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Development of Solid Biomass Production in Poland, Especially Pellet, in the Context of the World's and the European Union's Climate and Energy Policies

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Abstract: The aim of this research was to present the changes in biomass production, especially pellets in Poland, in the context of world's and European Union's (EU) climate and energy policy, compared to other renewable energy sources. We also analyzed the law concerning the biomass production in the EU. Finally, we have elaborated the prognosis of the pellet production on the world scale. We have used different methods to achieve the goals, among which the most important are the Generalized Autoregressive Conditional Heteroscedasticity (GARCH model) and prognosis. We also compared the results of pellet production in different countries in the European Union. The results were presented in tabular and graphic form. We have received the data from Eurostat and the Main Statistical Office (MSO) in Poland. Our research proves the increase of biomass and pellet production on the global scale. Moreover, global wood pellet production increased by 972% in the years 2005–2018. We can conclude that this increase was the result of increasing demand for renewable energy sources. The first research hypothesis assumed that the changes in the European Union Policy have impacted the increase of biomass production in the world. Our prognosis confirmed the second hypothesis that the development of pellets will increase as the result of increasing global demand. The use of more renewable energy sources is necessary to decrease the degradation of the environment.

Keywords: biomass production; pellet production; Poland; climate and energy policy; renewable energy sources

1. Introduction

In 1997, the European Council and the European Parliament adopted the "White Paper for a Community Strategy and Action Plan". It is worth mentioning that the share of renewable energy sources (RES) in gross internal energy consumption in the EU in 1997 was 6%. Then, the EU proposed an integrated Energy and Climate Change package in 2007. Moreover, in 2009, the EU established the Renewable Energy Directive (RED) promoting renewable energy sources. As a result, the EU established a goal of a reduction of 20% of

GHG emissions by 2020 compared to 1990, the increase of energy efficiency, and a 20% target of RES in final energy use, including 10% for biofuels [1]. Another goal in the energy policy is energy security, which is an important issue not only for countries and regions, but also for consumers [2].

The problems of climate change and pollution can be improved by renewable energy sources. Moreover, fossil fuels pollute the environment and contain substances that are hazardous for human health. The data from Eurostat [3] confirmed that renewable energy sources accounted for 17.5% of final energy consumption in the European Union in 2018 [4]. Biomass is the main source of renewable energy and it is produced mainly in rural areas. It also has a positive impact on the economic situation of farmers and forest owners [5].

Biomass is the largest potential source of energy in the world, including Poland [6]. The energy obtained from biomass accounts for 15% of the world's energy consumption, and it varies greatly depending on the country, ranging from 2–3% for developed countries and about 35% in the developing countries [7,8]. Biomass is everything that exists on Earth in the form of organic matter, all biodegradable substances of plant or animal origin. Biomass is left over from agricultural production, forestry residues, and industrial and municipal waste [9].

The main source of biomass is agriculture. Biomass can be a product from plant and animal production. It contains cellulose, hemicellulose, lignin and other ingredients. It contains major organic components useful in the production of fuels and chemicals [10]. Biomass in the literature is described as the whole organic matter that is biodegradable, including waste products from agriculture and other sources [11]. The surplus of biomass in agriculture can be considered an energy source. The vast majority of biomass is used in agricultural production. Poland, as well as Europe, are considered to be major sources of biomass [12]. Agriculture is also an energy consumer. The reduction of energy demand in agriculture can be achieved by optimizing "agricultural operations and deploying production technologies that are best suited to the cultivated crops and local conditions" [13,14]. Agricultural biomass is the key substrate in the production of solid biomass and first-generation biofuel [15–19].

Energy security is an important issue worldwide. It can be described as the availability of energy in any time and in different forms. It can have internal and external characteristics [20,21].

Biomass is a major source of renewable energy in the world. Particular attention was paid to solid biomass (woody biomass) that can be generated directly from harvest [22].

The differences of biomass and the possibility of its processing mean that it can be useful for energy production, mainly in local factories [23,24]. Biomass is the main source of renewable energy used for heat production, electric energy, and transport [25]. The most important producers of biomass are agriculture and forestry. Biomass includes biodegradable fractions of different products [26].

Biomass is processed into different products such as pellets and briquettes, and can be delivered worldwide [27]. One of the most important products from solid biomass are pellets. The market for pellets began in the 1980s. Not all countries entered the market at the same time. Some countries, for example, Poland, entered the market 15 years later. This had an impact on the state of the development of the market, which is not mature in many countries [28].

The improvement of energy security, reduction of greenhouse gases (GHG), and lower levels of fossil fuel usage can change the European economy into a more bio-based economy that will help to better manage natural resources and environmental benefits [29].

The largest region that influences world environmental policy is the European Union. The modern European Union (EU) is the only existing group of states that have arisen in the process of regional economic and environmental integration, which is near the stage of full integration [30]. The EU environmental policy must consider the diversity of environmental problems in different regions of the European Union.

In general, the range of instruments for the environmental direction of European policy has significantly expanded in recent years [31].

The aim of the paper was to present the changes in solid biomass utilization in Poland in the context of world and European environmental protection policies, especially pellets. To achieve this goal we needed to answer following questions:

1. What is the renewable energy mix in Poland, the EU, and the world?
2. What is the state of law concerning the renewable energy sources?
3. What is the prognosis of pellet production in Poland and the world?

From the literature and methods we have withdrawn the following hypotheses:

Hypothesis 1 (H1). *The changes in European Policy have impacted the increase of biomass production.*

Hypothesis 2 (H2). *The development of pellets will increase as the result of increasing global demand.*

The rest of the paper is organized as follows. We present a Literature Review pointing out the renewable energy regulations including the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement. Then, we present Materials and Methods, and Research Results with Discussion. The final part contains Conclusions.

2. Climate and Energy Policy

2.1. United Nations Framework Convention on Climate Change (UNFCCC)

The problem of climate change was first included in the political agenda of the international community in the mid-1980s. Scientists from different countries drew their first conclusions about the relationship between climate change and human activity. It was ratified by 195 countries [32]. The problem of climate change is global. The concern about the environment forced national governments to undertake actions to reduce the emission of greenhouse gases [33]. Climate change is becoming a priority issue [34]. Only policy intervention can reduce the crises that can be created by climate pollution [35].

The Convention was opened for signature on 4 June 1992 at the United Nations Conference on Environment and Development held in Rio de Janeiro, and came into force on 21 March 1994.

Currently, more than 190 countries are parties to the Convention. It was the first attempt to cap carbon emissions [36]. This includes all industrialized countries, all countries with economies in transition, and most developing countries [37].

2.2. The Kyoto Protocol

The further process of developing an international agreement on climate change refers to December 1997, when the Kyoto Protocol was adopted by delegates from more than 160 countries. The main provisions of the Kyoto Protocol included the determination of the permissible amount of greenhouse gas emissions in 2008–2012 for all industrialized countries participating in this agreement.

Over recent years, 55 million tons of gas emissions were sold in deals. In 2005, the European Union introduced the system of trade in quotas. After exiting the Kyoto Protocol, Russia, which generates 17% of gross greenhouse gas emissions, has become one of the largest suppliers of emission permits [38].

Since different countries had different degrees of interest in implementing the Kyoto Protocol, its ratification faced serious obstacles. In March 2001, the United States announced its decision not to participate in the Kyoto Protocol, and its ratification was threatened. The US position, in particular, was voiced at the UN conference on climate change in Buenos Aires in 2004, where the head of the US delegation, Harlan Watson, stated: “The Kyoto Protocol is not a scientific document, but a political one, so we are not going to participate” [39,40].

2.3. Post-Kyoto System of International Relations

The negotiations on a new post-Kyoto agreement for the period after 2012, that began in 2007, was unprecedented for the complexity and difficulty of problems covered, and the impact on the economic development of individual countries and humanity as a whole.

In August 2009, another round of international climate talks took place in Bonn (Germany). Negotiations in Bonn were carried out within the framework of two working groups. The first group, working under the aegis of the United Nations Framework Convention on Climate Change, was preparing a new text for the post-Kyoto agreement. The second action was a discussion of the possible extension of the Kyoto Protocol for the second period and the commitments of developed countries after 2012. Negotiations in Bonn were held in the form of informal meetings, focusing on convergence of the positions of the two groups in agreeing on a single text for the future agreement [41,42].

2.4. Paris Agreement

The implementation of the 2015 Paris Agreement requires support of the development of renewable energy not only in the EU, but also worldwide. The EU is playing an important role in the decarbonization of the EU according to the Paris Agreement [43]. The EU is trying to keep the rise above two degrees of Celsius below levels [44,45]. The legal norms play a key role in energy security. The energy policy is regulated by numerous documents and laws [46].

3. Materials and Methods

3.1. Data Sources

We used different sources of information. First, we presented the gross energy availability from solid biofuels in the EU. Further, we have examined the share of individual renewable energy carriers in obtaining energy from renewable sources in 2005–2018 in Poland. In the research section, we have also analyzed the changes in pellet production in the world and the EU. The sources of information were data obtained from Eurostat and Statistics Poland. We also used the Global Status Report 2019 to analyze the changes in RES in the world.

3.2. Methods

To analyze the changes in pellet production, we used the Augmented Dickey–Fuller test (ADF) to determine if the pellet production is non-stationary [47].

Finally, we calculated Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models that were elaborated by Engle [48] and Bollerslev [49] to analyze time series.

One of the most important applications of GARCH models is the description and forecasting of volatility, understood as a measure of uncertainty. In the case of GARCH models, such a measure of uncertainty is conditional variance or conditional standard deviation. GARCH models are the most commonly used models of variation. This is primarily because they allow the description of most of the empirical properties of the analyzed time series. In order to avoid problems related to the estimation of parameters of the ARCH model, the GARCH model is used. The GARCH model has all the advantages of the ARCH model, and also describes the variability of most time series better [50].

The models are widely used for risk management, and they can capture both volatility clustering and unconditional return distribution [51]:

$$\sigma^2{}_t = \alpha_0 + \alpha_1 y^2{}_{t-1} + \beta_1 \sigma^2{}_{t-1}. \tag{1}$$

In the GARCH notation, the first subscript refers to the order of the y^2 terms on the right side, and the second subscript refers to the order of the σ^2 terms [44]. The GARCH is used to analyze conditional variance. The process of variance is not stationary [51]:

$$y_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i y_{t-i} + e_t \tag{2}$$

$$e_t|\psi_{t-1} \sim t(v,\ 0, h_t) \tag{3}$$

$$h_t = \alpha_0 + \alpha_1 e_{t-1}^2 + \beta_1 h_{t-1} \tag{4}$$

where ψ_{t-1} denotes series history up to time $t-1$, $t(v,\ 0, h_t)$ is a Student t distribution with v degrees of freedom $(v > 2)$, and h_t is the conditional variance. Given the regularity conditions, $\alpha_0 > 0,\ \alpha_1 \geq 0,\ \beta_1 \geq 0$, the required stationarity condition is $\alpha_1 + \beta_1 < 1$. Additionally, due to the presence of autocorrelation, the roots of the polynomial $z^p - \varphi_1 z^{p-1} - \varphi_2 z^{p-2} - \ldots - \varphi_p = 0$ lie inside the unit circle. According to the GARCH models, the residual depends on the previous period's mean and variance [51]. The GARCH model can satisfactorily explain the volatility of an analyzed series [52].

The authors of the paper limited the analysis to the class of models AR (1)—GARCH (1,1) because it was dictated in previous research, as well as the fact that in most of the cases analyzed in the literature on the subject, process order selection autoregression at the AR (1) level and the GARCH process at the GARCH (1,1) level are sufficient to capture the autoregressive effect and heteroscedasticity [50,53].

We could not use the threshold GARCH (TGARCH) model because the defined conditional variance was not a linear piecewise function [54].

4. Results

4.1. Pellet Production in the World

The global supply of biomass was 55.6 EJ in 2018. Solid biomass plays an important role and constitutes 47.6% of total biomass. The solid biomass mainly includes wood chips, wood pellets, and traditional biomass sources. The next positions in biomass mix are taken by liquid biofuels (3.98%), municipal and industrial waste (1.45%), and biogas (1.36%) (Table 1). Such structures demonstrate the strong position of solid biomass in the energy mix [55]. A global increase of biomass was observed in 2005–2018. The biggest increase was observed in liquid biofuels (355.2%), biogas (166.70%), and industrial waste (151%). The solid biofuels recorded the smallest increase (11.20%) in the period.

Table 1. The supply of biomass globally in 2005–2018 (EJ).

Years	Total	Municipal Waste	Industrial Waste	Solid Biomass	Biogases	Liquid Biofuels
2005	45.60	0.96	0.45	42.80	0.51	0.87
2010	50.50	1.18	0.77	45.10	0.85	2.53
2015	53.20	1.38	0.90	46.20	1.29	3.45
2016	54.30	1.42	1.04	46.90	1.30	3.58
2017	54.90	1.44	1.07	47.30	1.33	3.72
2018	55.60	1.45	1.13	47.60	1.36	3.98
Change 2005–2018 (%)	21.90	51.00	151.00	11.20	166.70	355.20

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

The growth forecasts for renewable energy investments in the next 10 years are very optimistic. It is even estimated that the renewable energy market will be one of the fastest growing energy sources in the world, and its impact will be cross-sectoral [56].

According to Rokicki [57], the most important obstacles in production of renewable energy sources are the high costs of installation. Another obstacle can be the high investment cost in production facilities [58].

The growth for renewable energy is a consequence of economic development. Forecasts expect the demand for energy will increase in accordance with the population growth, automation, and modernization. The global demand for energy will increase worldwide about 1.6% each year. Renewable energy sources are very important in satisfying future demand for energy. These energy sources are emission-free and they contribute to worldwide power with fewer emissions of greenhouse gases (GHC) [59]. The concentration of greenhouse gases in the 21st century caused a rapid rise in the global temperature. Coal-fired power stations are considered to be the source of the pollutants. Most were built two decades ago and are responsible for 80–85% of pollution [60].

Renewable energy sources contribute to sustainable energy development worldwide, which include economic, technical, political, and social factors. Economic factors are linked to regional economic development. Technical factors indicated that the development of renewable energy sources will require new technologies. The political factors are the effects of policy solutions. Social factors are focused on social resources and ecological awareness [61]. To meet the environmental protection concerns, it is necessary to invest in renewable energy sources. These investments can help reduce greenhouse gases and increase energy security [62]. The renewable energy sources can replace fossil fuels that are estimated to be depleted in less than 50 years, and are responsible for most of greenhouse gas emissions [63].

As we can see from Figure 1, global wood pellet production has increased from 5.2 MMT (million metric tons) in 2005 to 55.7 MMT (million metric tons) in 2018. The increase reached 971% in the period. Such an increase is the effect of the increasing demand for renewable energy sources in the world.

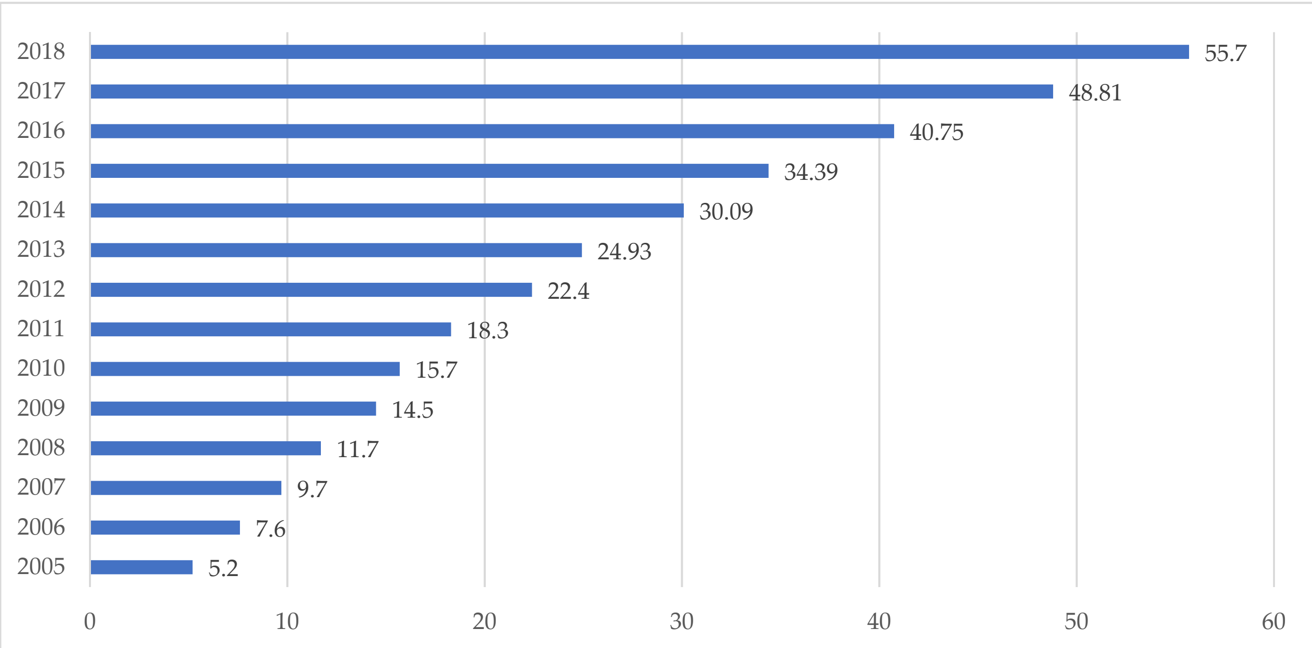

Figure 1. Global wood pellet production MMT (million metric tons). Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

4.2. Gross Energy Availability from Solid Biofuels in the EU

The policies concerning climate and energy in the European Union encouraged the development of renewable energy sources including biomass, biogas, and others. The basic benefits include support schemes for renewable energy sources. Moreover, using RES delivered economic and environmental benefits [1]. Each country of the EU included bioenergy policy in environmental policy. Furthermore, the production of biomass is also linked to agricultural policy [64].

Biomass is an organic substance created in the process of accounting solar energy [6]. Biomass also includes processed forms, such as pellets and briquettes [65]. Poland ranks seventh in terms of gross energy availability from solid biofuels in the EU (approx. 6.2 Mtoe) (Figure 2)

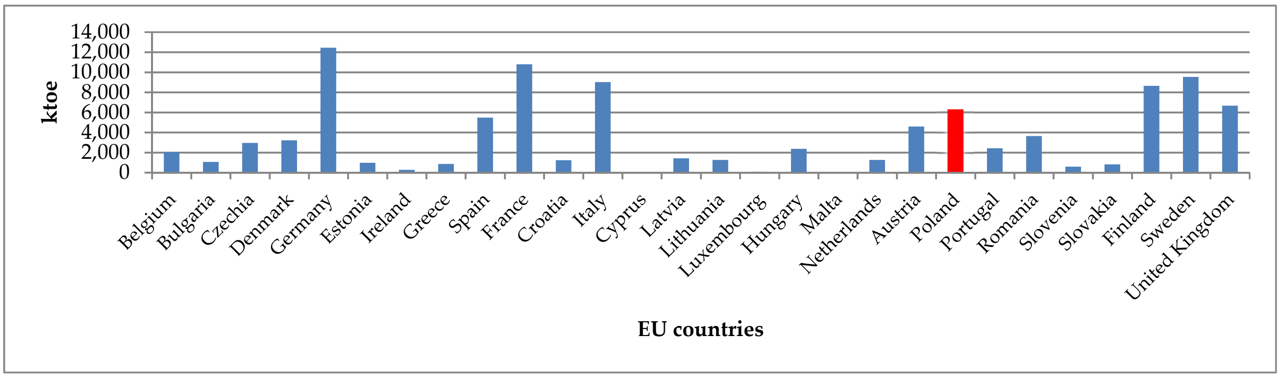

Figure 2. Gross energy availability from solid biofuels in the EU, 2017 (ktoe). Source: Eurostat. Own elaboration based on www.ec.europa.eu (accessed on 11 June 2021).

In 2017, the production of basic energy from renewable sources in the EU-28 amounted 226.5 million tons of oil equivalent (toe). Compared to 2004, this is an increase of 66% in the amount of renewable energy produced in the EU-28, which corresponds to an average annual increase of 4.7% [66].

Among renewable energy sources in the EU-28, the most important source is wood and other solid biofuels, which accounted for 42% of primary renewable energy production in 2017. Wind energy is on second place in terms of share of the renewable energy mix (13.8%), followed by hydropower (11.4%). Biogas accounts for 7.4% of the share in the production of energy from renewable sources, liquid biofuels were 7.4%, and solar energy was 6.4%. The thermal energy of the environment (captured by heat pumps) was 5%, geothermal energy was 3%, and the share of renewable waste increased to 4.4% [67].

In recent decades, the development of renewable energy sources (RES) has become one of the main goals of the energy policy of the EU countries, including Poland, where biomass receives special attention [64].

The decreasing energy sources of fossil raw materials and the need to reduce greenhouse gas emissions, especially CO_2, indicate the need to use RES [68].

The independence of the economy from fossil fuels and the reduction of greenhouse gas emissions are the main reasons for introducing renewable energy sources. Self-combustion of coal causes a significant deterioration of air quality through the emission of toxic substances such as SO_2, NO_2 and CO_2 [69].

Combating climate change and the desire to reduce CO_2 emissions and other harmful gases have made the EU's policy of counteracting the increase in pollutant emissions a priority task. As a result, a number of EU industry policies were subordinated and a common agricultural policy was launched, which is responsible for the functioning of the agricultural sector to support renewable energy. It has been contractually assumed that renewable fuels for the purposes of the climate package have zero emission [70].

Biomass requires considerably less investment than other types of renewable energy to produce a unit of energy. In economically developed countries, there is an over-production of food products, thanks to which, it is possible to use a part of agricultural land for the production of biomass for non-food purposes. Biomass is a solid fuel that can be stored compared to wind or solar energy. Creation of a new direction of agricultural production creates new jobs in agriculture and its surroundings, and increases agricultural income which stimulates the development of local industry and rural areas [71].

Renewable energy sources have lower emission of hazardous substances. The modern concept of bioeconomy includes the production of biofuels and other renewable energy sources [72]. Solid biomass is mainly used for heat and electricity, whereas biofuels can be used in transport.

Solid biofuels account for 44.6% of all RES consumed in the European Union and are the main source of clean energy [73,74]. Solid biomass is a very important stock for the production of heat and electricity (Table 2). Total gross heat production (ktoe) produced from solid biomass achieved the biggest increase (151.2%), the next highest was gross electricity production (100.6%) and gross inland consumption (49.3%). The smallest increase was achieved by primary energy production (43%).

Table 2. The production of heat and electricity from solid biomass in EU in the 2005–2019 (all plants).

Year	Total Gross Heat Production (ktoe)	Gross Electricity Production—CHP Plants (GWh)	Primary Energy Production (ktoe)	Gross Inland Consumption (ktoe)
2005	2844	29,891	67,757	68,715
2006	2882	33,837	69,423	70,950
2007	3089	34,642	72,889	74,202
2008	3373	37,373	76,795	78,127
2009	3535	41,275	79,507	81,460
2010	4786	46,932	86,238	89,016
2011	4585	49,146	82,271	84,851
2012	5432	53,202	88,845	91,188
2013	5794	49,878	90,616	93,761
2014	5723	51,225	87,341	91,211
2015	5803	50,557	91,881	95,586
2016	6276	54,269	93,662	98,183
2017	6603	56,688	64,691	99,592
2018	6771	55,708	95,284	100,371
2019	7144	59,976	96,896	102,596
Changes 2005–2019 (%)	151.2	100.6	43.0	49.3

Source: https://www.eurobserv-er.org/online-database/ (accessed on 11 June 2021).

In 2016, domestic primary energy production amounted to a total of 2,804,263 TJ (terajoules), of which renewable energy from solid biomass amounted to 265,780 TJ, giving a total of 265 petajoules (PJ) [75].

Reflecting the availability and current use of biomass compared to others, as carriers of renewable energy, gives us a picture of the advantage of this raw material over other sources of renewable energy in Poland.

4.3. Gross Energy Availability from Solid Biofuels in Poland

Poland has enormous potential, consisting of forest biomass, agricultural products, extensively used grassland, and special purpose crops as willow and poplar. On the other hand, the main source of biomass is forestry and the wood industry, as well as agriculture—partly derived from by-products and waste [74]. The technical potential of biomass in Poland is estimated at about 900 PJ/year [76].

Due to favorable climatic and soil conditions, Poland is obtaining energy from renewable sources of approx. 70% from biomass [77]. This is much more than the EU average for obtaining energy from biomass as a single carrier from renewable energy sources. Solid biofuels dominate other energy carriers, including the most popular wind energy, overtaking it by almost four times.

In order for biomass to be used in the process of conversion to secondary energy carriers, it is necessary to incur low material and energy expenditure for its acquisition. It can be used to produce heat, transport fuels, or electricity. The use of this raw material is increasing rapidly [76].

Poland's task is to meet the environmental protection requirements resulting from international obligations and agreements. This contributes to the increase in the amount of energy produced from renewable sources, including from biomass. The production of energy from biomass undoubtedly contributes to the reduction of environmental pollution [69].

Directive 2009/28/EC of the European Parliament and of the Council of April 23, 2009, on the promotion of the use of energy from renewable sources, obliges European Union countries, including Poland, to share renewable energy in the final gross energy consumption at the level of 15%. This is lower than the overall EU level (20%) [78]. In Poland, the share of energy from renewable resources in the overall energy balance is still too low, which is a problem [69]. The diversity of biomass and the possibilities of its processing make it ideal for the production of thermal energy, especially on the local market, as part of distributed and cogenerated energy [79].

The use of renewable energy sources in Poland is slowly becoming economically viable. Renewable energy sources in the country could play an important role in the economy, and biomass, especially from agriculture, should play a significant role in this, while contributing to the development of rural areas and agriculture [79].

Solid biomass production is strongly linked to rural areas. Poland is a country with great possibilities for the development of biomass because 93% of the total area is rural. The arable land share is 65% of the country, which shows the possibilities. Moreover, lower quality land including 34% of class V and VI can be used for energy crop production [80].

Finally, we have analyzed the renewable energy carriers from renewable energy sources in Poland (Table 3). As we can see, solid biofuels have the biggest share in Poland in the years 2005–2019. However, the share of solid biofuels decreased 26%, which raises a question about how much of the market will stay in solid biofuels. In the same period, the share of wind energy increased almost 4700%, fluid biofuels 385% and biogas 250%. Water energy decreased its share by −43%.

Table 3. Share of individual renewable energy carriers in obtaining energy from renewable sources in 2005–2019 in Poland. (%).

Specification	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
							%								
Solid biofuels	91.6	90.8	91.1	87.4	85.7	85.0	85.2	82.4	79.8	76.1	74.2	70.6	67.8	68.1	65.5
Solar energy	0.0	0.0	0.0	0.02	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.7	0.9	1.4
Water energy	4.2	3.7	3.4	3.4	3.3	3.6	2.7	2.1	2.4	2.3	1.7	2.0	2.4	1.9	1.7
Wind energy	0.3	0.5	0.9	1.1	1.5	2.0	3.7	4.8	6.0	8.1	10.5	11.9	14.0	12.2	13.7
Biogas	1.2	1.3	1.3	1.7	1.6	1.6	1.8	2.0	2.1	2.5	2.5	2.8	3.0	3.2	3.1
Liquid biofuels	2.6	3.5	2.3	5.4	7.0	6.6	5.8	8.0	8.1	9.1	9.1	10.1	10.0	10.0	10.3
Geothermal energy	0.2	0.3	0.2	0.23	0.24	0.2	0.2	0.17	0.22	0.25	0.24	0.24	0.25	0.3	0.2
Municipal waste	0.0	0.0	0.0	0.00	0.01	0.04	0.4	0.4	0.39	0.45	0.45	0.85	1.01	1.1	1.0
Heat pumps	-	-	-	0.27	0.30	0.31	0.30	0.31	0.44	0.55	0.55	0.58	0.62	2.4	2.6

Source: https://www.eurobserv-er.org/online-database/ (accessed on 11 June 2021).

The data in Table 3 are very optimistic for Poland because problems with energy exists. For example, most of the buildings in rural areas are old and have not been modernized, as well as having poor thermal installation. That is why the usage of biomass for heating rural homes is important [81]. The share of renewable energy sources in the energy balance will increase in Poland as result of requirements and development of the sector [82].

The production of heat and electricity from solid biomass in Poland is presented in Table 4. As we can see, the solid biomass production in Poland increased in the years 2005–2019. The highest increase was observed in total gross heat production (628.3%), gross electricity production (339.1%), primary energy production (149%) and gross inland consumption (158.3%).

Table 4. The production of heat and electricity from solid biomass in Poland in 2005–2019 (all plants).

Year	Total Gross Heat Production (ktoe)	Gross Electricity Production—CHP Plants (GWh)	Primary Energy Production (ktoe)	Gross Inland Consumption (ktoe)
2005	60	1375	4166	4166
2006	63	1822	4326	4324
2007	89	2253	4417	4395
2008	118	3214	4739	4751
2009	233	4691	5190	5190
2010	252	5663	5866	5866
2011	318	6862	6351	6351
2012	450	8552	6988	6988
2013	373	5718	6837	6837
2014	334	7269	6180	6755
2015	297	7069	6597	6884
2016	319	6913	6415	6620
2017	279	3893	6211	6341
2018	320.1	3833	6146.9	6347.2
2019	377	4662.8	6208.4	6596
Changes 2005–2019 (%)	628.3	339.1	149.0	158.3

Source: https://www.eurobserv-er.org/online-database/ (accessed on 11 June 2021).

Solid biomass is the most important source of renewable energy, not only in Poland but also in Europe and the world. Poland has good conditions for the production of solid biomass. It has 2 million hectares of less productive land that can be useful in biomass production. Poland is a major source of solid biomass because the farmland area per person is 0.41 ha., whereas in EU-15 the area is 0.19 ha. Biomass is mainly used for heat production in Poland [12]. It can be used for pellet and briquet production, too. The storage and transport of pellets and briquets have many advantages mainly because of saving time, as well as surface storage and lower costs of transport [83].

Forests play an important role as the pellet source in the process of conversion of woody biomass into conventional. Forests also play an important role in the process of carbon dioxide absorption from the atmosphere. The value of forests can be estimated in its role in culture, tradition, and aesthetic and spiritual values [84]. The proper utilization of forests can improve the sustainable management of this natural resource and also sustainable development of society [85].

However, the development of renewable energy sources meets many obstacles in Poland. The main problem is imports of cheaper biomass from markets outside the EU. Pellets from biomass from Russia, Ukraine, and Belarus are cheaper compared to the Polish production. Moreover, strict requirements of biomass combustion factories including average and long-term contracts are also factors hindering the development of biomass in Poland [86].

The production of biomass in Poland is particularly important in the context of fossil fuel usage. Poland is the second largest EU coal consumer after Germany [87]. Poland, as a country, is an important producer of hard coal (70.7 million tons in 2016) and importer (8.3 million in the same period) [88]. Most of the electricity is produced in Poland from hard coal (92%) and heat (about 89%) [89].

One main product of biomass is pellets. They can be produced both from wood and straw. The data in Figure 3 show that wood pellet production increased from 160 thousand metric tons (TMT) to 1300 (TMT) in 2005–2019. The increase of more than 800% shows the possibility of potential production in Poland.

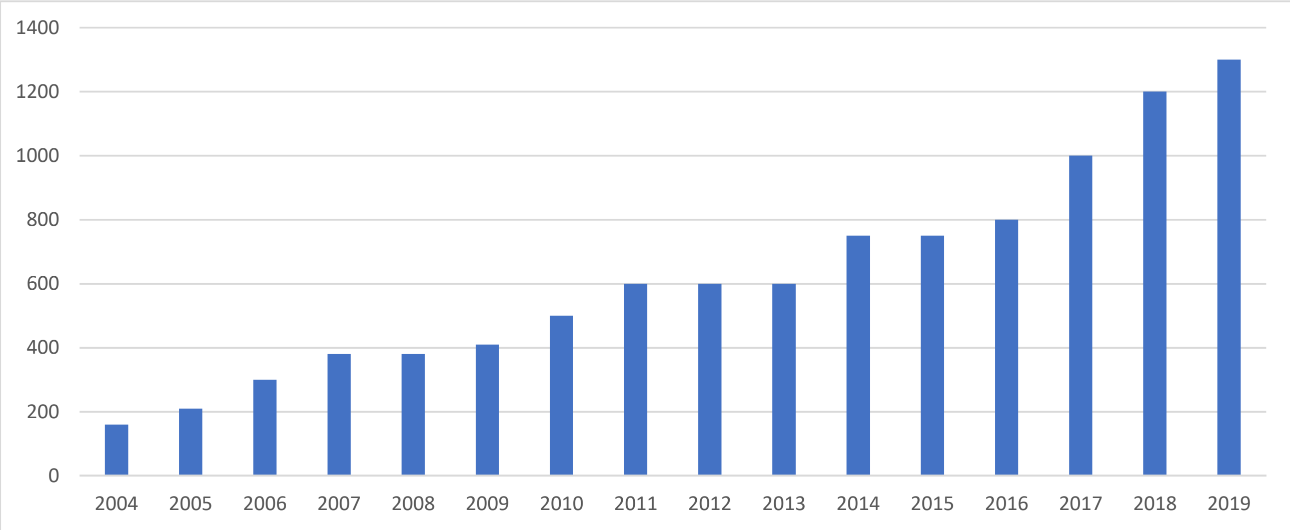

Figure 3. Pellet production in Poland (thousand metric tons—TMT). Source: https://www.eurobserv-er.org/online-database/ (accessed on 11 June 2021).

4.4. Descriptive Statistics of Wood Pellet Production in the World and EU

Table 5 shows the descriptive statistics of global pellet production. As we can see, the coefficient of variation reached a high level of 89.06%. The average global wood pellet production was 18.59 million metric tons.

Table 5. Descriptive statistics of global wood pellet production in 2005–2018 (MMT).

Statistics	Value
Average	18.59
Median	14.50
Minimal	1.70
Maximal	55.70
Standard deviation	16.56
Coefficient of variation	89.06
Skewedness	0.88
Kurtosis	−0.32

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Skewedness and kurtosis measure the asymmetry of the data [51,52]. However, kurtosis is useful in thin tails. For example, in the normal distribution, skewedness describes the extent to which the analyzed distribution is different from the normal distribution. The skewedness was positive, whereas kurtosis was negative.

Europe is a very important producer of renewable energy. However, the production of renewable energy sources are diversified in Europe. Iceland (70.551%), Norway (64.717%) and Sweden (48.446%) achieve the largest average share of renewable energy sources (Table 6). The Eurostat data [4] show that the smallest average share of renewable energy sources was achieved in Malta (3.1353%), Luxemburg (3.8492%) and Netherlands (4.7304%).

Increasing climate change, which goes hand in hand with the increase in population, contributes to air pollution through the use of conventional fuels. This causes a continuous increase in energy demand. The steps taken by the EU offer a chance to improve the situation, as well as the possibility of dealing with research issues and taking appropriate steps to prevent future actions of states in its harmful contribution to the devastation of our planet.

Table 6. Descriptive statistics of share of renewable energy sources in Europe in 2005–2019 (MMT).

Country	Median	Minimum	Maximum	Std. Dev.	Coefficient of Variation	Skewed-Ness	Kurtosis
	15.29	9.63	19.73	3.30	21.89	−0.26	−1.27
European Union 28 countries	14.03	8.56	18.88	3.35	24.06	−0.18	−1.27
Belgium	6.68	1.89	9.92	2.76	44.76	−0.25	−1.39
Bulgaria	14.99	9.09	21.56	4.49	30.24	−0.08	−1.51
Czechia	11.88	6.77	16.24	3.41	29.11	−0.18	−1.55
Denmark	24.43	14.84	37.20	7.53	30.06	0.18	−1.35
Germany	12.99	6.20	17.35	3.34	26.97	−0.34	−0.92
Estonia	25.33	15.97	31.89	5.13	21.29	−0.27	−1.24
Ireland	6.79	2.38	11.98	3.08	45.67	0.10	−1.22
Greece	12.45	7.16	19.68	4.35	34.91	0.13	−1.48
Spain	14.07	8.34	18.36	3.49	25.48	−0.30	−1.31
France	12.97	9.34	17.21	2.63	20.34	0.05	−1.32
Croatia	26.07	21.99	28.97	2.49	9.71	−0.20	−1.53
Italy	14.23	6.32	18.27	4.10	29.78	−0.49	−1.15
Cyprus	6.69	3.07	13.90	3.51	46.96	0.43	−0.81
Latvia	35.01	29.62	40.98	3.77	10.78	0.00	−1.33
Lithuania	20.69	16.48	26.04	3.61	17.00	0.04	−1.54
Luxembourg	3.02	0.89	8.97	2.19	56.98	0.82	0.01
Hungary	12.67	4.36	16.20	3.50	29.78	−0.71.	−0.69
Malta	2.35	0.10	8.49	3.10	98.99	0.47	−1.28
Netherlands	4.59	2.03	8.77	1.81	38.21	0.55	−0.18
Austria	32.10	22.55	33.81	3.58	11.70	−1.08	−0.11
Poland	10.66	6.89	12.16	2.06	21.21	−0.39	−1.54
Portugal	24.59	19.21	30.87	4.21	16.42	−0.02	−1.39
Romania	22.83	16.81	25.03	2.98	13.64	−0.63	−1.13
Slovenia	21.22	18.40	23.16	1.53	7.33	−0.41	−0.95
Slovakia	10.24	6.36	16.89	2.81	27.88	0.60	0.26
Finland	33.50	28.81	43.08	4.88	13.99	0.25	−1.44
Sweden	49.08	38.68	56.39	5.45	11.27	−0.32	−1.09
Iceland	72.15	58.84	78.19	5.81	8.24	−0.99	−0.16
Norway	64.13	57.10	74.63	5.28	8.16	0.26	−1.07
United Kingdom	4.43	1.09	12.34	3.68	67.32	0.49	−1.05

Source: https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do (accessed on 11 June 2021).

The coefficient of variation informs us about the changes that took place in renewable energy sources in European countries. As we can see, the largest changes were found in Malta (99%), Luxemburg (56.97%) and Ireland (45.68%).

The highest share in renewable energy sources has solid biomass. It is mainly produced from straw, wood and other ingredients. It can be used in the combustion or as a source to produce different products such as pellet.

Table 7 presents the descriptive statistics of wood pellet production in the EU. Germany (2.0871 Mtoe), Sweden (1.4286) and Poland (730.00 Mtoe) achieved the highest average production of pellet in the European Union. The coefficient of variation was the highest in Latvia (172.80%), France (93.43%) and Austria (79.71%).

A normally distributed variable can be described by skewedness and kurtosis near zero [90,91]. Skewedness was negative for Germany, Sweden, France, Austria, Estonia, and Spain, which means that the mean of negatively skewed data was less than the median. Kurtosis was negative in all countries. Our results depend only on stationarity and the existence of some moments as it was achieved by other authors [51].

Europe is also an important pellet producer. Table 7 shows the main pellet producers in the EU. Poland is in seventh place as the producer of pellet with the amount of 950 million metric tons. The biggest producers in 2017 were: Germany (2.250 million metric tons), Latvia (1.55 million metric tons) and Sweden (1.42 million metric tons). The average pellet production in the EU increased 50.5% in 2011–2017. The biggest increases of pellet production were observed in Estonia (189.5%), Spain (129.2%) and France (127.3%). Only Portugal recorded a decrease in pellet production in 2011–2017 (−48.7%).

Table 7. Descriptive statistics of wood pellet production in the EU in 2004–2018 (MMT).

Country	Average	Median	Minimum	Maximum	Standard Deviation	Coefficient of Variation (%)	Skewed-Ness	Kurt-Osis
Germany	2.08	2.10	1.88	2.25	0.15	7.34	−0.16	−1.57
Latvia	242.44	1.55	1.10	980.00	418.94	172.80	1.06	−0.72
Sweden	1.42	1.42	1.31	1.55	0.10	7.18	0.12	−1.65
France	419.06	550.00	1.04	950.00	408.37	97.45	−0.03	−1.69
Austria	534.75	893.00	1.00	962.00	499.64	93.43	-0.28	−1.91
Estonia	467.44	500.00	1.00	900.00	372.60	79.71	−0.13	−1.34
Poland	730.00	610.00	600.00	950.00	161.66	22.15	0.38	−1.73
Spain	396.43	410.00	240.00	550.00	134.62	33.96	−0.01	−1.64
Portugal	653.57	700.00	500.00	800.00	112.20	17.17	−0.48	−1.05
Total	12.53	13.10	9.47	14.25	1.86	14.89	−0.65	−1.07

Source: Eurostat. Energy. Share of energy from renewable sources (nrg_ind_ren). https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_ren&lang=en (accessed on 11 June 2021).

4.5. Stationarity of Solid Biomass and Pellet Production in the World and Poland

In order to analyze changes in total gross heat production and pellet production, the Dickey–Fuller test was carried out, which examines the stationarity of time series [92]. The results presented in Table 8 show that the p value is quite large, which does not justify rejecting the hypothesis H0 which states that the series is non-stationary due to the presence of the unit root. The values of the mean, variance and autocorrelation function change over time, which proves that the time series are not stationary. On the other hand, the H1 time series hypothesis is stationary, i.e., static and dynamic properties remain unchanged at any time shift, and therefore, the mean value and variance of the time series elements are constant [93].

Table 8. ADF test for total gross heat production from solid biomass and pellets.

Specification	Coefficient of Autocorrelation	p Value	t Statistics
Total gross heat production from solid biomass	0.032	0.525	−1.456
Global wood pellet production in the world	−0.041	1.000	4.394
Wood pellet production in Poland	−0.010	0.998	1.408

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Finally, we conducted the ADF test with intercept, and with intercept and trend (Table 9). We took the differences and did the ADF test once again and achieved the stationary variables. Autocorrelation of the first-order suggests that the variables were stationary. The ADF test proved the existence of unit root.

The empirical evidence suggests that there is no serial correlation for the total gross heat production from solid biomass because the $\alpha 1 < \beta 1$, which suggests that the conditional variance is independent from previous observations (Table 10).

According to our prognosis, the wood pellet production in the world will slightly decrease (Table 11). This can be the effect of looking for cheaper and cleaner sources of renewable energy.

Table 9. ADF test for total gross heat production from solid biomass and pellet with differences.

Specification	ADF Test with Intercept				ADF Test with Intercept and Trend			
	Coefficient of Autocorrelation	p Value	t Statistics	Autocorrelation of First-Order Residuals	Coefficient of Autocorrelation	p Value	t Statistics	Autocorrelation of First-Order Residuals
Total gross heat production from solid biomass	−0.925	0.056	−3.048	0.001	−1.003	0.145	−3.106	−0.029
Global wood pellet production in the world	0.099	0.989	0.597	−0.336	−0.807	0.126	−3.141	−0.069
Wood pellet production in Poland	−0.805	0.077	−2.845	0.069	−1.494	0.016	−3.819	0.007

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Table 10. Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model of total gross heat production from solid biomass.

Specification	Coefficient	Std. Error	z	p Value
Constant	326.48	14.96	21.82	0.000
Alpha (0)	460.03	674.87	0.68	0.50
Alpha (1)	0.34	0.30	1.14	0.26
Beta (1)	0.45	0.20	2.25	0.02
Arithmetic mean of the dependent variable—258.80				
Standard deviation of dependent change—122.24				
Likelihood log—89.39				
Akaike's information criterion—188.77				
Bayesian Schwarz criterion—192.31				
Hannan–Quinn criterion—188.73				
Unconditional variance of model error—2269.56				
Likelihood-ratio test for the (G) ARCH: Chi-square (2)—11.7486 [0.031]				

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Table 11. Prognosis of global wood pellet production.

Years	Prognosis	Std. Error	95% Confidence Interval
2019	377.0	330.4	(295.2–450.8)
2020	377.3	52.54	(274.3–480.3)
2021	375.6	68.95	(240.4–510.7)
2022	374.2	77.82	(221.7–526.7)
2023	373.1	73.11	(210.2–536.0)

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Table 12 presents maximum-likelihood estimates for the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model.

The empirical evidence suggests that there is no serial correlation for the analyzed series. The conditional t distribution is distinctly fatter-tailed than the normal. For global wood pellet, the $\alpha 1 < \beta 1$ which suggests that the conditional variance is independent from previous time series.

Our final step was to prepare a prognosis of global wood pellet production. Our prognosis suggests that the global wood pellet production will increase almost 81% (Table 13). Even though other renewable energy sources will increase their share in the energy mix, the pellets, which are organic, increase also.

Poland is an important producer of wood pellets in Europe. Polish pellet production reached 1.3 million metric tons. Most were used by residential consumers, 25% by commercial or industrial entities, and 13% by commercial stakeholders to produce energy for heat for sale [94].

Table 12. Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model of global wood pellet production.

Specification	Coefficient	Std. Error	z	*p* Value
Constant	15.61	3.36	4.65	0.000
Alpha (0)	9.70	17.56	0.55	0.58
Alpha (1)	0.91	0.61	1.50	0.13
Beta (1)	1.000	0.52	1.93	1.00
Arithmetic mean of the dependent variable—24.26929				
Standard deviation of dependent change—15.73396				
Likelihood log—52.05360				
Akaike's information criterion—114.1072				
Bayesian Schwarz criterion—117.3025				
Hannan–Quinn criterion—113.8114				
Unconditional variance of model error—111.913				
Likelihood-ratio test for the (G) ARCH: Chi-square (2)—11.7486 [0.00281081]				

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Table 13. Prognosis of global wood pellet production.

Years	Prognosis	Std. Error	95% Range
2019	64.79	0.73	(63.35–66.23)
2020	75.25	0.74	(73.79–76.70)
2021	87.33	0.75	(85.85–88.80)
2022	101.27	0.76	(99.76–102.77)
2023	117.36	0.79	(115.82–118.91)

Source: Own elaboration based on Ren21 Renewables. Global Status Report 2019.

Table 14 presents the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model of wood pellet production in Poland. The empirical evidence suggests that there is no serial correlation for the analyzed series. The conditional *t* distribution is distinctly fatter-tailed than the normal. For global wood pellet, the $\alpha 1 < \beta 1$, which suggests that the conditional variance is independent from previous observations.

Table 14. Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model of wood pellet production in Poland.

Spcification	Coefficient	Std. Error	Z	*p* Value
Constant	609.73	58.67	10.39	0.00
Alpha (0)	7895.39	8796.84	0.89	0.36
Alpha (1)	0.83	0.50	1.65	0.09
Beta (1)	1.05	0.461	0.00	1.00
Arithmetic mean of the dependent variable—621.2500				
Standard deviation of the dependent variable—333.3042				
Log-of-Plausibility—109.9101				
Akaike's information criterion—229.8201				
Bayesian Schwarz criterion—233.6831				
Hannan–Quinn criterion—230.0179				
Unconditional variance of model error—46 712.7				
Likelihood-ratio test for the (G) ARCH: Chi-square (2)—10.4431 [0.00539905]				

Source: Own elaboration based on https://www.eurobserv-er.org/online-database/ (accessed on 11 June 2021).

Table 15 shows the prognosis of wood pellet production in Poland. As we can see, the production of wood pellets could increase as the result of changing policy, increased demand for renewable energy sources, and the development of the wood processing industry.

Table 15. Prognosis of wood pellet production in Poland (TMT).

Year	Prognosis	Error	95% Range
2020	1450.91	60.85	1331.64–1570.18
2021	1613.48	80.72	1455.27–1771.69
2022	1792.17	99.57	1597.01–1987.32
2023	1988.56	118.40	1756.49–2220.63
2024	2204.42	137.762	1934.41–2474.43

Source: https://www.eurobserv-er.org/online-database/ (accessed on 11 June 2021).

Poland, an important producer of pellets in the EU, is responsible for a reduction of emissions of greenhouse gases into the atmosphere. The projection of pellet development will undoubtedly decrease the gas emissions that are responsible for global warming which creates losses for the environment and the economy as a whole [95].

Poland is achieving more energy from renewable energy sources each year because the EU imposed a duty to adjust emissions in all countries. Poland's aim was to achieve 15% of renewable energy sources of gross energy consumption in 2020. Poland has a good climate and soil conditions for plant cultivation for energy purposes. Many lands can be devoted to cereals, rapeseed, straw, and forest. The forest cover in Poland is over 30% and it is a basic source for timber waste. Basket willow and other energy plants can be harvested in Poland for energy [96].

5. Discussion

The development of renewable energy sources depends on global demand from clear energy. Its development is also regulated by law.

The European Union established the necessary reduction of GHG gases (greenhouse gas) emission reduction by 80–95% by 2050. Such an ambitious goal can be achieved by using renewable energy sources which could be increased between 55% and 75% in gross final energy consumption in 2050. Moreover, changing to a competitive green economy requires constant changes in law concerning climate, environmental pollution levels, and renewable energy sources [1].

However, to achieve these ambitious goals, the EU must make significant investments. In some EU countries, the investment levels are insufficient and actions should be taken to avoid shrinking the green economy [97]. Such an investment should amount to 60–70 billion euros to achieve the planned development of a green economy, which is very important for humans [98].

This green economy based on biomass instead of fossil fuels will generate constant changes in agricultural, economic, and social systems. This economy can also be called a bio-based economy "or a knowledge-based bio-economy". This approach generates many benefits for sustainable development, and perspectives for people and the environment [29]. This economy is described as a low-carbon and resource-efficient strategy that will improve energy security and human well-being [99]. According to this concept, the use of raw materials, innovation development, and biotechnology in different sectors is necessary [100].

The European Union enabled each member state to decide its own ways to increase renewable energy use. This bottom-up approach gives independent choice for each member state to elaborate its way to meet the goal, and the European Commission is monitoring the activities. The production of biomass plays an important role in policies of member states [97].

Biomass has an important role in EU strategies that restrict energy security and climate change reduction. It can contribute to the decrease of carbon dioxide concentrations in the atmosphere. Supporting plant production enables carbon dioxide storage in vegetation and substitution of fossil fuels [101].

Sustainable agricultural production and biomass utilization require intensive, productive technologies to enable high yield achievements from plants. The increasing demand for energy and rational use of energy sources are of particular interest in the European

Union. The changing of replacement of traditional fossil fuels are inhibited by high costs of new technologies and low pace of legislations [11].

Moreover, the increase of biomass can be achieved by using land that is not valuable for agricultural production. Willow, miscanthus, and other plants deliver solid biofuels and do not require good land. The further utilization of existing resources and intensification of current production can also be the source of the development of bioenergy production [102]. This can create a competition between good quality lands that can be used for food production and for renewable energy crops. Another reason that can create the market for renewable energy sources are production costs. Lower costs of biomass compared to fossil fuels can stimulate the development of renewable energy sources [103].

The development of bioenergy requires an evaluation of the bioenergy potential. This should be done not only globally but also on a regional scale. Each EU country has different potential for different renewable energy sources and the strategy should be adjusted to existing resources [104].

The usage of biomass has advantages and disadvantages. The most important advantages include: the safety of transport compared to gas, a low balance of carbon dioxide, the possibility of using low quality lands for energy purposes and the possibility to create jobs in rural areas. The most important disadvantage is the low energy value of biomass, and some parts of biomass are only accessible seasonally [105]. The other barriers to the development of biomass include: small biomass markets, poor subsidies for crops devoted to energy purposes, or the lack for emission control systems for energy installation [106].

In many countries, the development of alternative energy is stimulated, including a partial transition to biofuels and the deployment of capacity for its production. The consequences of this step are ambiguous as intensive production of biofuels might significantly raise the price of food, deplete the soil, and increase water scarcity. Already, the production of biofuels is called as a cause of rising grain prices.

However, all these steps are not sufficient to keep the Earth's temperature at a relatively safe level [107].

Solid biomass is a major source of renewable energy mainly used for heating in Poland and Europe. However, its share in renewable energy sources is decreasing. The future of solid biomass in Poland and the European Union will depend on various factors such as wood and straw access. It is worth mentioning that the possibility of using straw in biomass production and using it in heating depends on agriculture development and its utilization in animal production. Some regions of Poland suffer from the lack of straw because of intensive cow production [12].

The solid biomass can help the countries to achieve planned goals. In China, non-fossil energy in primary energy consumption should be increased from 15% to 20% in the 2020–2030 [108]. In the EU-28, the achievement is of 40% mitigation in domestic GHG emissions over the period 2021–2030. Moreover, the contribution of renewable energy sources in total energy consumption should reach about 32% by 2030. Finally, the target of about 32.5% increase in energy efficiency in 2030 at EU level should be reached [109]. Global actions should be taken to secure a likely chance of meeting the 2 °C target in the future. A 2030 target of 67% below 1990 for the EU-28, a 2025 target of 54% below 2005 for the USA or a 2030 target of 32% below 2010 for China should help to solve the problem of achieving a fully decarbonized world [110,111].

6. Conclusions

The usage of energy from renewable sources is increasing worldwide. Biomass is actually the most important source of renewable energy. Pellets can be a good example of solid biomass. The international market for biomass and pellets is increasing. The European Union is an important producer and consumer of biomass [105]. The further development of the biomass market requires a proper climate and energy policy.

In general, environmental policy remains the most important activity of the European Union. In this area, an extensive system of environmental legislation has been formed, the norms of which are successfully implemented in practice. Each member state should adjust its own policy to the general requirements of the EU [38].

Our research demonstrates the development of solid biomass production in the world, EU, and Poland. Such an increase can demonstrate the increasing demand for renewable energy sources created by environmental policy.

Poland is an important biomass and pellet producer in the EU. It has large potential for solid biomass production. However, the further development of solid biomass depends not only on agriculture and forestry, but also the pace of other renewable energy source developments [84]. However, about 28% is distributed on the domestic market. It can be the result of a small investment in burning installations, as well as instability of prices and supply [112]. Most of the pellet and biomass are achieved in Poland from forest waste. However, biomass can be obtained from perennial energy crops, such as Salix coppice (*Salix* spp.), Sida hermaphrodita (Virginia mallow) and Miscanthus giganteus, which can be cultivated on poorer quality agricultural land [113]. The market for pellets is increasing because the EU is importing about one third of the pellets used [114]. The largest producer of pellets in the EU is Germany, and the largest consumers are the United Kingdom and Italy [115].

Our prognosis demonstrates that wood pellet production will increase in the world and Poland. Such a result can be achieved by the support of renewable energy in European policy. Climate change and environmental protection will play an important role in world policy.

Our research confirms both hypotheses positively. Environmental policy is becoming stricter and requires an increase of global awareness by society. Our common environment is in danger and the policy should protect it.

The analysis of the wood pellet production in the EU proved that kurtosis was negative in all countries. Skewedness was negative for Germany, Sweden, France, Austria, Estonia, and Spain, which means that the mean of negatively skewed data was less than the median [116,117].

The ADF test proved that the analyzed variables were not stationary. That is why we took the differences and did the unit root test, achieving the stationary variables.

Moreover, the GARCH model confirmed that there is no serial correlation for the analyzed series. The conditional variance is independent from previous observations. Based on the obtained results, it can be concluded that modeling the series of pellet production by means of models is entirely sufficient AR (1)—GARCH (1,1) with conditional normal distribution [118–120].

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References

1. Scarlat, N.; Dallemand, J.-F.; Fahl, F. Biogas: Developments and perspectives in Europe. *Renew. Energy* **2018**, *129*, 457–472. [CrossRef]
2. Brodziński, Z.; Brodzińska, K.; Szadziun, M. Photovoltaic Farms—Economic Efficiency of Investments in North-East Poland. *Energies* **2021**, *14*, 2087. [CrossRef]
3. Ren21 Renewables. *Report Global Status Report*; REN21: Paris, France, 2019; p. 336. Available online: https:/www.ren21.net/report/global-status-report/URL (accessed on 11 June 2021).
4. Eurostat. Energy. Share of Energy from Renewable Sources (nrg_ind_ren). Available online: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_ren&lang=en (accessed on 11 June 2021).
5. Stolarski, M.; Warmiński, M.; Krzyżaniak, M.; Olba-Zięty, E.; Akincza, M. Bioenergy technologies and biomass potential vary in Northern European countries. *Renew. Sustain. Energy Rev.* **2020**, *133*, 110238. [CrossRef]
6. Grzybek, A.; Gradziuk, P.; Kowalczyk, K. *Słoma Energetyczne Paliwo*; Wydawnictwo Wieś Jutra Sp. z o.o.: Warszawa, Poland, 2001; p. 15. (In Polish)
7. Lewandowski, W.M. *Proekologiczne Odnawialne Źródła Energii*; Wydawnictwo WNT: Warszawa, Poland, 2012; Volume 322. (In Polish)
8. Roszkowski, A. Bioenergia—Pola i lasy zastapia węgiel, ropę i gaz? *Inżynieria Rolnicza* **2009**, *13*, 243–257. (In Polish)
9. Chochowski, A.; Krawiec, F. *Zarządzanie w Energetyce. Koncepcje, Zasoby, Strategie, Struktury, Procesy i Technologie Energetyki Odnawialnej*; Wydawnictwo Difin: Warszawa, Poland, 2008; pp. 80–83. (In Polish)
10. Abbasi, T.; Abbasi, S.A. Biomass energy and the environmental impacts associated with its production and utilization. *Renew. Sustain. Energy Rev.* **2010**, *14*, 919–937. [CrossRef]
11. Roszkowski, A. Energia z biomasy—Efektywność, sprawność i przydatność energetyczna. *Problemy Inżynierii Rolniczej* **2013**, *1*, 98.
12. Zbytek, Z.; Adamczyk, F. Możliwości wykorzystania biomasy stałej. Część 2. Sposoby określania potencjału biomasy stałej i doboru maszyn do jej zbioru. *Technika Rolnicza Ogrodnicza Leśna* **2017**, *3*, 6–9.
13. Szempliński, W.; Dubis, B.; Lachutta, K.M.; Jankowski, K.J. Energy Optimization in Different Production Technologies of Winter Triticale Grain. *Energies* **2021**, *14*, 1003. [CrossRef]
14. Pawlak, J. Efficiency of energy inputs in polish agriculture. *Rocz. Nauk Roln.* **2012**, *1*, 121–128. (In Polish)
15. Sokólski, M.; Jankowski, K.J.; Załuski, D.; Szatkowski, A. Productivity, Energy and Economic Balance in the Production of Different Cultivars of Winter Oilseed Rape. A Case Study in North-Eastern Poland. *Agronomy* **2020**, *10*, 508. [CrossRef]
16. Budzyński, W.S.; Jankowski, K.J.; Jarocki, M. An analysis of the energy efficiency of winter rapeseed biomass under different farming technologies. A case study of a large-scale farm in Poland. *Energy* **2015**, *90*, 1272–1279. [CrossRef]
17. Davis, S.C.; Anderson-Teixeira, K.J.; DeLucia, E.H. Life-cycle analysis and the ecology of biofuels. *Trends Plant Sci.* **2009**, *14*, 140–146. [CrossRef] [PubMed]
18. Ajanovic, A. Biofuels versus food production: Does biofuels production increase food prices? *Energy* **2010**, *36*, 2070–2076. [CrossRef]
19. Demirbas, A. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. *Energy Convers. Manag.* **2008**, *49*, 2106–2116. [CrossRef]
20. Marks-Bielska, R.; Bielski, S.; Novikova, A.; Romaneckas, K. Straw stocks as a source of renewable energy. A case study of a district in Poland. *Sustainability* **2019**, *11*, 4714. [CrossRef]
21. Bielski, S.; Marks-Bielska, R.; Zielińska-Chmielewska, A.; Romaneckas, K.; Šarauskis, E. Importance of Agriculture in Creating Energy Security—A Case Study of Poland. *Energies* **2021**, *14*, 2465. [CrossRef]
22. Keles, S.; Kar, T.; Bahadir, A.; Kaygusuz, K. Renewable energy from woody biomass in Turkey. *J. Eng. Res. Appl. Sci.* **2017**, *6*, 652–661.
23. Wyszomierski, R.; Bórawski, P.; Jankowski, K. Pozycja Polski w produkcji biomasy na tle innych krajów Unii Europejskiej. *Roczniki Naukowe SERiA* **2018**, *20*, 177–183. (In Polish)
24. Gostomczyk, W. Konkurencyjność odnawialnych źródeł energii. *Roczniki Naukowe SERiA* **2014**, *16*, 55–61. (In Polish)
25. Bartosiewicz-Burczy, H. Ekonomika wykorzystania energii źródeł odnawialnych do produkcji energii elektrycznej. *Energetyka* **2002**, *7*, 458–463. (In Polish)
26. Rokicki, T.; Perkowska, A.; Klepacki, B.; Bórawski, P.; Bełdycka-Bórawska, A.; Michalski, K. Changes in energy consumption in Agriculture in the EU countries. *Energies* **2021**, *14*, 1570. [CrossRef]
27. Faaij, A. Modern biomass conversion technologies. *Mitig. Adapt. Strateg. Glob. Chang.* **2006**, *11*, 343–375. [CrossRef]
28. Flizikowski, J.; Mroziński, A. *Inżynieria Aglomeracji Biomasy*; Graftpol Agnieszka Blicharz-Krupińska: Wrocław, Poland, 2016; (In Polish). Available online: https://studiaoze.utp.edu.pl/pliki/publikacje/Projekt%20Norweski%20-%20Aglomeracja%20Biomasy.pdf (accessed on 11 June 2021).
29. McCormick, K.; Kautto, N. The bioeconomy in Europe: An Overview. *Sustainability* **2013**, *5*, 2589. [CrossRef]
30. Butorina, O.V. European Union after the crisis: Decline or rebirth?, Vestn. MGIMO Univ., No. 4, 71–81 (2013). Available online: http//:eng.globalaffairs.ru/articles/a-europe-without-the-european-union/ (accessed on 11 June 2021).
31. Gusev, A.A. Modern environmental policy. *M IMEMO RAN* **2006**, *205*, 4.
32. Ford, J.; Maillet, M.; Pouliot, V.; Meredith, T.; Cavanaugh, A.; Team, I.R. Adoption and indigenous peoples in the United Nations Framework Convention on climate change. *Clim. Chang.* **2016**, *139*, 429–443. [CrossRef]

33. Bakhtiari, F. International cooperative initiatives and teh United nations Framework Convention on Climate Change. *Clim. Policy* **2018**, *18*, 655–663. [CrossRef]
34. Tompkins, E.L.; Amundsen, H. Perceptions of the effectiveness of the United Nations Framework Convention on Climate Change in advancing national actions an climate change. *Environ. Sci. Policy* **2008**, *11*, 1–13. [CrossRef]
35. Gibb, C.; Ford, J. Should the United Nations Framework Conventuion on Climate Change recognize climate migrants? *Environ. Res. Lett.* **2012**, *7*, 1–9. [CrossRef]
36. Aichele, R.; Felbermayr, G. Kyoto and the carbon footprint of nations. *J. Environ. Econ. Manag.* **2012**, *63*, 336–354. [CrossRef]
37. Baumert, K.A.; Herzog, T.; Pershing, J. *Navigating the Numbers Greenhouse Gas Data and International Climate Policy*; World Resource Institute: Washington, DC, USA, 2005; Available online: http://pdf.wri.org/navigating_numbers.pdf (accessed on 11 June 2021).
38. Bielski, S. Conditions of biomass production for energy generation purposes in Poland. *Folia Oecon. Stetin.* **2011**, *10*, 238–249. [CrossRef]
39. Faure, M.; Gupta, J.; Nentjes, A. *Climate Change and the Kyoto Protocol The Role of Institutions and Instruments to Control Global Change*; Edward Elgar Publishing: Cheltenham, UK, 2003; Available online: https://www.e-elgar.com/shop/gbp/climate-change-and-the-kyoto-protocol-9781843762454.html (accessed on 11 June 2021).
40. The Problem of Climate Change: The Results of 2007 and Further Perspectives [Electronic Resource]. Available online: http://global-climate-change.ru/ (accessed on 11 June 2021).
41. Hutchins, D.A.; Jansson, J.K.; Remairs, J.V.; Rich, V. Climate change microbiology—Problems and perspectives. *Nat. Rev. Microbiol.* **2019**, *17*, 391. [CrossRef] [PubMed]
42. Climate Negotiations in Bonn: One More Step on the Way to Copenhagen [Electronic Resource]. Available online: http://global-climate-change.ru/ (accessed on 11 June 2021).
43. Costa, A.; Sanchez, P.; Macron, E.; Canete, M. Lisbon Declaration, Lisbon. Available online: Thhps://ec/Europa.Eu/info/sites/info/files/Lisbon_declaration_energyinterconnections_final.pdf (accessed on 25 March 2021).
44. *Energy Sector Strategy 2019–2023 as Approved by Board of Directors at Their Meeting of 12 December 2018*; European Bank for Reconstruction and Development: Strasburg, France, 2018; Available online: Downloads/energy-sector-strategy%20(1).pdf (accessed on 11 June 2021).
45. Wyszomierski, R.; Bórawski, P.; Dunn, J.W. Development of Renewable Energy Source in Poland on the background of the European Union. *Probl. Econ. Law* **2019**, *3*, 12.
46. Ouyang, T.; Huang, H.; He, Y.; Zang, Z. Chaotic wind power time series prediction via switching data-driven models. *Renew. Energy* **2020**, *145*, 270–281. [CrossRef]
47. Lajdová, Z.; Bielik, P. Vertical price transmission analysis: The case of milk in the Slovak dairy sector. *Appl. Stud. Agribus. Commer. APSTRACT* **2013**, *7*, 89–96. [CrossRef] [PubMed]
48. Engle, R.F. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica* **1982**, *50*, 987–1006. [CrossRef]
49. Bellerslev, T. Generalized autoregressive conditional heteroskedasticity. *J. Econom.* **1986**, *31*, 307–327. [CrossRef]
50. Hillebrand, E. Neglecting parameter changes in GARCH models. *J. Econom.* **2005**, *129*, 121–138. [CrossRef]
51. Daryanto, A.; Sahara, D.A.S.; Singa, A.R. Climate change and milk price volatility in Indonesia. *Int. J. Econ. Financ. Issues* **2020**, *10*, 282–288. [CrossRef]
52. Hossain, A. Forecasting volatility of processed milk products in the framework of ARCH model. *Int. J. Mod. Sci. Technol.* **2018**, *3*, 190–195.
53. Efimowa, O.; Serletis, A. Energy markets volatility modelling using GARCH. *Energy Econ.* **2014**, *43*, 264–273. [CrossRef]
54. Wu, J. *Threshold GARCH Model: Theory and Application*; The University of Western Ontario: London, ON, Canada, 2010; Available online: https://publish.uwo.ca/~{}jwu87/files/JobMarketPaper_JingWu.pdf (accessed on 11 June 2021).
55. Global Bioenergy Statistics. 2020. Available online: https://www.greengrowthknowledge.org/research/global-bioenergy-statistics-2020 (accessed on 11 June 2021).
56. Nawrot, Ł.; Bednarska, M.; Zmyślony, P. Odnawialne źródła energii w gospodarce turystycznej jako obszar badań naukowych. *Warsztaty z Geografii Turyzmu* **2014**, *87*. (In Polish) [CrossRef]
57. Rokicki, T. Sustainable Development in Energy Sector in the European Union Countries. *Econ. Sci. Rural Dev.* **2016**, *43*, 108–115.
58. Gołasa, P. Agricultural Biogass Production and the Development of Prosumer Energy in Poland. *Econ. Sci. Rural Dev.* **2015**, *37*, 134–141.
59. Islam, M.A.; Hasanuzzaman, M.; Rahim, N.A.; Nahar, A.; Hosenuzzaman, M. Global renewable energy-based electricity generations and smart grid system for energy security. *Sci. World J.* **2014**, 1–13. [CrossRef]
60. Pazheri, F.R.; Othman, M.F.; Malik, N.H. A review on global renewable electricity scenario. *Renew. Sustain. Energy Rew.* **2014**, *31*, 835–845. [CrossRef]
61. Xu, X.; Wei, Z.; Ji, Q.; Wang Ch Gao, G. Global renewable energy development: Influencing factors, trend predictions and countermeasures. *Resour. Policy* **2019**, *63*, 101470. [CrossRef]
62. Ellaabban, O.; Abu-Rub, H.; Blaabjerg, F. Renewable energy resources: Current status, future prospects and their enabling technology. *Renew. Sustain. Energy Rev.* **2014**, *39*, 748–764. [CrossRef]
63. Demibras, A. Global renewable energy projections. *Energy Resour. Part B* **2009**, *4*, 212–224. [CrossRef]
64. Faaij, A.P.C. Bio-energy in Europe: Changing technology choices. *Energy Policy* **2006**, *34*, 322–342. [CrossRef]

65. Sala, K. Przemysłowe wykorzystanie biomasy w Polsce. Przesłanki i bariery. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* **2017**, *31*, 150. (In Polish) [CrossRef]
66. Zakrzewska, B.; Rojek, K.; Rola, O.Z.E. w europejskim systemie energetycznym. *Logistyka* **2019**. (In Polish) [CrossRef]
67. GUS. *Energia 2019*; GUS: Warszawa, Poland, 2019. (In Polish)
68. Jasiulewicz, M. *Znaczenie Rolnictwa w Rozwoju Energetyki Rozproszonej Jako Formy Rozwoju Zrównoważonego Obszarów Wiejskich*; Instytut Ekonomii i Zarządzania, Politechnika Koszalińska: Koszalin, Poland, 2009; Volume 157. (In Polish)
69. Ociepa-Kubicka, A. Wykorzystanie Biomasy w Przedsiębiorstwach Energetycznych. In Proceedings of the ECOpole, Opole, Poland, 15–17 October 2014; p. 279. (In Polish) [CrossRef]
70. Gostomczyk, W. *Wykorzystywanie Biomasy Energetycznej do Kreowania Rynku Pracy*; Politechnika Koszalińska: Koszalin, Poland, 2015; pp. 162–163. (In Polish)
71. Czeczko, R. Biomasa Rolnicza w Energetyce. *Autobusy Tech. Eksploat. Syst. Transp.* **2012**, *13*, 102–104. (In Polish)
72. Wicki, L. Changes in land use for production of energy crops in Poland. *Roczniki naukowe Ekonomii Rolnictwa i Rozwoju Obszarów Wiejskich* **2017**, *104*, 37–47. [CrossRef]
73. Stolarski, M.; Niksa, D.; Krzyżaniak, M.; Tworkowski, J.; Szczukowski, S. Willow productivity from small- and large-scale experimental plantations in Poland from 2000 to 2017. *Renew. Sustain. Energy Rev.* **2019**, *101*, 461–475. [CrossRef]
74. Gostomczyk, W. *Udział Biomasy Energetycznej w Realizacji Idei Zrównoważonego Rozwoju*; Politechnika Koszalińska: Koszalin, Poland, 2013; pp. 396–397. Available online: https://journals.pan.pl/Content/97228/mainfile.pdf?handler=pdf (accessed on 11 June 2021). (In Polish)
75. Ile Energii w Polsce Wytwarzamy z OZE? Available online: https://www.green-projects.pl/energia-oze-wytwarzanie-polska-statystyki/ (accessed on 11 June 2021). (In Polish).
76. Bartoszewicz-Buczy, A. *Potencjał i Energetyczne Wykorzystanie Biomasy w Krajach Europy Środkowej*; Instytut Energetyki, JEN: Warszawa, Poland, 2012; p. 860. (In Polish)
77. GUS. *Energia ze źródeł Odnawialnych*; GUS: Warszawa, Poland, 2018. (In Polish)
78. Jasiulewicz, M. Produkcja energii z Agro biomasy w Polsce na tle wybranych krajów Unii Europejskiej. *Roczniki Naukowe SERiA* **2015**, *18*, 94. (In Polish)
79. Gostomczyk, W. Pozycja Polski na europejskim rynku biomasy energetycznej. *Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu* **2011**, *13*, 122–125. (In Polish)
80. Kurowska, K.; Kryszak, H.; Bielski, S. Determinants of biomass production for energy purposes in northeastern Poland. *Eng. Rural Dev.* **2014**, *13*, 29–30.
81. Księżopolski, K.; Drygas, M.; Promińska, K.; Nurzyńska, I. The Ecconomic Effects of the New Patterns of Energy Efficiency and Heat Sources in Rural Single-Family Houses in Poland. *Energies* **2020**, *13*, 6358. [CrossRef]
82. Janik, W.; Kaproń, H.; Paździor, A. Uwarunkowania rozwoju produkcji energii elektrycznej na bazie źródeł odnawialnych. *Rynek Energii* **2018**, *2*, 22–27. (In Polish)
83. Wyszomierski, R.; Bełdycka-Bórawska, A.; Bórawski, P.; Jankowski, K. Ocena opłacalności wykorzystania biomasy na cele energetyczne ze szczególnym uwzględnieniem peletu. *Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu* **2017**, *18*, 296–302. (In Polish)
84. Hall, P. Sustainable production of forest biomass for energy. *For. Chron.* **2002**, *78*, 391–396. [CrossRef]
85. Ryttel, R.; Ingerslev, M.; Kilpeläinen, A.; Torssonen, P.; Lazdina, D.; LöF, M.; Madsen, P.; Muiste, P.; Stener, L.-G. Increased forest biomass production in the Nordic and Baltic countries—A review on current and future opportunities. *Silva Fenn.* **2016**, *50*, 1–33. [CrossRef]
86. Krawiec, F. (Ed.) *Odnawialne Źródła Energii w Świetle Globalnego Kryzysu Energetycznego*; Difin: Warsaw, Poland, 2010. (In Polish)
87. Koryś, K.A.; Latawiec, A.E.; Grotkiewicz, K.; Kuboń, M. The review of biomass potential for agricultural biogas production in Poland. *Sustainability* **2019**, *11*, 6515. [CrossRef]
88. Climate and Energy Policies in Poland. 2017. Available online: http://www.europarl.eutopa.eu/RegData/etudes?BRIE/2017/607335?IPOL_BRI(2017)607335_EN.pdf (accessed on 5 May 2021).
89. World Energy Council. Available online: https://www.worldenergy.org/data/resources/country/poland/coal/ (accessed on 5 May 2021).
90. Teresienė, D.; Dubauskas, G. Modelling stock price of Lithuanian manufacture of milk and dairy products companies' volatility with GARCH models. *Manag. Theory Stud. Rural Dev.* **2008**, *13*, 154–161.
91. Bai, J.; Ng, S. Tests for Skewness, Kurtosis, and Normality for Time Series Data. *J. Bus. Econ. Stat.* **2005**, *23*. [CrossRef]
92. Dickey, A.F.; Fuller, W.A. Distribution of the estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc.* **1979**, *74*, 427–431.
93. Sobczyk, M. *Statystyka*; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2005.
94. *Wood Pellets Market Brief*; United States Department of Agriculture, Foreign Agricultural Service: Washington, DC, USA, 2020. Available online: https://www.fas.usda.gov/data/poland-wood-pellets-market-brief (accessed on 11 June 2021).
95. Jezierska-Thöle, A.; Rudnicki, R.; Kluba, M. Development of energy crops cultivation for biomass production in Poland. *Renew. Sustain. Energy Rev.* **2016**, *62*, 534–545. [CrossRef]
96. Igliński, B.; Iglińska, A.; Kujawski, W.; Buczkowski, R.; Cichosz, M. Bioenergy in Poland. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2999–3007. [CrossRef]

97. Kitzing, L.; Mitchell, C.; Morthorst, P.E. Renewable energy policies in Europe: Converging or diverging? *Energy Policy* **2012**, *21*, 192–201. [CrossRef]
98. De Jager, D.; Klessmann, C.; Stricker, E.; Winkel, T.; de Visser, E.; Koper, M.; Ragwitz, M.; Held, A.; Resch, G.; Busch, S.; et al. Financing Renewable Energy in the European Energy Market. In *By Order of the European Commission, DG Energy*; Ecofys: Utrecht, The Netherlands, 2011; TREN/D1/518-2008.
99. Scarlat, N.; Dallemand, J.-F.; Monforti-Ferrarion, F.; Nita, V. The role of biomass and bioenergy in a future bioeconomy: Policies and facts. *Environ. Dev.* **2015**, *15*, 3–34. [CrossRef]
100. IEEP. 2014. Available online: http://www.ieep.eu/assets/963/KNOSSOS_Green_Economy_Supporting_Briefing.pdf (accessed on 11 June 2021).
101. Ghaffariyan, M.R. Review of European biomass harvesting technologies. *Silva Balc.* **2010**, *11*, 5–20.
102. Bentsen, N.S.; Felby, C. Biomass for bioenergy in the European Union—A review of bioenergy resources assessments. *Bentsen Biotechnol. Biofuels* **2012**, *5*, 25. [CrossRef]
103. Van Dam., J.; Faaij, A.P.C.; Lewandowski, I.; Fischer, G. Biomass production potentials in Central and Eastern Europe under different scenarios. *Biomass Bioenergy* **2007**, *31*, 345–366. [CrossRef]
104. Long, H.; Li, X.; Wang, H.; Jia, J. Biomass resources and their bioenergy potential estimation: A review. *Renew. Sustain. Energy Rev.* **2013**, *26*, 344–352. [CrossRef]
105. Olkuski, T.; Stala-Szlugaj, K. Międzynarodowy rynek pelletów drzewnych. *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk* **2018**, *105*, 75–84. (In Polish) [CrossRef]
106. Baum, R.; Wajszczuk, K.; Pepliński, B.; Wawrzynowicz, J. Potential for agricultural biomass production for energy purposes in Poland: A review. *Contemp. Econ.* **2013**, *7*, 63–74. [CrossRef]
107. Ban Ki-moon Considers the Conference in Copenhagen "A Step Forward" [Electronic Resource]. Available online: http://unepcom.ru (accessed on 11 June 2021).
108. Peng, L.; Zhang, Y.; Li, F.; Wang, Q.; Chen, X.; Yu, A. Policy implication of nuclear energy's potential for energy optimization and CO_2 mitigation: A case study of Fujian, China. *Nucl. Eng. Technol.* **2019**, *51*, 1154–1162. [CrossRef]
109. EC. In-Depth Report on the Results of the 2030 Climate Target Plan Open Public Consultation. 2020. Available online: https://ec.europa.eu/clima/sites/default/files/eu-climate-action/docs/2030_ctp_opc_report_en.pdf (accessed on 11 June 2021).
110. Meinshausen, M.; Jeffery, L.; Guetschow, J.; Du Pont, Y.R.; Rogelj, J.; Schaeffer, M.; Höhne, N.; Elzen, M.D.; Oberthür, S.; Meinshausen, N. National post-2020 greenhouse gas targets and diversity-aware leadership. *Nat. Clim. Chang.* **2015**, *5*, 1098–1106. [CrossRef]
111. Kulovesi, K.; Oberthür, S. Assessing the EU's 2030 climate and energy policy framework: Incremental change toward radical transformation. *RECIEL* **2020**, *29*, 151–166. [CrossRef]
112. Mikołajczak, E. The conditions of pellet production development in Poland. *J. Agrib. Rur. Dev.* **2010**, *2*, 93–100.
113. Stolarski, M.J.; Szczukowski, S.; Tworkowski, J.; Krzyżaniak, M.; Gulczynski, P.; Mleczek, M. Comparison of quality and production cost of briquettes made from agricultural and forest origin biomass. *Renew. Energy* **2013**, *57*, 20–26. [CrossRef]
114. AEBIOM. Statistical Report 2017. European Bioenergy Outlook. 2017. Available online: http://www.aebiom.org/wp-content/uploads/2017/10/KF17-v2.pdf (accessed on 22 May 2021).
115. Nagy, D.; Balogh, P.; Gabnai, Z.; Popp, J.; Oláh, J.; Bai, A. Economic Analysis of Pellet Production in Co-Digestion Biogas Plants. *Energies* **2018**, *11*, 1135. [CrossRef]
116. Bai, J.; Ng, S. *Tests for Skewness, Kurtosis, and Normality for Time Series Data; Boston College Working Papers in Economics No. 501*; Boston College Department of Economics: Chestnut Hill, MA, USA, 2001.
117. Park, H.M. Univariate Analysis and Normality Test Using SAS, STATA, and SPSS. Available online: http://cef-cfr.ca/uploads/Reference/sasNORMALITY.pdf (accessed on 12 February 2021).
118. Fiszeder, P. *Modele Klasy GARCH w Empirycznych Badaniach Finansowych*; Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika w Toruniu: Toruń, Poland, 2009. Available online: http://www.home.umk.pl/~{}piter/Modele_klasy_Garch.pdf (accessed on 11 June 2021).
119. Ghahramani, M.; Thavanewaran, A. A note on GARCH model identifying. *Comput. Math.* **2008**, *55*, 2469–2475.
120. Kumar, D.; Maheswaran, S. Modelling asymmetry and persistence under the impact of sudden changes in the volatility of Indian stock market. *IIMB Manag. Rev.* **2012**, *24*, 123–136. [CrossRef]