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The Role of Renewable Energy Sources in Electricity Production in Poland and the Background of Energy Policy of the European Union at the Beginning of the COVID-19 Crisis

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Abstract: Electricity production in Poland is stable and ranges from 160–170 TWH a year. The share of renewable energy sources (RES) is increasing. Poland increased its share from 6.9% in 2010 to 12.7% in 2019 and 16.1% in 2020. The share of hard and brown coal decreased in Poland from 87.8% in 2010 to 73.5% in 2019. Wind energy (9.2%) and natural gas (9.2%) are the most important sources of RES in electricity production. The purpose of this research is to discover the changes in renewable energy production, and the impact on electricity production in Poland. Our research showed the extent of development of RES in Poland and other countries of the European Union. The share of renewable energy sources in electricity production increased as the effect of energy policy of the European Union. We also evaluated the impact of the COVID-19 crisis on the renewable energy market and electricity production in Poland, and other countries of the European Union. Because of the shortage of data, we presented changes at the beginning of the COVID-19 crisis in 2019–2020. First, we described the sustainable development and energy policy of the European Union. Then, we described and used methods, including regression analysis, as the most important method. We also found that the power capacity in Poland increased, with the increases coming from solar radiation (11,984%), wind energy (437.8%) and biomass installations (324.7%) in 2010–2020. The biggest electricity producers in the EU are France and Germany. These countries also use nuclear energy, which helps to meet the increasing demand. To check the impact of power installed from renewable energy carriers we conducted a regression analysis. This method provided a correlation between electricity production from renewable energy sources and investments in renewable energy carriers. We wanted to discover the impact of RES installations, and their impact on electricity production in Poland. The statistical analysis was based on data from 2010–2020. Our research points out that the most important factors shaping electricity production were installations using energy from solar radiation and hydropower installations.

Keywords: renewable energy sources; electricity production; energy policy; the COVID-19 crisis

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1. Introduction

Renewable energy sources (RES) play a key role in delivering clean energy in the European Union (EU) and the world. Such energy sources prevent rises in temperature for the world's climate. Moreover, the EU will be the modern economy using RES. The problem of energy diversification and decreasing the contamination of the environment is particularly important. Renewable energy sources deliver clean energy, which can solve many problems with greenhouses gases emissions. Moreover, strict European Union energy policy forces member states to increase their energy independence from Russia. Renewable

energy sources are also important in electricity production and electricity is a key factor in the economy, population, imports and exports [1]. Electricity production and demand also has an impact on gross domestic product (GDP) creation in the economy [2,3].

Energy is mainly used in electricity, heat, and motor fuel. Fossil fuels deliver about 82% of primary energy [4]. In Poland, 90% of electricity was produced from coal in 1960–2008. Environmental awareness and European Union policy forced Polish government to reduce the utilization of coal [5]. Today, coal and lignite create 80% of the electricity, whereas in Europe it is 25% [6]. Hard coal and lignite are the main source of electricity in the world. In Poland, for example, hard coal and lignite generated more than 56% of primary energy and more than 85% of electricity production [7].

Moreover, the use of coal creates the problem of mining wastes. The problem has national and international repercussions [8]. However, the share of fossil fuels in electricity production is decreasing, because they generate climate change and have a big carbon footprint. Fossil fuels affect people worldwide, especially in low-income communities. The negative impact is strengthened in populations with inadequate nutrition and poverty [9]. Most countries vowed to reduce coal consumption, for example, China by 15% by 2040, compared to 2016 [10,11]. Moreover, coal utilization creates environmental problems, including ash production as an effect of combustion, and sulfur and mercury removal [12].

The economic situation for the energy sector in Poland was influenced by the post-communist countries at the beginning of the 1990s. Poland was self-sufficient in coal production, but after accession to the European Union it had to adjust to a new energy policy [13]. In the long term, the strategy of the European Union directed on hard coal reduction may lead to negative effects [14]. The most important criteria for purchasing coal by consumers is its price [15]. This situation is particularly evident today, during war between Russia and Ukraine, which led to a tremendous increase in the price of coal. Poland had to import more than 6 million tons of coal to fill the demand in the market in 2022. The cost of environmental fees for CO_2 emission allowances impacted the level of the price increase for energy in Poland. The costs for green certificates are responsible for 60% of the price increase for energy for consumers. The EU trading system of green certificates should be discussed, and the reliable levels of emissions should be elaborated upon. Polish hard coal mining is becoming less competitive because of increasing prices of coal [16]. The future of Polish mining depends on coal preparation, coal quality and the exploitation system. Moreover, the decisive role will depend on environmental regulation and policy [17].

RESs include biomass, wind energy, photovoltaics, biofuels, biomass and heat pump [18]. Biomass and other renewable energy sources are the tool which help to resolve the problems of environmental contamination [19]. The production of electricity from wind and solar energy has increased worldwide. However, these kinds of energy can be unstable and dependent on weather conditions. Wind produces less energy on windless days and solar produces less energy when there is less snow in winter [20].

The most important advantages in energy production for non-renewable energy sources is that they produce electricity and heat at lower costs. However, renewable energy sources are more economically sustainable [21]. Fossil fuels should be abandoned because the world is going to decrease the temperature 2 °C above pre-industrial levels [22]. Carbon dioxide and methane are the main greenhouse gasses coming from fossil fuels, which are responsible for global heating [23].

The literature providing information about RES, fossil fuels and electricity production is readily accessible [20,21,24]. However, little attention is given to the impact of the COVID-19 crisis on the renewable energy and electricity production sector. Our paper contributes to the existing literature on RES and the impact of the COVID-19 crisis on this sector. When the COVID-19 virus spread across the entire world it had tremendous impact on human health, causing not only disease but also the deaths of many people. Therefore, policy frameworks should consider the impact of a health event not only in the health sector, but also in energy and other sectors [25]. Some concerns include the social and

economic sphere and the increase of electricity prices. In 2019, the electricity price increased +9.7% and in 2020 reached +14.1%. In September 2021 the electricity price reached the level 401 PLN/MWH net compared to 239 PLN/MWH net in October 2020 [26].

The purpose of this research was to present the development of RES in relation to electricity production in Poland, in the context of the EU at the beginning of the COVID-19 crisis. An attempt was made to answer the following questions:

1. What is the share of renewable energy sources in energy production and consumption in Poland, and what is the impact of the COVID-19 crisis on the sector?
2. What development of renewable energy sources has been observed and what is the contribution to energy production in Poland at the beginning of the COVID-19 crisis?
3. What policies influence the development of renewable energy sources?

The following research hypotheses were formulated based on a review of the literature:

Hypothesis 1 (H1). *The share of renewable energy sources production in Poland has improved after accession to the European Union (EU), but at the beginning of COVID-19 it decreased as a result of lower demand for electricity.*

Hypothesis 2 (H2). *The European Union (EU) policies support the development of renewable energy sources in Poland, which has a positive impact on clean energy production.*

The paper includes the following parts: Section 1 is introduction, and Section 2 literature review. Later, we present Section 3 which is the methods. The main sections are the research results and discussion. The final section is the conclusion.

2. Conditioning and Energy Policy of the European Union and World

Renewable energy sources deliver clean energy preventing climate before temperature rise, and foster the development of the economy of EU. The climate changes limited to the increase of carbon dioxide (CO_2) force the European Union to elaborate policy. The new policy should be adopted to lower the original level of CO_2 [27].

The problem of energy can be solved by delivering eco-efficiency and sustainable development introduction. This can be achieved by elaborating processes reducing methane and greenhouse gas emissions, drainage water and by processing waste [28,29].

Smog, as the effect of fossil fuel utilization, can be reduced by natural and environmental policy, which aims to reduce the so-called stock emissions [30]. This is a very big problem in the transition of Polish and other European Union countries towards a carbon economy. Poland, whose energy system is based on fossil fuels, has a problem with the transformation of this sector [31].

In the mining industry, the supply side of policies include limiting carbon, solving down investments in fossil fuel and reducing the cost of production [32]. The biggest producers of coal, such as China, elaborated national standards to adopt the environmental requirements. The local coal-product standards have been elaborated and there is a strong pressure on clean manufacturing for coal production and consumption [33]. China as a leader of coal production is also big emitter of CO_2, which causes environmental problems to the country. Coal production, processing and utilization is a challenge for many coal mines [34]. Moreover, energy efficiency improvement required investigations in coal pre-drying, energy equipment, boilers and power plant [35].

Europe is another big producer of coal and the mining industry. The area is particularly vulnerable to environmental protection [36]. Many countries of the European Union face a shock decrease of hard coal prices, caused by their inefficiency. Such a dramatic situation in many coal plants was observed in 2012 and 2014 [37]. Moreover, the current dramatic situation on the energy sector in the European Union, caused by the war between Russia and Ukraine, will lead to many coal plants collapsing. That is why energy plants should take up proper strategies to develop in the market. Those proper strategies should be to adjust to business and environmental conditions, and the companies should change, along

with the changing environment, and take up organization reaction. The changes should have a positive impact on financial results and improve competitiveness [24]. Poland has adopted an energy policy through to 2030. The Polish energy sector is undergoing major challenges, including increasing demand for electricity, insufficient installation for energy, and low supplies of gas from Russia. Polish policy includes the improvement of efficiency for energy, energy security, the diversification of electricity sources, and pollution reduction. According to that policy, the demand for energy from RES in 2030 should be: electricity (33,296 Ktoe), wind (1530 Ktoe), solid biomass (994 Ktoe) and biogas (592 Ktoe). These numbers should lead to an increase in the use of RES in final energy consumption to 15% in 2020, an increase in the share of biofuels to 10% in 2020, and the greater protection of forests and the environment [38].

The theory describing sustainable development and energy is wide in the European Union. Worth mentioning is the 'Agenda 2000', which introduced the European Union's rural development policy focused on resource management and climate preservation [39]. The Common Agricultural Policy (CAP) is the main policy regulating the development of farms and rural areas in European Union countries. More and more attention withing this policy is paid to the clean environment, greening agriculture and renewables. This is due to the fact that agriculture is delivering goods for nutrition, but also for energy (biomass, biogas) and the landscape. In economic theory, goods include environmental aspects, production, food production and others [40].

The European Union energy policy is the Renewable Energy Directive (RED) of 2009, which had an aim of "20/20/20''. This included 20% as the renewable energy target and 10% as the energy target for the transport sector [37]. Another important directive was approved in 2018 and was called the Renewable Energy Directive (RED II). The directive set a new target of 32% of renewable energy sources and 14% for transport by 2030 [41].

Additionally, the European Union prepared the Communication on the European Green Deal, aimed at carbon neutrality by 2050. This Green Deal will result in several changes from the previous document RED II [41].

In 2014, the European Council maintained the direction of counteracting climate change and approved four goals for the 2030 perspective for the entire EU, which, after revisions in 2018 and 2020, have the following shape:

- the reduction of greenhouse gas emissions by 55% compared to 1990 emissions;
- at least a 32% share of RES in gross final energy consumption;
- an increase in energy efficiency by 32.5%;
- to complete the internal EU energy market.

The Polish energy policy is based on the European Union policy, and it is in line with the core of the policy. Pillars of the Polish energy policy through to 2040 are [42]:

1. just transformation;
2. a zero-emission energy system;
3. good air quality.

Detailed objectives of Poland's energy policy through to 2040 are:

1. the optimal use of own energy resources;
2. the development of electricity generation and network infrastructure;
3. the diversification of supplies and the expansion of the network infrastructure of natural gas, crude oil and liquid fuels;
4. the development of energy markets;
5. the implementation of nuclear energy;
6. the development of renewable energy sources;
7. the development of heating and cogeneration resources;
8. improved energy efficiency.

However, the COVID-19 pandemic contributed to the climate and environmental crises negatively impacting human health, and these circumstances will undoubtedly change the policy of the EU. The development of RES will not only be a challenge but will also

deliver environmental benefits, such as: a reduction of greenhouse gas, such as CO_2 and methane; improve the management of biomass stock; and introduce new technologies in photovoltaics, wind and other renewable energy installations [43].

3. Materials and Methods

3.1. Data Sources

The EUROSTAT was the main source of data for this study. These are data presented in Eurostat databases and are accessible worldwide. These data are free of charge [44].

Other sources of data were derived from Statistic Poland and current information for 1990–2019 [45]. According to the data, the most important electricity producers are China, the USA, India and Russia. The largest increases in global electric production were observed in China (1108%) and India (441.6%) in 1990–2019. The USA is also a big producer of electric and it takes second place after China. In Poland, production increased by 20.2% and in Russia 3.3%, in 1990–2019 (Table 1).

Table 1. Electric energy production in the world in 1990–2019.

Year	TWH	China (TWH)	%	USA (TWH)	%	India (TWH)	%	Russia (TWH)	%	Poland	%
1990	11,957.4	621.2	5.2	3232.8	27.0	287.8	2.4	1082.2	9.1	136.3	1.1
2000	15,555.2	1355.6	8.7	4052.3	26.1	571.4	3.7	877.8	5.6	145.2	0.9
2010	21,569.8	4207.2	19.5	4394.3	20.4	937.5	4.3	1038.0	4.8	157.7	0.7
2019	27,004.7	7503.4	27.8	4401.3	16.3	1558.7	5.8	1118.1	4.1	163.9	0.6

Source: Own elaborations based on [40].

3.2. Methods

To analyze changes in the development of RES in the EU and Poland we employed different analyses. First, regression analysis.

This model shows the impact of independent variables on the dependent variable (electricity production from renewable energy sources in Poland (GWh)). The basis of using the variables was the possibility to access the data. The data describes the most important investments in installations in renewable energy in Poland. These investments impact electricity production from RES in Poland.

The multivariable regression function can be written as follows [46]:

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \ldots + \alpha_k X_k + \xi, \quad (1)$$

where

Y—dependent variable;

X_i—explanatory variables (i = 1, 2, . . . , k);

ξ,—random component;

α_0—intercept of regression function;

α_i—structural parameters of the model (i = 1, 2, . . . , k).

We used the method of least squares to perform the regression analysis. We used the Statistica 13.3 program for data analysis. The method is widely used to analyze the results.

The selection of dependent variables resulted from their importance for energy production from renewable energy sources and the accessibility of the data. The selection of the independent variables was made based on the substantive justification of their impact on the production of renewable energy sources. In this respect, exogenous variables were considered. Then, from the set of presented variables, variables with high autocorrelation were eliminated [46]. We chose a few variables that had a statistically significant effect on the production of electricity from renewable energy sources.

To achieve the proper results, we chose the explanatory variables that were characterized by high volatility and were not correlated with each other. They were correlated with the explained variable: the production of electricity from renewable energy sources. The set of variables that influence electricity production from renewable energy sources are:

X_1—installations using biogas;
X_2—installations using biomass;
X_3—installations using the energy of solar radiation;
X_4—installations using wind energy;
X_5—installations using hydropower.

The explained variable was: Y_1—electricity production from renewable energy sources in Poland (GWh).

4. Results

4.1. Share of Renewable Energy Sources (RES) in the European Union (EU)

Renewable energy sources (RES) have been developed in the EU. The share of renewable energy in heating and cooling will increase by about 1.1% on average annually in the years 2020–2030. Additionally, the use of biomass will play a key role in increasing energy from RES [47].

The main source of RES in Poland is biomass, which is mostly obtained from forests. Typically, developing countries use biomass from forests but more developed countries, like those in western Europe, use a wider mix of renewable energy sources [48].

The COVID-19 crisis had an impact on RES in the EU. In 2020, compared to 2019, lockdowns resulted in declines in the use of gasoline (−13%), diesel (−9.4%), bioethanol (−10.1%) and biodiesel (−3.5%) [41]. The COVID-19 crisis led to the decrease in the value of the renewable energy market supply in 2020. In spite of the impacts of the pandemic, China the US, the UK, India and Spain represented 70% of new wind installations [48]. The COVID-19 crises was a challenge for the renewable energy sector, which resulted in the disruption of manufacturing facilities, companies, supply chains and transition to renewables [49].

To improve the situation, renewable energy technologies should be implemented, which helps to organize the usage of these sources [50]. As we can see from Figure 1, the largest share of renewables in the EU came from Sweden and Finland; that was the effect of energy sources from wood and other renewables. In Poland and other EU countries, there is a shift to RES because they have lower carbon emission and produce clean energy. Moreover, the global increase of energy demand with an average annual rate of 2.2 percent created the need to replace conventional resources based on hard coal and lignite. The replacement of fossil fuels requires an investment in a smart grid, which can be adjusted and installed in local conditions [51].

The existing stage of energy infrastructure is not in a good position. The electricity use in line requires amendments of the line and additional investments. This is particularly important in the decarbonization process to avoid climate contamination. The electricity infrastructure is extremely important [52]. For many years, the development of economies was based on the exploitation of natural resources, causing environment degradation. In addition to that, the increasing demand for hard coal and lignite caused the harmful waste to increase [53].

The COVID-19 crisis also affected electricity production and consumption worldwide. Declines in investments, staff layouts and reduced commercial activities have all been observed. The COVID-19 crisis undoubtedly caused a decrease in the energy sector due to less demand in production and consumption [54]. However, the lockdown did have a positive impact on the environment, through the reduction of emissions of greenhouse gasses [55].

As we can see, the share of electricity from renewable sources in the gross final consumption of energy in the electricity sector was the highest in 2020 (16.24%). At the beginning of the COVID-19 pandemic, the volatility in the global economy and lockdowns

created a drop in renewable installations (Figure 2). The global fossil energy and renewable energy markets are undergoing big crises that will also impact Polish markets [56].

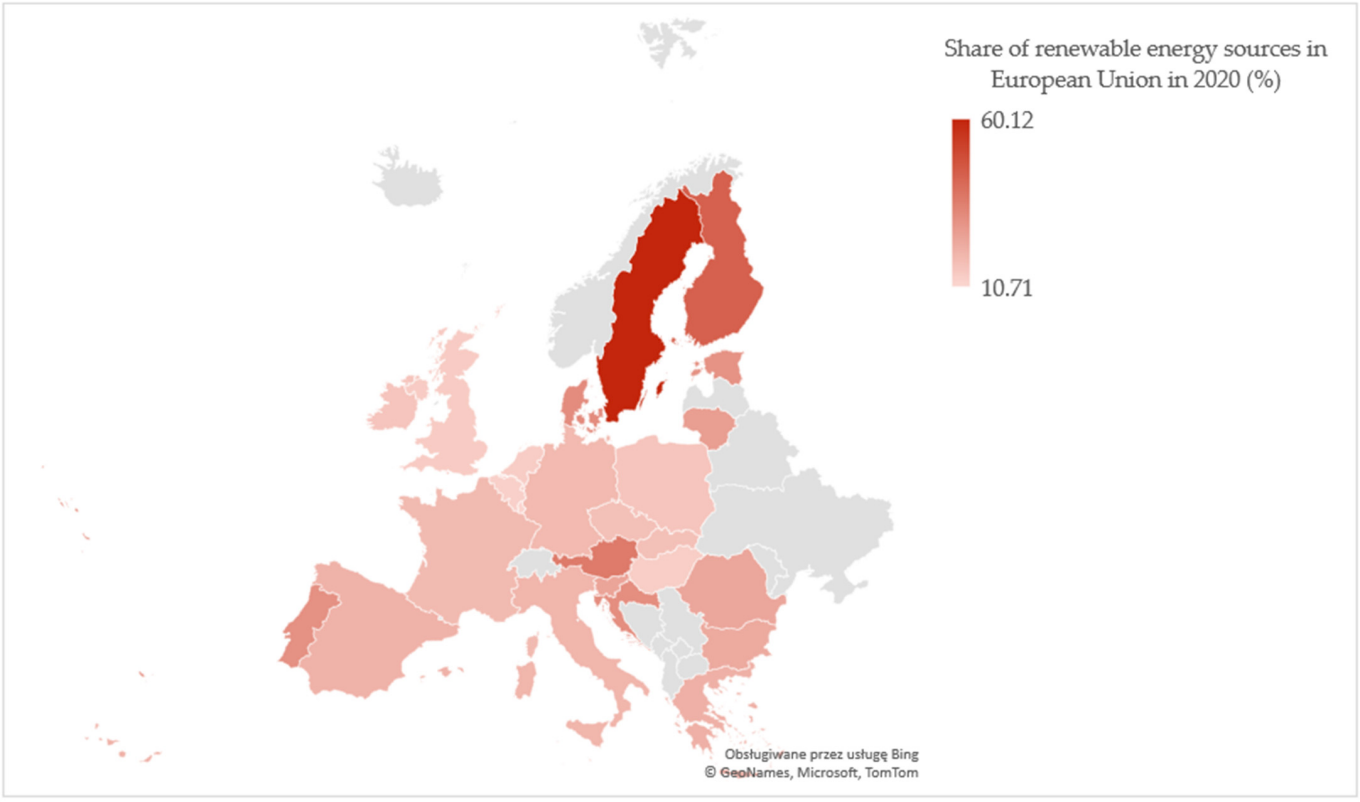

Figure 1. Share of renewable energy sources in European Union in 2020. Source: own elaborations based on [43].

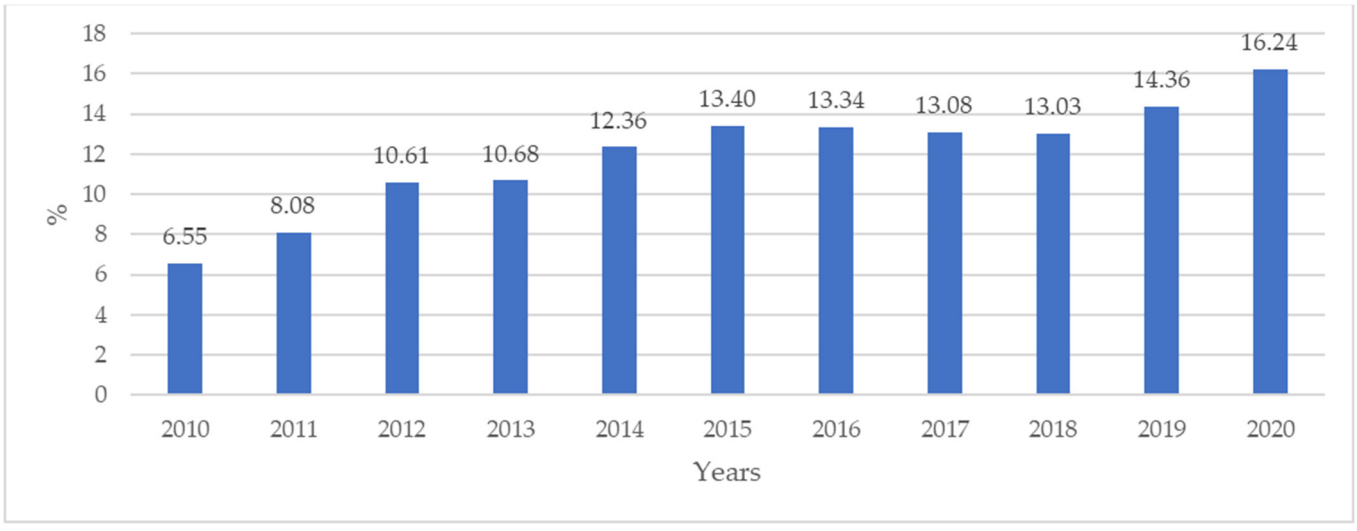

Figure 2. The share of electricity from renewable sources in the gross final consumption of energy in the electricity sector in Poland (%). **Source:** own elaborations based on [44].

The system of green certificates in Poland regulates the functioning of energy companies in order to obtain the proof of origin of electricity; otherwise, they must pay a compulsory fee [19]. The costs of daily CO_2 emissions increased from EUR 30/ton in January 2020 to EUR 85/ton in December 2021. In Poland, the highest electricity price

increase was observed. The COVID-19 pandemic caused the global electricity price increase, material cost increases and disruptions in supply chains [57].

The Polish electricity system is dominated by electricity from hard and brown coal. However, the share of hard and brown coal in electricity production decreased from 87.8% in 2010 to 73.5% in 2019 (Figure 3). The changes observed in the structure of electricity production in Poland are the effect of global problems. Pollution from the use of fossil fuels is increasing global warming and continuing the exploitation of natural resources. As a result, the effects on migrations, not only of animals but also people, can be observed [58].

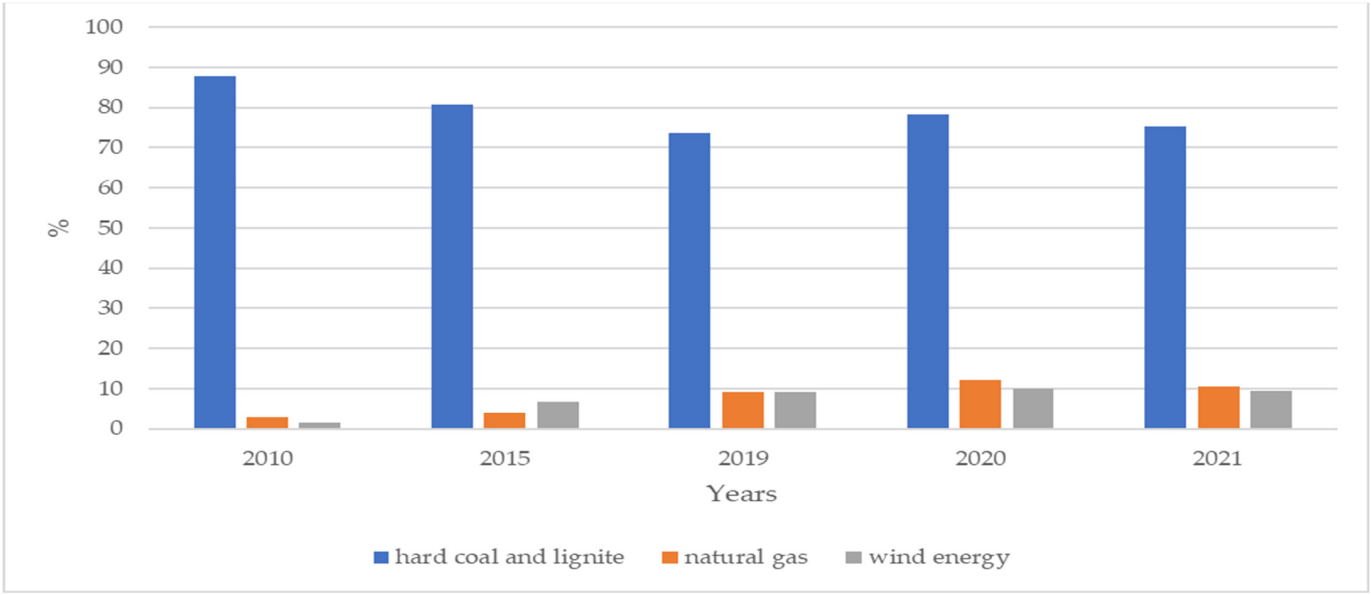

Figure 3. The structure of electricity production in Poland in 2010–2021 (%)**. Source:** own elaborations based on [44].

Wind energy and natural gas increased their share of electricity production in Poland from 2010–2019. However, Poland belongs to the European Union and this region has had problems with the energy markets. The problems occurred not only in the EU but also in Asia, where such countries like India had low market volatility and low carbon sources for energy generation [59].

The COVID-19 pandemic impacted the energy sector, too. The mobility of people decreased during lockdowns and economies shrunk. The changes resulted in a 50% reduction in the demand for transportation, resulting in global crude oil price reductions. Moreover, the inter-continental trade from China to Europe and other countries decreased, causing a decrease in technologies being imported [60].

Poland is increasing installation capacity from renewable energy sources. The biggest capacity was installed in 2020 from wind energy (6347.1 MW) and biomass installation (1512.9 MW), and the smallest in biogas (255.7 MW) and hydro energy installation (976 MW). The installed capacity increased in all sectors. The largest increase was from solar energy installations. This was due to the development of photovoltaic (PV) and changed regulations for consumers. Large increases in RES came from installations of wind energy, a 438% increase in 2020 compared to 2010, and for biogas production with an increase of 208% (Table 2).

Table 2. Power of installed capacity in Poland (MW).

Year	Power Installed in Poland [MW], as at 31 December 2020				
	Installations Using Biogas	**Installations Using Biomass**	**Installations Using the Energy of Solar Radiation**	**Installations Using Wind Energy**	**Installations Using Hydropower**
2010	82.884	356.190	0.033	1180.27	937.044
2011	103.487	409.680	1.125	1616.361	951.390
2012	131.247	820.700	1.290	2496.74	966.103
2013	162.241	986.873	1.901	3389.541	966.103
2014	188.549	1008.245	21,004	3833.832	977.007
2015	212.497	1122.670	108.00	4582.036	981.799
2016	233.967	1281.065	187.25	5807.416	993.995
2017	235.373	1362.030	287.09	5848.671	988.377
2018	237.618	1362.870	561.98	5864.443	981.504
2019	245.366	1492.875	1539.26	5917.243	973.095
2020	255.699	1512.885	3954.96	6347.111	976.047
Changes 2010 = 100%	208.5	324.7	11,984	437.8	4.2

Source: own elaborations based on [44].

The solar system helps the photovoltaic system (PV) to produce energy. The photovoltaic (PV) and wind installations are becoming more popular not only in Poland but also in the EU and around the world. These kinds of energy help to decrease the use of fossil fuels and carbon dioxide emissions (CO_2). Moreover, these kinds of energy installations are based on small microgrid systems, which can be easily adjusted to local conditions [61]. The microgrid systems also have difficulties in implementation because of power quality, voltage, sustainability and other factors [62]. However, microgrids have more advantages because they can reduce greenhouse gas emissions and deliver cheap, clean, and reliable power [63]. The investment in microgrid installation can reduce the costs of electricity and increase comforts for customers [64].

Even though the development of RES has increased, this sector has still had a number of challenges. The operation of solar projects had supply disruptions. Different categories of solar had problems worldwide; however, the biggest issues were observed in rooftop solar systems [65].

However, the COVID-19 pandemic had an influence on the whole energy and renewable energy sector. Jobs were put at risk and the unemployment rate increased. The energy companies met the barrier of demand for electricity [66]. The increase of RES in Poland and other countries of the European Union are due to climate and energy policy goals of the EU, which are directed at greenhouse gas reduction by 55% in 2030, compared to 1990 [46].

As we can see from Table 2, the power capacity in Poland is increasing. This situation suggests that we cannot rely on coal and lignite because they are detrimental to the environment. Moreover, the high health aspects of raw materials are obstacles to their development [67].

4.2. Electricity Production in Poland and the EU

Electricity production is a key issue in the development of energy sectors worldwide. The development of the energy sector depends on policy, consumer needs and modern technologies. Moreover, the development of energy systems depends on its efficiency, investments and renewable energy sources [68].

The demand for electricity is increasing. It is an important input for the development of the economy. It is used in almost all kinds of human life, for example in industry, services, agriculture, heating and transport [69]. Another important issue is electricity consumption prediction. It helps to adjust facilities and energy industry to increase demand. Energy

supply is important for not only consumers households, but also for communes and whole countries and regions [70].

The production of electricity in Poland is stable and it ranged from 157.7 TWH in 2010 to 163.5 TWH in 2019. However, the biggest electricity production was in 2017—170.5 TWH and 2019—170 TWH (Figure 4).

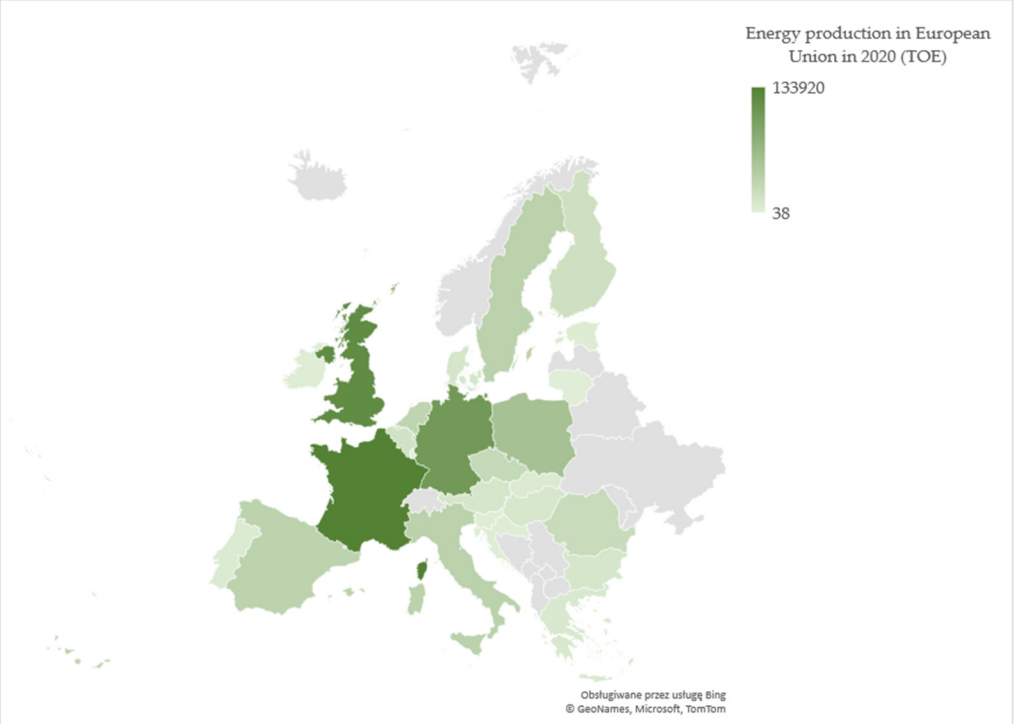

Figure 4. Energy production in European Union countries in 2020 (TOE). Source: own elaborations based on [43].

At the beginning of COVID-19 electricity production decreased as the effect of lower energy demand. This led to big problems with power installation and energy markets, which suffered from continuous changes. As we can see from Figure 5, the production of renewable energy decreased in 2019–2020. Then, in 2021 the production increased as recovery of the energy markets from the COVID-19 crisis; consumption, for example, is similar to production and in 2021 it was 174.4 TWH, which is a little bigger than production. The deficit was overcome by importing energy from Ukraine.

Analysis of the structure of electricity sources presented in Figure 6 prove that the most important source of energy in Poland is hard coal (44.3%) and lignite (24.4%). The following positions are taken by renewable energy sources, such as wind power installations (13.6%), natural gas (7.6%) and photovoltaic power plants (5.2%). These results are quite promising, and they point out that Poland has the chance to be a leader in RES and transform its energy economy into one using modern renewables.

The smallest share in renewable energy sources was gained by gas from coal seams, hydroelectric power plants and pumped storage power plants. This is because Poland does not have its own technology and has to import it from other EU countries and across the world. Moreover, Polish consumers are not fully convinced about the new technologies and their installation requires higher inputs on investments (Figure 6).

The effect of selected variables on the production of electricity from RES are presented in Table 3. The production of electricity from RES was the explained variable. The explanatory variables are in the Materials and Methods section.

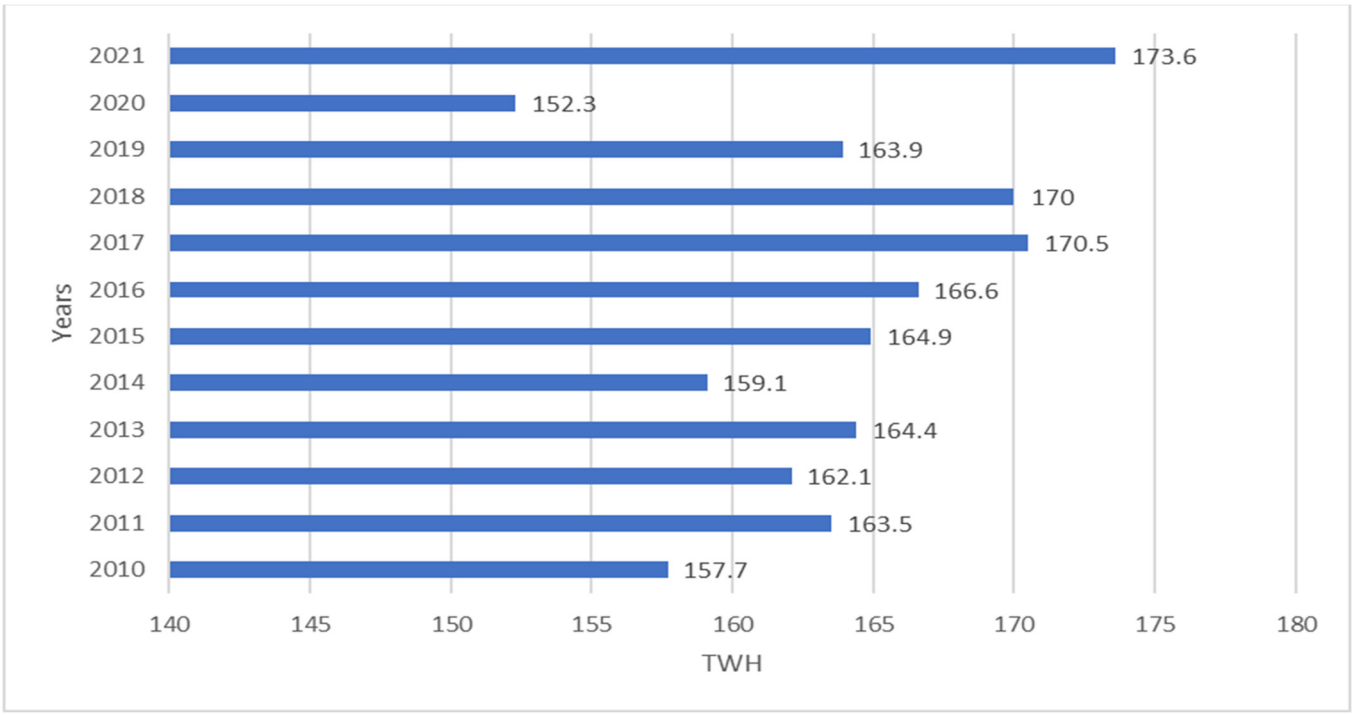

Figure 5. Electricity production in Poland in 2010–2021 (%)**. Source:** own elaborations based on [44].

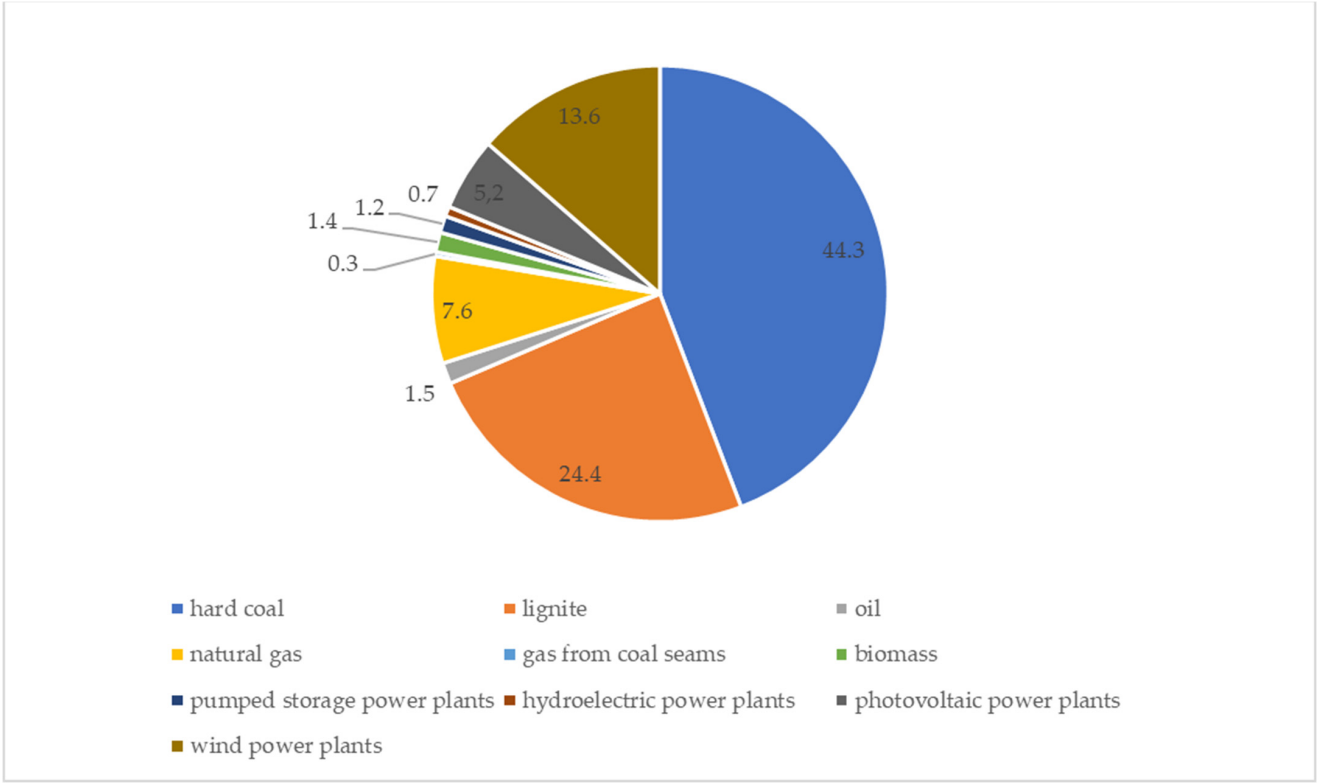

Figure 6. Structure of electricity production sources in Poland in 2022 year (%). **Source:** own elaboration based on [71].

Table 3. Results of the multiple regression analysis investigating the relationship between the dependent variable Y_1 (electricity production from renewable energy sources) and the explanatory variables.

	Coefficient	Std Error	Student's *t*-Test	*p*-Value
Intersept	−3.229	1.253	−2.628	0.046
X_1—Installations using biogas	−6568.65	12765.2	−0.514	0.628
X_2—Installations using biomass	−880.39	1018.7	−0.864	0.427
X_3—Installations using the energy of solar radiation	905.72	109.9	8.242	0.000
X_4—Installations using wind energy	−36.11	371.12	−0.097	0.926
X_5—Installations using hydropower	35,998.6	13643.2	2.639	0.046
Arithmetic means of the dependent variable	257,487.3	Standard deviation of dependent change		790,048.4
Sum of squares of residuals	2.77	Standard error of residuals		235,513.2
R-squared determination coefficient	0.955	Corrected R-square		0.9111
F(9, 197)	21.506	The *p*-value for the F-test		0.002
Likelihood logarithm	−147.35	Critical Information Akaike criterion		306.673
Critical Bayesian Schwarz criterion	309.060	Critical Hannan–Quinn criterion		305.168

Source: own elaboration based on [44].

As we can see from Table 3, the most important variable was X_3—installations using the energy of solar radiation and X_5—installations using hydropower. The results demonstrate that electricity production from renewable energy sources depended mostly on these factors. The developed model fitted the data well, as evidenced by a high R^2 ($R^2 = 0.91$; $F = 21.506$). Table 3 indicates that 91% of the variations of energy production are caused by independent variables. The F-statistics demonstrate a highly significant level for the model. Based on the equation, investment in solar energy will cause 1,47 TWH in Poland. Moreover, investments in installations using biogas will cause 1.15 TWH in Poland.

The regression equation is as follows:

$$Y_1 = -3.229 + -6568.65X_1 - 880.39X_2 + 905.72X_3 - 36.11X_4 + 35998.6X_5$$

The model explains the development of electricity production from renewable energy sources in Poland. Biomass, which has the biggest deliver of electricity, did not have such impact. The trend with the use of biomass will change, its share will decrease, whereas the share of energy from wind and photovoltaic will increase. Hydropower installations, which are also important, will not play a decisive role in Poland as its share in energy production is small.

The choice of model was carried out based on data analysis. We did three tests to analyze the model: the Durbin-Watson test, the White test and the Breush-Pagan test. The test results are presented in Table 4. Based on the research results from Table 4, we cannot reject the null hypotheses of these tests. The null hypothesis in the Breusch-Pagan test is about the lack of differentiation of individual effects and cannot be rejected. The *p* values for three tests are quite high.

Table 4. Results of the tests for the model.

Tests	Explained Variable-Electricity Production from Renewable Energy Sources	*p* Value
Durbin-Watson test	2.56645	0.213
White test	11.000	0.357
Breusch-Pagan test	3.343	0.647

Source: own elaboration based on [44].

5. Discussion

Renewable energy sources are future energies, which has an influence on the EU economy. In the 21st century, the world faced many challenges including important events like the COVID-19 crisis, and the war between Russia and Ukraine. Research showed that the COVID-19 crisis caused a decrease in the use of fossil energy and renewable energy in the European Union [41].

The effect of the COVID-19 crisis resulted in decreased levels of air pollution. However, the lockdown had a negative impact on the economy and health levels of society. The use of fuels and other sources of energy decreased, causing a drop in climate contamination. Conversely, the relaxation in lockdown increased pollution emissions to the environment [54].

The Polish and European Union system is based on emission trade. Energy companies should have green certificates, which confirm property rights and support the production of energy from renewable energy sources [19].

The Polish energy system is undergoing changes from a command-and-control economy to a free market economy. However, the economy transformation caused both unemployment and energy consumption to increase. The fossil fuel market is declining because of requirements of the European Union, with the focus on creating a carbon-free economy by 2050. The COVID-19 crisis and the war between Russia and Ukraine deepened the problem of energy shortage. Renewable energy sources are an opportunity for the Polish energy sector because the coal sector is inefficient to meet demand. The cost of importing coal from Russia was lower than Polish production.

The development of RES and its share in energy production depends on policy makers. They should take into account all aspects of the development and the state of infrastructure, including lines and buildings. Local government should consider social consultancies, which help to define the problem and generate better solutions. Sustainability should be a priority and investment in renewable energy sources should be linked with innovations transfer.

Another important issue with the development of RES and their impact on electricity production is the importation and transfer of technologies. The innovative technologies must be adjusted to local conditions, which can be a problem. Moreover, the reduction of financial support for the mining industry may cause a lower use of hard coal and lignite, enhancing the need for electricity from more renewable energy sources.

Our research showed the key role of investments in developing renewable energy sources. Wind and photovoltaic will play a major role in energy production in Poland. The share of RES from biomass will decrease. Hydropower installation will fill the gap in the energy mix in Poland.

6. Conclusions

The Polish coal industry is undergoing crisis because of the policy of the European Union forcing the common market to introduce a carbon free environment. The sector needs the necessary investment, but the European Union is going to be a carbon free market by 2050. The problem will be solved by replacing carbon mines by renewable energy sources and nuclear energy [72–74]. A very important role will be played by agriculture, which delivers both biomass and biogas, but also leads to environmental degradation [75].

The results of the present study indicate that significant changes in the development of RES in the EU have occurred. Moreover, the COVID-19 crisis led to a reduction in demand for renewable energy sources with the drop in economic growth [48].

At the beginning of the COVID-19 crisis, the EU and the world observed a positive environmental impact globally because of the lower emissions of greenhouse gasses. The lockdown during COVID-19 positively impacted the environment [55]. However, the COVID-19 pandemic had negative impacts on both the health sector and the economy. Future policies should be characterized by financial support to reduce the negative effects of pandemics and to harmonize human existence with nature. The policy should include an

holistic approach with different strategies, such as reducing the use of cars and promoting e-mobility and a low-carbon environment [60].

Our research showed the need for the continued development of renewable energy sources in Poland and other countries of the European Union. However, Poland still depends on fossil fuels, such as hard coal and lignite. The expanded analysis shows that the biggest share of energy production is still from hard coal (44.3%) and lignite (24.4%). Additionally, renewable energy sources are playing a more important role because the share of wind power is 13.6% and photovoltaic 5.2%.

The results of the regression analysis show that the coefficients of X_3—installations using the energy of solar radiation and X_5—installations using hydropower, were positive, showing that they are driving forces in the production of electricity from renewable energy sources. Based on these results we can recommend that the drivers of electricity production from RES should increase economic growth.

The installations in RES are developing well but the pace is not sufficient to cover the deficit in electricity production. RESs can fill in production deficiencies but the pace of their development should be faster. The investment in installations using the energy of solar radiation and installations using wind energy should be increased.

Our research also has implications for policy makers. For example, the photovoltaic installation obstacles should be eliminated. Next, a cost reduction should be implemented. The installation of a 10 MW system for household use is about PLN 40,000. This is too large a cost for the average family, which struggles with economic crisis. The next challenge to be solved with policy changes is energy storage from photovoltaics. The energy system is not prepared for storage, and energy is currently gathered by a national company. A policy promoting the local storage of energy from PV and other RES should be established.

This work analyses the impact of installations of RES on the production of electricity from these sources. Our research proved that the investment in renewable energy power installations helped to increase electricity production. Hypothesis 1, assuming that the share of renewable energy sources production in Poland have improved after accession to the EU, has been positively verified. Poland and other countries of the EU were obliged to increase the share of electricity production from RES. Until 2020, Poland had to reach 15% of renewable energy use in total energy. Poland fulfilled its obligations and reached the level of 16%.

Hypothesis 2, assuming that the EU policies support the development of renewable energy sources in Poland, which has a positive impact on clean energy production, has been verified. The EU and the national government of Poland is providing support for renewable sources installation, which creates demand for these energy sources.

This research also has limitations. The most important is the problem with access to the newest statistical data. The problem with access decreases the efficiency of this research and limits the possibility of other discoveries. Other limitations can be the problems with COVID-19 pandemic assessments. All the literature proves its negative impact on societal health and the economy, but no current research directly examines the impact on the energy sector.

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Nomenclature

°C	Degrees Celsius
CAP	Common Agricultural Policy
CO_2	Carbon dioxide
EU	European Union
GDP	Gross Domestic Product
PEP	Polish energy policy
PV	Photovoltaic
PLN	Polish currency zloty
RED	Renewable energy directive
RES	Renewable Energy Sources
UK	United Kingdom
USA	United States of America

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