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Perspectives of Biodiesel Development in Poland against the Background of the European Union

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Abstract: Biofuels are becoming more important in the renewable energy sources mix. Liquid biofuels are products of agriculture. Bioethanol can be prepared from corn, beetroot and other plants. Biodiesel is mainly made from rapeseed. This paper presents information about biodiesel development in Poland, as well as some background information about its development in the European Union (EU). We analyzed the data about biofuels in the literature, and provide statistical data about liquid biofuel in Poland and other countries of the EU. The aim of the study is to assess the viability of liquid biofuel development in Poland. The base for biodiesel production in Poland and the EU is rapeseed. The production yields and sown area of rapeseed increased in Poland from 2005–2020. This was due to integration and European Union policies which aim to supply clean energy. The energy mix in Poland differs from that of the EU. Solid biofuels have made up the biggest share of renewable energy sources in Poland (73.4%) and the EU (40.1%). Poland has smaller share of wind energy, biogas, heat pump, water energy, solar anergy, municipal waste and geothermal energy in its renewable energy sources compared to the rest of the EU. Only with solid and liquid biofuels is the share of renewable energy sources larger in Poland compared to the EU averages. Poland has decreased its share of solid biofuels and water energy among its renewable energy sources, while other sources have increased. Poland is investing to increase its renewable energy sources. To analyze the opportunities for biodiesel production in Poland, we used the scenario method of analysis. We outlined three scenarios. The first is increasing the production of biodiesel by 3% each year for the next three years. The second is production remains unchanged, i.e., at the 2020 level. The last scenario is decreasing production by 3% each year. According to the first scenario, the total demand for rapeseed for energy and food purposes will be 375 thousand tons in 2025. Such a scenario is very likely to occur because of the growing demand for biodiesel and edible oil. The current situation with Ukraine and the Russian Federation will create an increase in demand for rapeseed, leading to higher prices.

Keywords: liquid biofuels; renewable energy source; biofuels; biodiesel

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1. Introduction

Renewable energy sources include solid biomass, biofuels, wind energy, geothermal and solar energy. The share of solid biomass in the renewable energy sources mix is decreasing while the that of biofuels, wind and solar energy is increasing [1].

The global energy situation is not stable at present because of global warming, greenhouse (GHG) gas emissions and the depletion of fossil fuels. Fossil fuels such as oil, coal and gas are becoming increasingly scarce [2]. Additionally, these resources are risky because they are non-renewable, and are expensive because their consumption creates greenhouse gasses (GHG) [3]. Global warming and energy security concerns have moved attention to renewable energy sources, which play a significant role in energy security, sustainable development and the preservation of the environment [4]. Energy security is a key issue which is facing many challenges, for example: energy price changes, increasing demand, production growth, dependence on inputs, geopolitical uncertainties, wars and others [5].

The biggest CO_2 emitter is China; however, this country is also the biggest producer of photovoltaic (PV) and wind power (WP) [6]. Developed and developing countries with adequate solar radiation are moving toward photovoltaic energy and wind [7]. The efficiency of renewable energy sources depends on many factors, for example, production costs, improvements in the performance of photovoltaics and wind turbines, the growth of industries and global conditions [8]. Global changes have been observed in the energy sector; for example, savings on demand side, energy production efficiency improvements and reduced use of fossil fuels [9–14]. Renewable energy sources such as wind and solar have great potential; however, their share is smaller [15].

Liquid biofuels are becoming increasingly important in the energy mix in the European Union (EU). Concern about reducing emissions of CO_2 and other harmful gasses has forced the EU to look for renewable energy sources. The depletion of coal, gas and oil could threaten the world's energy needs [16]. The rapid development of renewable energy has attracted significant attention because of its economic benefits, security and advantages in terms of climate change [17]. However, the energy from renewable sources has disadvantages, because it needs to be procured, delivered and stored.

Access to and the costs of biocomponents are becoming threats to the development of the energy sector. The demand and profitability of biofuels are determined by governmental regulations, import taxes, subsidies, etc. [18].

The development of biofuels has created green workplaces in the sector and is helping to achieve sustainable development [19]. However, such development, as well as that of other renewable energy sources such as biomass, wind, solar and others, depends on environmental, economic and social factors [20].

One of the most important problems in the development of biofuels is the supply chain. Problems with the supply of rapeseed, corn, and other basic resources for biofuel production create uncertainty [21]. However, biofuels are the most promising potential alternative to reduce dependency on fossil fuels. Previously, biofuels were a niche energy source. However, they have since become relevant to the global market [22].

The development of liquid biofuels and other renewable energy sources is helping to achieve sustainable development, focusing on economic, social, and environmental issues. Moreover, the sustainable development concept can encompass institutional, cultural, organizational, and technical issues [23].

Agriculture is important factor in the production of biodiesel and bioethanol [24]. The Common Agricultural Policy (CAP) of the EU supports a better standard of living of farmers and care for the natural environment [25]. Agriculture is an important supplier of public goods for sustainable development [26]. The classical three-dimensional approach for sustainability is not exhausting for farms. They are important in the self-provision of nutritious food [27]. Farms are also important in biodiesel and solid biofuels development, so the energy and food nutritious approach should be incorporated within the framework of classical sustainability.

The growing demand for energy in the twenty-first century and increasing concern about the environment have forced the world to look for renewable energy sources (RES). Biodiesel, bioethanol, biomass, wind, solar, and geothermal can replace fossil fuels to meet energy needs [28,29].

The EU is the most important producer of biodiesel; the United States (US) produces mostly bioethanol. Biodiesel can be used in a clean form or together with diesel. Biodiesel can be produced from a wide range of feedstock [30], such as rapeseed, soybeans, sunflower, palm oil, and others. It can also be blended with fossil diesel and can be used as stable biodiesel. It also has an impact on the development of farms and boosts their incomes. Nowadays, rapeseed production is the most promising, which has led to price increases [31].

Bioethanol can be made from corn. Although crops comprise the main costs of biofuel production, they are the most important part of future energy sources [32]. The use of bioethanol requires construction changes in internal combustion engines [33].

There are four generations of biofuels [29]:

1st generation: produced mainly from rapeseed and corn;

2nd generation: produced from products having no nutritional basis;

3rd generation: made from genetically modified biomass;

4th generation: made from non-conventional biomass and other products such as algae.

The profitability of the biofuel sector is determined by new processing technologies. The aim of these technologies is to reduce the cost of production of biofuels [18].

The development of liquid biofuels depends on legal conditions. The European Union declared its intention to derive at least 10% of its energy from renewable sources by 2020 [19].

The development of liquid biofuels depends on EU policy. Its aim is to increase energy efficiency and security, the development of renewable energy sources, the development of competitiveness, and to reduce the impact on the environment [34]. The EU is supporting renewable energy development and stimulates the promotion of environmentally friendly products [35]. In this regard, the EU is using tools such as direct payments support, climate protection, and pro-ecological sources of heat and fuel for farms [24]. The most important driver for the development of global biodiesel production is the Common Agricultural Policy (CAP) of the EU. The development requires that more arable land be devoted to rapeseed production [36].

The European Commission is managing the development of renewable energy sources. The Green Deal is an example of European policy aiming at achieving climate neutrality by 2050 [37,38]. Policy actions include investments of at least €1 trillion in renewable energy sources [39]. As such, the European Union can be described as a leader in actions aimed at looking for alternative energy sources [40].

Another driver for the development of biofuels is global prices of raw materials. These prices depend on various factors such as yields, production, and global conditions such as international trade, wars, and weather conditions [36].

The development of biodiesel production depends on the expanded production of future raw material such as oilseed. Vegetable oil is converted to biodiesel in the process of transesterification [41].

The aim of this research is to describe the development of biodiesel in Poland against the background of the EU. In more detail, the primary aim is to determine the share of liquid biofuels in the renewable energy mix in Poland and in other countries of the EU.

To achieve this goal, we had to answer the following questions:

1. What is the share of liquid biofuels and how has it changed?
2. What factors determine the development of liquid biofuel development in the EU?

Hypothesis 1 (H1). *Biodiesel production in the EU is strongly correlated with rapeseed production.*

Hypothesis 2 (H2). *Liquid biofuels cause the competition between the nutrition, fodder, and petrochemical sectors.*

The paper is organized as follows. First, we present the historical development of liquid biofuels in the EU. Second, we present the methodology for our analyses. Third, we describe the research results. Next, the authors of the paper present a discussion. The final part is our conclusion.

2. Materials and Methods

2.1. Material

The main sources of data for our analyses were Eurostat and Statistics Poland. We analyzed biofuel development from 2000–2020.

Rapeseed is the main source for biodiesel production in Poland. The development of biodiesel has created competition between the fodder, food, and petrol industries in Poland. Moreover, the war in Ukraine has impacted biodiesel production and increased the price of rapeseed. First-generation biofuels are produced from rapeseed. Polish accession to the EU had an impact on the area of rapeseed sown, which increased from 550 thousand hectares to 900 thousand hectares from 2005–2020. Rapeseed yield also increased from 30.3 dt/ha to 31.5 dt/ha in 2005–2020. As a consequence, the harvest of rapeseed increased from 1632 thousand tons to 3124.8 thousand tons during this the period. The COVID-19 pandemic did not have a strong negative impact on sown area, yields, or the harvest of rapeseed in Poland (Figure 1).

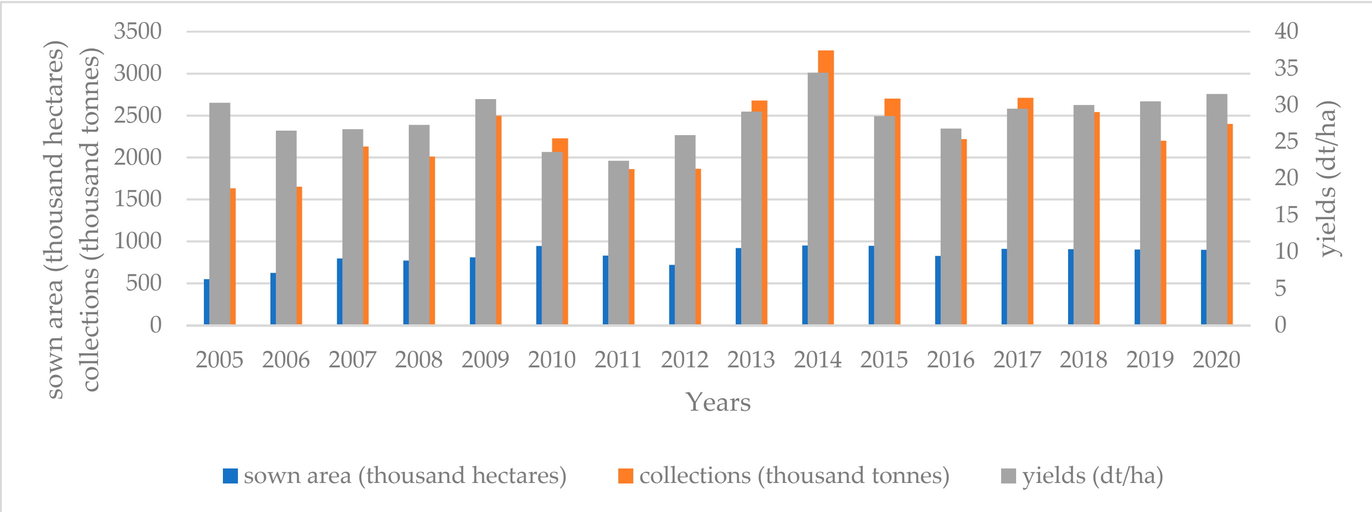

Figure 1. Sown area, yields, and collection of rapeseed in Poland. Source: own elaborations based on the rapeseed market [42].

2.2. Methods

The scenario method was used to check the perspectives for biodiesel production in Poland. Scenario methods are used to analyze discontinuous changes, i.e., changes that are not an extrapolative continuation of the processes taking place in the environment in the past at a given time. Their use dates back to the early 1970s. General Electric and Shell Nederland are the precursors in this field [43].

The scenario method is particularly valuable in the process, as opposed to the result. With this method, alternative strategies can be developed and assessed, managers can be encouraged to think more flexibly, and consensuses can be built. Assessing the likely outcomes of using different strategies in different scenarios will help identify which are the best and facilitate the development of a contingency plan [44].

We have elaborated three scenarios for biodiesel production:

- The first, in which the production of biodiesel will increase by 3% each year;
- The second, in which production will stay at 2020 levels;
- The third, in which production will decrease each year by 3%.

In order to elaborate these scenarios, we used following variables: diesel consumption, demand for esters, demand for rapeseed, processing of rapeseed, edible oil, nutritious aims, loses, and total demand. One of the most important problems in preparing these scenarios was to evaluate the contribution of raw materials. It was assumed that Poland is self-sufficient in rapeseed and biodiesel production. The scenarios were elaborated based on the OECD-FAO prognosis. Although such prognoses can be prepared using different methods [45–51], the OECD-FAO one is considered to be the most precise.

3. Results

3.1. Renewable Energy Production in Poland against the Background of the European Union

Renewable energy sources are among the most important factors determining economic growth in Poland and elsewhere [52,53]. The share of individual renewable energy sources carriers in Poland changed in 2007–2019. The shares of solid biofuels and water energy decreased by 28% and 47.7%, respectively.

The most promising source of renewable energy is wind, which increased from 0.9% to 13.7% in 2007–2019 (Table 1). Wind farms are continuing to expand in Poland, and several are planned on the Baltic Sea to create energy from offshore farms.

Table 1. The share of individual renewable energy sources in Poland in 2007–2019 (%).

Specification	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Solid biofuels	91.1	87.4	85.7	85.0	85.2	82.4	79.8	76.1	74.2	70.6	67.8	68.1	65.56
Solar energy	0.0	0.02	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.7	0.9	1.40
Water energy	3.4	3.4	3.3	3.6	2.7	2.1	2.4	2.3	1.7	2.0	2.4	1.9	1.78
Wind energy	0.9	1.1	1.5	2.0	3.7	4.8	6.0	8.1	10.5	11.9	14.0	12.2	13.72
Biogas	1.3	1.7	1.6	1.6	1.8	2.0	2.1	2.5	2.5	2.8	3.0	3.2	3.15
Liquid biofuels	2.3	5.4	7.0	6.6	5.8	8.0	8.1	9.1	9.1	10.1	10.0	10.0	10.36
Geothermal energy	0.2	0.23	0.24	0.2	0.2	0.17	0.22	0.25	0.24	0.24	0.25	0.3	0.26
Municipal waste	0.0	0.00	0.01	0.04	0.4	0.4	0.39	0.45	0.45	0.85	1.01	1.1	1.08
Heat pumps	-	0.27	0.30	0.31	0.30	0.31	0.44	0.55	0.55	0.58	0.62	2.4	2.69

Source: own elaborations based on [54].

Liquid biofuels are a promising energy source; their share increased from 2.3% to 10.36% in 2007–2019. They are important because they can reduce GHG emissions. Moreover, Poland is a big producer rapeseed, which is a basic product for biodiesel production. Polish farms are eager to harvest rapeseed because of higher prices.

Biogas also has great potential for development in the future. Its share increased from 1.3% to 3.15% over the same period. There are about 300 biogas plants in Poland, whereas in Germany, there are about 10,000. However, Poland has great potential for the production of biogas. The development of this renewable energy source requires further investments on farms to produce biogas from agricultural manure.

Geothermal, municipal waste, and solar energy make up the smallest shares in renewable energy sources, at 0.26%, 1.08%, and 1.40%, respectively.

As we can see from Figure 2, Poland has great potential for the development of renewable energy sources, because its share of carriers is smaller than that of the EU. Only in solid and liquid biofuels does Poland have a bigger share in renewable energy sources compared to the EU. These differences are the effect of different energy sources in Poland compared to other countries in Europe. Poland has extensive forest resources, accounting for 31% of its total land. Agriculture also produces straw, which can be effectively used for energy purposes. Other countries in Europe, i.e., mainly Mediterranean countries, have better access to water and can produce more energy from onshore and offshore wind farms. Moreover, photovoltaics in many European Union countries are better developed than in Poland because of higher economic incentives and longer sunny days. The possibility of gathering energy from photovoltaics in Poland is rather limited; energy produced in this way is bought by the Polish national company ENERGA mostly in summer and autumn, when the days are longer.

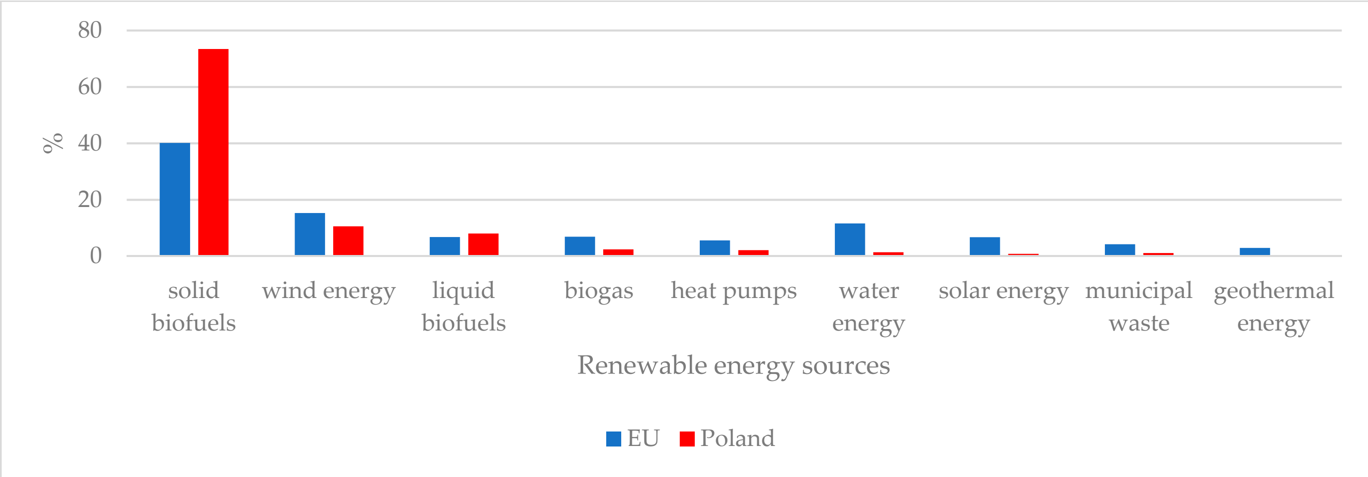

Figure 2. Obtaining energy from renewable sources in the EU-28 and Poland. Source: GUS—Energia ze źródeł odnawialnych w 2020 [55].

3.2. Rapeseed Production in Poland as the Main Source for Biodiesel

The sown area of rapeseed changed in Poland in 2005–2020. The biggest sown areas were in 2014 (951 thousand hectares), 2015 (947 thousand hectares), and 2010 (624 thousand hectares). The smallest sown areas were in 2005 (550 thousand hectares) and 2006 (624 thousand hectares). The changes of sown area were due to individual decisions of farmers and the effect of subsidies and increasing prices for rapeseed (Figure 3).

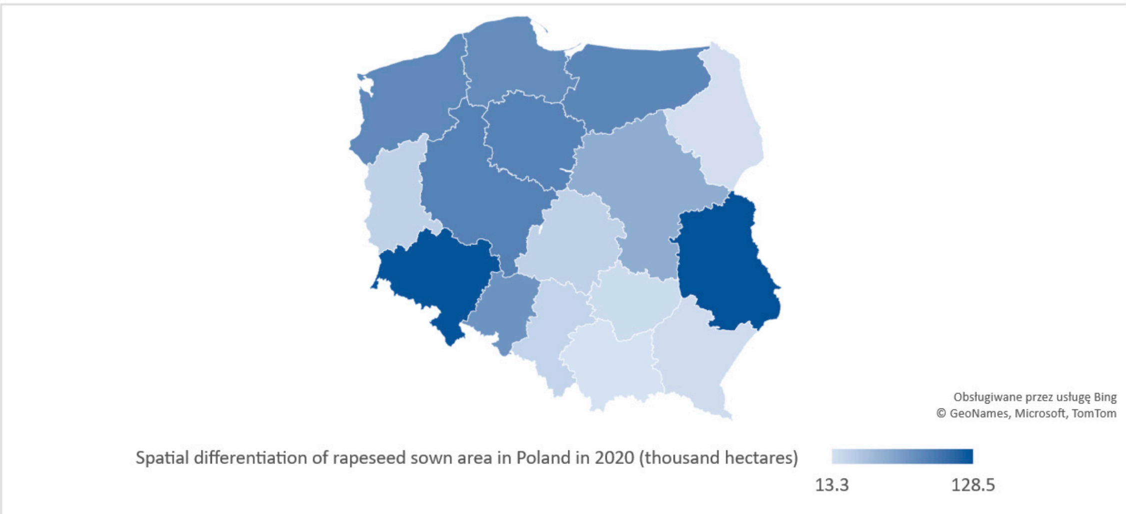

Figure 3. Spatial differences of rapeseed sown area in Poland in 2020 (in thousands of hectares). Source: own elaborations based on the rapeseed market [42].

Poland achieved the highest yields of rapeseed in 2014 (34.4 dt/ha), 2020 (31.5 dt/ha) and 2009 (30.8 dt/ha). The smallest yields occurred in 2011 (22.4 dt/ha), 2010 (23.6 dt/ha), and 2012 (25.9 dt/ha). Yields of rapeseed are the effect of weather and the extent of usage of mineral fertilizers. Land quality is also important for yields, because rapeseed is a very demanding plant. Rapeseed yields are regionally diverse in Poland. The highest yields were achieved in Podkarpackie and Wielkopolskie voivodeship (33.6 dt/ha), Pomorskie voivodeship (33.4 dt/ha) and Kujawsko-pomorskie voivodeship (33.3 dt/ha) in 2020. In the same year, the lowest yields were observed in Świętkorzyskie voivodeship (27.4 dt/ha), Lubuskie voivodeship (28.5 dt/ha) and Lubelskie voivodeship (29.8 dt/ha).

The collection of rapeseed depends on sown area and yields. The biggest collections of rapeseed were in 2014 (3276 thousand tons) and 2015 (2700 thousand tons) and 2017

(272 thousand tons), when the sown area was above 910 thousand hectares. In 2020, the rapeseed sown area accounted for 980.9 thousand hectares, yields 31.9 dt/ha, and production 2400 thousand tons [42].

The production of rapeseed is regionally diverse. Germany, France, and Poland are considered to be the main producers, with these three countries being responsible for 52% of Europe's rapeseed production. However, countries such as Romania, Czechia, Hungary, Denmark, and Slovakia are also substantial producers [53]. The European Union is the biggest producer of rapeseed, followed by Canada, China, India, Australia, and Ukraine [54].

In Poland, the biggest areas of rapeseed cultivation were Lubelskie voivodeship (128.5 thousand hectares), Dolnośląskie voivodeship (127 thousand hectares), and Wielkopolskie voivodeship (91 thousand hectares). The smallest sown areas in 2020 were Małopolskie voivodeship (13.3 thousand hectares), Świętokrzyskie voivodeship (18.6 thousand hectares), and Podlaskie voivodeship (18.3 thousand hectares). Such variation is the effect of the feasibility of plant production in Poland. West and north Poland have the best conditions for the development of rapeseed.

Rapeseed collection is based on sown area and yields. The highest collections were in 2020 in Dolnośląskie voivodeship (390.5 thousand tons), Lubelskie voivodeship (383.5 thousand tons), and Wielkopolskie Voivodeship (305.8 thousand tons). The smallest were in Małopolskie voivodeship (42.5 thousand tons), Świętokrzyskie voivodeship (50.8 thousand tonnes), and Podlaskie voivodeship (59.2 thousand tons).

The Renewable Energy Directive required the EU to derive at least 20% of its total energy from renewables by 2020. At least 10% of transport fuels came from renewable sources in 2020. Another Directive, i.e., (EU) 2015/51, or the so called "iLUC Directive", set out a cap for the contribution of biofuels at 7% [56–61].

All voivodeships in Poland increased their share of sown area after accession to the EU. The biggest increases of rapeseed area occurred in Podlaskie voivodeship (546%), Małopolskie voivodeship (239.3%), and Śląskie voivodeship (174.6%). The smallest increases were in Zachodniopomorskie voivodeship (26.6%), Opolskie voivodeship (29.2%), and Warmińsko-mazurskie voivodeship (48%). This research proves that voivodeships with the smallest sown areas of rapeseed increased their sown areas the most, while those with the biggest sown area increased it the least (Figure 4).

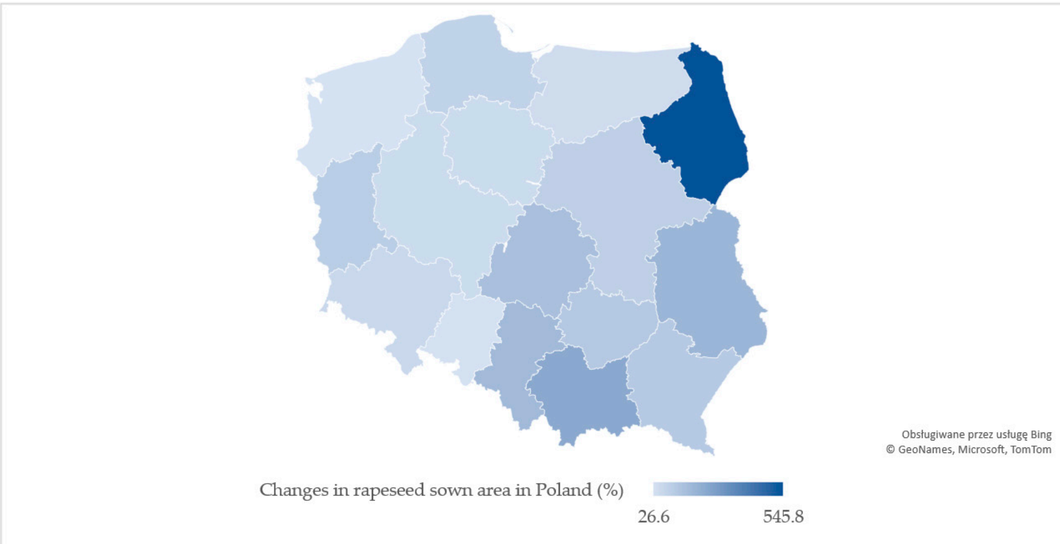

Figure 4. Changes in rapeseed production in Poland in 2005–2020 (%). Source: own elaborations based on rapeseed market [42].

Rapeseed production helps to achieve sustainability. This plant can improve soil fertility, serving as a good crop between corn harvests, as well as delivering oxygen (CO_2) and organic material to the land. However, this plant requires further genetic diversity [53].

3.3. Scenarios for Rapeseed Production in Poland

One of the research aspects was the preparation of scenarios regarding the production of biodiesel and rapeseed in 2021–2025 in Poland, considering the forecasts of the OECD-FAO (Figure 5). Three scenarios were developed: an increase in production by 3% per year, a decrease by 3% per year, and no change in demand. To develop these scenarios, the following variables were applied: use of rapeseed for food purposes; use for the production of biodiesel; and losses. The assumptions were based on the generally available data of the Central Statistical Office (CSO) [42] for the years 2005–2020 and data on NCW (National Indicative Targets).

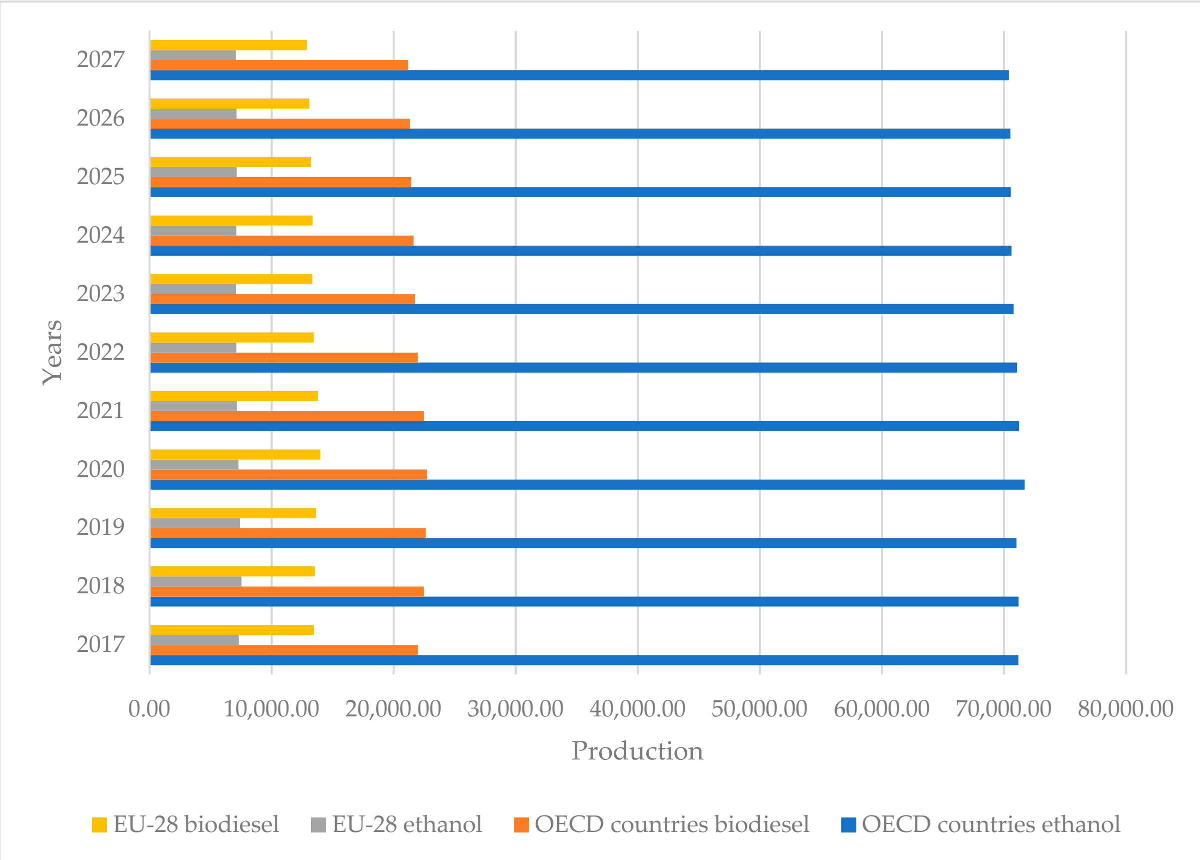

Figure 5. Biodiesel and ethanol production and outlook. Source: FAOSTAT 2018. OECD-FAO Agricultural Outlook 2018–2027: BIOFUEL—OECD-FAO Agricultural Outlook 2018–2027. https://stats.oecd.org/Index.aspx?DataSetCode=HIGH_AGLINK_2018 (accessed on 10 June 2021) [54].

The scenarios for the years 2013–2020 were prepared by Boczar [62]. He assumed consumption of rapeseed for food purposes at a level of 800 thousand tons for the scenario assuming a decrease in demand, 1 million tons for the scenario assuming no change, and 1.2 million tons for the scenario assuming an increase in demand in 2013–2020. These assumptions are consistent with the data presented in the literature, which show that the consumption of rapeseed for food purposes amounted to 1.3 million tons in 2020 [63,64].

The forecast of changes in the developed scenarios covered a period of five years, which made it possible to capture upward or downward trends in rapeseed production.

Before developing the three scenarios, we analyzed the outlook presented in the OECD-FAO. As shown in Figure 4, both biodiesel and bioethanol production will decrease in EU and OECD countries in 2023–2027. Ethanol production will decrease by 1% and 0.5% in OECD and EU countries, respectively, from 2023–2027. Biodiesel production will decrease in OECD-FAO countries by 3.5%, and in the EU by 4%.

Rapeseed market analyses showed that since Poland's accession to the EU, there have been upward trends in all variables; these formed the basis for the development of scenarios in this research (Table 2).

Table 2. Assumptions for the scenario of an increase in demand for rapeseed by 3% annually.

Years	NCW (%)	Diesel Oil Consumption (in Thousands of Tons)	Demand for Esters (in Thousands of Tons)	Rapeseed Demand for Energy Purposes (in Thousands of Tons)	Processing (in Thousands of Tons)	Crude Edible and Technical Rapeseed Oil (Thousands of Tons)	Food Purpose (Thousands of Tons)	Losses (in Thousands of Tons)	Total Demand for Rapeseed (in Thousands of Tons)
2022	8.5	16,192	1114	2513	3205	1306	1010	98	3523
2023	8.5	16,677	1148	2588	3302	1345	1010	101	3598
2024	8.5	17,178	1182	2666	3401	1386	1010	104	3676
2025	8.5	17,693	1218	2746	3503	1427	1010	107	3756

Source: own elaboration based on [42].

The first scenario assumes an increase in the demand for rapeseed of 3%. The basis of this analysis was data from 2020 (Table 2). Our scenarios are prepared for 2022–2025, so they are newer than those elaborated by Boczar [62]. Our scenarios also add additional variables, such as losses of rapeseed and crude edible and technical rapeseed oil. The global conditions in which the scenarios will be verified are completely different. This scenario considers an increase in the demand for rapeseed for food purposes by 1% and an increase in the demand for biodiesel of 3% per year. The need to increase the production of rapeseed and biodiesel will increase demand. This scenario is in opposition to the OECD-FAO's prognosis for EU countries. Increasing the demand for rapeseed oil for energy purposes will necessitate the allocation of larger areas of land for its cultivation. In this day and age, given Ukraine's war with the Russian Federation and the reduction of grain and oil production in Ukraine, this scenario seems unlikely. Although the increase in rapeseed and cereal prices will encourage farmers to increase production, it will also increase the cost of fuels. It is also unreasonable to expect an increase in imports from the East to Poland, given the situation in Ukraine. In the global biodiesel market, other factors will also be decisive, such as the sales of esters, crude oil prices, changes in GDP, inflation index, the USD/PLN exchange rate, the production and export of rapeseed oil, and the prices of agricultural raw materials [65].

The demand for rapeseed for food purposes will be stable in the analyzed period, accounting for around 1010 thousand tons. Such an evaluation assumes the stable consumption of edible oils in Poland.

This scenario is likely to occur in Poland. According to statistics in Poland, the sown area, yield, and collection of rapeseed as the main source for biodiesel production increased by 1% in 2021 compared to 2020 [42]. Taking into account even a smaller increase in area and rapeseed production at the level of 1% per year, this would require a much larger area for sowing.

The second scenario assumes no changes in the demand for rapeseed. Data from 2020 were used as the basis (Table 3) for this scenario. At the same time, no change in the use of turnips for food and non-food purposes was assumed. The total annual demand for rapeseed would amount to approximately 3450 thousand tons per year, of which 1010 thousand tons would be for food purposes and 2440 thousand tons for esters. This demand for rapeseed would be covered by domestic production on an area of approximately 950 thousand square meters, with a yield of 29 dt/ha and imports of about 500 thousand tons. Such a situation would cause some stabilization on the market, and the growing demand for rapeseed to produce biofuels could be supplemented with second and third generation biofuels. Such a scenario is related to the constant production of rapeseed, which means no change in the rapeseed cultivation area for existing producers, thereby hindering access to the market for new suppliers. Moreover, stabilization in production could limit the development of rapeseed processing in the country. This scenario will probably not occur for various reasons. First, it is impossible for production to be stable. Second, the conditions for agricultural production are very dynamic. The unstable situation in Ukraine will have an impact on food production worldwide. Third, EU policy for renewable energy sources will also have impact on the production of edible oil and biodiesel.

Table 3. Assumptions for the scenario of no change in the demand for rape.

Years	NCW (%)	Diesel Oil Consumption (in Thousands of Tons)	Demand for Esters (in Thousands of Tons)	Rapeseed Demand for Energy Purposes (in Thousands of Tons)	Processing (in Thousands of Tons)	Crude Edible and Technical Rapeseed Oil (Thousands of Tons)	Food Purpose (Thousands of Tons)	Losses (in Thousands of Tons)	Total Demand for Rapeseed (Thousands of Tons)
2022	8.5	15,720	1082	2440	3112	1268	1010	95	3450
2023	8.5	15,720	1082	2440	3112	1268	1010	95	3450
2024	8.5	15,720	1082	2440	3112	1268	1010	95	3450
2025	8.5	15,720	1082	2440	3112	1268	1010	95	3450

Source: own elaboration based on [42].

The third scenario assumes a reduction in the demand for rapeseed by 3% per annum (Table 4). The adoption of such a level resulted from the observed decrease in the production of crude rapeseed oil in 2018 compared to 2017 [42]. With a total demand for rapeseed in 2025 amounting to 2241 thousand tons and the harvest of 28 dt/ha, the cultivation area will be 714.3 thousand hectares. Such a situation would result in an increase in the acreage of cultivation. However, such an increase in sowing would be an unfavorable phenomenon for the natural environment [66]. A share of cereals in the structure of crops above 70% may result in the sterilization of the soil, greater occurrence of fungal diseases, and a reduction in yields. Moreover, the implementation of this scenario would result in a limited possibility of meeting the EU obligations and obtaining a 10% share of biofuels in the total fuel consumption. This scenario is like the prognosis of OECD-FAO. However, Poland is a rather agricultural country and higher prices will be an incentive for rapeseed producers to increase production.

Table 4. Assumptions for the scenario of a 3% decrease in demand for rapeseed.

Years	NCW (%)	Diesel Oil Consumption (in Thousands of Tons)	Demand for Esters (in Thousands of Tons)	Rapeseed Demand for Energy Purposes (in Thousands of Tons)	Processing (in Thousands of Tons)	Crude Edible and Technical Rapeseed Oil (Thousands of Tons)	Food Purposes (Thousands of Tons)	Losses (in Thousands of Tons)	Total Demand for Rapeseed (Thousands of Tons)
2022	8.5	15,248	1049	2367	3018	1230	978	92.2	2459.2
2023	8.5	14,791	1018	2296	2928	1193	950	89.4	2385.4
2024	8.5	14,347	988	2227	2840	1157	922	86.7	2314.0
2025	8.5	13,917	958	2160	2755	1123	894	84.1	2244.1

Source: calculations based on [42].

There is a possibility that this scenario will not occur in the market. The conditions in the Polish rapeseed market are determined by the situation in the EU. The production of rapeseed in the EU in 2022 should increase significantly compared to that of 2021. Ukraine will produce about 3 million fewer tons in 2022 compared to 2021. This will create a shortage in the European and world rapeseed markets which will have to be compensated for by production in other countries.

4. Discussion

The production of renewable energy sources is increasing in the European Union as a result of environmental policies. Concerns about global warming and CO_2 emissions, as well as the need to provide enough energy, have forced governments and policy-makers to look for renewable energy sources [4].

Poland has good sources for renewable energy production, i.e., biodiesel. In Poland, more than 50% of rapeseed production is dedicated to biodiesel. Such a situation proves that the potential for rapeseed and biodiesel production are high. Rapeseed still has potential for further development in Poland and the EU. Its production can be affected by better varieties and improved technology. However, the possibilities of increasing the sown area are limited.

Biodiesel is an old and well-known source of energy. It was developed by Rudolph Diesel in 1900 using peanut oil. Its application in compression ignition (CI) engines revolutionized the world [67]. Biodiesel is an important source of energy because it is helping to achieve energy security in Poland, Europe and other countries. However, its production depends on natural strategies which may change over time [5].

Biodiesel is mainly produced in west and north Poland. Such locations are due to the natural resources there. The share of liquid biofuels in Poland is bigger than in the EU. Poland is a rather agricultural country with good conditions for rapeseed production. Such a situation and unstable market conditions in Ukraine, which is an important producer of grains and oils, will encourage Polish producers to increase production. The shortage of rapeseed in the Ukrainian market in 2022 will have to be compensated for by production in other countries. This will result in greater hunger and will increase the migration of people, especially from the Middle East, who will move in search of food.

5. Conclusions

Improving energy security is a central element of sustainable development in the European Union (EU). Renewable energy sources are gaining attention worldwide because they are considered to be clean and environmentally friendly. The data and analysis presented in this study showed an increase in the use of liquid biofuels in the renewable energy sources mix in the EU. The development of renewable energy sources such as biofuels, biomass, photovoltaic, and wind can help achieve sustainable development. However, this development needs to be supported by stricter policies [2]. The sustainable development concept concerns not only the environment and the economy, but also the social, energy conservation, production, and consumption dimensions [67]. There are many kinds of biofuels, among which biodiesel and bioethanol are the most important [68–70].

Our research proved that Poland is an important producer of rapeseed and biodiesels which are the first generation of biofuels. Such a situation is a consequence of good conditions for rapeseed production, particularly in west and north Poland, where the biggest farms are located. Poland has increased the sown area and yields of rapeseed. Production technology has improved as a result of new machinery implementation and new varieties of rapeseed being used.

Our research demonstrates the development of rapeseed production in Poland as the main source of first-generation biodiesel. After Polish accession to the EU, the rapeseed sown area increased from 550 thousand hectares to 900 thousand hectares. Moreover, the harvest of rapeseed increased from 1632 thousand tons to 3124.8 thousand tons.

It is difficult to predict the situation in the rapeseed market and the production of biodiesel in Poland and other EU countries. Ukraine's war with the Russian Federation will have a negative impact on the production of sunflower oil and rapeseed oil. This will encourage farmers in Poland and other countries of the EU to increase production, confirming the first scenario. As such, the situation in Poland will probably resemble the first scenario, i.e., with a 3% increase in rapeseed and biodiesel production each year. This may occur because the war in Ukraine will shorten the supply of grains and oils due to production and supply chain delivery problems. The increasing demand for rapeseed in

Poland will have an impact on prices. This will cause good conditions for producers, on one hand encouraging them to increase production and, on the other, increasing the prices of edible oils and biodiesel.

According to an OECD-FAO prognosis, the production of biodiesel will decrease by 4% in the next years. Global trends will be supported by scenario three, i.e., the reduction of biodiesel and rapeseed production. However, Poland will not probably follow this trend. It is worth mentioning that the prognosis was elaborated before the war in Ukraine, and it is impossible to predict the situation in the future because it is changing.

Our research confirms hypothesis 1 (H1), according to which biodiesel production in the EU is strongly correlated with rapeseed production. Most biodiesel is classified as first generation. Second, third, and fourth generation biofuels are in the early stages of introduction into the market.

The second hypothesis 2 (H2), i.e., that liquid biofuels cause competition between the nutrition, fodder, and petrochemical industries, was also positively verified. A lack of rapeseed in the market causes an increase in its prices. Moreover, the war is leading to increased prices, causing global problems.

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Nomenclature

CAP	Common Agricultural Policy
CI	Compression ignition
CO_2	carbon dioxide
CSO	Central Statistical Office
Dt/ha	100 kg per hectare
EU	European Union
FAOSTAT	United Nations Statistics Division of the Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	greenhouse gasses
NCW	National Indicative Targets
OECD-FAO	Food and Agriculture Organization of the United Nations
PLN	Polish currency
PV	photovoltaics
RES	Renewable energy sources
US	United States
USD	United State Dollar
WP	wind power

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