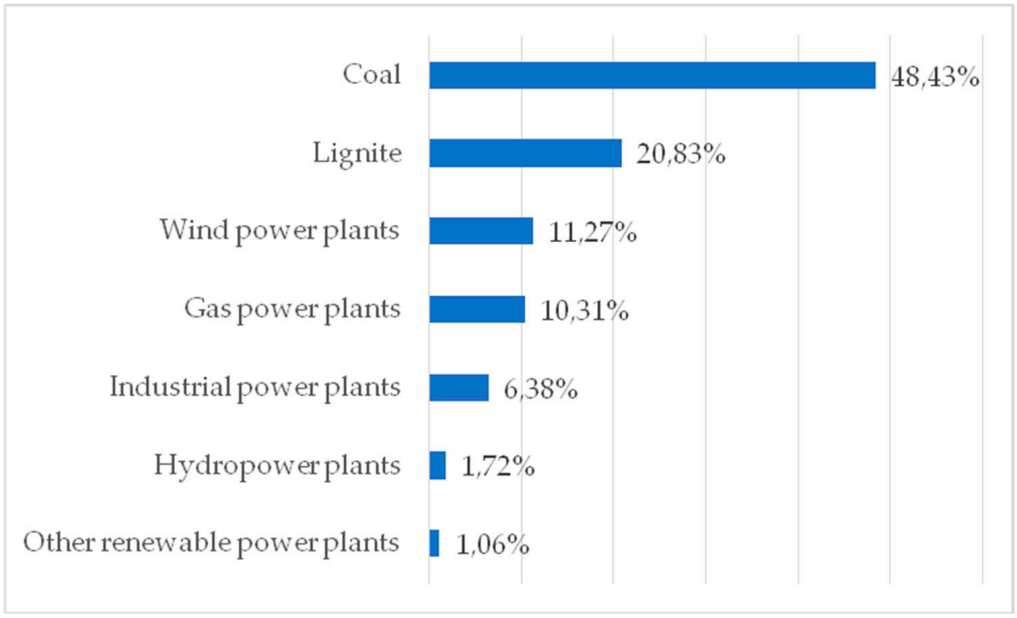

Figure 2. The structure of electricity production (%) in Poland in December 2020 [64].

An analysis of the political economy of coal in Poland over three decades from 1990 to 2019 by means of the triple embeddedness framework has shown that by disjoining the socio-political aspects from the economic ones, it is possible to distinguish the main factors affecting the different contexts. Research results have indicated that from a socio-political perspective, it is justified to continue using coal, while most economic reasons emphasise the value of total or gradual withdrawal from it. The opposition to abandoning coal results from the significant position of the coal industry and the government that supports it. Moreover, the private interests of the coal regime are protected due to the connections between coal companies and the government. The majority of coal corporations are state owned. Trade unions in Poland play the role of effective interest groups engaging in political decisions. This makes it difficult to undermine political support for coal. Poland is considered to be a country lagging behind in the implementation of the European climate and energy policy and striving to protect domestic coal [65]. The direction of development of Poland's electricity sector, which assumes continued dependence on hard coal and lignite-based power generation for a long time to come, has been criticised for years. It has been pointed out that the biggest threat to coal and nuclear power is the emergence of a so-called "death spiral" that could give these types of assets orphan status [66]. Research on the attitude of Polish society to the role and significance of coal and the future of Upper Silesia has shown that the lines of conflict in the postulate of abandoning coal are political and ideological at the level of public opinion. Advocates of the coal status quo are supporters of the right-wing Law and Justice and Confederation parties. Support for energy transition and environmental demands is mostly expressed by left and liberal groups. People living in big cities, as well as better educated and less religious ones, are more welcoming to the energy transition [67]. There is a social consensus in Poland that the government should financially succour measures aimed at transforming Upper Silesia into a region producing clean energy.

On the one hand, in one study, over 63% of respondents claimed that Poland should give up on pushing for an energy policy based on hard coal (Figure 3), while on the other hand, as many as 94% of the respondents took the position that the government should support the development of companies producing clean energy, in which miners will find jobs.

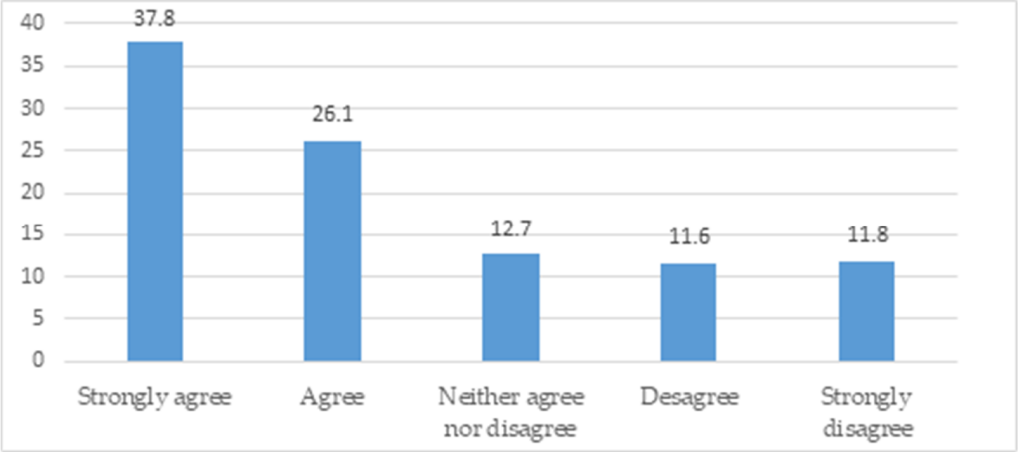

Figure 3. Should Poland give up coal-based energy? (data in %; CATI method; N = 1100; 2020) [68].

Neither differences in education, nor place of residence, nor class position or even political views differentiated views on this matter. The only group finding this view slightly less popular were supporters of populist Confederation (78%) [67]. The reforms must be wide-ranging, based on a wide political consensus and not biased against the coal sector. Future energy mixes and corresponding technologies should be carefully designed, matched and should remain stable in the long term. Coal-based power capacity being near the end of its lifetime provides an economically viable option to commence a fuel switch and the following technology replacement. Real benefits and costs of the energy transition should be fairly allocated to all stakeholders and communicated to society. The social costs and implications in coal-dependent regions may be high, especially in the short-term perspective, but then the transformation will bring profits to the whole society [69].

To be part of the ongoing EU energy transition, Polish policies aimed at reducing coal production should be included in policy packages linked to the introduction of renewable energy and structural policies that address related negative social impacts [14].

3.4. Offshore Wind Energy

Research on the economic risks of transition, combining a bottom-up optimisation model, a top-down macroeconomic model and a stakeholder-driven FCM model, has demonstrated that policies promoting RES deployment are associated with higher economic returns than schemes maintaining the status quo. However, capital availability, exogenous technological progress of RES technologies, international relations, cost/availability of gas and nuclear technology and ETS permit prices are key uncertainties that could potentially change the evaluation of any transition option [70].

In Poland, starting from the 1990s, RES began to grow in importance, their share in the fuel and energy balance being 0.85% in 1993 and rising to 2.5% in 2000 [71]. Research has revealed that Poland still has a lot of work to do in the field of renewable energy development. The forecasts are also not optimistic and show that it will be difficult for Poland to achieve the planned share of energy produced from RES at the level of 18.4% in 2025 if decisive action is not taken. Considering the fact that in 2030 the share of energy produced from renewable energy sources should amount to 23%, attaining the goals assumed in the plans is unrealistic for Poland for the time being [72].

European energy and climate strategies, which determine the rules and principles of energy transformation in accordance with the concept of sustainable development, assume a significant share of offshore wind energy in achieving climate neutrality of the European Union and energy security in Europe. In Poland, policymakers are trying to create favourable conditions for the development of offshore wind energy. In this case, there is a political consensus [73].

Poland has the greatest potential for offshore wind energy development in the Baltic Sea region, as reflected in the plans of investors preparing to carry out their projects in Polish maritime areas. According to estimates, by 2030, from 9 GW to 14 GW of offshore wind energy capacity will be generated in the Baltic Sea. However, the profitability of producing wind energy in the region varies. The most attractive locations are in the southern part of the Baltic Sea, which does not freeze during the winter season and is close to the main centres of electricity demand. The Polish part is to account for approx. 30% of the potential of the entire Baltic Sea. It is assumed that by 2040, offshore wind farms will have an installed capacity of 8–10 GW. The projected share of electricity from these installations will be 13.2% in 2030 and 19.3% of national electricity production in 2040. It is estimated that investments in offshore wind farms by 2030 may increase Poland's gross domestic product by PLN 60 milliard and, additionally, CIT and VAT revenues by PLN 15 milliard [74] (average exchange rate 1 euro = 4,6 PLN; August 2021). Furthermore, it is assumed that the first offshore wind farm will be commissioned in 2026, which is possible thanks to the Act of 17 December 2020 on the promotion of electricity generation in offshore wind farms (Journal of Laws of 2021, item 234) [75]. Moreover, the Development Plan scenarios for meeting current and future electricity demand for 2021–2030, already include offshore wind capacity of 3.6 to 10.1 GW by 2030.

Research focusing on the assessment of investments in offshore wind farms planned in Poland in the coming years in terms of the most sustainable investments, characterised by high efficiency and potentially having a strong impact on increasing the dynamics of economic development in the coming years, has shown that Baltica 2 is the most preferred [72]. The Baltica 2 offshore wind farm will be located over 30 km into the sea, at the level of Ustka and Łeba. The place of its connection to the transmission network will be a 400 kV switching station in a new substation, which is being planned by Polskie Sieci Elektroenergetyczne (Polish Power Grids, Poland), in accordance with the Transmission Network Development Plan for 2021–2030 approved this year by the President of the Energy Regulatory Office. The commissioning of the Baltica 2 offshore wind farm is planned to take place before 2030 [76].

There is a political consensus in Poland to develop this sector. The main political challenges include, first of all, the actual linking of the development of offshore wind energy with the implementation of climate policy and the ability to effectively implement political decisions taken in this field, which are reflected, among others, in strategic documents, legal solutions and many executive regulations. One of the biggest ongoing challenges involves identifying the location of the installation terminal. Investors applying for participation in Phase I of the support scheme for offshore wind farms must decide on the location of the port from which key orders will be executed by 31 March 2021. Without infrastructure capable of acting as an installation terminal, there is a risk that offshore wind energy projects will not be completed on time or that the installed capacity of planned projects will be reduced.

Offshore wind farms are to become one of the cornerstones of the Polish energy mix, so another challenge is to effectively involve Polish entrepreneurs in the development of this sector. Currently, work on signing and implementing the "Polish Offshore Sector Deal", i.e., the "Declaration of Cooperation for the Development of Offshore Wind Energy in Poland" by representatives of the Polish government, investors and entities participating in the offshore wind energy supply chain is under way.

Gaining public acceptance for wind farm development will depend on the applied communication, participatory procedures and education for sustainable development. Poland is at the beginning of the road to developing this sector. Therefore, low awareness of local communities and communities associated with the use of marine and coastal areas of the actual risks and opportunities associated with wind farm development may become a barrier to offshore wind farm development. Energy education is considered to be an effective way to raise awareness and activate the society while taking steps towards the rational use of energy [77]. Research has shown that there is a deficit of this issue in the

curricula. Therefore, teacher training is considered necessary, as well as making teachers knowledgeable about the principles of sustainable development in order to lead to a change in attitudes, not only at the school level, but also in everyday life [78].

3.5. Nuclear Energy

Poland is one of the EU countries that does not have nuclear power plants. However, the beginnings of nuclear power development in Poland date back to the mid-1950s. In 1955, the construction of an experimental research reactor began, and in 1970, the Maria reactor was constructed, which currently remains the only active nuclear reactor in Poland [79].

The first step in the development of Polish nuclear power involved the Żarnowiec nuclear power plant. Following the Chernobyl accident, the number of public protests against the construction of nuclear power plants rose sharply [80]. The intensity of the protest led to the decision to hold a referendum. The result of the referendum, however, did not lead to an immediate decision to abandon the construction, due to low voter turnout—it was not until September 1990 that a second nuclear power plant was to be built in Klempicz. As a result of social protests in April 1989, then Minister Tadeusz Syryjczyk suspended preparatory work. In this case, abandoning the decision to build a nuclear power plant was also caused by the catastrophic economic situation of the country.

Further attempts in this area have been limited to strategic planning only. The subsequent government documents, The Energy Policy of Poland until 2025 (adopted in 2005) and the Energy Policy of Poland until 2030 (adopted in 2009), envisaged the use of nuclear energy in Poland. In 2009, the Polish Nuclear Power Programme, dedicated to the development of the sector, was adopted, which outlined the construction of power plants by 2020. However, the Fukushima nuclear disaster put these plans on hold. The new PEP 2040 also assumes the use of nuclear energy in Poland. The first nuclear unit with a capacity of 1–1.6 GW is expected to be commissioned in 2033, with subsequent units to be commissioned every 2–3 years—the entire nuclear programme assumes the construction of six units by 2043. At the same time, this technology has great potential to diversify the structure of energy generation at a reasonable cost. A significant part of the nuclear programme can be implemented with the participation of Polish companies.

The implementation of nuclear power requires early legal changes to streamline the programme, as well as the completion of the financing model [81]. The construction of a nuclear power plant has gained public understanding and acceptance in Poland. The 2020 survey indicated that some 51.2% of respondents supported nuclear power as an alternative to coal, with opponents accounting for 30.0% and the undecided making up 18.7%.

However, the catastrophe in Fukushima in 2011 intensified Poles' sceptical attitude towards the nuclear power industry, which since then has predominated over support for it. Currently, however, this predominance is smaller than it was years ago. Two fifths of respondents were in favour of building nuclear power plants in Poland (39%, an increase by 5 percentage points since the previous measurement in 2018) and 45% of respondents (a decrease by 5 points) were against it.

The development of the nuclear power industry in Poland was more often supported by men than women (55% and 25%, respectively). Advocates of building power plants outweighed those who were opposed to it among the younger group of respondents (under 35 years of age), respondents with higher education and residents of the largest cities (with a population of at least 500,000), as well as among managers and specialists, technicians and middle staff, private entrepreneurs, skilled workers and respondents with the highest income per person in a household (PLN 3000 and more). On the other hand, apart from women, respondents aged 55–64, having primary or basic vocational education, unskilled workers, administrative and office workers, respondents working on private farms (including farmers), with low per capita income (below PLN 1500) and people dissatisfied with their own financial situation were opposed. Political views were not so important in this respect, but it can be noticed that people with left-wing views were more in favour of construction than the average, while opposition was expressed by those who

identified themselves with the political centre. The declarations of the respondents with the right-wing orientation were, in turn, almost equally divided. The potential voters of the Left and Confederation Freedom and Independence were noticeably more often than others adherents of the development of the nuclear energy industry in Poland, which in the case of both of these electorates may be associated with a relatively lower average age. They also dominated among the supporters of the Civic Coalition, although the positions here were more diverse. Sceptics predominated among the supporters of Szymon Hołownia's Poland 2050 and the United Right, as well as among Poles in general.

The survey "Current problems and events" was carried out by Public Opinion Research Centre (CBOS) [82] according to the mixed-mode procedure on a representative named sample of adult residents of Poland, drawn from the Universal Electronic System for Registration of the Population. Each respondent chose one of the following methods: a direct interview with the interviewer (CAPI method), a telephone interview after contacting the CBOS interviewer (CATI) using the contact details that the respondent received in the announcement letter from CBOS or access to a web survey was possible on the basis of the login and password provided to the respondent in the announcement letter from CBOS. In all three cases, the survey had the same set of questions and structure. The survey was carried out from 6 to 16 May 2021 on a sample of 1163 people (including: 54.8% using the CAPI method, 30.0% using CATI and 15.2% using CAWI). CBOS has been carrying out statutory research under the above-described procedure since May 2020, in each case providing the proportion of direct, telephone and internet interviews.

Potential challenges to the implementation of the plans to build a nuclear power plant include high investment costs, the need to provide adequate human resources (for the construction of the power plant, its proper operation and technical supervision), the choice of technology supplier, as well as the identification of the appropriate location for the first and subsequent nuclear power plant units and the commissioning of a new repository for low- and intermediate-level radioactive waste. In particular, the latter challenges may be problematic in terms of public acceptance due to the potential existence of NIMBY syndrome regionally and locally. It should be emphasised here that the use of nuclear energy in Poland is unavoidable in the long term [83]. It will be a kind of "back-up" for the Polish industry in case of problems in the production of energy from renewable sources [84,85]. The energy transformation should not entail side effects like interruptions in energy supplies to companies of key importance for the economy of the state.

According to the provisions of the PEP2040, a zero-emission energy generation system, parallel to the traditional structure, is to be created in Poland within the next 20 years. Coal is to be used to produce electricity only to alleviate shortages; the conventional power industry is to undergo a transformation, but no one is to be harmed as a result of it. In 2040, more than half of the installed capacity is to come from zero-emission sources. Nuclear energy is expected to play a special role in this process. In addition to the offshore wind power industry, it is to be a strategic new area of the Polish economy.

The comparison of the political vision of the energy transformation (PEP2040) with the energy situation in Poland at the time of its adoption shows that one of the determinants of the success of the Polish path will be the process of transition from a coal-based energy culture to sustainable one, in which the transformation of mining regions will play a decisive role. Social issues are the most important barrier to the transformation of energy culture. In Silesia, about 7000 people per 100,000 of those employed are connected with mining. A quick closure of mines without creating alternative jobs can result in very high unemployment. Social anxiety about the loss of "future" and "identity" is a challenge that requires drawing up and executing a "social contract".

According to the PEP 2040 project, demand for capacity should be satisfied by drawing on domestic resources. Although the share of coal will decrease—to 56–60% in 2030—it is necessary to replace it with new sources, including gas units, nuclear energy and renewable sources, mainly photovoltaics and offshore wind farms.

In this case, the most important challenges are economic ones, which are dominated by the issue of sources of financing for the two new planned energy sectors: the offshore wind power industry and the nuclear power industry. The provisions of the PEP2040 also emphasise the fact that the implementation of the strategy will mean clean and environmentally friendly energy. Due to the current difficult situation of the energy sector, as well as the long-term perspective of investment processes, the state's energy policy should be the subject of a broad political consensus. The effective development of the nuclear energy industry will require great determination from the Polish state and its decision-makers. Building a series of nuclear power reactors is a challenge for decades [86].

3.6. Cost of Energy Transformation

With the current state of knowledge, it is not possible to indicate all the costs of the energy transformation in Poland by 2040. It is not possible as it consists of too many aspects, some of which are non-quantifiable. The total costs, apart from the obvious and quantifiable costs of closing hard coal and lignite mines, include the estimated costs of necessary investments in new energy sources, wind and nuclear energy, include social, health and environmental costs.

In the case of social costs, it is difficult to calculate the exact amount of financial resources needed for, for example, retraining of employees leaving the mine, the cost of creating new jobs or social support for the inhabitants of the regions undergoing restructuring. We can estimate the gains related to environmental protection, with the probable extension of life expectancy in regions with a lower degree of air pollution, but also a longer period of paying retirement benefits or medical support for an increased number of people aged 60/65+. These are just a few examples from the immeasurable categories, as well as the ethical question about the economic value of health or life.

The second uncountable profit/loss category is the local and regional improvement of environmental conditions, closely related to the improvement of the quality of life and its length. However, in this case, it is also impossible to indicate the amount of profits related to the reduction of environmental pollution for humans or the total environment. The results of the research on costs (profits/losses) carried out so far in regions where the energy transformation has been successfully carried out indicate, however, that the total profits outweigh the losses [87–89].

Compared to the assessment of social, health and environmental costs, it is easier to estimate the technical and investment costs related to the closure of hard coal or lignite mines. It is also possible to indicate the size of the necessary investment outlays for the development of renewable energy sources necessary to ensure the country's energy security.

As indicated in the document Poland's Energy Policy until 2040, approved by the Polish government and signed by the Ministry of Climate and Environment, the cost of the proposed energy transformation of Poland may reach PLN 1600 billion (approximately EUR 360 billion at the exchange rate from June 2021) [90]. Such a high cost results from the assumption that the transformation must be carried out in a socially acceptable manner, maintain the competitiveness of the Polish economy and ensure energy security. By 2040, the estimated cost of changes in the fuel and energy sectors will amount to approx. PLN 867–890 billion. Additional costs, including changes in households, services, transport and agriculture related to the energy transformation, will require another approx. PLN 745 billion [90].

When analysing the costs of developing hydrogen-based energy, two types of energy sources were taken into account, which, according to the government's plans, are to replace energy based on fossil resources—wind and nuclear power plants. Conclusions and results from the research conducted in the field of obtaining energy in wind farms [91–93] clearly indicate that despite the existing difficulties, the unit cost of obtaining electricity has been decreasing in the last ten years, allows for a high return on investment and is competitive in relation to other energy sources. In the case of nuclear energy, the costs of acquiring electricity are also competitive in relation to energy from fossil fuels. However, the cost of

building a nuclear power plant in Poland, estimated in 2018, ranged from PLN 40 billion to PLN 70 billion, depending on the assumed target capacity, the technology adopted and the selected location. Assuming the construction of four nuclear power plant units, each with a capacity of 1000 MW, in the same location, the cost of its implementation in 2018 amounted to PLN 40 billion to PLN 45 billion [94].

4. Discussion

The research carried out with the use of the methods provided in the above work shows many aspects and problems relating to the energy transformation process in Poland. In the literature on the subject, individual researchers have usually dealt with selected aspects of this process, which was confirmed by Kungl and Hess (2021) [20]. The research undertaken so far has shown that the process of energy transformation towards sustainable development is extremely complicated and many transitions have not been completed, and will only be achieved on the basis of a set goal and adapted tools, including financial ones. As Loorbach and Rotmans [95] noted already in 2006, there is a question of the possibility of managing this process. Each of these transitions consists of processes of co-evolution involving changes in needs, desires, institutions, culture and practices. The results of the research by Kemp, Loorbach and Rotmans (2007) [96] confirmed the need for radical changes in functional systems and in government policy, but also in current governance systems (social orientation), natures and patterns of interaction in collective issues). However, on the basis of previous works [43,97–99], it should be concluded that although a full-fledged energy transformation is cost-intensive, it becomes economically and technically feasible. Currently, most of the necessary technologies are fully available and their costs have significantly decreased. Thus, the cost of transition would be similar to the cost of maintaining the existing system if appropriate policies and regulations were put in place [100]. The research that has been undertaken has shown that in Poland, the basic factors determining the effective energy transformation include political, social and economic conditions, which confirms the earlier conclusions of the research by Lee and Yang [101]. We are dealing here with a feedback loop, as economic development and technological innovations as well as political and social changes necessary in the energy transformation process [102] are at the same time its effect.

In the analysed case of the energy transformation in Poland, one of the main, even basic, elements of the transformation is the decarbonisation of the economy. In Poland, it is associated with both political processes and social and technological changes. On the other hand, technological change, often characterised by three main stages of invention, innovation and dissemination [103], encounters many market, system and institutional failures and requires a multi-faceted political intervention, as confirmed in their works by P. Twomey (2012) [104] and Geels (2014) [102], and on the example of Oslo by Ystmark Bjerkan and Seter [13]. The issues of systemic reforms of the hard coal mining industry [60,65] and failures of the entire energy sector in Poland [14,24,36] are similar.

On the basis of the analysis of changes in greenhouse gas emissions (Table 1) and the share of individual energy sources, it can be concluded that the policies from the Polish government since the beginning of economic and political changes (1989) have been ineffectual in this respect. The Polish government, as stated by Zoll [53], the main actor in the process of energy transformation and decarbonisation, is simply ineffective. Additionally, to some extent, it has become a hostage of mining trade unions for many years, opposing the reduction of hard coal mining in the country, which was also indicated by Brauers and Oei [14].

In this context, the Europeanisation pressure is obvious, which makes it necessary to accelerate the energy transformation in the countries least advanced in these reforms, i.e., in Poland. The creation of a coherent energy regime and the achievement of a political and social consensus as to its shape, assumptions and instruments may constitute the basis for an effective energy transformation of Poland, the cost of which is estimated by the Ministry of Climate and Environment at PLN 260 billion. The projected (2021) costs of the energy

transformation may even reach PLN 1600 billion. Unfortunately, as shown by the current costs of large investments planned in Poland, they are sometimes even 50–70% higher. As was the case with the new water route through the Vistula Spit, or the first stage of the construction of the power plant in Ostrołęka.

In Poland, uneconomical coal mining, inevitable investments in energy infrastructure, rising air pollution and pressure from the European Union may give a new political impulse to move away from coal in line with international and regional climate goals. However, the research has shown that policies aimed at reducing carbon production and use are needed to achieve political feasibility, implemented together with social and structural policy measures that address a just transition for the affected regions [83].

However, a realistic and, above all, effective social policy in the field of decarbonisation requires understanding the necessity of this process, which determines energy culture. As shown by the analysis of the results of public opinion polls (Figure 2), although 51% of respondents supported the process of abandoning coal-based energy, as many as 30% of respondents were against this policy. Therefore, it should be borne in mind that the implementation of the EU's energy and climate policy goals, as well as the energy transformation, may face many complex political, social and economic challenges [105].

The political challenges include the sceptical attitude of the ruling right-wing elite towards the EU's Green Deal. As indicated in the text, the conservative electorate of right-wing parties in Poland is relatively reluctant to change, in which it perceives primarily a threat to the existing economic order, in which classic energy based on the use of fossil fuels plays a special role. The Polish right, represented mainly by the conservative electorate and strong in its electoral support (as evidenced by the current policy of the Polish government of M. Morawiecki), will probably not agree to a far-reaching energy transformation. However, it is realistic to fulfil the minimum postulates required by the EU in relation to the member states. Among the societal challenges is the potential resistance of society to the fact that the energy transition is already associated with rising energy costs and, thus, an additional burden on household budgets [106].

Meeting EU priorities requires specific measures to be taken by national governments, including infrastructure investments in the energy sector (e.g., construction and expansion of transmission networks adapted to renewable energy, construction of energy storage facilities), implementation of additional systems to increase energy efficiency (in particular in the heating sector) and intensification of activities aimed at reducing emissions in the transport sector, together with enterprises for the development of electromobility. This is just a short excerpt from a long list of extensive economic modernisation processes to be undertaken in the coming years. Their implementation will undoubtedly increase citizens' costs of living and the costs of running a business for entrepreneurs [107], which is sure to cause social discontent and resistance. In practice, it will also lead to an increase in energy poverty. Therefore, the energy transformation in Poland requires investments in an educational and information campaign on the policy of climate neutrality. There is evidence that such campaigns are effective even among conservative climate sceptics [108]. The most important economic barriers include the prospect of high financial costs of the energy transformation. Poland produces over 80% of its energy from hard coal and lignite [62].

Another problem is the issue of energy security. Reducing mining and closing mines to meet the EU's energy targets means serious problems for the hard coal mining industry and the entire region of Silesia. Therefore, the long-term strategy of the government PEP 2040 emphasises the significant role of coal in the national energy balance.

Social sciences are seen as increasingly useful for studying the energy transition process [109]. Previous approaches either ignored the social interactions that shape energy use (e.g., acceptability of energy technologies and attitudes to changes in the energy system) or viewed these as operating independently of the technical aspects of the system. Moreover, these approaches did not take into account the fact that energy transformations take place in various economic, systemic and socio-cultural conditions [31]. The attention was paid to energy culture as an interesting research area in the context of factors influencing the pace

of energy transformation. The approach to researching the energy transformations of countries that are trying to move from a carbon-based culture to a sustainable culture seems to be particularly interesting, starting the transformation with political decisions. The results of the research, data analysis and literature on the subject confirmed the conclusions of Green [110], who noted that decarbonisation of the world economy would create many losers, and Hiteva and Sovacool (2016), who argued that coal withdrawal is inevitably related to energy justice [111].

5. Conclusions

The culture of coal energy is deeply rooted in the consciousness of Polish society. Hard coal mining has been seen as a key industry for the national economy since World War II. The mining industry is associated with Poland's energy security and independence. For many years, the extraction and sale of coal to foreign markets was the strength of the Polish economy. Everything has changed with global and European efforts to protect the climate. Polish mining is today a problem for the national economy. It is unprofitable, is characterised by over-employment and, in addition, the extraction methods are outdated due to the lack of new technological investments. An additional problem is the frequent accidents in mines caused by methane explosions. Nevertheless, society's attachment to this industry is very strong (especially in Silesia). The mining industry means jobs for them. They do not take into account the economic or climatic aspects. Miners are a very strong economic lobby in Poland. Their resistance to the energy transformation may be an important factor blocking efforts to implement the European Green Deal.

Our research shows that Poland is actively involved in attempts at energy transformation, which can be seen in their strategic long-term actions that were included in PEP 2040. Nevertheless, the strategy itself may turn out to be insufficient. Its implementation requires considerable effort, which entails high costs for the entire economy and for society. The key to the Polish energy transformation may be whether the assumptions will be implemented in a consistent and determined manner.

The energy transformation is one of the key areas of activity of the European Union. Poland, as a member state, should adapt to this goal. Our study showed that the implementation of the assumptions of the European Green Deal may be very difficult, or even impossible, for Poland until 2050. Nevertheless, there is a consensus both among the political elite and in society that energy transformation is needed. Even if the immediate social and financial costs are high, this challenge is worth taking up. Its implementation corresponds to the long-term needs of the Polish economy, provides scope for sustainable development and allows for following global megatrends. It is important to be aware that actions taken today affect future generations of Poles and all Europeans.

The energy transformation will require significant sacrifices, both on the part of enterprises and society. Enterprises must take up new investment challenges, open up to new business models, and change existing technologies. This comes at a high cost. The projected costs of the energy transformation may even reach PLN 1600 billion (approximately EUR 360 billion at the exchange rate from June 2021). By 2040, the estimated expenditure on changes in the fuel and energy sectors will amount to approx. PLN 867–890 billion. Additional costs, including changes in households, services, transport and agriculture related to the energy transformation, will require another approx. PLN 745 billion.

On the other hand, the society will have to accept the rising energy prices, the loss of jobs in the mining industry and the necessity to change the current professional profile of people working in the mining industry. This can mean problems for many social groups. There is also a possibility of a temporary increase in the problem of energy poverty. Overall, prosperity appears to be possible in the future, but the path to achieving it will require sacrifice.

Our research proves that the implementation of the assumptions of the European Green Deal in Poland will be very complicated. Firstly, analysing the conclusions from the history of the Polish energy sector, many strategic programmes have failed. They remained

only à la carte assumptions. These failures were not effectively accounted for. Secondly, the Polish energy industry is quite archaic and is based on the use of hard coal. Giving up this medium will be extremely complicated due to the strong resistance of the mining lobby. Thirdly, the implementation of new technologies in the field of renewable sources and nuclear energy requires significant financial outlays. Without significant support from the European Union funds, the national budget is unable to undertake such measures. If Poland receives such support, it will take several decades to implement the activities effectively. To sum up, in the next thirty years Poland will not be able to achieve the assumed effects of the energy transformation, which is in contradiction with the official declaration of the government in regards to 2050.

6. Limitation of Research

We are aware that the issues presented in the text are extremely complex. It was possible to significantly expand the spectrum of the analysed issues, but at the cost of the quality of the analysis. We limited our research in particular to the scope indicated as part of the research objectives. The main goal was to verify the central hypothesis.

We believe that the analysed issues could be extended to include economic issues, but that was not our intention. In the manuscript, we have referred to Geels' triple embeddedness framework, however, due to the fact that this model is dedicated to understanding the co-evolution of the coal sector and its surroundings (it also enriches the theory of research on innovation), we used it in relation to the part devoted to the transformation of mining regions. The aim of our work was more general and, therefore, we did not treat this framework as a starting point for our analysis. Geels also pointed out that the model does not take into account a large part of social determinants, strongly focusing on the aspects of the game of interests, lobbying and recognising political and economic processes as variables explaining the co-evolution. In our opinion, economic aspects need to be elaborated on in a separate text because they pose a serious challenge to the Polish energy transformation.

Similarly, the legislative dimension deserves to be extended. The creation and implementation of new laws is one of the preconditions for the successful implementation of any policy. A strategy without an appropriate legal framework becomes only an à la carte record. It does not bind individual participants in political, economic and social processes. The legislative dimension has not been further developed in the article due to the fact that the new legal framework is under preparation in Poland. This makes it difficult to objectify the scientific narrative.

The innovation of our research consists primarily in identifying and diagnosing problem areas related to the energy transformation. We used the case of Poland as an example. We examined the specificity of the Polish energy sector. We believe that our text will contribute to broadening the scientific debate in Europe and the world about the main difficulties in making changes to climate neutrality in individual countries.

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