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Article

Biogas as fuel for the lowest-level power plants

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Abstract: In the face of European climate policy, the aim of which is to achieve climate neutrality by 2050, we are still looking for alternatives to traditional fossil fuels. Apart from the obvious solutions offered by wind and solar energy, it is worth paying attention to a still undeveloped, but potentially developing branch of energy, which is generating energy from biogas. Poland currently produces 638 million m^3 of biogas per year and has biogas installations with a total installed capacity of 276 MW. However, these numbers still do not fully satisfy both Polish possibilities and needs. This study analyzes the current use of this fuel in the Polish energy sector, as well as the possibilities and future prospects for biogas as a fuel for distributed generation power plants in Poland. The current review of the use of biogas as a fuel clearly indicates that biogas is not a commonly used renewable energy source with a total share of power among other RES sources of 4.2%. The analyses also indicated that the maximum theoretical Polish potential for biogas production may reach even 4.2 billion m^3. At the end of the article, simple financial analyses were made regarding the profitability of investments in agricultural biogas plants, and their results showed a high profitability of investments in such energy units (theoretical payback periods of financial outlays are only 4 years).

Keywords: biogas; Poland; energy; economy; biowaste

1. Introduction

Both in Europe and in Poland, the main priority is the development of distributed generation. The production of energy that meets local needs can significantly relieve the energy system and facilitate the energy transformation of the country in accordance with the provisions contained in the European Green Deal and the REPowerEU program [1,2]. Biogas-fired power plants are suitable for distributed generation operations and fit into the framework of the previously mentioned European climate policies.

Europe is the world leader in the production of electricity from biogas. According to research from 2015, the total installed capacity in biogas power plants amounted to 10.4 GW in Europe alone, and in total in the world 15 GW. The electricity produced from biogas at that time was 80 TWh in the world, of which as much as 58 TWh was created in Europe [3]. On a European scale, biogas accounted for 6.7% of all energy produced by renewable sources [4]. Currently, almost 17 billion m^3 of this fuel is produced in the European Union, and according to REPowerEU, these numbers are to more than double by 2030 [5]. In addition, most of the biogas produced is to be processed into more energy-efficient biomethane. Transport is the only sector in the EU whose emissions are still growing despite European climate policies. This is where biomethane is to be used, which, when used as automotive fuel, could be used to power up to 29,000 trucks per year by 2025 [6]. Poland, together with France, Germany, Italy and Spain is among the five countries with the greatest potential for biomethane production in the EU [5].

The European leader in both biogas production and energy from this fuel is Germany. In this country, biogas accounts for as much as 14% of electricity produced from renewable sources. The main catalyst for the dynamic development of this sector in Germany was the perfectly adapted legislation that came into force at the beginning of the new millennium. As a result, there were 9527 biogas plants in Germany in 2022 [7]. The largest increase in the number of biogas plants occurred between 2010 and 2015, when as many as 2300 were built. It is worth noting that to provide substrate for such a huge number of power plants, as much as 10% of agricultural land in Germany is used for this purpose. After years of dynamic development of biogas plants, there is a slow but clear trend of their extinction. Smaller power plants are being closed, because the market favors large investors. Despite this, the value of installed capacity in biogas plants remains constant because the mainly small units that are being closed are being replaced by rarer but more powerful ones. Germany has an installed capacity in biogas installations of around 6.2 GW, although it is worth adding that the German government still sets itself the task of increasing the capacity to 8.4 GW by 2030 [7].

Biogas is still the subject of research conducted in Europe to further increase our possibilities in the field of energy production from renewable energy sources and where possible to replace natural gas with biogas. It should not be forgotten that one of the main reasons for the creation of the REPowerEU program was the Russian aggression against Ukraine and its impact on the European energy sector. The development of biogas technologies is therefore also to some extent intended to reduce the demand for natural gas commonly used to power gas power plants, previously mainly imported from Russia. Due to the high level of agriculture in the Ukrainian economy, biogas is being considered as one of the options for ensuring energy security of this country after the end of the war. This option would be based on a base of sugar factories, producing sugar, e.g., from common sugar beets. There are plans to create so-called clusters, which, operating in the food and agricultural industry, would use biogas (produced from biowaste generated within the food and agricultural industry) to provide themselves with energy independently of the central energy sector. Ukraine currently produces almost 230 million m^3 of biogas and has 68 biogas plants with a total installed capacity of 105 MW. According to estimates, the construction of another 348 plants could allow the replacement of liquid methane used in Ukraine with biomethane [8].

2. Biogas in Poland

According to data for 2022, there were installations in Poland with a total installed capacity of 276 MW. In 2012, it was 131 MW [9]. The increase in capacity in the years 2005–2022 can be observed in the above graph (**Figure 1**). Although the increase in this type of installations over 10 years more than doubled, in 2016 there was a significant slowdown in their development in Poland. Additionally, it should be noted that there is still significant potential for the development of this method of obtaining energy. It is worth noting the percentage share of energy generated from renewable sources, for which biogas is only 4.2%. For example, in Germany, the European leader in terms of the use of energy from biogas, it was 14% [10]. Such a large scale of biogas use was achieved there thanks to the increased use of all kinds of agricultural waste for its production, of which there is no shortage in Poland either.

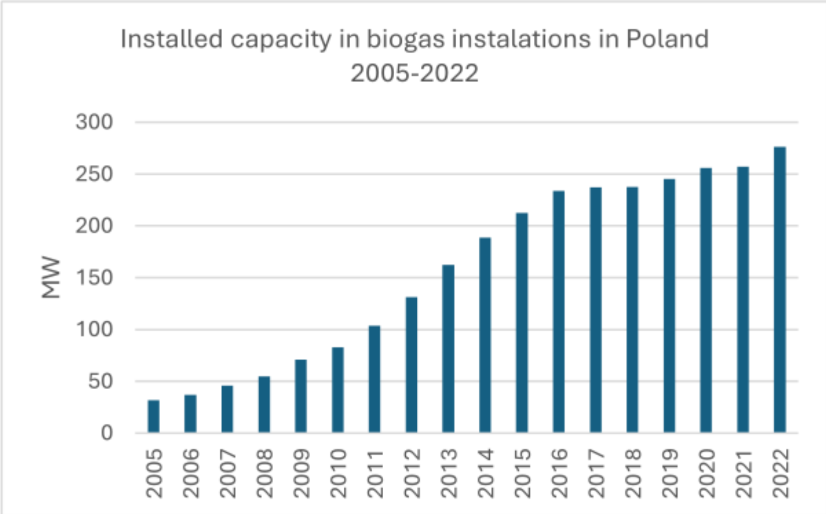

Figure 1. Installed capacity in biogas-fired power plants in Poland 2005–2022. Own study based on GUS [9].

According to 2018 data presented in "Agricultural Biogas—An Important Element in the Circular and Low-Carbon Development in Poland" [11] Poland directs over 4 million Mg of various substances to the production of agricultural biogas. The most common ones are presented below:

Distillers' grains:

Distillers' grains had the largest share among the substrates used for biogas production. Their consumption for production at that time amounted to almost 840,000 Mg which was 21% of total mass of substrates. They are characterized by easily fermentable carbohydrates, which allows obtaining biogas with a high methane content.

Fruit and vegetable residues:

Fruit and vegetable residues accounted for 19% of all substrates. Although they are not a particularly high-quality substrate, their frequent use was mainly due to their easy availability and low purchase prices.

Liquid Manure:

Liquid Manure like distillers' grains, is characterized by a large amount of easily fermentable compounds that are conducive to biogas production. Its use for biogas production in 2018 reached 18.9%. As a result of its use for biogas production, the myth of a "stinking" biogas plant is present in society. In reality, a biogas installation must be tight so it cannot emit an odour.

Maize silage:

Maize silage accounted for 12% of the biogas produced. It is very efficient in producing this fuel, so fields were often planted with maize to cover the shortage of substrate demand.

Beet pulp:

Beet pulp produced during sugar production from sugar beets, like maize, is very effective in terms of obtaining biogas from it. It constituted 7% of the total mass used for biogas production.

Other:

In this category, a large share is held by, among others, sewage from the agri-food industry, as well as expired food, with a share of 12.6% and 8.6%, respectively.

The amount of substrates directed to biogas production is presented in the graph below. It is easy to notice that the category "Other" reaches almost 900 thousands Mg—this only shows the variety of ways in which we can produce biogas (**Figure 2**).

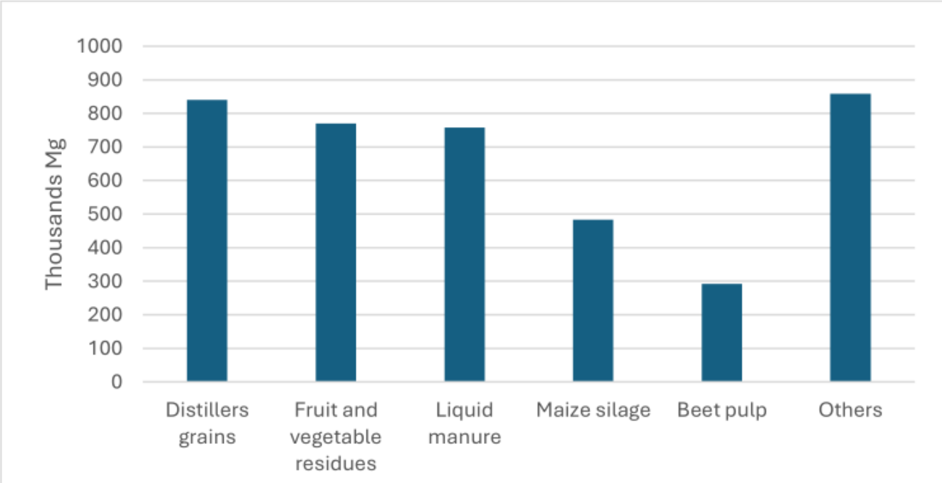

Figure 1. The use of substrates for biogas production in Poland in 2018. Own study based on data [11].

Most biogas plants produce biogas to generate electricity, most (i.e., 65% of the units) [12] we also include small power plants, i.e., those with a capacity of 50 kW to 1 MW. In accordance with §3, section 1, point 4 of the Regulation of the Council of Monsters of 9 November 2010 on undertakings that may have a significant impact on the environment, investments involving installations for the production of agricultural biogas with an installed electrical capacity of no more than 0.5 MW, or generating an equivalent amount of agricultural biogas used for purposes other than electricity production, are excluded from the catalogue of undertakings with a significant impact on the environment. This law seems to have a particular impact on decisions on the construction of power plants using agricultural biogas, because 76% of units of this type do not exceed 0.5 MW [12]. Investors do not decide on such a solution because in such a case the investment work will be significantly longer due to the need to carry out additional checks [13]. It is worth noting that small power plants should not be perceived negatively, but quite the opposite, because they fit perfectly into the policy of distributed generation. Units of this type most often operate within the framework of being supplied only with bio-waste from nearby farms, without the need for cultivation typically focused on use for biogas production. A country with a dominant number of small biogas plants is for example Switzerland, where there is a ban on growing plants for energy purposes, because of which the average value of the capacity of local biogas plants is 0.33 MW [14]. For comparison, the average capacity of a biogas plant in Poland is approximately 530 kW [12].

According to the research presented in "Regional Diversification of Potential, Production and Efficiency of Use of Biogas and Biomass in Poland" [15] in 2012, only three voivodeships: Kuyavian-Pomeranian, Warmia-Masuria and Lubuskie achieved high biogas efficiency values for heat production, while by 2018 there were only four voivodeships (the Wielkopolska voivodeship joined the group). It is worth noting that the Wielkopolska voivodeship significantly developed the food and agricultural industry in its territories in the years 2012 to 2018, which provided significant amounts of bio-waste for biogas production. On the other hand, because of the conducted research, it was determined that the Podlaskie voivodeship, despite its large cattle population, achieves only 2.1% of biogas production capacity. In comparison to the Polish average estimated value of 6.4%. However, this result seems to be even more different in the context of the fact that it is the Podlaskie voivodeship that has the largest cattle population in Poland, the breeding of which can provide the substrates needed for biogas production. The production of heat from biogas also requires further development. Although the overall heat production from biogas has increased by 99%, the efficiency limit for heat production from this biofuel has basically remained at the 2012 level: in 2012, the average boiler efficiency value was 8.37 MJ/m^3, while in 2018 it was 8.42 MJ/m^3. Increasing the efficiency of heat production from biogas plants may, especially in less populated regions, lead to them replacing combined heat and power plants, which in Poland are currently mostly fuelled by non-ecological coal.

Since 2010, Poland has been implementing programs aimed at increasing the amount of biogas produced in the country. The program entitled: "Directions of development of agricultural biogas plants in Poland in 2010–2020" specified that by 2022, biogas production would increase to 1.7 million m^3 [16]. Currently, in Poland we produce 638 million m^3 of biogas per year, which means that over the course of 12 years, biogas production was only 38% of the expected results. It is also worth adding that in the program's assumptions, each commune was to have its own biogas plant. There are currently 388 biogas installations in Poland, of which 166 are agricultural [17], while there are over 2200 municipalities. According to the data presented in the study entitled "Identification of Key Factors for the Development of Agricultural Biogas Plants in Poland" [14] the main problems related to the slow pace of development include, among others, the very long period of making decisions about the construction of new units, often caused by both the ignorance of the society and the actual features discouraging local communities from having biogas plants in the area. This primarily concerns the odours emitted by the stored substrate or its fermentation itself. The key to further development of this technology is to make the society aware of the real advantages and benefits of biogas plants, both on a local and national scale.

The division of biogas plants by capacity for 2023 is presented in the graph below. As mentioned earlier, most biogas plants are located in the range below 0.5 MW, in particular between 50 and 500 kW (**Figure 3**).

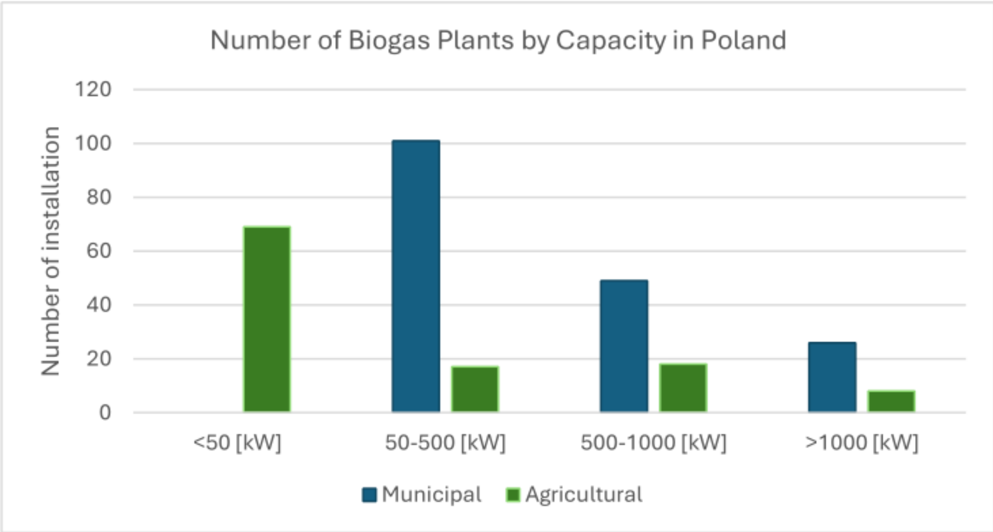

Figure 3. The structure of selected biogas plants according to their power. The study was based on data from z [12].

3. Materials and methods

This study has determined and presented the content concerning the calculation of the Polish biogas potential, as well as the profitability of investing in energy-generating biogas plants. To determine the value of Poland's biogas production potential, mainly statistical data, including predictions were used. Our own financial analyses are based on estimated costs included in other articles and scientific reports or construction studies. The final results of the financial analysis were presented using the NPV coefficient, which we use to present the costs recovered from the investment over time.

4. The potential of Polish biogas

European and Polish reports attempt to identify opportunities to increase biogas production, and thus also energy production from this source.

As part of the study: "Development of Renewable Energy Sources in the Context of Threats Resulting from Low-Altitude Emissions in Rural Areas in Poland: A Review" [18] The estimated production value of biogas in Poland, from all sources, amounted to 4.2 billion m^3. This is a value 7 times greater than what is currently produced in Poland. If 1 m^3 of biogas corresponds to 6 kWh [19], i.e., energy equivalent of 25 TWh, considering that in Poland we currently produce 178.8 TWh of electricity [20] by using the maximum potential of biogas we could cover almost 14% of the demand for domestic energy. However, this is not the maximum of Polish possibilities, because as is the case in Germany, some of the agricultural crops in the country can also be used to produce substrate for biogas plants.

According to the research presented in "The potential of biogas production for selected municipal waste landfills in the Łódź voivodeship" [21] from one ton of municipal waste in Polish conditions, 60 to 180 m^3 of biogas can be produced. In the latest reports of the Central Statistical Office on the generated municipal waste, we learn that in Poland we already produce almost 13.5 million tons of it [22]. Thanks to the introduction of selective waste collection (mandatory for all households nationwide from 2022), it is much easier to access bio-waste that does not require further selection. Using estimates from the "Biogas Report in Poland 2022" [17], and the Central Statistical Office data, we can determine the Polish biogas production potential:

In subsequent calculations we assume the following data:

- The annual mass of municipal waste is 13.5 million Mg [22]
- Bio-waste accounts for approximately 30% of all waste [17]
- The level of selective waste collection is estimated at about 70%–80% [17]
- The level of possibility for the fermentation process to biogas is about 80% [17]
- On average, we obtain 120 m^3 of biogas from one ton of waste [21]
- The dry matter content of municipal waste is 35% [23]

Calculation of the mass of bio-waste (MB) that can be directed to biogas production:

$$\mathrm{MB} = MMW \cdot SB \cdot ESC \cdot FWL$$

Data used for calculations:

Mass of municipal waste per year in Poland: $MMW = 13.5\, mil\, \frac{Mg}{year}$

Share of bio-waste in municipal waste: $\mathrm{SB} = 0.3$

Effectiveness of selective collection of municipal waste: $\mathrm{ESC} = 0.75$

Fermentable Waste Level: $\mathrm{FWL} = 0.8$

$$\mathrm{MB} = 13.5\, mil\, \frac{Mg}{year} \cdot 0.3 \cdot 0.75 \cdot 0.8$$

$$\mathrm{MB} = 2.43\, mil\, \frac{Mg}{year}$$

So, we can assume that we can direct over 2.4 million tons of bio-waste per year to biogas production. Then, assuming that the average value of biogas production is 120 m^3 per ton of bio-waste and the dry matter content in municipal waste is 35%, we can determine the potential for biogas production from this source.

Calculations of the potential for biogas production from municipal waste (PBP):

$$\mathrm{PBP} = MB \cdot BO \cdot DMC$$

Data used for calculations:

Mass of bio-waste that can be directed to biogas production: $MB = 2.4\, mil\, \frac{Mg}{rok}$

Biogas obtained from 1 ton of biowaste: $\mathrm{BO} = 120 \frac{m^3}{Mg}$

Dry matter content in the substrate: $\mathrm{DMC} = 0.35$

$$\mathrm{PBP} = 2.4\, mil\, \frac{Mg}{year} \cdot 120 \frac{m^3}{Mg} \cdot 0.35$$

$$\mathrm{PBP} = 100.8\, mil\, \frac{m^3}{year}$$

This means that Poland's theoretical potential for producing biogas from municipal waste (PPBOK) may reach up to 100 million m^3 per year.

Much greater possibilities, which are still largely unused, can be found in the production of biogas from manure. In the report "A spatial analysis of biogas potential from manure in Europe" [24] the production capacity of agricultural biomethane was determined in 1700 million m^3, if biomethane constitutes approx. 65% of biogas, it can be assumed that the production capacity of this type of biogas will amount to as much as 2600 million m^3.

The total potential for biogas production in Poland from municipal waste and manure is (PPB):

$$\text{PPB} = APBP + PBP$$

Data used for calculations:

Agricultural biogas production potential: $APBP = 2600\ mil\ m^3$

The potential of producing biogas from municipal waste: $PBP = 100\ mil\ m^3$

$$\text{PPB} = 2600\ mil\ m^3 + 100\ mil\ m^3$$

$$\text{PPB} = 2700\ mil\ m^3$$

In total, this amounts to 2.7 million m^3, which is a value that allows for the generation of 16.2 TWh of electricity per year (if 1 m^3 of biogas guarantees 6 kWh of electricity) [19]. It should of course be remembered that the hard-to-define part of bio-waste is already widely used and directing the entire production of this type of waste is not possible. However, considering that Poland currently produces 178.8 TWh of electricity [20] assuming the conditions presented above, the country could produce as much as 9% of energy annually using biogas from the above sources.

5. Biogas-fuel for the lowest-level power plants

As we already know, a significant part of biogas plants are units classified as small power plants and micro-installations—that is, basically all those structures that do not exceed 1000 kW. They constitute almost 88% of all biogas plants [12]. The development of such units is facilitated by economic and geolocation aspects, which we will analyse below.

The basic issue to consider when investing in a biogas plant is what power it should have. Due to the previously mentioned legal situation related to the necessary analysis of the impact on the environment for biogas plants with a capacity of 500 kW or more, entrepreneurs often decide to build slightly smaller facilities, i.e., 499 kW. In turn, the most common biogas plant capacity in Poland is 44 kW. Such a micro-installation, due to its low costs and low demand for substrate, which can often be supplied by several farms, means that units with such power are responsible for 12% of all biogas installations in Poland. Below is a financial analysis of the scenario regarding the investment in biogas plants with a capacity of 499 kW and a micro-installation with a capacity of 44 kW.

Biogas plant with a capacity of 499 kW

1) Estimated investment outlays do not exceed 10,000,000 PLN.
   - The project costs up to 500,000 PLN.

   This is 5.9% of the construction costs of the planned infrastructure [25].

- The construction of buildings and infrastructure will cost approximately 1,800,000 PLN

Three fermentation chambers with a total capacity of 5000 m^3 at a building cubic capacity of 300 PLN/m^3 is 1,500,000 PLN, plus additional costs of building open warehouses, access roads and control rooms will not exceed 300,000 PLN [26].

- Technology and necessary installations cost approx. 7,000,000 PLN.

The costs include fermentation reactors, cogenerators, and gas installation systems [17].

- Construction supervision costs are approximately 250,000 PLN.

Assumed costs at the level of 3% of construction costs.

- Land costs 65,000 PLN.

Assuming construction on medium-quality land, the average cost of such land in Poland is 65,000 PLN per hectare [27].

- Operating costs amount to 1 million PLN per year.

Substrate is 675,000 per year.

Depending on the type of substrate, prices vary significantly, hence we assume a value of 50 PLN per ton and a demand for substrate of 13,500 tons per year, based on [17].

Service and maintenance costs and maintenance up to 300,000 PLN per year

Assuming a staff of 3 people and regular inspections.

2) Revenues from energy production amount to over 3,300,000 PLN per year.

- The selling price of electricity is 872 PLN /MWh [28].

For installations with a total installed electrical capacity of less than 500 kW, using only agricultural biogas to generate electricity, it is 872 PLN /MWh [28].

- The number of working hours is 8400 per year.

Assuming 15 days off work (e.g., due to renovation work).

- The annual amount of energy sold is 3,800 MWh.

The biogas plant will produce 4200 MWh of electricity per year (8400 h) [17]. The consumption of produced energy for the needs of the biogas plant operation and nearby infrastructure is assumed at 10% [29]. This means 3800 MWh of electricity that can be resold.

3) The payback period for this scenario is 4 years and 4 months.

- Annual income (AI) is 2,600,000 PLN.

$$\mathrm{AI} = AR - AE$$

Data used for calculations:

Annual revenues (from energy production): $AR = 3{,}300{,}000\ PLN$

Annual expenses: $AE = 1{,}000{,}000\ PLN$

$$\mathrm{AI} = 3{,}300{,}000\frac{PLN}{year} - 1{,}000{,}000\frac{PLN}{year}$$

$$\mathrm{AI} = 2{,}300{,}000\frac{PLN}{year}$$

- Payback period:

$$\text{PB} = \frac{CE}{AI}$$

Data used for calculations:

Capital expenditure: $CE = 10{,}000{,}000\ PLN$

Annual income: $AI = 2{,}300{,}000\ \frac{PLN}{year}$

$$\text{PB} = \frac{10{,}000{,}000\ PLN}{2.3\ mil\ PLN}\, year$$

$$\text{PB} = 4.35\ year$$

This means a payback period of 4 years and 4 months.

4) Evaluation of the entire investment—NPV coefficient.

- Formula to calculate NPV [30]:

$$\text{NPV} = \sum_{t=0}^{n} \frac{NCF_t}{(1+i)^t}$$

where: NPV—net present value, NCF_t—cash flows in particular years, i—interest rate, t = 0, 1, 2, . . ., and n—another year of the calculation period.

Biogas plant with a capacity of 44 kW

1) Estimated investment outlays do not exceed 2,500,000 PLN.

- The project costs up to 150,000 PLN.

This is 6.9% of the construction costs of the planned infrastructure [25].

- The construction of buildings and infrastructure will cost approximately 250,000 PLN

Three fermentation chambers with a total capacity of 500 m^3 at a building cubic capacity of 300 PLN/m^3 is 150,000 PLN, plus additional costs of building open warehouses, access roads and control rooms will not exceed 100,000 PLN [26].

- Technology and necessary installations cost approx. 2 million PLN.

The costs include fermentation reactors, cogenerators, and gas installation systems [17].

- Construction supervision costs are approximately 67,500 PLN.

We assume costs at the level of 3% of construction costs.

- Land costs 30,000 PLN.

Assuming construction on medium-quality land, the average cost of such land in Poland is 65,000 PLN per hectare [27].

- Operating costs amount to 100,000 PLN per year.

We assume that it comes from our own farm, and we do not incur additional costs for its purchase.

Service and maintenance costs and maintenance up to 100,000 PLN per year.

Assuming 1 staff and regular inspections.

2) Revenues from energy production amount to over 290,000 PLN per year.

- The selling price of electricity is 872 PLN/MWh [28].

For installations with a total installed electrical capacity of less than 500 kW, using only agricultural biogas to generate electricity, it is 872 PLN/MWh [28].

- The number of working hours is 8400 per year.

Assuming 15 days off work (e.g., due to renovation work)

- The annual amount of energy sold is 330 MWh.

The biogas plant will produce 370 MWh of electricity per year (8400 h) [17]. The consumption of produced energy for the needs of the biogas plant operation and nearby infrastructure is assumed at 10% [29]. This means 330 MWh of electricity that can be resold.

3) The payback period for this scenario is 13 years and 2 months.

- Annual income (AI) is 190,000 PLN

$$\mathrm{AI} = AR - AS$$

Data used for calculations:

Annual revenues (from energy production): $AR = 290{,}000\ PLN$

Annual spendings: $AS = 100{,}000\ PLN$

$$\mathrm{AI} = 290{,}000\ \frac{PLN}{year} - 100{,}000\ \frac{PLN}{year}$$

$$\mathrm{AI} = 190{,}000 \frac{PLN}{year}$$

- Payback period:

$$\mathrm{PB} = \frac{CE}{AI}$$

Data used for calculations:

Capital expenditure: $CE = 2{,}500{,}000\ PLN$

Annual income: $AI = 190{,}000 \frac{PLN}{year}$

$$\mathrm{PB} = \frac{2{,}500{,}000\ PLN}{190{,}000\ PLN} year$$

$$\mathrm{PB} = 13.2\ year$$

This means a payback period of 13 years and 2 months.

4) Evaluation of the entire investment—NPV coefficient.

- Formula to calculate NPV [30]:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{NCF_t}{(1+i)^t}$$

where: NPV—net present value, NCF_t—cash flows in particular years, i—interest rate, *t* = 0, 1, 2, . . ., and *n*—another year of the calculation period.

It should be remembered that the results obtained above are purely estimated, as we do not consider several additional, yet key factors that can significantly affect the investment, for example by significantly changing the NPV coefficient, both for the better and for the worse. Factors such as potential loan costs, interest coverage, and alternative discount rates (here assumed at 8%) may significantly impact NPV results. Since we are dealing with a renewable energy installation, in their case we often also have the possibility of external financing and subsidies, which, for example, under the

"Energy for the countryside" program can cover up to 65% of the investment value (up to PLN 20 million) [31].

Regardless of the above, because of our calculations, it is easy to see an obvious positive NPV coefficient for a larger investment and a negative one for the smaller one - micro-installation as it is shown in **Tables 1** and **2**. One of the market relationships is that the speed of its return increases with the size of the investment, in the case of biogas plants this is primarily due to the more than 10-fold difference in the production capacity of energy, which we then sell, of course increasing our profit. The results obtained also seem to confirm the trend we mentioned in the context of biogas in Germany, where smaller units are gradually being phased out and replaced by installations with higher capacity [7]. Nevertheless, it should be remembered that micro-biogas installations have a slightly different purpose compared to power plants of various sizes. Their main use is to generate energy for the owner's needs. The most profitable in their case is to completely cover their energy demand, so that they do not need to draw additional energy from the outside (from the central system). Such energy is clearly more expensive than that sold at previously established so-called reference prices. These prices determine the costs of selling energy to the system, defining their value at the level of 90% of the reference price [11]. If the micro-installation would cover only the energy demand for the owner's farm, the actual profitability of the investment would be significantly higher. Returning to the 499 kW biogas plant, we can state the high profitability of such a project, which is best evidenced by its payback period of just over 4 years, as well as a high NPV coefficient of 12.581 million PLN (assuming an investment period of 20 years).

Table 1. NPV coefficient for the scenario investment in a biogas plant with a capacity of 499 kW, assuming the biogas plant will operate for 20 years and an assumed interest rate of 8%.

Coefficient	Value
Interest rate	8%
NPV	12,581,000 PLN

Table 2. NPV coefficient for the scenario investment in a 44 kW biogas plant, assuming the biogas plant will operate for 20 years and an assumed interest rate of 8%.

Coefficient	Value
Interest rate	8%
NPV	−634,551 PLN

6. Summary

The content presented in the above material seems to speak strongly in favour of the widespread use of biogas as fuel for the lowest-level power plants. Distributed generation is one of the main steps that should be taken on the way to a complete energy transformation not only in Poland. The use of biogas plants as small power plants but also as micro-installations is a step in the right direction. Using only waste from manure and municipal waste, Poland can potentially produce up to 2.700 million m^3 of biogas, which is over 4 times more than is currently produced in the country. The plans presented in projects such as: “Directions of development of agricultural biogas plants in Poland in the years 2010–2020”, regarding the construction of at least one biogas plant in each commune, have not been implemented to a satisfactory degree and steps should be taken to achieve them as soon as possible. In the case of Poland, it is very important to follow in the footsteps of Germany, where, above all, legislative support opened the door to the great “boom” that biogas plants became there. Therefore, subsidy programs, such as the aforementioned “Energy for the countryside”, seem very positive, as they encourage entrepreneurs to invest in biogas installations, investments in which can already be described as positively promising. An example presented for a biogas plant with a capacity of 499 kW, the investment outlay for which theoretically pays off after about 4 years (depends on electricity prices).

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