Anita **BEDNAREK** • Anna M. **KLEPACKA** • Aleksandra **SIUDEK**

DEVELOPMENT BARRIERS OF AGRICULTURAL BIOGAS PLANTS IN POLAND

Anita **Bednarek** (ORCID: 0000-0001-9164-3148) – *Goodvalley Agro S.A.*

Anna M. **Klepacka** (ORCID: 0000-0002-2828-5429) – *Warsaw University of Life Sciences, Institute of Economics and Finance*

Aleksandra **Siudek** (ORCID: 0000-0003-3903-1990) – *Warsaw University of Life Sciences, Institute of Economics and Finance*

Correspondence address:
Nowoursynowska Street 166, 02-787 Warsaw, Poland
e-mail: anna_klepacka@sggw.edu.pl

ABSTRACT: The article aims to identify barriers related to developing agricultural biogas plants in Poland. The secondary data was supplemented by primary data from a questionnaire conducted among employees of an enterprise whose biogas production is one of the elements of the circular economy. The results of the research revealed that the majority of respondents indicated external, systemic and developmental obstacles. The largest percentage of responses concerned the lack of stable legal regulations in the scope of renewable energy sources, including biogas plants, and the lack of programs financing the construction of agricultural biogas plants. Moreover, the respondents pointed to the proposals that could improve the development of agricultural biogas plants in the future. The respondents considered updating and ensuring the profitability of investments in the situation of significantly higher expenditures, growing costs of business and debt servicing through the reference price as a significant motivator, as well as inclusion in the support system of tariffs guaranteeing a stable income for at least 15 years. Barriers to developing agricultural biogas plants in Poland remain unchanged, and the awareness of the positive impact of agricultural biogas plants on many levels is still very low.

KEYWORDS: barriers, development, agricultural biogas plants, Poland

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Introduction

The world of biogas installations is particularly developed in the United States, where biomethane is primarily used for the production of electricity. China is also a big producer of bioenergy production, where the main idea of the existing installations is the production of energy for heating purposes. Europe currently produces 3 billion m^3 of biogas and biomethane in total, which corresponds to the total gas demand of Belgium. By 2030, it is estimated that Europe can produce 35 billion m^3 of biogas, which is 10% of the total gas demand in the European Union. By 2050, the combined production of biogas and biomethane could reach 95 billion m^3, which in turn could cover 30-40% of the total gas demand in 2050 (European Biogas Association, 2022). In terms of the number of installations, Germany is the leader, but the biogas market is also developing successfully in the UK, Italy, France, the Czech Republic, and Denmark, which is possible thanks to the pro-ecological economy conducted there (Eurobserv'er, 2020; Gostomczyk, 2017).

Agricultural biogas plants are not only installations that are part of the energy sector operating in the renewable energy sources sub-sector (Nikiciuk, 2019) but also an underestimated element of the agricultural sector. The use of agricultural biomass for the production of energy, liquid and gaseous fuels can be considered to be one of the most promising directions for the development of renewable energy sources (RES) (Ignaciuk & Sulewski, 2021; Kisiel et al., 2006).

The potential of biogas production in Poland is still underestimated (Biomass Media Group, 2020). Estimated at several billion m^3 annually, it is comparable to the potential of our western neighbours. In Poland, annually, about 120 million tons of manure and slurry and at least 8 million tons of straw from cereals and rape are produced, which translates into a relatively high energy potential of the agri-food sector itself (Ustawa, 2015) in terms of agricultural biogas production, which could even exceed 7.8 billion m^3 annually (Ministerstwo Aktywów Państwowych, 2019). Table 1 presents a list of the most popular raw materials used for the production of agricultural biogas in 2020. Agricultural biogas plants operating in a sustainable manner are those that produce agricultural biogas from substrates that cannot be used in any other way (e.g. as feed, as a fertiliser ingredient, etc.). We are talking here primarily about waste and residues from agricultural activity, waste from agricultural and food processing, and other by-products of agricultural origin. These substrates can be used in an optimal way, preferably as part of a circular economy.

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Table 1. List of the most popular raw materials used for the production of agricultural biogas in 2020

Type of raw material	Amount [thousand t]
Distillery decoction	914.5
Slurry	764.4
Residues from fruits and vegetables	679.6
Maize silage	497.6
Food processing waste	346.6
Technological sludge from the agricultural and food industry	225.3
Beet pulp	210.4
Waste from the dairy industry	131.5
Expired food	117.2
Manure	91.7
Waste plant mass	87.5
Slaughterhouse waste	83.1
Green mass	38.2
Fruits and vegetables	35.9
Fowl manure	27.7
Grass and grain silage	26.7
Fats	25.6
Waste from the production of vegetable oil	11.8
Straw	7.7
Protein and fat waste	3
Digestate	1.6
Catering waste	1.5

Source: Magazyn Biomasa (2022a).

Unfortunately, according to the Institute of Fuel and Energy Technology, there are only over 340 biogas plants in Poland, including 137 agricultural biogas plants (Lajnert, 2022; Energy Regulatory Office, 2022; Krajowy Ośrodek Wsparcia Rolnictwa, 2022b).

The institution keeping the register of agricultural biogas producers in Poland is the General Director of the National Center for Agricultural Support (KOWR) (Act, 2015). KOWR is a state legal entity that supports the development of renewable energy sources in rural areas, both through information and promotion campaigns contributing to the dissemination of knowledge (Krajowy Ośrodek Wsparcia Rolnictwa, 2022a), as well as through participation in green energy development projects for agricultural biogas plants (Krajowy Ośrodek Wsparcia Rolnictwa, 2020). According to the register of agricultural biogas producers, as of November 11, 2022, there are 117 entities in Poland (Krajowy Ośrodek Wsparcia Rolnictwa, 2022b) whose annual capacity of the agricultural biogas production plant is 563 163 631m^3, with a total installed electrical capacity of 138,218 MW$_e$ (Krajowy Ośrodek Wsparcia Rolnictwa, 2022b).

Table 2. Range of installed electrical capacity of agricultural biogas plants in Poland by power and voivodships in 2022

Voivodship	Power [kW]					Total	
	< 100	>100 i < 500	> 500 i < 999	> 999 i < 2.000	> 2.000	Amount	Power [kW]
Dolnośląskie	-	1	4	5	-	10	11 111
Kujawsko-Pomorskie	1	-	-	4	1	6	9 073
Lubelskie	1	-	5	1	2	9	10 794
Lubuskie	-	3	3	1	-	7	5 288
Łódzkie	-	1	4	3	-	8	7 932
Małopolskie	-	1	1	-	-	2	1 148
Mazowieckie	1	5	5	1	1	13	11 307
Opolskie	-	-	1	1	-	2	2 199
Podkarpackie	-	4	2	1	-	7	4 994
Podlaskie	1	-	8	2	-	11	9 273
Pomorskie	-	2	5	3	2	12	14 144
Śląskie	-	1	1	-	-	2	1 495
Świętokrzyskie	-	-	1	-	-	1	800
Warmińsko-Mazurskie	-	5	7	5	-	17	15 342
Wielkopolskie	-	5	6	4	2	17	19 150
Zachodniopomorskie	-	2	9	4	-	15	14 168
Total	4	30	62	35	8	139	138 218
Power [kW]	264	13 288	56 013	49 209	19 444		

Source: authors' work based on Krajowy Ośrodek Wsparcia Rolnictwa (2022b).

The agricultural biogas plant in Zbiersk, in the Wielkopolskie voivodship (10,120,000 m^3/year and 3,500 MW$_e$, respectively) has the highest annual efficiency among all agricultural biogas plants in the country. In total, 53% of the installed capacity belongs to Goodvalley, which was the first in Poland who had built an agricultural biogas plant in Pawłówko (Przechlewo commune, Człuchów district) in 2005. Table 2 presents the range of installed electrical capacity of agricultural biogas plants in Poland by power and voivodeships.

Biogas plants with a capacity of nearly 1 MW (37 installations) and nearly 0.5 MW (22 installations) are the most used. This is due to the fact that units with a capacity of up to 1MW are covered by the support system in the form of guaranteed prices (the so-called FIP without the need to participate in the auction). However, for units with a capacity below 0.5 MW, it is not necessary to carry out an environmental impact assessment. Most of the installations are located in the Wielkopolskie Voivodship (over 19 MW – 17 biogas plants) and Warmińsko-Wazurskie Voivodship (over 15 MW – 17 installations). However, one agricultural biogas plant in Świętokrzyskie has very low power produced (800 kW), despite favourable substrate possibilities (agricultural land constitutes over 60% of the area, while the number of cattle is approx. 156 thousand heads, pigs approx. 196 thousand heads, and chicken poultry 6,035 thousand heads) (Statistics Poland, 2021). Among the registered biogas plants, one does not produce energy, and biogas is intended for sale to another producer (Lubelskie Voivodship). On the other hand, two biogas plants partly sell biogas to third parties, and three biogas plants partly burn biogas in a boiler, including one in a feed material dryer.

One of the motivators for the development of the biogas sector in Poland is the assumptions of the European Green Deal and the implementation of the European Union (EU) strategy to reduce CH4 and the plan to reduce CO_2 emissions by 55% by 2030 (European Parliament resolution, 2021). Additionally, it may also be the so-called methane tax (on cows and sheep) or a scale for assessing the carbon footprint of goods in commercial circulation in the EU.

A limitation related to the development of the agricultural biogas sector in Poland is the strong dependence on the support system (Ignaciuk & Sulewski, 2021), without which, with relatively high investment and operating costs, biogas projects cannot exist, especially if compared to wind projects or PV installations. Moreover, organisational and legal barriers should also be considered important (Klepacka, 2019; Powałka et al., 2013).

The objective of the agricultural strategy "from farm to fork" adopted in May 2020 is to guarantee food security while reducing the negative impact of agriculture on the environment. An agricultural biogas plant should be a natural complement to the production cycle for each breeding of animals with a size greater than 100 LU. Closing the circulation in agriculture by using an agricultural biogas plant for the recycling of natural fertilisers enables the effective management of biogenic elements, thus reducing their losses and

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reducing the negative impact of a farm on the natural environment (Ceny rolnicze, 2022). The justification for taking up the topic of barriers to the development of agricultural biogas plants in Poland were two key issues. Firstly, rising electricity and gas prices and the spectre of gas shortage on the European market due to the geopolitical situation, i.e. the armed conflict in Ukraine. In the current situation, independence from external gas suppliers is an opportunity for the development of domestic agricultural biogas production. Secondly, the proposed legislative changes as part of the amendment to the RES Act (Ceny rolnicze, 2022), mainly in the field of the biogas and biomethane market, which is also a consequence of the signing of the "Agreement on cooperation for the development of the biogas and biomethane sector" (gramwzielone.pl, 2022) on the initiative of the Minister of Climate and Environment (Climate and Environment Ministry, 2021).

An overview of the literature

Agricultural biogas plants operating worldwide (Igliński et al., 2020; Yousuf et al., 2016), and their history, depending on the sources, dates back to the 10th century BC or slightly later (Bond & Templetion, 2011; Chasnyk et al., 2015). functioning of agricultural biogas plants is associated with both opportunities and barriers, which are classified according to various typologies.

The research gap that the article fills in the literature on the subject indicates the use of a typology of barriers to local development. The purpose of the study, which is to identify barriers related to the development of agricultural biogas plants, fits in that gap.

Earlier studies present barriers to the functioning of agricultural biogas plants without any particular use of the typology (Pawlak, 2013; Mateescu et al., 2008). Other studies indicate the following barriers: political, economic, social, and technological (Situmeang et al., 2022; Igliński et al., 2020) supplemented with market barriers (Monjurul et al., 2022; Nevzorova & Kutcherov, 2019). At the same time, the literature points out the following issues applied to barriers to biogas technologies in rural areas: financial and economic; market; social and cultural; regulatory and institutional; technological and infrastructural, as well as information (Mittal et al., 2018).

Research methods

The descriptive method was used to achieve the goal of this article. The sources of materials were the literature on the subject, legal acts, industry literature and materials provided by the company that first "appeared" with agricultural biogas plants on the Polish market. The secondary data is sup-

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plemented with primary data obtained based on a questionnaire conducted among employees of the company, whose biogas production is one of the assets of the circular economy.

The survey questionnaire consisted of two parts: descriptions of respondents (e.g. gender, age, education, position, work experience, and place for a living) and 3 questions concerning barriers to the development of agricultural biogas plants. The first question concerned the respondent's request to assign an obstacle/barrier to its typologies (Table 1). Barriers were assigned a typology according to four criteria (Sekuła, 2005) (Table 1):

1. Sources of formation:
   - internal obstacles that occur at the local level,
   - external obstacles caused by regional, national and even global environments.
2. Probability of overcoming:
   - relative barriers that can be removed with the use of additional economic, legal and organisational measures,
   - absolute barriers, the overcoming of which is unprofitable from the perspective of the costs incurred, obtained profits and time involved.
3. Universality of occurrence (universality of impact):
   - systemic barriers, which are a limitation for all territorial units and do not result from irrational management, lack of competence of local authorities or unfavourable characteristics of the area,
   - local barriers that occur when the impact range is narrowed to a certain area, and the impact force has a local dimension.

Types of impact on development:
   - hindering or preventing development,
   - slowing down development processes,
   - preventing the initiation and sustainment of development processes.

The second question was to indicate the importance of these barriers on a scale from 1 to 5 (1 – not important, 5 – very important). The third question concerned broadening the scope of the barriers and making them valid on a scale from 1 to 5 as well.

Results of the research

Barriers to the development of agricultural biogas plants according to the typology used in the opinion of the respondents

28 people participated in the survey, and out of them, 43% were women. The average age of the respondents was 42, including the average age of women at 38. 40% of respondents (including 35% of women) declared a managerial position or specialist position. The remaining persons (of which

11% were women) declared the position of director (3%), operator (7%) and office worker (10%). Among the respondents, less than 30% (7% were women) are employed in biogas plants or collaborate with the biogas department. The total average work experience for all respondents was 10 years, including the average 6 years of work experience of people closely related to biogas plants. 60% of the respondents live in rural and urban-rural areas. Besides, 79% of the respondents declared higher education (including incomplete higher education).

In the first question, the respondents were asked to assign barriers to the development of agricultural biogas in the typology used. The results are presented in Table 1.

Table 3. Assignment of barriers to the development of agricultural biogas in the typology used in the opinion of the respondents

Barrier type/typology	Internal obstacles	External obstacles	Relative barrier	Absolute barrier	Systemic barrier	Local barrier	Development obstacles
	[%]						
Lack of stable legal regulations in the field of renewable energy sources, including biogas plants	7	75	11	14	75	11	50
Lack of consistency in implementing positive changes, programs, plans	39	32	39	7	39	18	57
High investment outlays/costs	46	32	31	29	7	4	57
Lack of programs financing the construction of agricultural biogas plants	0	50	14	11	61	0	39
Planning constraints (local development plan, study of the conditions and directions of spatial development in the commune)	43	36	21	0	32	57	32
Location and size of an agricultural biogas plant	46	14	32	4	32	54	7
Problems with obtaining connection to the power grid	11	46	29	11	43	25	39
No justification for special cases of biogas purification	25	21	21	32	29	4	18
Defining digestate1 – fertilizer or waste?	14	50	29	4	61	4	29
Proper operation of biogas plants and high operating costs	50	21	32	14	32	7	21

[1] digestate (post-fermentation mass) – solid-liquid by-product (Cecchi et al., 1988; Schievano et al., 2009).

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Barrier type/typology	Internal obsta-cles	External obsta-cles	Relative barrier	Absolute barrier	Systemic barrier	Local barrier	Deve-lopment obsta-cles
	[%]						
Public and legal burdens (mainly local taxes and fees)	29	50	21	18	50	21	21
Local protests mainly due to the lack of knowledge about the functioning of agricultural biogas plants	57	25	18	7	14	39	36

The results of the research indicated that the vast majority of respondents indicated external, systemic and developmental obstacles. The largest percentage of responses concerned the lack of stable legal regulations in the field of renewable energy sources, including biogas plants (75%, 75%, and 50%, respectively) and the lack of programs financing the construction of agricultural biogas plants (50%, 61%, and 39% respectively). In addition, an important issue related to the definition of digestate (50%, 61%, and 29% respectively) and problems with obtaining the conditions for connection to the power grid (46%, 43%, and 39% respectively). In responses to the second question concerning the importance of barriers on a scale from 1 to 5, the respondents rated the highest importance of the barriers, apart from the lack of stability of the law on renewable energy, which was assessed as a very important barrier (89%), indicated high investment expenditure (75%) and the correct operation of the biogas plant and high operating costs (71%). Moreover, the respondents pointed to the proposals (also rated on a scale from 1 to 5) that could improve the development of agricultural biogas plants in the future. The respondents considered it very important to update and guarantee the profitability of investments in the situation of much higher expenditures, growing operating costs, and debt servicing through the reference price, as well as including in the support system tariffs that guarantee stable income for at least 15 years (50% of respondents' answers respectively). Among the important factors, 75% of respondents indicated the introduction of facilities in the purchase of land with an area of more than 1 ha for the construction of biogas plants, and 68% of respondents emphasized the significance of the competencies of administrative bodies and the timeliness of the procedure.

In the further part of the work, a list of barriers was used according to their weight in % share in the typology of assignment in the opinion of the respondents.

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External obstacle, systemic and development barrier. Lack of stable legal regulations in the field of renewable energy sources, including biogas plants

The Act on Renewable Energy Sources (RES) of 2015 was amended 32 times, including 20 times in 2019-2021. Despite this, the key requirements set out in the Market and by the RED II Directive have not been implemented so far (Teraz Środowisko, 2022).

Until the act on renewable energy sources is passed in February 2015, all issues related to the operation of agricultural biogas plants were regulated in the Act of April 10, 1997 – Energy Law (hereinafter referred to as the Energy Law), which imposed an obligation on agricultural biogas plants to have a license to generate electricity. Since 2010, companies using agricultural biogas plants have been exempt from this obligation. Act of January 8, 2010 amending the Act – Energy Law and amending certain other acts, a definition of agricultural biogas was introduced, and pursuant to Art. 9 p.2 and 3, biogas plants were entered into the register of enterprises producing electricity from agricultural biogas kept by the Agricultural Market Agency, whose duties were taken over by the National Center for Agricultural Support.

In accordance with the energy law and later the RES Act, agricultural biogas plants received support for energy produced from renewable energy sources in the form of the so-called "Green certificates" in the RES Property Rights market, operating since December 28, 2008 (TGE, 2022a). As a result of a long-lasting sharp decline in the prices of green certificates, which have fallen more than twice (TGE, 2022b) since the beginning of their existence with the next amendment to the RES Act, on 1 July 2016, the obligation to present certificates of origin for energy from renewable sources (green certificates) for redemption has changed (Act, 2016; Palusiński, 2016). The 15% obligation was reduced in the second half of 2016 to 14.35% in order to distinguish a dedicated level of the obligation to redeem certificates of origin confirming energy production from agricultural biogas, the so-called blue certificates, which amounted to 0.65%.

The prices of green certificates in recent years have been much lower than the prices of blue certificates, which were slightly higher than the level of the substitution fee, i.e. about PLN 300/MWh. The comparison of certificate prices in the years 2016-2022 is presented in Figure 1.

The instability of the legal regulations concerned not only the renewable energy support system, but also related to the produced energy support system in cogeneration. Cogeneration means combined energy production, which is the production of electricity and heat in one technological process as a result of the combustion of e.g. gas or biogas, including agricultural. The so-called "Yellow certificates" were a significant support not only for agricultural biogas plants – the prices of yellow certificates were at the level of the

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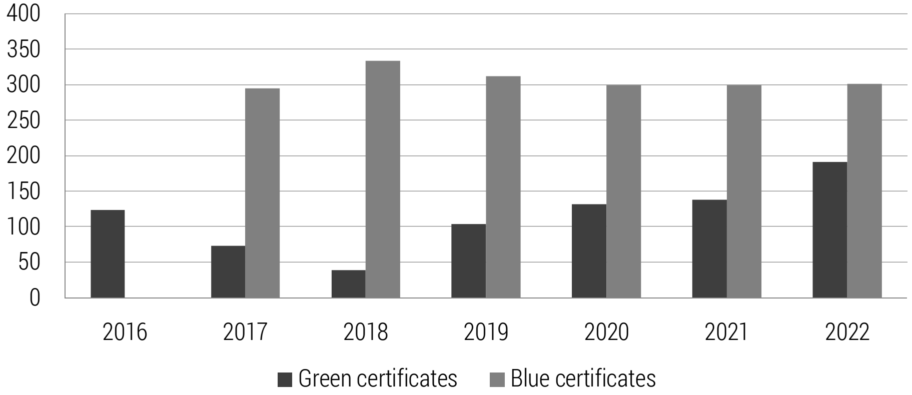
substitution fee, so they amounted to approx. PLN 100-125/MWh (WNP, 2014).



Note: 1 EURO=4.6858 PLN (Narodowy Bank Polski, 2022)

Figure 1. Average prices of certificates in 2016-2022 [PLN/MWh]

Source: authors' work based on TGE, 2022b.

However, due to the lack of enactment of the regulation on the amount of the obligation to obtain and submit for redemption certificates of origin for energy from cogeneration, energy entrepreneurs selling energy to end users were not obliged to purchase yellow certificates and fulfill the statutory obligation. This was, along with the sharp drop in green certificate prices, one of the main causes of the crisis in which the biogas industry in Poland plunged in 2013. Due to this situation, many biogas projects were suspended or even abandonment. The existing biogas plants, began to bring losses so severe that many of them faced bankruptcy (Krzemiński, 2014).

The yellow certificate system was reintroduced in April 2014, but the obligation to redeem certificates was limited only to the year in which the cogeneration energy was produced. An important issue in the period of the lack of yellow certificates was the possibility of applying for the so-called purple certificates, i.e. certificates of origin for energy from a methane-fired unit introduced in 2010, the amendment to the Energy Law Act, the price of which oscillated around PLN 60/MWh (Energy Regulatory Office, 2018). The system of yellow and purple certificates was in force until the end of the 2018, with the settlement obligation until June 30, 2019. It was replaced by the Act of December 14, 2018 on the promotion of electricity from high-efficiency cogeneration, which made it impossible to combine support systems, which consequently meant that agricultural biogas plants receiving support

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in the form of blue certificates cannot benefit from the support system for high-efficiency cogeneration.

For new agricultural biogas plants (under the feed-in tariff system, the so-called FIT, FIP or auctions), the inability to use the support for energy production in high-efficiency cogeneration was compensated by the differentiation of reference prices for electricity produced from agricultural biogas or from agricultural biogas from high-efficiency cogeneration (110 PLN/MWh price difference) (Regulation of the Minister of Climate and Environment, 2021).

Subsequent changes took place on July 14, 2018, when the provisions of the Act of June 7, 2018 amending the Act on renewable energy sources and certain other acts (Journal of Laws of 2018, item 1276) came into force, introducing inter alia new forms of support for electricity generation from renewable energy sources – the so-called feed-in-tariff system of feed-in tariffs (Energy Regulatory Office, 2018).

In accordance with the adopted regulations, renewable energy installations with a capacity of less than 500 kW may join the FIT system (Szwarc, 2021). After obtaining a certificate from the President of the ERO about the possibility of using the FIT system, the generator sells the generated electricity, the so-called obligated sellers (appointed by the President of the ERO based on the highest volume of sales to end users connected to the distribution network in a given area) at prices equal to 95% of the reference price applicable on the date of submission of the FIT, less public investment aid, if applicable.

The system of additional payment to the market price (FIP) may be used by installations with a total installed electrical capacity of not less than 0.5 MW and not more than 1 MW (Szwarc, 2021). Under this system, they can obtain the right to cover 90% of the negative balance, i.e. the difference between the reference price and the average electricity prices on the Polish Power Exchange. These prices are subject to annual indexation with the average annual total consumer price index for the previous calendar year published by the President of the Central Statistical Office. In the case of the FIP support system, similarly to the FIT system, the reference price should be reduced by the public investment aid obtained, if any. In November 2021, the reference price level in the FIT system, for which investors could sell electricity from agricultural biogas, produced in high-efficiency cogeneration, was PLN 722/MWh (95% of PLN 760/MWh) (Szkwarek, 2021). In the FIP system, the reference price for electricity generated from agricultural biogas in high-efficiency cogeneration is PLN 700/MWh, which means that an agricultural biogas plant may receive support at the level of PLN 630/MWh (90% of PLN 700/MWh) (Regulation of the Minister of Climate and Environment, 2021).

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On October 30, 2021, further amendments to the act were introduced under the Act of September 17 amending the Act on renewable energy sources and certain other acts (Journal of Laws 2021, item 1873), allowing participation in the FIT/FIP system for 24 additional months for renewable energy installations that received certificates of origin for a minimum period of 5 years. Therefore, the additional 24 months in the FIT/FIP system can be used by installations that are in the process of using the certificates of origin system and installations for which the maximum 15-year period of using the certificates of origin system has already expired. The total duration of using the support system may not exceed 17 years (Szwarc, 2021). Contrary to the simple FIT/FIP system, the auction system for installations with a capacity above 1 MW is a challenging mechanism, as it requires an obligation to supply energy under the pain of high penalties, for the price proposed in the auction, which, after winning, is reduced by public investment aid. Settlement of the energy volumes declared in the auction takes place in three-year periods.

In 2014, a guarantee of origin system started operating in Poland, which was implemented as part of the implementation of selected assumptions of the 2009 EU RES Directive. The role of the guarantee of the origin of electricity is to certify the end user of the generation of electricity in RES and the related environmental values resulting from the avoided emission of greenhouse gases. No property rights arise from guarantees of origin, and their current market value is at the level of a few PLN.

The barrier related to the lack of stable legal regulations concerns primarily the frequency of changes and their impact on the functioning of the industry. The Renewable Energy Sources Act of 2015 was amended thirty-two times, including 20 times in 2019-2021. And still does not contain key provisions of the so-called Market Directive, the implementation of which has a huge impact on the development and operation of agricultural biogas plants in Poland. Changes in regulations and their adaptation to changing market realities take too long, which results in a lack of trust in the legal system in its broadest sense and is often the decisive factor in not implementing biogas investments.

Development barrier, internal barrier, relative barrier, systemic barrier. Lack of consistency in implementing positive changes, programs, plans

In 2010, the government adopted the program “Directions for the development of agricultural biogas plants in Poland in 2010-2020”, which was to stimulate the economy of Polish countryside, make it partially energy-independent and help achieve the targets for the share of energy from renewable sources (gramwzielone.pl, 2013; NIK, 2018). The Polish countryside was

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about to change. The ambitious plan provided for the construction of an average of one biogas plant with a capacity of approx. 1 MW in each municipality that had the conditions to do so. In practice, this meant about 2,000 such installations, the total capacity of which was to be 2,000 MW. The Ministry of Economy estimated that biogas plants will produce biogas corresponding to 10% of the national consumption of natural gas. The plan was never implemented. On the contrary, the interest in agricultural biogas plants has been gradually decreasing since 2012 due to changes in legal regulations and the unfavourable situation on the green certificates market. If the plan were implemented, about 2,000 agricultural biogas plants in Poland would have been built; it would have given the power system a distributed and fully controllable source of energy with a capacity and production volume compared to the commissioning of the planned nuclear power plant (Grzybek et al., 2020). The costs of the nuclear power plant are at least several billion PLN higher than the construction of an agricultural biogas plant, and the first effects could be achieved just one year after inception.

In addition, it would improve the energy infrastructure and increase the competitiveness of Polish agriculture and would stimulate the development of local entrepreneurship (Ministerstwo Gospodarki, 2010). The implementation of the assumptions of the "Directions for the development of agricultural biogas plants in Poland in the years 2010-2020" would also contribute to the achievement of the objectives indicated, among others, in the Energy Policy of Poland until 2040, which assume: optimal use of own energy resources, expansion of production infrastructure, development of energy markets, renewable energy sources, heating and cogeneration, as well as to improve the energy efficiency of the economy, and thus to improve energy security. Due to the location of the agricultural biogas plant, local documents and plans are also important, such as low-emission economy plans, which set goals and directions in terms of improving air quality, energy efficiency, reducing pollutant emissions, including greenhouse gases, local development plans, which formulate objectives and describe strategies aimed at achieving social, economic and spatial development, or plans for the supply of heat, electricity and gaseous fuels, which define and specify the commune's energy policy. Regionally, this is prepared in the strategies of voivodships.

Development barrier, internal obstacle. High investment outlays

Agricultural biogas plants are complex installations, which consist of many elements, such as buildings: technical building with a CHP module and pump building, tanks: for components, preliminary, mixing, fermentation, post-fermentation, electrical installations and networks with a transformer station, water supply networks, sanitary, technological networks with a

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pump system and component networks, e.g. with a moving floor, biogas treatment network with a desulphurisation tank, heat network with boiler room technology, separator, automation and control, component yards, roads, etc.

Such complexity of the installations means that the investment outlays for this type of project are much higher than the outlays for photovoltaic installations or wind turbines, which, compared to agricultural biogas plants, may deem to be rather basic. In 2010-2012, the amount of expenditure on an agricultural biogas plant with a capacity of 1 MW ranged from PLN 13 to 16 million. Currently, it is estimated that the construction of a 1 MW installation requires an investment of over PLN 20 million.

Table 4. Investment outlays for biogas plants with three different plant capacities – calculation as of December 31, 2021*

Year of construction	Biogas plant with installation capacity (kWel / kWt)		
	625/690	1 063/1 088	2 126/2 206
	2010	2011	2009
Investment outlays for construction [PLN]	9 500 000	13 000 000	15 300 000
Total investment outlays [PLN]	10 000 000	15 000 000	21 500 000
Electricity production [MWh]	5 200	8 500	17 000
Production efficiency [%]	94.98%	91.28%	91.28%
Thermal energy production [GJ]	22 300	38 500	55 000
Heat surplus (to be used) [GJ]	5 800	15 000	16 300
Number of animals [JPD]	12 300	1 200	9 300
Share of electricity from biogas plants in the energy used for energy production [%]	17.69%	19.29%	18.82%
Amount of energy used for energy production [MWh/year]	920	1 640	3 200
Share of electricity from biogas plants in the energy used on the farm [%]	6.92%	8,59%	34,12%
The amount of energy consumed on the farm [MWh/year]	360	730	5 800
Share of electricity from biogas plants in the energy used in other / remote farms [%]	11.63%	15.92%	14.55%
Amount of energy used in other/remote farms [MWh/year]	2 593	6 130	8 000
Substrate costs [PLN/year]	1 700 000	2 200 000	6 200 000
Total direct costs other than the cost of the substrate [PLN/year]	1 400 000	1 700 000	3 000 000

Note: 1 EURO=4.6858 PLN (Narodowy Bank Polski, 2022).
* The costs increased significantly by about 30-40% after February 24, 2022.

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The analyses carried out in the literature show that at the assumed level of costs and outlays, investments in agricultural biogas plants do not provide, in most of the analysed cases, a return on the invested money (Sulewski et al., 2016). As an example, Table 2 presents the investment outlays for biogas plants with different plant capacities.

The cost of the substrate is the largest cost driver in the case of agricultural biogas plants, mainly in those using corn silage as a substrate, the price of which depends on the market price of corn grain. The use of silage should therefore be limited to silage from part of the green maize. Agricultural biogas plants should mostly use second-generation raw materials, e.g. waste straw or other by-products of agricultural origin, which have no other possibility of use and are cheap. Corn silage should only be a supplementary raw material, especially where the technology of the biogas plant was adapted to a specific substrate – only then it makes economic sense.

It is also noteworthy the barriers that appear at the design stage and during the technological start-up, which is not without significance during operation. The basic problem at the design stage is the wrong assumption as to the power and size of the biogas plant, which often results from administrative and legislative reasons and not from functional and technical aspects, e.g. a biogas plant up to 0.5 MW does not require an environmental impact assessment. An undersized biogas plant may struggle with such problems as insufficient amount of heat necessary in the fermentation process, especially thermophilic, inflexible technology in terms of raw materials, e.g. too small tanks, inefficient mixers, etc. At the start-up stage, it is very important to carry out the fermentation correctly, so proper feeding of the bacteria. Disturbance of fermentation at any stage may cause the biogas plant to work unstable, and thus it will not achieve the intended efficiency. This problem also applies to the exploitation stage. It is not without significance for the proper functioning of the biogas plant is the service and technological supervision, including properly carried out inspections and servicing of installations, as well as controlling the basic parameters of the biogas plant.

Systemic barrier, external obstacle, development barrier. Lack of programs financing the construction of agricultural biogas plants

The construction of a biogas plant requires the involvement of large capital, and investors most often do not have the funds that would allow the project to be implemented without external support (Filipiak, 2020). When deciding on a biogas investment, consideration needs to be taken regarding the financing formula and possibilities offered by: banks, leasing companies, as well as other institutions that offer dedicated support programs in the form of grants and loans.

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Among the investment financing formulas, three proposals should be mentioned: financing on the investor's balance sheet (corporate finance) or off-balance sheet (project finance). It is also possible to combine the forms of financing: use the form of balance sheet financing as a limited liability company for the time of construction, and after the technical acceptance of the project, create a special purpose company and continue its operation under the project finance, refinancing it with a long-term loan. As a result, the risk for lenders is reduced (which leads to lower costs of the loan at the construction stage and the refinancing loan), and it is easier to start an investment while maintaining the benefits of using the project finance formula at the stage of operation of the installation.

It is also possible to combine the forms of financing: use the form of balance sheet financing as a limited liability company for the time of construction, and after the technical acceptance of the project, create a special purpose and continue its operation under project finance, refinancing it with a long-term loan.

Unfortunately, there are only a few possibilities for obtaining financing. It is difficult to find a standardised offer dedicated to biogas plants in the banks offer. However, the National Fund for Environmental Protection and Water Management offered only two active programs offering subsidies and preferential loans for biogas plants. The first is Energia Plus (a program offering subsidies up to 50% of eligible costs) and loans (up to 85% of eligible costs, loan amounts from PLN 0.5 to 300 million). The second is Agroenergia, in which the form of support is a subsidy (up to 50% of eligible costs, but not more than PLN 1.8 million for sources up to 150 kW; PLN 2.2 million for sources with a capacity of 150-300 kW, but not more than 2, PLN 5 million, if the investor applies for support for the construction of an installation with a capacity of 300-500 kW) and loans up to 100% of eligible costs.

Provincial Funds for Environmental Protection and Water Management also have preferential loans for ecological investments usable for biogas plants. For agricultural activity, the Agency for Restructuring and Modernization of Agriculture offered its help, after an individual assessment of the project, under the Rural Development Program for 2014-2020. Moreover, it is possible to obtain the support after an individual assessment of a given project, e.g. as part of PFR investment funds, ARP loans, loans granted by BGK and loans from commercial banks secured with BGK guarantees (de minimis or Biznesmax with subsidy). However, when making financial commitments, it should be remembered that the main obstacle for both financing entities and investors themselves is the high risk of biogas projects, which do not always take into account the responses to potential threats at the stage of investment implementation and operation of a biogas plant (Filipiak, 2020).

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It is worth mentioning that on June 1, 2022, the European Commission approved the National Plan for Reconstruction and Increasing Immunity (KPO), under which Poland should obtain approximately EUR 36 billion (ACCREO, 2022). The funds were broken down into non-repayable instruments, such as grants, with € 23.850 billion, and repayable instruments, with € 12.11 billion. Among the five main thematic components, there is also "Green energy and reduction of energy intensity (around EUR 14.3 billion). The objectives of the subsidy include, inter alia, the construction of waste storage and management facilities, as well as sewage treatment plants and biogas plants.

Local barriers, internal obstacle. Planning constraints

According to the Supreme Audit Office, "Documents specifying the spatial policy of communes are often outdated and incomplete, which significantly limits their role in the spatial management system" (NIK, 2017). In Poland, the most important decisions regarding the destination and development of land are taken by municipalities. One of the basic factors that are taken into account when looking for real estate for investment purposes, including biogas plants, is information about whether the plot is covered by a local spatial development plan (Local Development Plan) and what are the provisions of this plan. The energy use of biogas plant products means that it should be included in the draft assumptions for the plan for supplying the commune with heat, electricity and gas. It should be ensured that the planned biogas plant is included in other local documents, such as the study of the conditions and directions of the spatial development of the commune, environmental protection program, low-emission economy plan, draft assumptions for the heat, electricity and gas fuel supply plan, to which the head of the commune, mayor, or president is obligated, under the Energy Law, etc.

In addition, when planning an investment in a biogas plant, ambiguous interpretation of the provisions determining the investment process needs to be taken into account, e.g. regulations in the field of construction law, real estate management, and protection of agricultural and forest land. Therefore, questions arise: Does the land for an agricultural biogas plant need to be de-agriculturalized? Is the biogas plant an agricultural structure? Is the biogas plant built for agricultural purposes?

Depending on the answer provided by the authorities participating in the investment process – the procedure may be completely different, as there are no standardised approaches to this type of project in Poland, and most importantly, there are no legal provisions that would prevent freedom of interpretation. It should also be remembered that the exclusion from the production of agricultural land produced from soils of mineral and organic ori-

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gin, classified as classes I, II, III, IIIa, IIIb, and agricultural land of classes IV, IVa, IVb, V and VI produced from soils of organic origin, and also the land referred to in article 1. 2 clause 1 items 2-10 of the Act on the protection of agricultural land and forest land intended for non-agricultural and non-forest purposes, may take place after the issuance of a decision authorising such an exemption.

Referring to the possibility of recognising an agricultural biogas plant as an agricultural goal in itself, it should be ruled out that the biogas plant is an industrial activity within the meaning of Art. 4 pts 26 of the Act on the Protection of Agricultural Land and Art. 3 point 12 of the Energy Law (Act, 1997).

The location and size of the biogas plant is not adapted to local conditions

When considering the construction of a biogas plant, the type of feedstock, its quantity and quality, and specifying its availability on the local market need to be determined at the start. The most commonly used raw material in an agricultural biogas plant is slurry, stillage and various types of silage. Straw, which is a by-product of plant production, is also becoming more and more popular (Ginalski). The availability of the listed substrates and other raw materials that meet the statutory definition of agricultural biogas has a decisive impact on the location of an agricultural biogas plant. Transport of substrates, mainly those with a high water content, such as slurry, is expensive and reduces the efficiency of energy production, and is also inadvisable from the point of view of environmental protection. The most optimal and appropriate solution is to build an agricultural biogas plant in the immediate vicinity of the raw material supplier, e.g. in the vicinity of a farm, so that slurry can be delivered via a pipeline directly to the biogas plant, without affecting the environment and the immediate surroundings.

In Poland, there are many cases where the location or size is not adapted to local conditions. We are talking primarily about such installations in the case of which the feedstock is not in the immediate vicinity or on the local market, but is transported from considerable distances, which is neither economically nor environmentally justified. Biogas plants should develop where there is a supply of waste from agricultural production and the agri-food industry, as well as agricultural raw materials of the second category. The most optimal solution for an agricultural biogas plant is its operation within an integrated farm. The location far from the place of sale of the feedstock to the biogas plant increases the risk of insufficient feedstock for biogas production or an increase in costs in this regard to levels that do not allow to ensure financial liquidity. It is even riskier if a given installation participates in the auction system and has to meet the obligation to sell the amount of electricity declared during the auction. The stability of a biogas plant depends mainly

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on the stability of the fermentation process, and without a stable supply of raw material, it is impossible to achieve and may indicate oversizing of the installation. It is also important to undersize the biogas plant in the case when a certain amount of substrate is provided. An example is a situation in which a small agricultural biogas plant operates in the immediate vicinity of a large pig farm, but due to its size and power, it is not able to produce waste heat sufficient to carry out the fermentation process and heat the livestock buildings. An important issue, both in terms of location and size, is to ensure the appropriate area of land for fertilisation with an organic fertiliser in the form of digestate, remembering to limit nitrogen application to 170 kg/ha.

An important issue that directly concerns the location barrier is that agricultural biogas plants operate at a considerable distance from potential heat recipients, which significantly reduces the economy of biogas plants and is a kind of waste in the case of biogas plants producing energy in cogeneration because unused heat goes to the cooler. The size of the biogas plant must therefore be adapted to the local raw material resources, to the local demand for thermal energy, as well as to the needs of the biogas plant itself, which in thermophilic fermentation requires a large amount of heat in the technological process.

In the case of new investments, potential electricity consumers in the immediate vicinity may also be important from the point of view of problems with obtaining connection conditions to the power grid.

External obstacle, systemic barrier. Problems with obtaining a connection to the power grid

The development of renewable energy sources in Poland will not accelerate without decisive investments in power grids and without changing the way they are managed (Act, 1997). In Poland, the operator of the electricity transmission system is Polskie Sieci Elektroenergetyczne S.A. (PSE). PSE cooperates with energy companies/operators who distribute gaseous fuels or energy. These enterprises are required to conclude a grid connection agreement with entities applying for it. In the first instance, connections include the installation of a renewable energy source, if technical and economic conditions meet the conditions for connection to the network and reception. Refusals to conclude a grid connection agreement or to connect a renewable energy source installation are, unfortunately, quite common.

According to the data published by the energy regulatory office, the number of connection refusals in 2021 increased by 70% compared to 2020 and amounted to 3,751 cases. These were mainly PV micro-installations. In 2015-2021, over 6,000 applications to connect to the grid were rejected for installations with a total capacity of approximately 30 GW. This is almost 50% of

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the currently installed capacity in all types of energy sources in Poland as of May 2022. This is a result close to the total capacity of coal-powered and lignite-powered units in 2021. Refusals to connect the highest RES capacity were in 2021, and it was as much as 15 GW (Globenergia, 2022). An unconnected or shut-down installation does not generate electricity, so self-consumption also does not occur. The solution could be energy storage and changes in the capacity market, including the release of the capacity blocked by wind and solar installations in favour of stable generation sources, which could supplement this capacity in periods of low efficiency. Unfortunately, this type of action requires systemic changes.

Absolute barrier. The need for biogas treatment

Biogas can be used for energy purposes locally by coupling the generated fuel with a biogas combustion unit or, after purification, introduced into the gas network and, after transmission, further used for energy purposes (PIGEOR, 2015). Despite the fact that, in accordance with the legal status in force, it has been possible to introduce purified agricultural biogas to the gas distribution network for several years, so far, no installation of this type has started operating in the country (NIK, 2018). For producers of agricultural biogas injected into the network, which is not subject to the concession obligation (Ustawa, 2003), there was no indication in the regulations of the competent authority which should participate in the process of testing the so-called “Incentive effect” (Act, 2017). Another form of biogas use can be bio-LNG, i.e. liquefied biomethane, which, due to the density of the stored energy and, therefore, the small volume of fuel, is an excellent solution for transport. It can be a solution for the energy and heating sectors, wherever there are no gas networks or they are located at considerable distances from the generation site.

A significant limitation is also the high expenditure on installations for biogas purification to network parameters and/or condensation.

At the moment, there is no installation producing bio-LNG in Poland, mainly due to high investment outlays and all the barriers referred to in this study. However, due to the current geopolitical situation and high prices of natural gas and energy, bio-LNG may, under certain conditions, be competitive with natural gas. The interest in this product is growing, mainly among enterprises pursuing decarbonisation goals in accordance with their own policy of implementing ESG non-financial reporting objectives (Environmental, Social Responsibility and Governance). Moreover, it is popular among enterprises operating on the fuel market obliged to meet the indicative targets set out in relevant legal regulations, such as the Act of 25 August 2006 on biocomponents and liquid biofuels (NCW – the indicative national target, which for 2023 is 8.9%) and the Act of August 25, 2006, on the Fuel Quality Monitoring and Control System (NCR – National Reduction Rate, which is 6%) (Magazyn Biomasa, 2022b). Examples of installations for the production of bioLNG operate in Europe, e.g. in Germany or the Netherlands.

Biogas as a product can be injected into local gas networks without increasing its quality parameters and without the necessity to incur huge expenditures on biogas purification installations. A biogas plant can be built on the outskirts of a municipality with a district heating network with its own gas-fired boiler houses, to which a gas pipeline supplying biogas to the boiler room can be built. However, this is justified only where the local gas network is not integrated with the natural gas network.

System barrier, external obstacle. Defining digestate – fertiliser or waste?

In the light of the law in force, the digestate may or may not be considered waste. Pursuant to Art. 2 point 6c of the Act of 14 December 2012 on waste, it is stated that "the provisions of the Act do not apply to (...) other, non-hazardous, natural substances derived from agricultural or forestry production used in agriculture, forestry or for the production of energy from such biomass by means of processes or methods that are neither harmful to the environment nor endanger human life and health. " The definition of waste states that "any substance or object which the holder discards intend or is required to discard" allows the digestate to be treated as waste or as a by-product subject to trade. In order for the digestate to be considered a by-product, the procedure presented in Art. 11 of the Act on Fertilizers and Fertilization, i.e. "producer of the object or substance referred to in Art. 10, is obliged to submit to the voivodeship marshal (...) the notification of recognition of the object or substance as a by-product.

On the farm without biogas plant, animal manure in the form of slurry can be used in arable fields as fertiliser without the need to conduct microbiological tests. In the case of a biogas plant and slurry processing in a biogas plant, tests are mandatory and result from legal regulations. According to the veterinary requirements, the animal by-product after processing by a biogas plant is still an animal by-product, even though it is registered as an organic fertiliser, which means that the buyer of such fertiliser must have appropriate permits for the use and transport of this fertiliser. An individual farmer without support from the administration has a difficult path to obtaining such a permit. What's more, if it were to be sold, the carrier and the buyer must have a veterinary identification number (WNI), which is associated with the registration of the means of transport by the carrier and confirmation of the purchase of the fertiliser by the buyer. Such interpretative duality

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is quite a significant barrier affecting for the operation of both planned and existing biogas plants.

Internal obstruction. High operating costs

In addition to the selection of appropriate devices and components for a biogas plant already at the design stage, it is equally important to strictly control their technical condition during operation, which has a significant impact on the functioning of the biogas plant and its efficiency. This is associated with high operating costs, which are also influenced by payroll costs, as biogas plants are not maintenance-free installations. An average biogas plant with a capacity of 1 MW requires constant service and therefore employs a minimum of 5 people. A large part of the operating costs is also the cost of the raw material in the form of silage or straw, the price of which increases every year. With the current prices of raw materials, services and all other components, the average technical cost of generating 1 MWh of energy ranges from PLN 800-1000/MWh.

External obstacle, system barrier. Public and legal burdens (mainly local taxes and fees)

Another barrier to the operation of biogas plants is the issue of their taxation (Aromiński, 2017). In the opinion of entities operating biogas plants only as part of agricultural activity (i.e. energy is not sold outside), the installation should be taxed with agricultural tax and not with the real estate tax because it serves agriculture and is used only for the purposes of agricultural activity, and is not strictly an economic activity. In the opinion of the tax authorities, the objects consisting of a biogas plant (buildings and structures) are related to economic activity, and at the same time, the agricultural land on which the biogas plant facilities are located is therefore occupied for economic activity, which results in charging real estate tax, which for the owner of an agricultural biogas plant is a much higher burden compared to agricultural tax (from PLN 100,000 to PLN 200,000 per year).

Moreover, there is often a twofold interpretation of the regulations in the context of tanks that meet the statutory definition of a building. In some communes, administrative employees recognise the tanks as structures (taxed with real estate tax in the amount of 2% of their value) (Ustawa, 1991); in others, they are treated as buildings (taxed on the area). From the taxpayer's point of view, it is more advantageous to tax tanks as buildings, where the tax burden may be twice lower than in the case of taxing tanks as structures, due to the fact that the book value of the tanks, which is the tax base, amounts to several million PLN.

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Internal obstacle, local barrier. Local protests mainly due to the lack of knowledge about the functioning of agricultural biogas plants

Investments in the construction of agricultural biogas plants also encounter social resistance, most often caused by the fear of the emission of noxious odours among local communities (Ceny rolnicze, 2022). In addition, local communities indicate, inter alia, unfavourable factors related to the functioning of biogas plants, such as water and soil contamination for monoculture crops; negative impact on the health of residents; a significant drop in land prices in the area; reducing the chances of agritourism development, increasing the nuisance of road traffic, as well as their destruction by vehicles delivering feedstock (Wawer, 2016).

A distorted image of the real social support for RES investments, through loud actions of a small group of opponents, may suggest that the majority of residents are against this type of investment. As a result, policymakers are under pressure and changing their attitude toward biogas investments.

Discussion/Limitation and future research

The research carried out by Igliński et al. (2020), who used the barrier typology according to the PEST method (political, economic, social, technological), indicating the lack of social awareness of the production and use of biogas, lack of knowledge transfer related to investment risk in biogas plants, as well as limited availability and capacity of the electricity network in rural areas. The last element, problems with obtaining connection conditions to the power grid, despite a different typology of barriers, was also indicated by the respondents whose opinions are described in the article. It should be emphasised that in the case of both studies, knowledge from specialists dealing with the subject of agricultural biogas was used, directly or indirectly, mainly due to their place of employment.

The issue of the functioning of agricultural biogas plants should be considered from more than just the perspective of barriers. The positive aspects of its operation should also be indicated, which may be the basis for further research on developing agricultural biogas plants in Poland. The opportunities include calculating the carbon footprint for biogas plants and calculating the emissions avoided thanks to agricultural biogas. An additional opportunity for the development of agricultural biogas plants is their operation within cluster structures, the development of the concept of a “green gas card”, as well as local distribution networks.

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Conclusions

Agricultural biogas plants undoubtedly deserve a distinction because they operate in rural areas based on a circular economy with the participation of numerous stakeholders. Despite the fact that agricultural biogas plants have been operating in Poland for over 17 years, barriers to the development of agricultural biogas plants in Poland remain unchanged, and the awareness of the positive impact of agricultural biogas plants on many levels is still very low.

The survey results indicated that most respondents pointed to external, systemic and developmental obstacles. The highest percentage of responses concerned the lack of stable legal regulations in renewable energy sources, including biogas plants, and the lack of financing programs for constructing agricultural biogas plants. In addition, an important issue related to the definition of digestate and problems with obtaining connection conditions to the power grid. Apart from the lack of stability of the law on renewable energy sources, the most important barriers among the respondents indicated high investment expenditures, proper operation of biogas plants and high operating costs. This theme also appeared in elements that could improve the development of agricultural biogas plants in the future. The respondents considered it very important to update and guarantee the profitability of investments in the situation of significantly higher expenditures, growing costs of business and debt servicing through the reference price, as well as inclusion in the support system of tariffs guaranteeing a stable income for at least 15 years. In addition, among the important factors, the respondents pointed to the introduction of facilitations in the purchase of land with an area of more than 1 ha for the construction of a biogas plant and the importance of the competence of administrative bodies and the timeliness of the procedure.

The impact of biogas plants on the local community is also significant through the creation of new and interesting jobs and the development of modern technologies that, thanks to a cogeneration unit, generate heat consumed locally for heating or technological purposes, especially by the agri-food industry. This subject may become of future research because it is worth remembering that this way of operating makes biogas plants favour local entrepreneurship not only in the field of energy biomass production but, above all, in the field of agrotechnical and technical services and favour new ventures based on constant access to energy, especially thermal energy (dryers, greenhouses, distilleries, farms).

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The contribution of the authors

Conception – AMK (50%) and AB (50%); literature review – AMK (50%) and AB (50%); acquisition of data – AMK (50%) and AB (50%); analysis and interpretation of data – AMK (50%) and AB (50%); writing – original draft AMK (50%) and AB (50%); writing – review & editing – AMK (33%), AB (33%), AS (33%). The authors have read and agreed to the published version of the manuscript.

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