

Review

# Problems of Selected Sectors of Biofuels for Transport in Poland

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**Abstract:** The paper discusses issues related to the sectors of biofuels for transport. Development directions of those sectors and factors limiting the growth rate thereof are analysed. At present, researchers' attention is increasingly focused on development of the alternative fuels sector. Moreover, issues related to waste used in the sector of alternative fuels are now among the leading undertakings of environmental engineering. The authors have analysed the potential of biofuels sectors in Poland taking into account the EU's legislative requirements. The paper contains a discussion of the sector of esters, liquid biofuels, sector of lignocellulose, sector of liquid bio-hydrocarbons and, additionally, pays attention to the sector of electromobility as one of the most attractive and prospective sectors in terms of emission reduction.

**Keywords:** bioethanol; methyl esters; biogas; biocomponents market; sector value; environmental engineering; mechanical engineering



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## 1. Introduction

Negative environmental effects of using petroleum-based fuels in transport have resulted in an increased focus on development of alternative fuels and their growing use in transport related purposes [1–3]. Among others, alternative fuels include electromobility, hydrogen, biofuels (including bioethanol, bioesters, biogas, biohydrogen, synthetic biofuels), natural gas (including biomethane) in the form of compressed natural gas (CNG), liquefied natural gas (LNG) and liquefied petroleum gas (LPG). Biomethane obtained from purified biogas may be a transport fuel as well. In places where it is produced, it is much cheaper than petrol and diesel fuel. Its popularity in Poland is low, infrastructure for biomethane refuelling is missing, just as vehicles adapted to using this fuel [4]. It is desirable that alternative fuels, next to their properties allowing substitution of hydrocarbon-based ones, are characterised with high efficiency, acceptable prices and a renewable character [5]. Pursuant to directives on promoting the use of energy from renewable sources [6,7], using such fuels in transport within the European Union (UE) is obligatory [8].

The principles governing development and operation of infrastructure designed for using alternative fuels in transport in Poland are identified in the Act of 11 January 2018 on electromobility and alternative fuels [9], which implements the EU directive 2014/94/EU on the deployment of alternative fuels infrastructure [10]. The objectives and support instruments for development of the market and infrastructure with respect to electricity and natural gas in the form of CNG and LNG, used in road transport and in water transport,

are contained in the National Policy Framework for the Development of Alternative Fuels Infrastructure document [11,12].

Member states are obligated to ensure a minimum 10% share of renewable energy in terminal consumption of energy in transport in 2020 [6], while by 2030 the share ought to increase to at least 14% [7]. Whereas methyl esters and bioethanol were for a long time the most efficient method enabling fulfilment of such obligations in Poland, nowadays—due to numerous limitations, including technical barriers (so-called blending wall)—the use of other biocomponents and renewable fuels is also necessary. An increasingly important role in this context is played by Hydrogenated Vegetable Oils (HVO), constituting a raw material with enormous potential [13], in the case of which there is no blending wall and, therefore, which may be added to liquid fuels above technical standards applicable in the case of methyl esters and bioethanol.

One should also emphasise that an interesting and promising method for acquiring energy used in transport in Poland is biogas obtained from the network of agricultural biogas plants, of which several dozen work for the transport industry. Biogas plants are an interesting and prospective source of biogas—a source of energy with high emission reduction if the substrates are various faeces and production waste from agricultural farms [14–16].

The main goal of the authors is to divide alternative fuels into basic types, and to take into account electromobility, to conduct an orderly review of literature data (secondary research) in the field of the macro and competitive environment. A sector inquiry was planned and implemented by sector value (primary research). As standard, apart from the data related to the sector potential/production capacity, the NIT (National Indicator Target) was also examined.

## 2. Methodology

Research methods included in the group of primary and secondary research were used in the study. The primary research consisted in conducting telephone interviews with managers of companies that produce alternative fuels. The group of respondents were owners or persons responsible for managing these enterprises. Since the companies producing alternative fuels in Poland are small and medium-sized companies, the semi-structured interviews were appropriate. The questions asked concerned, inter alia, barriers related to the development of the sector. This question allowed us to find out what barriers exist in enterprises and which of them are considered by the owners to be the most difficult to overcome. This type of research is classified as qualitative research in which one learns about the motives of action, assesses the situation, and does not use statistical tools.

The second group of research was secondary research in which a critical review of the literature was made and trade journals, EU directives, and national regulations were analysed.

The applied approach to the literature review allowed the authors to integrate the research that has been carried out so far, which has been continuously carried out for many years, and to provide qualitative and quantitative insights into the research topic [8,14,17]. Data collection and analysis was carried out, as well as a deep focus on the analysed cases [18].

Moreover, the research concerning biofuels is carried out since many years as on-going study. The value of sectors has been investigated by the authors since 2007. The multi-criteria method M.E. Porter was adopted for the research on the value of sectors. Porter's method has been used successfully since 2007 for almost all RES sectors in various studies and publications [8,14].

For secondary research as mentioned: the results of own research from previous years were used, confirmed, and verified, including sector values; publications and studies of institutions and organizations of proven credibility. The method of sector value calculation consists in identifying the main criteria for assessing the sector (s) under scrutiny, assigning

a value to each criterion on a 0–3 scale, summing up the values of all criteria for a given sector and divided into the number of criteria. The number of criteria in this study was 15.

### **3. Renewable Energies for Transport in EU and Poland: Actual Data and Regulatory Constraints—Contribution to Discussion**

#### *3.1. European Union's Objectives on Renewable Energy in Transport*

Pursuant to Directive 2009/28/EC [6], member states were obligated to ensure in 2020 a minimum 10% share of renewable energy in terminal consumption of energy in transport. Initial plans involved the use of so-called conventional biofuels, produced from high starch plants, sugar plants and oilseed plants as well as plants cultivated for energy purposes as main crops on arable lands (produced from food and fodder plant species) to accomplish that objective [19]. Subsequently, the objective was defined in more detail in Directive 2015/1513/EC [20], pursuant to which the share of biocomponents and conventional biofuels within the minimum set for 2020 could not exceed 7%. At the same time, the Directive marked the beginning of the period of promoting advanced biocomponents and biofuels, i.e., those produced from the raw materials enumerated in part A of the appendix to the discussed directive (algae, straw, or cobs cleaned of corn grains) [21] or in domestic legislation—from raw materials not suitable for consumption (not being competitive towards the food and fodder markets). Advanced biocomponents and biofuels as well as those produced from used cooking oils and animal fats may be recorded at a double quantity in connection with accomplishment of the obligation imposed by the EU [22].

Directives 2009/28/EC and 2015/1513/EC identified binding objectives for the European Union regarding the share of renewable energy in transport in 2020. Evaluation in terms of fulfilment thereof will commence in 2022; evaluation basis will be data calculated by the European Statistical Office EUROSTAT and reports submitted by individual member states [23]. On the other hand, Directive 2018/2001/EU [7] identified the target on renewable energy share by 2030. Pursuant to the Directive, the share ought to be equal to 14% (the threshold defined as the “minimum share” to be achieved).

Sustaining the mechanism applicable to date, the share of biocomponents, biofuels and biogas produced from certain raw materials will be considered to be twice as high in the energy balance of the member states using them [24,25]. That concerns both advanced biocomponents and biofuels, as well as biogas (produced from raw materials enumerated in part A of appendix IX to the Directive (including waste and residues from the forestry and timber sector, algae), and those produced from other raw materials enumerated in part B of that appendix (used edible oils and animal fats). With the intention to support industrial development of advanced biofuels, it was also agreed by way of Directive 2018/2001/EU that the share of such biofuels in energy consumption in transport ought to be at least 3.5% by 2030. The Directive establishes the possibility to depart from the limit if the member state concerned is able to evidence problems connected with availability of appropriate raw materials for production of advanced biofuels [7].

Sustaining the limit lowering utilisation of conventional biofuels, introduced by means of Directive 2015/1513/EC, Directive 2018/2001/EU stipulates that their share in 2030, on the one hand, must not exceed 7% of terminal energy consumption in the transport sector and, on the other hand, must not be greater by more than 1% as compared with their share recorded in 2020 [26].

#### *3.2. History, Current Status and Prospects for Transport Biofuels in Poland*

Poland has a rich tradition in the field of biofuels for transport. Fuels other than fossil-based ones were used in transport in Poland as early as before World War II. App; 10 mL/year of industrial ethanol was added to petrol. In the 1970s, wood waste was processed at ZPC Świecie to the form of lignocellulosic ethanol (acidic and inefficient method). It was the first plant of this kind worldwide. In the 1990s, the plants of ZPC Polmos mastered the technology of blending ethanol (dehydrated agricultural distillate)

with petrol, with the production capacity above 100 mL/year. The raw material for production of bioethanol was agricultural distillate obtained from low-capacity farming distilleries (usually 100–200 kL/year, after upgrading app. 1 mL/year) [27].

Poland's competitive position in the sector of biocomponents, including in particular bioethanol, was relatively high before joining the EU. Producers of agricultural distillate, processed to the form of bioethanol, developed the original Eko-Mix 20 fuel with a 20% share of bioethanol and, consequently, they associated high expectations with the European market. Politicians were planning to produce Polish ethanol for EU member states on a level of as much as 4–5 bnL/year.

Yet, Poland's joining the EU in 2004 resulted in changes related to bioethanol production techniques; small agricultural distilleries ceased to play an important role due to cost related reasons, but mainly due to low or even negative reduction of CO<sub>2</sub> emissions in the case of fuel basing on agricultural distillate [28–30]. Over 2 decades, the number of agricultural distilleries fell to a few dozen only at present [31]. Nowadays, agricultural distilleries are more modern and their capacity reaches several million litres of distillate per year, they apply the cold mashing method, but they usually do not operate and do not cooperate in the area of biofuels [32,33].

What is more, after 2004 there appeared a new and more efficient biocomponent: methyl esters of higher fatty acids of rapeseed oil, added in a respective volume to diesel fuel (with Trzebinia Refinery as the first large scale producer). Subsequent years saw the market appearance of growing numbers of those biocomponents producers, especially that excise duty reliefs or financial support for erection of respective installations constituted a strong incentive for investing in this sector.

National production capabilities regarding biofuels for transport (conventional ones) were developing very dynamically, while limitation of excise duty reliefs took place in 2011 (elimination of excise duty reliefs). Plants purchased for Polish producers were on a mature level, there were few installations on the experimental level; consequently, competitiveness of Polish biocomponents was not high and Poland, instead of being an exporter as planned [34] imports nearly 50% biocomponents. After Poland's admission into the EU, the high number of plants in Poland was falling gradually. Despite strong political support, production of esters by farmers for farms' own needs was not successful.

### 3.3. Production and Usage

In order to ensure constant growth in terms of renewable energy usage in domestic transport (and, as a result, to strive towards fulfilment of EU obligations), the so-called National Index Target (NIT) is used in Poland and the EU. It is defined as the "minimum share of other renewable fuels and biocomponents contained in fuels used in all modes of transport within the overall quantity of liquid fuels and liquid biofuels used during a calendar year in road and railway transport, calculated according to their calorific value" [33]. The NIT fulfilment obligation rests upon entities performing intra-Community production, imports or purchases of liquid fuels or liquid biofuels. In order to be able to account biocomponents towards the National Index Target, they must meet the so-called sustainable development criteria (including the criterion related to greenhouse gas emission reduction), identified in detail in the Act on biocomponents and liquid biofuels [35]. To promote biocomponents produced from non-food ingredients or waste (enumerated in Appendix 1 to the Act), they are eligible to be recorded at a double quantity in connection with NIT fulfilment.

According to data of the National Centre for Agriculture Support, as at 26.03.2021 production of biocomponents used for fulfilment of the NIT was conducted in Poland by 24 entities. Total annual capacity of registered plants used for production of methyl esters is app. 1382k tonnes (1549 mL), while the capacity of plants used for bioethanol production is equal to 731k tonnes (939 mL) [36]. Three of the above entities deal with the production of HVO (one of them, Polski Koncern Naftowy ORLEN S.A., has three plants). Total annual production capacities of this biocomponent, as declared by the producers, are equal to 417k

tonnes (540 mL) and are more than twice as high as the capacities declared at the beginning of 2020 (as at 02.01.2020—202k tonnes (261.5 mL) [37]). In addition to the biocomponents referred to above, producers have a plant for production of biohydrogen whose annual production capacity is 1120 mL, and a biopropane plant (35.5 mL). Table 1 presents data on the number of plants producing particular kinds of biocomponents.

**Table 1.** Number of plants producing biocomponents in Poland.

Kind of Biocomponent	Number of Plants
bioethanol	13
methyl esters	9
bio-hydrocarbons	3
biopropane	2
biohydrogen	1

Source: own analysis based on: [36].

There are two plants which produce two kinds of biocomponents: bioethanol with methyl esters and bio-hydrocarbons and biopropane, and one plant producing three kinds: bio-hydrocarbons, biopropane and biohydrogen.

Among bioethanol producers, annual capacity of installations at the main three factories is 550 mL, which accounts for app. 58% of the capacity of all producers of this biocomponent, whereas annual capacity of the installations for production of methyl esters belonging to the main three producers is equal to 1015.65 mL, which accounts for over 66% of all plants (Table 2).

**Table 2.** Main producers of biocomponents in Poland.

Producers of Bioethanol	Annual Plant Capacity in Million Litres	Producers of Methyl Esters	Annual Plant Capacity in Million Litres
DESTYLACJE POLSKIE Sp. z o.o. Oborniki	150	ORLEN Południe S.A Trzebinia	314
BIOAGRA S.A Warsaw	275	EUROSERVICE Zakłady Przemysłu Tuszczowego w Surochowie Sp. z o.o. Jarosław	475,65
BGW Sp. z o.o. Poznań	125	BIOAGRA-OIL S.A Tychy	226

Source: own analysis based on [36].

Table 3 presents the quantities of biocomponents produced in Poland in 2016–2020. Production of liquid bio-hydrocarbons was first registered in 2018, whereas production of propane-butane was registered in 2020. Production of biocomponents entitling double registration in connection with NIT fulfilment (due to ingredients used to produced them) has been recorded since 2018. The quantity of such biocomponents produced in Poland in 2020 was more than four-times higher (123.7k tonnes) than in 2018 (30.1k tonnes).

**Table 3.** Biocomponents meeting the sustainable development criteria, produced in Poland in 2016–2020 (in thousands t).

Component \ Year	2016		2017		2018		2019		2020	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
bioethanol	193.88	-	203.65	-	197.62	6.27	212.97	12.48	201.6	17.17
methyl ester	867.40	-	896.96	-	859.44	23.82	877.14	83.00	846.31	106.27
liquid bio-hydrocarbons	-	-	0.00	-	0.26	-	0.01	0.05	2.14	0.23
bio propane-butane	-	-	0.00	-	-	-	-	-	-	0.03

(1) biocomponent which does not entitle double registration in connection with NIT fulfilment. (2) biocomponent which entitles double registration in connection with NIT fulfilment. Source: own analysis based on data regarding production of biocomponents, published by the National Centre for Agriculture Support for the period 2016–2020 [38].

Products obtained under intra-Community purchases are used, next to domestic production, in connection with NIT fulfilment. These include both pure biocomponents and those contained in the biofuels and liquid fuels purchased. The quantities and kinds of biocomponents from intra-Community purchases (both pure and contained in biofuels and liquid fuels), which meet the sustainable development criteria but do not entitle double registration in connection with the National Index Target, are presented in Table 4. Apart from quantities presented in the table, 7.1k tonnes of pure esters and 0.1k tonnes of esters contained in fuels and liquid biofuels, which entitiled double registration in connection with NIT fulfilment, were purchased in 2020.

**Table 4.** Quantities and kinds of biocomponents from intra-community purchases in 2016–2020, meeting the criteria of sustainable development, but not entitling double registration in connection with NIT (in thousand tonnes).

Component \ Year	2016	2017	2018	2019	2020
Pure biocomponents					
Bioethanol	73.79	74.21	64.04	66.50	64.46
Ester	166.66	253.14	301.94	290.48	300.49
Liquid bio-hydrocarbons	-	-	-	1.00	-
Biocomponents contained in fuels and liquid biofuels					
Bioethanol	13.33	25.83	25.04	25.14	21.42
Ester	57.16	31.75	56.32	52.40	45.80
Liquid bio-hydrocarbons	-	-	4.09	-	-

Source: own analysis based on data concerning imports or intra-community purchases of biocomponents, published by the National Centre for Agriculture Support for 2016–2020 [39].

Despite high production potential for biocomponents in Poland, it is poorly utilised, in app. 30% regarding bioethanol and 69% regarding esters.

Moreover, for many years now, Poland has been importing app. 50% biocomponents.

### 3.4. Poland as Compared with the European Union

According to estimates published in September 2020 in the EurObserv'ER report [40], consumption of biofuels in the European Union (including Great Britain) in 2019 amounted to 17.8 Mtoe (Table 5). The great majority (99.9%) of those biofuels fulfilled the sustainable development criteria identified in the Directive on renewable energy sources.

**Table 5.** Estimated consumption of biofuels for transport in the European Union (including Great Britain) in 2019 (ktoe).

	<b>Total Consumption of Biofuels</b>	<b>Consumption of Biodiesel</b>	<b>Consumption of Bioethanol</b>
<b>European Union</b>	<b>17,826.0</b>	<b>14,349.7</b>	<b>3206.7</b>
Selected member states			
France	3197.0	2543.8	653.3
Germany	2746.0	1940.0	749.0
Great Britain	1807.8	1349.1	444.8
Spain	1721.9	1592.5	129.4
Sweden	1520.8	1251.0	144.8
Italy	1317.0	1245.7	30.4
<b>Poland</b>	<b>1019.7</b>	<b>836.4</b>	<b>183.2</b>

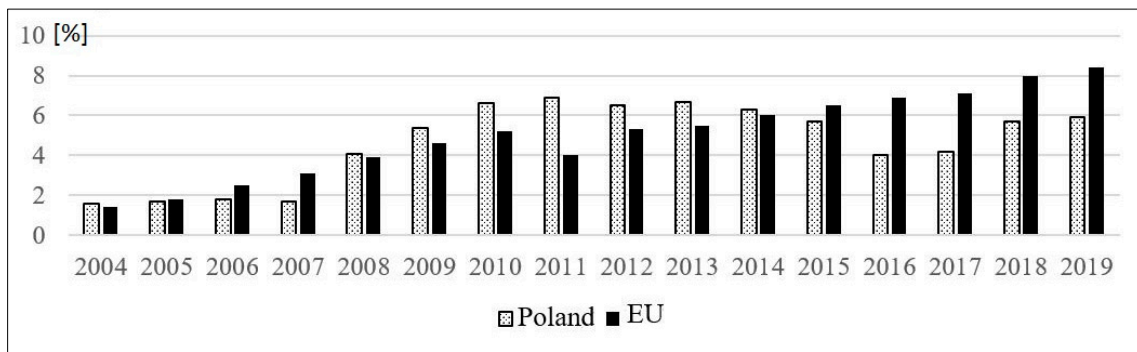
Source: [26].

The biofuels market of the European Union is dominated by the sector of esters (biodiesel). It includes both traditional methyl esters and hydrogenated vegetable oils (HVO), obtained in the process of hydrotreating of vegetable oils or animal fats. According to EurObserv'ER, consumption of biodiesel in EU transport in 2019 was equal to 14.3 Mtoe (which accounted for over 80% of overall biofuel consumption). To compare, the consumption of bioethanol, directly mixed with petrol or previously processed into ETBE (a mixture of bioethanol with an oil refining by-product—*isobutene*), was 3.2 Mtoe (18% of overall consumption of biofuels). Next to biodiesel and bioethanol, EU's transport (including Great Britain) in 2019 also used app. 269.6 ktoe of biogas fuels (1.5%).

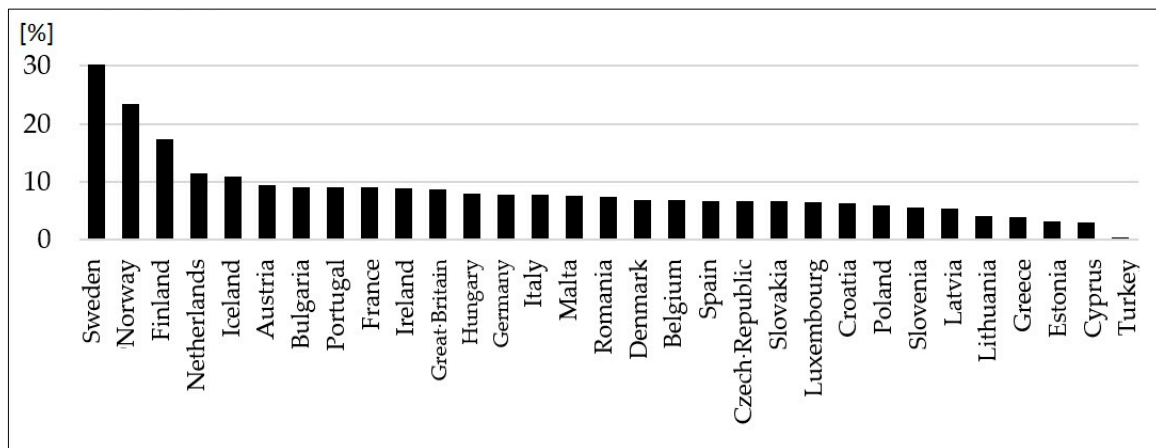
According to preliminary data collected by EurObserv'ER, consumption of biofuels covered by double registration in the share of renewable energy in energy consumption in transport in 2019 exceeded 4.8 Mtoe (including 3.5 Mtoe of biofuels produced from used frying oils or animal fats, and 1.3 Mtoe of advanced biofuels).

According to the EurObserv'ER report, the highest quantity of biofuels (biodiesel, bioethanol and biogas fuels) was consumed in 2019 in France (3197 ktoe), followed by Germany (2746 ktoe) and Great Britain (1807.8 ktoe). As compared with all member states of the European Union, Poland took the 7<sup>th</sup> place with its consumption of biofuels on the level of 1020 ktoe, including 836 ktoe of biodiesel and 183 ktoe of bioethanol (Table 5).

Data of the European Environment Agency (EEA) published in December 2020 show that the share of energy from renewable sources in terminal energy consumption in transport in the European Union in 2019 was equal to 8.4% (Figure 1). That denotes an 8% increase as compared with 2004. According to EEA's figures, the share in Poland in 2019 was 5.9% and was over 3.5-times higher than in the year when Poland joined the EU. In 2019, the highest share of renewable energy in the energy consumed in transport was recorded in Sweden (30.3%), Norway (23.5%) and Finland (17.4%). On the level of the European Union, annual growth regarding the share of renewable energy in terminal consumption of energy in transport has been observed since 2011, which shows continuous progress towards achievement of the objective set in the Directive on renewable energy sources (10% in 2020). Yet, as in some countries this share is low (Figure 2), achievement of the objective set for 2020 is highly unlikely [40].



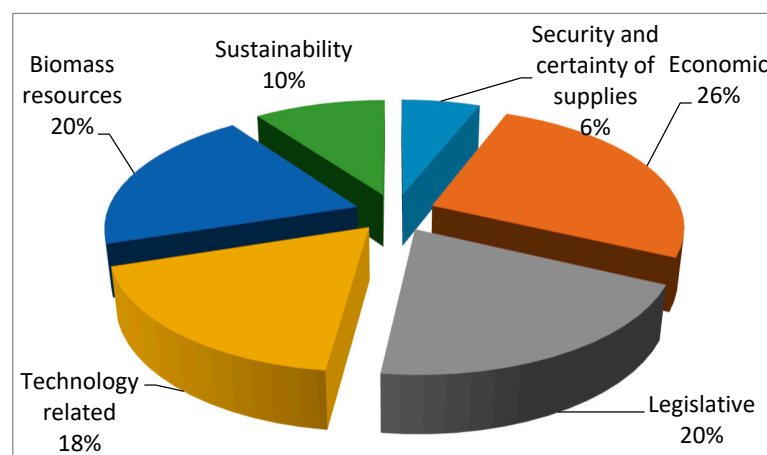
**Figure 1.** Share of energy from renewable sources in total energy consumed in transport in Poland and the European Union (including Great Britain) in 2004–2019 (%). \* Until 2010, all biofuels were taken into consideration while calculating the share of energy from renewable sources in total consumption of energy in transport. Since 2011, biofuels must meet additional requirements (so-called sustainable development criteria) to be considered therein. Source: European Environment Agency (EEA). 2020. Use of renewable energy for transport in Europe [40].



**Figure 2.** Share of energy from renewable sources in transport in selected countries in Europe in 2019 (%). Source: [40].

### 3.5. Barriers in Accomplishment of Tasks Connected with Biofuels for Transport

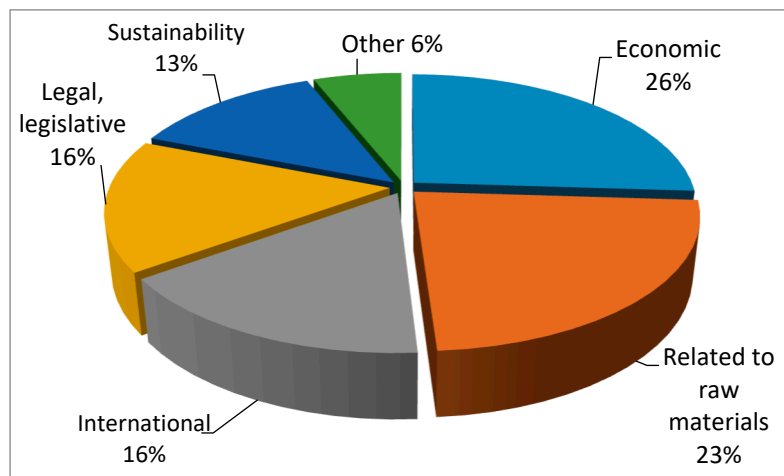
Barriers, or factors limiting the development capability of the sectors of biofuels for transport and the possibility to accomplish specific criteria assumed in directives are evolving, but the change is not dynamic. General barriers connected with the first Directive 2003/30/EC were presented in the chart in Figure 3 [34] during the REFUEL project conference.



**Figure 3.** Barriers hindering implementation of Directive 2003/30/EC in 2005. Source: [34].



In connection with this publication, a survey was conducted in the last quarter of 2020 among producers of biocomponents in Poland, which focused on barriers hindering development of the biocomponents sector in connection with Directive 2009/28/EC (and subsequent directives). The survey was carried out among producers of—mainly—advanced biofuels, among six Polish companies, owners of SMEs (small and medium-sized enterprises). Aggregated data are presented in Figure 4.



**Figure 4.** Barriers hindering development of the biocomponents sector enterprises in Poland in 2020. Source: own analysis.

Similar to the previous survey conducted in 2005, the results of the current research show that the greatest barrier perceived by owners of the surveyed companies is still the economic barrier. Support involving excise duty reliefs for producers was eliminated in 2011, while other support methods are obviously ineffective. As far as conventional biocomponents are concerned, only the minimum, mandatory volume of biocomponents has been produced since 2012. There are only a few companies on the Polish biocomponents market that achieve the effect of scale, while other new and small companies operate in a niche, at higher costs. At the beginning of operation, frequently at the stage of work over the technology, new technologies are uneconomical. Poland usually imports major plants for production of biocomponents, so a wider perspective of supply chain is required [41]. However, some producers undertake the effort to develop or modify technologies, which requires significant resources.

Another type of barrier is related to raw materials, which results from several reasons:

- in the case of biomass used for production of conventional biofuels, competitive towards food, barriers are usually due to low terminal reduction of the biocomponent
- in the case of biomass used for production of advanced biocomponents, biomass is usually waste-based, but used by many markets competitively towards one another and, consequently, becoming difficult to access.

Furthermore, significant and very problematic factors are international and legal ones (in total: 32%). This is a conglomerate of combined factors causing greatest problems.

Poland is still adapting to international factors in the area of the law (implementation). The adaptation process involved destruction of the whole bioethanol industry (inefficient, two-phase industry with zero or negative CO<sub>2</sub> reduction), which was replaced by the single-phase bioethanol industry built after 2004 for enormous amounts of money, with the production capacity of app. 700 mL/year. In effect of implementation of Directive 2009/28/EC, investments launched previously were already outdated in terms of technical, technological and sustainable development aspects. Focus was placed on advanced biocomponents and biofuels. What is more, the sector of advanced biocomponents frequently becomes surprised in terms of legal changes, as proposed amendments are not consulted

with it in advance. Changes are actually incompatible with the market situation. A similar situation took place with methyl esters, another conventional biocomponent. The sector was built in Poland from a scratch (beginning around 2005), with significant legal difficulties (Trzebinia Refinery). Amended preferences related to biofuels were established by the EU already in Directive 2009/28/EC. Potential of Trzebinia Refinery as a company is high enough to let it cope with unexpected decisions. Usually, investments of this type ought to have the right to live on the market for at least 20 years (capital intensive investments). The system of changes and legal aspects in the EU concerning biocomponents is inconsistent.

Instead of several decades of prosperity, a lack of support for conventional biofuels after 2030 has been announced. There is an explanation that problems with the atmosphere have allowed quick action and assumptions in the Green Order strategy.

### 3.6. Other Problems of the Biofuels Sector in Poland

In addition to the above barriers against development of the biofuels sector, fulfilment of the NIT and falling value of the sectors may be the problem of this industry.

The NIT obligation is one of the main instruments for accomplishment of the objective established by the RED (Renewable Energy Directive), i.e., suitable share of renewable energy in transport [6].

According to a list maintained by President of the Energy Regulatory Office (data as at 12.05.2021), there are 18 entities in Poland obliged to fulfil the National Index Target in 2021 [42]. An entity executing the National Index Target is obliged to ensure during the respective calendar year at least the minimum share of other renewable fuels or biocomponents contained in fuels used in all modes of transport. Next to the established NIT level, the Act establishes a reduction coefficient concerning identification of the minimum share of biocomponents, which was set at 80% for 2020–2022 [43], whereas the subsequent amendment modified it to 82% [44]. What is more, amendment of the Act on biocomponents from 2017 introduced a mechanism of the substitute charge, based on which an entity executing the NIT, which documents fulfilment of that obligation on the predefined minimum level may pay a substitute charge [43]. Since 2020, the minimum level of fulfilment of this obligation will be—as already mentioned—82%, while the remaining part may be settled by way of the substitute charge. Thus, the reduction coefficient allows adjustment of the level of NIT to a level which is achievable by the obligated entities.

Table 6 presents, in a retrospective and prospective view, values of the NIT indicators, reduction coefficients and the substitute charge for 2012–2022 (according to the Act on biofuels) as well as actual share of renewable energy in transport until 2019.

**Table 6.** NIT values and share of renewable energy in Polish transport in 2012–2020.

Year	NIT <sup>1</sup> %	Reduction Coefficient <sup>1</sup>	Substitute Charge <sup>1</sup>	Actual Share <sup>2</sup> of Renewable Energy in Transport
2012	6.65	0.85	-	6.5
2013	7.1	0.85	-	6.6
2014	7.1	0.85	-	6.2
2015	7.1	0.85	-	5.6
2016	7.1	0.85	-	3.9
2017	7.1	0.82	0	4.2
2018	7.5	0.86	85	5.6
2019	8.0	0.82	85	6 *
2020	8.5	0.82	80	

**Table 6.** *Cont.*

Year	NIT <sup>1</sup> %	Reduction Coefficient <sup>1</sup>	Substitute Charge <sup>1</sup>	Actual Share <sup>2</sup> of Renewable Energy in Transport
2021	8.7	0.82	80	
2022	8.8	0.82	80	

<sup>1</sup> Act on biocomponents and liquid biofuels of [35,43–46]. <sup>2</sup> [47]. \* Result of industry experts' estimates.

Data contained in column 2 of the table present the assumed NIT value for Poland, whereas columns 3 and 4 present the calculation algorithm.

The last column of the table contains the coefficient of renewable energy usage in transport for particular years, whose level significantly differs from the NIT value.

Sector value is another important parameter examined. Value of sectors producing biocomponents, such as methyl esters and conventional bioethanol (produced from food related raw materials), is the object of analyses carried out since 2007. The evaluation method and the very evaluation of sector value from recent years are presented in greater detail in [8,48] At the beginning, upon emergence of the sectors, their value was high and exceeded 60%.

At present, the sectors are unattractive due to several reasons. First, as a result of using conventional biofuels, CO<sub>2</sub> emission reduction is limited (impact of reduction on 2006), yet bioethanol has the value of 28%, while the value of biodiesel is 27.5% (decrease which occurred as a result of announced plans to limit sales of diesel fuel and engines). One ought to emphasise that these are still the primary sectors for NIT calculation. It has been announced that neither of these sectors will be supported in the EU after 2030, which will additionally reduce their value.

Lignocellulosic ethanol (advanced biocomponent) was another promising sector, with a high CO<sub>2</sub> emission reduction. High production capacities of this sector were expected in several places over the world; however, due to economic and technology related reasons, there occurred a breakdown (which is why analyses were not continued after 2018; the breakdown occurred, among others, because of a non-competitive and highly priced biocomponent).

Analyses performed since 2018 involve comparisons with the sector of electricity used in transport (electromobility), while since 2019, with the sector of liquid bio-hydrocarbons.

The Table 7 shows the percentage of selected Polish sectors of alternative fuels in transport. The data presented in the Table 7 shows the direction of development of alternative fuels used in transport.

**Table 7.** Values of selected Polish sectors of alternative fuels used in transport in 2012–2021 (%).

Evaluated Sector	Year of Analysis									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Conventional methyl esters	43.2	41.7	34.5	33.5	33.4	32.1	31.6	31.5	32.0	27.5
Conventional bioethanol	33.3	37.5	27.3	26.7	26.6	22.8	22.3	24.0	25.0	28.0
Lignocellulosic ethanol	-	56.9	66.2	66.2	69.5	70.6	71.1	-	-	-
Electromobility	-	-	-	-	-	-	70.6	72.5	65.0	57.0
Liquid bio-hydrocarbons								58.3	61.2	64.0

Source: own analysis.

Another analysed sector is the sector of electromobility. Value of the electromobility sector is high, which is typical for young, rising sectors with a high potential. According

to plans, the number of electrical cars in Poland was expected to reach 1m by 2025, while electricity requirements were expected to rise to 2.4 TWh.

However, based on the electromobility sector's achievements so far, one may conclude that the figure planned for 2025 is unachievable. Consequently, value of the sector decreased by 8% according to experts' evaluations. The business model and business strategy in production systems in this sector will be required in the future to accurately calculate the value of the sector [49].

Despite systematic growth in the number of electric and plug-in hybrid electric vehicles (PHEV), it has not been possible to approach the planned number of electric vehicles or charging points as compared with the numbers contained in the National Policy Framework [11,50]. Due to insufficient support instruments, it has not been possible to accomplish the expected growth rate of the sector in recent years.

An important reason thereof could have been liquidation of the Low-Emission Transport Fund, which was—among others—expected to enable subsidising purchases of new electric vehicles, or failure to introduce a special tariff in order to reduce charging service prices. Yet, an increase in the growth rate should be expected in the years to come. It ought to be supported by new support forms proposed in the draft Act on electromobility and alternative fuels, adoption of the Polish Hydrogen Strategy until 2030 with a 2040 perspective and decisions on construction of the IZERA vehicle factory, where production is planned to begin in 2024.

Electromobility does make sense and positive environmental impact, if it bases on electricity obtained mainly from RES or other non-emission sources [48]. It is also worth mentioning that electromobility involves new technical and technological solutions in terms of engine and vehicle construction, supported by knowledge from the field of mechanical engineering (robustness, reliability or durability).

The last one of the analysed sectors is the sector of liquid bio-hydrocarbons. The sector has been researched by the authors for a short period only—since 2019. Advantages of liquid bio-hydrocarbons have been mentioned hereinbefore. Technologies connected with this biocomponent are developing very dynamically and are characterised with high CO<sub>2</sub> emission reduction. Liquid bio-hydrocarbons will be among the fundamental biocomponents used to accomplish the 14% energy share in transport by 2030.

The sector of liquid bio-hydrocarbons is increasingly widespread, has an enormous potential and offers beneficial product characteristics, including those connected with CO<sub>2</sub> emission reduction. Its value is growing in a linear manner, by app. 3% each year.

#### 4. Conclusions

The aim of the publication is to publish research on the problems faced by the alternative fuels and biofuels sectors in Poland in the context of the legal conditions of the European Union. The latest results show that in Poland there is actually no biofuel sector with a sufficiently high value that would enable the implementation of another NBT (14% in 2030).

The conducted research showed that the production capacity of conventional biofuels in Poland does not guarantee that the basic indicators, including NIT now and in the future, will be met. The bioethanol and methyl ester sectors, well developed in previous years with large financial outlays, are used in Poland to a small extent (30% bioethanol), about 60% esters.

The value of the conventional biofuels sectors is steadily declining, and with the planned changes in fuel requirements (including alternative fuels), the situation with regard to bioethanol and esters is unlikely to improve. The more so that there is a prediction of a 10-year restriction on the introduction of cars to the market, both for crude oil (with the addition of bioethanol) and diesel oil (with the addition of esters).

Therefore, there is a good future ahead of vehicles covered by the general name of electric (electromobility), e.g., hybrids, electric or hydrogen cells. There is a chance in the electromobility sector, but the 2-year economic fluctuation now requires strong

partners from the automotive sector. Therefore, the production of electric vehicles in Poland should rather be based on the experience of well-known concerns, taking into account own technical thought. Additionally, such a path is effective, and is currently envisaged.

Poland is a country with rich traditions in the field of biofuels for transport, including, in particular, bioethanol. Still before joining the EU, Poland had significant production capabilities in this field and plans for major exports of biocomponents after becoming an EU member state. At present, the country's production capabilities regarding conventional biofuels are at 1382k tonnes for esters and 731k tonnes for bioethanol. The capacities are utilised at 68% in the case of esters and only 30% in the case of bioethanol and Poland, instead of becoming an exporter, imports nearly app. 50% of biocomponents. Biofuels and their production and implementation are particularly important from the point of view of environmental engineering—with respect to sustainable utilisation of resources, which allows maintaining the environment's self-regeneration and self-cleaning abilities.

NIT (precise annual data are missing) is executed by means of the assumed value, reduction coefficient and the substitute charge. Thus, comparisons between consumption of renewable energy in transport, as published by Eurostat, is difficult and incompatible.

As main operating problems, biofuel producers in Poland currently refer to economic, international, legal—i.e., legislative- and raw material-related problems. Similar results were rendered by a survey among companies during validity of Directive 2003/30/EC (over a decade earlier).

Polish producers consider such frequent changes in the legal EU environment (every couple of years) unacceptable, since investments are made for decades (long period of return from investment versus short validity period of legal conditions).

The sector value examined in 2021 was 27.5% for esters and 28% for bioethanol and conventional biocomponents, and it has remained on a similar level for several years already; a slight decrease for esters and, considering measurement error, unchanged for bioethanol.

The low value is caused by several factors; in most cases, the year 2030 is mentioned as the border date for supporting conventional biofuels. Environmental aspects have accelerated significantly in recent years.

For advanced biofuels, the values are much higher, but the value of new sectors has always been and still is higher at the beginning, upon emergence of the sectors. It was only decreasing at a more mature stage.

The development of the promising sector of lignocellulosic bioethanol has slowed down, with the main reason thereunder being the economic surroundings and price.

To compare, value of the electromobility sector is already falling, even though it is a new sector. That is caused, among others, by absence of an adequate and consistently implemented strategy. The situation of the sector is expected to be improved soon by new legal acts and documents regarding utilisation of electricity and hydrogen. It is worth mentioning that in the world the use of hydrogen and electricity is constantly developing [51].

Thus, the most interesting—next to esters and conventional bioethanol (need to accomplish the high NIT value on an ongoing basis by nearly 10 more years)—may be the sector producing liquid bio-hydrocarbons (HVO and similar) as well as the electromobility sector, which will be the subject of the next paper.

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## References

1. Kruk, A. Definicje normatywne biopaliw ciekłych i biokomponentów oraz ich wzajemne zależności. *Młody Jurysta Kwart. Stud. Dr. Wydziału Prawa Adm. UKSW* **2019**, *64*–76. [CrossRef]
2. Agarwal, A.K.; Gautam, A.; Sharma, N.; Singh, A.P. Introduction of Methanol and Alternate Fuel Economy. In *Methanol and the Alternate Fuel Economy*; Springer: Singapore, 2019; pp. 3–6.
3. Stančin, H.; Mikulčić, H.; Wang, X.; Duić, N. A review on alternative fuels in future energy system. *Renew. Sustain. Energy Rev.* **2020**, *128*, 109927. [CrossRef]
4. Pomykała, R. Biogaz paliwem dla transportu (Biogas as a fuel for transport). In Proceedings of the Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie—Forum Recyklingu, Poznań, Poland, 22–24 November 2011; Volume 11, p. 45.
5. König, A.; Siska, M.; Schweidtmann, A.M.; Rittig, J.G.; Viell, J.; Mitsos, A.; Dahmen, M. Designing production-optimal alternative fuels for conventional, flexible-fuel, and ultra-high efficiency engines. *Chem. Eng. Sci.* **2021**, *237*, 116562. [CrossRef]
6. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy From Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC. Available online: <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028> (accessed on 15 May 2021).
7. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L200> (accessed on 15 May 2021).
8. Kupczyk, A.; Mączyńska-Sęczek, J.; Goliś, E.; Borowski, P.F. Renewable Energy Sources in Transport on the Example of Methyl Esters and Bioethanol. *Processes* **2020**, *8*, 1610. [CrossRef]
9. Ustawa z Dnia 11 Stycznia 2018, r. O Elektromobilności i Paliwach Alternatywnych. (The Act of January 11, 2018 on Electromobility and Alternative Fuels). Dz.U. 2018 Poz. 317. Available online: <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU2018000317> (accessed on 15 May 2021).
10. Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the Deployment of Alternative Fuels Infrastructure Text with EEA Relevance. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0094> (accessed on 15 May 2021).
11. Krajowe Ramy Polityki Rozwoju Infrastruktury Paliw Alternatywnych. (National Policy Framework of the Development of Alternative Fuels Infrastructure). Warszawa, 29 Marca 2017. Available online: [File:///C:/Users/User/Downloads/DRO\\_Krajowe\\_ramy\\_polityki\\_rozwoju\\_infrastruktury\\_paliw\\_alternatywnych.pdf](File:///C:/Users/User/Downloads/DRO_Krajowe_ramy_polityki_rozwoju_infrastruktury_paliw_alternatywnych.pdf) (accessed on 15 May 2021).
12. Burchart-Korol, D.; Gazda-Grzywacz, M.; Zarebska, K. Research and Prospects for the Development of Alternative Fuels in the Transport Sector in Poland: A Review. *Energies* **2020**, *13*, 2988. [CrossRef]
13. Rimkus, A.; Stravinskis, S.; Matijošius, J. Comparative study on the energetic and ecologic parameters of dual fuels (diesel–NG and HVO–biogas) and conventional diesel fuel in a CI engine. *Appl. Sci.* **2020**, *10*, 359. [CrossRef]
14. Goliś, E.; Kupczyk, A. Sektor biogazowni rolniczych w Polsce (The agricultural biogas plant sector in Poland). In *Innowacyjne Technologie Pozyskania Energii Odnawialnej*; Romaniuk, W., Ed.; Instytut Technologiczno-Przyrodniczy: Falenty, Poland, 2020; Volume XXVI.
15. Wojdalski, J.; Grochowicz, J.; Ekielski, A.; Radecka, K.; Stepniak, S.; Orłowski, A.; Florczak, I.; Drozd, B.; Zelazinski, T.; Kosmala, G. Production and properties of apple pomace pellets and their suitability for energy generation purposes. *Rocz. Ochr. Środowiska* **2016**, *18*, 89–111.
16. Borowski, P.F. Nexus between water, energy, food and climate change as challenges facing the modern global, European and Polish economy. *AIMS Geosci.* **2020**, *6*, 397–421. [CrossRef]
17. Centobelli, P.; Cerchione, R.; Esposito, E.; Oropallo, E. Surfing blockchain wave, or drowning? Shaping the future of distributed ledgers and decentralized technologies. *Technol. Forecast. Soc. Chang.* **2021**, *165*, 120463. [CrossRef]
18. Yin, R.K. *Case Study Research and Applications: Design and Methods*; SAGE Publications Inc: London, UK, 2018.
19. Subramaniam, Y.; Masron, T.A.; Azman, N.H.N. Biofuels, environmental sustainability, and food security: A review of 51 countries. *Energy Res. Soc. Sci.* **2020**, *68*, 101549. [CrossRef]
20. Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 Amending Directive 98/70/EC Relating to the Quality of Petrol and Diesel Fuels and Amending Directive 2009/28/EC on the Promotion of the Use of Energy from Renewable Sources. Available online: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32015L1513> (accessed on 15 May 2021).
21. Kim, E.J.; Kim, S.; Choi, H.G.; Han, S.J. Co-production of biodiesel and bioethanol using psychrophilic microalga *Chlamydomonas* sp. KNM0029C isolated from Arctic sea ice. *Biotechnol. Biofuels* **2020**, *13*, 1–13. [CrossRef]



42. Urząd Regulacji Energetyki. Wykaz Podmiotów, Które Są Zobowiązane Do Realizacji Narodowego Celu Wskaźnikowego. (Energy Regulatory Office List of Entities that are Required to Achieve the National Indicative Target) (stan na 12.05.2021). 2021. Available online: <https://rejstry.ure.gov.pl/> (accessed on 12 May 2021).
43. Ustawa z Dnia 24 Listopada 2017 R. O Zmianie Ustawy o Biokomponentach i Biopaliwach Ciekłych oraz Niektórych Innych Ustaw. Dz.U. 2017 Poz. 2290. The Act of November 24, 2017. Available online: <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20170002290> (accessed on 15 May 2021).
44. Ustawa z 19 Lipca 2019 r. O Zmianie Ustawy o Biokomponentach i Biopaliwach Ciekłych oraz Niektórych Innych Ustaw. (Dz. U. Poz. 1527). The Act of July 19, 2019. Available online: <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20190001527> (accessed on 15 May 2021).
45. Ustawa z 30 Listopada 2016 r. O Zmianie Ustawy—Prawo Energetyczne oraz Niektórych Innych Ustaw. (Dz. U. Z 2016 R. Poz. 1986). The Act of November 30, 2016. Available online: <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20160001986> (accessed on 15 May 2021).
46. Ustawa z Dnia 14 Sierpnia 2020 r. O Zmianie Ustawy o Biokomponentach i Biopaliwach Ciekłych oraz Niektórych Innych Ustaw Dz.U. 2020 Poz. 1565. The Act of August 14, 2020. Available online: <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20200001565> (accessed on 15 May 2021).
47. Eurostat. Share of Energy from Renewable Sources in Transport, 2004–2019. 2020. Available online: [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable\\_energy\\_statistics#Share\\_of\\_renewable\\_energy\\_more\\_than\\_doubled\\_between\\_2004\\_and\\_2019](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics#Share_of_renewable_energy_more_than_doubled_between_2004_and_2019) (accessed on 6 August 2021).
48. Mączyńska, J.; Krzywonos, M.; Kupczyk, A.; Tucki, K.; Sikora, M.; Pińkowska, H.; Bączyk, A.; Wielewska, I. Production and use of biofuels for transport in Poland and Brazil—The case of bioethanol. *Fuel* **2019**, *241*, 989–996. [[CrossRef](#)]
49. Gomes, J.G.C.; Okano, M.T.; Otola, I. Creation of indicators for classification of business models and business strategies in production systems. *Pol. J. Manag. Stud.* **2020**, *22*, 142.
50. Sendek-Matysiak, E.; Łosiewicz, Z. Analysis of the Development of the Electromobility Market in Poland in the Context of the Implemented Subsidies. *Energies* **2021**, *14*, 222. [[CrossRef](#)]
51. Xia, T.; Rezaei, M.; Dampage, U.; Alharbi, S.A.; Nasif, O.; Borowski, P.F.; Mohamed, M.A. Techno-Economic Assessment of a Grid-Independent Hybrid Power Plant for Co-Supplying a Remote Micro-Community with Electricity and Hydrogen. *Processes* **2021**, *9*, 1375. [[CrossRef](#)]