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ANALYSIS OF THE POTENTIAL OF THE ŁÓDŹ REGION IN TERMS OF A BIOGAS PLANT CONSTRUCTION

Abstract
The aim of this article is to analyze the potential of the Łódzkie voivodship in terms of a biogas plant construction, in the context of the Polish government's position in the field of sustainable energy development plans, biogas energy and the economic conditions related to investments in biogas engineering. In order to diagnose the potential of the Łódzkie voivodeship, in the context of the mentioned elements, the results of the research conducted among the entities generating organic waste were presented, analyzed and interpreted. The article ends with conclusions, research recommendations and a SWOT analysis of the Łódź region in terms of biogas production.

Key words
biogas plant, biomass, waste, organic waste, waste disposal, organic waste production, alternative energy sources

Introduction

The most advanced biogas production plants were created over the course of the past 20 years in Germany and Denmark. A similar trend, at a later stage, can be observed in other "Old Union" countries. Favorable agricultural conditions in such countries as Poland, Hungary and Lithuania have contributed to increased interest in the development of biogas (see: Table 1).

Table 1. Production of primary energy from solid biomass in the EU in 2009 and 2010 expressed in Mtoe .

COUNTRY	2009	2010
Germany	11.217	12.230
France	9.368	10.481
Sweden	8.621	9.202
Finland	6.473	7.680
Poland	5.190	5.865
Spain	4.494	4.751
Austria	4.097	4.529
Romania	3.838	3.583
Italy	2.760	3.019
Portugal	2.856	2.582
Czech Republic	1.968	2.094
Latvia	1.737	1.739
Denmark	1.422	1.657
Hungary	1.469	1.489
Great Britain	1.357	1.442
Netherlands	1.014	1.033
Lithuania	1.002	1.002
Estonia	0.843	0.924
Belgium	0.722	0.858
Greece	0.799	0.812
Bulgaria	0.766	0.788

Slovakia	0.647	0.740
Slovenia	0.537	0.572
Ireland	0.189	0.197
Luxembourg	0.034	0.040
Cyprus	0.009	0.010
Malta	0.000	0.000
European Union	73.430	79.318

Source: EurObserv'ER – November 2011.

Concentration around RES, including around biomass, is particularly noticeable in the energy industry in Poland, which has increased its interest in agriculture. Ensuring energy security, protecting the environment and increasing competitiveness is also considered a priority for the development of the Polish economy. The next stage in this regard was the establishment of the climate and energy package, which assumed the achievement of 20% of the share of Renewable Energy Sources in the EU's total energy balance, and the subsequent stage was the development of the National Renewable Energy Action Plan, adopted by the Council of Ministers on December 7, 2011. The plan includes an obligation for Poland to achieve a 15% share of RES in gross energy consumption. There are many factors considered here, such as the renewable sources of energy and raw materials for fuel production and the state of the power engineering system. It was also assumed that the main pillar of renewable energy source development in Poland would be to increase the use of biomass. [54] According to the estimates of the programme - Kierunki Rozwoju biogazowni rolniczych w Polsce w latach 2010-2020, w Polsce (Directions for the Development of Agricultural Biogas Plants in Poland in 2010-2020), approx. 1.7 billion m^3 of biogas can be produced in Poland per year. Once treated, such an amount would suffice to cover about 10% of the gas demand and would provide an additional 125,000 MWhe of electricity and 200 MWhc of heat. It is also envisaged that thanks to biogas plants, it will be possible to reduce carbon dioxide emissions by 3.4 million tons per year. [55] A very important effect that is also included in the program's assumptions is the creation of so-called Local Value-Added Chains. This is to be achieved through "economic activation of rural areas, increased employment among local communities and business entities in the agricultural and renewable energy sectors (Green Jobs). Other expected effects include, among others, an increase in the income of local governments and the use of environmentally friendly farming in Natura 2000 areas to develop the use of renewable energy sources. [56] The programme also includes a provision on the need to intensify the development of research programmes regarding new techniques and technologies used in agricultural biogas production, including continuing the works on improving the process of methane fermentation, biogas treatment for biomethane production, or development of technologies for conversion of biogas into electricity and heat.

The economic aspect of the construction of biogas plants

By analyzing the economic aspects of the construction of biogas plants, the most important issues are the costs associated with the construction of biogas plants, the acquisition of the necessary technologies, payback time, access to substrates, raising capital, and the possibility of obtaining grants and the location of the biogas plants.

According to the research conducted, the economic efficiency of biogas plant construction varies in Poland, depending on the profitability, the individual location specificity and the different support mechanisms. The construction of biogas plants in commercial conditions has not proven to be economically viable. [57] Investing in biogas technology is economically justified if it is possible to obtain external funding at a level of at least 60-70%. Thus, the most profitable is the construction of large agricultural biogas plants with a funding rate of at least 75% of the total investment[58].

An important element affecting the economics of substrate acquisition is the cost of transporting it from the potential producer to the biogas plant, where it will be fermented. The distance of the facility from the biogas

[54]http://www.mg.gov.pl/files/upload/12326/KPD_KE.pdf

[55] http://www.biogazownierolnicze.pl/biogazownierolnicze,article,0,77,145,kierunki-rozwoju-biogazowni-rolniczych-przyjete-przez-rade-ministrow.html

[56]Kierunki rozwoju biogazowni rolniczych w Polsce w latach 2010-2020, dokument przyjęty przez Radę Ministrów w dniu 13 lipca 2010r.

[57] K. Kosewska, J. Kamiński., Analiza ekonomiczna budowy i eksploatacji biogazowni rolniczych w Polsce, „Inżynieria Rolnicza" 1 99/2008, p. 189.

[58] Ibidem, p.193

plant should not exceed 20 km, because the cost of transport will have a negative impact on the economics of the entire process[59]. The diagram below shows the basic elements that a potential investor should analyze at the investment planning stage.

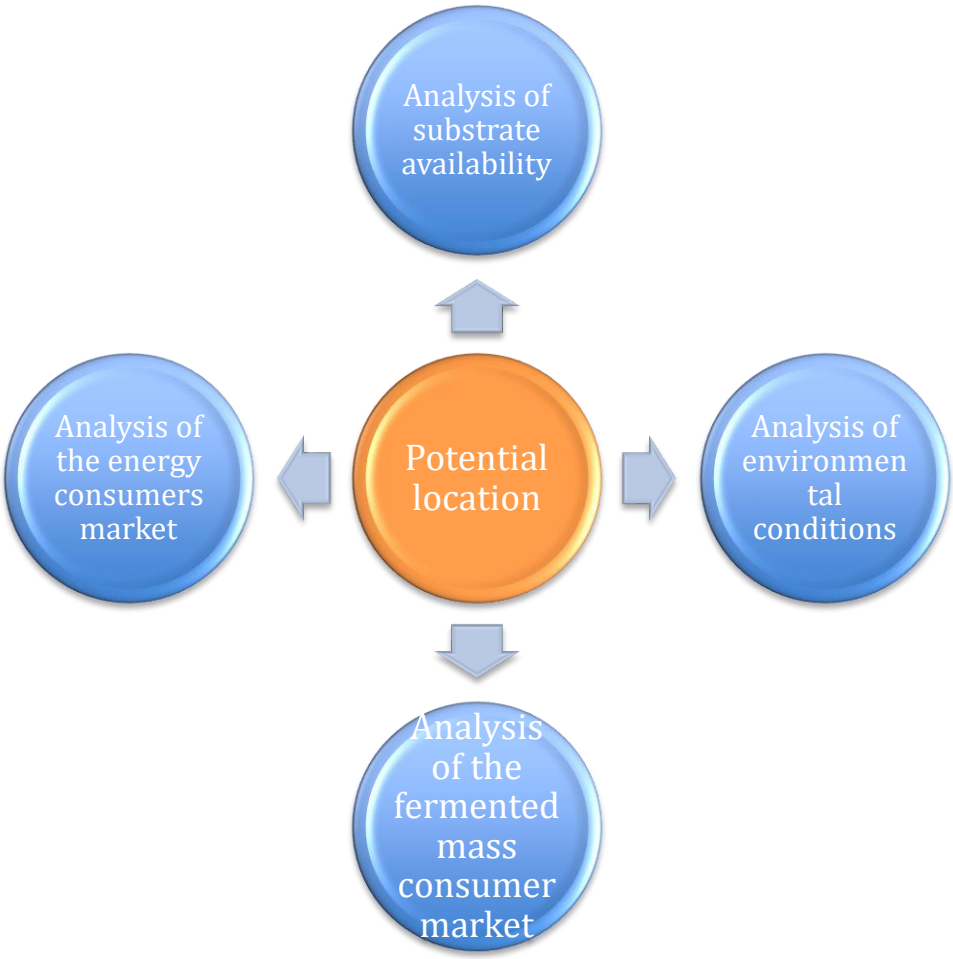


Diagram 1. Concept of biogas plant construction.
Source: K. Sobótka, Prezentacja pt. "Biogaz rolniczy – produkcja i wykorzystanie", Mazowiecka Agencja Energetyczna.

The graph contains four key elements that should be analyzed prior to the investment process. In situations where analysis of one of the elements of the investment is unfavorable, it is important to consider it.

The potential of the Łódź region in terms of generating organic waste for biogas production in a biogas plant - research results

The increase in interest in biogas plants and the economic aspects associated with their construction has inspired research among entities generating organic waste in the Łódź region (51), which were aimed at:

- Determining the potential of the Łódź region in terms of generating organic waste for biogas production in a biogas plant.
- Designating the place with the largest concentration of facilities capable of supplying organic waste to the biogas plant;
- Identifying the potential of building a biogas plant for the needs of the facilities generating the largest amount of organic waste.

[59]http://www.agroenergetyka.apra.pl/index.php?content=1472

The research utilizes the CATI (Computer Assisted Telephone Interview) technique. In CATI-based research, the interview with the respondent is conducted via telephone and the interviewer reads the questions and records the answers using a special computer script.

The sample selection was purposeful. The research covered the entities from the Łódzkie voivodship, which are potential suppliers of organic waste to the biogas plant. These entities were found in the Internet company database at www.ptk.pl , Panorama Firm and www.ditel.pl .

As a result of the research conducted, the distribution of organic waste generating facilities in the Łódzkie voivodship was established, including food processing plants, dairies, slaughterhouses, pig farms and distilleries.

Map 1. The distribution of organic waste generating facilities in the Łódzkie voivodship was established, including food processing plants, dairies, slaughterhouses, pig farms and distilleries.
Source: Dudojć M., ekspert Centrum Badań i Innowacji Pro-Akademia.

The map, which is the direct result of the study, identifies potential and optimal areas for investing in biogas plants. It also allows for the identification of the entities generating organic waste. At the same time, the analysis of the map clearly indicates that the largest concentration of facilities is at the capitals of county towns.

The number of economic entities generating organic waste in individual counties of the Łódzkie voivodeship is presented in Table 2.

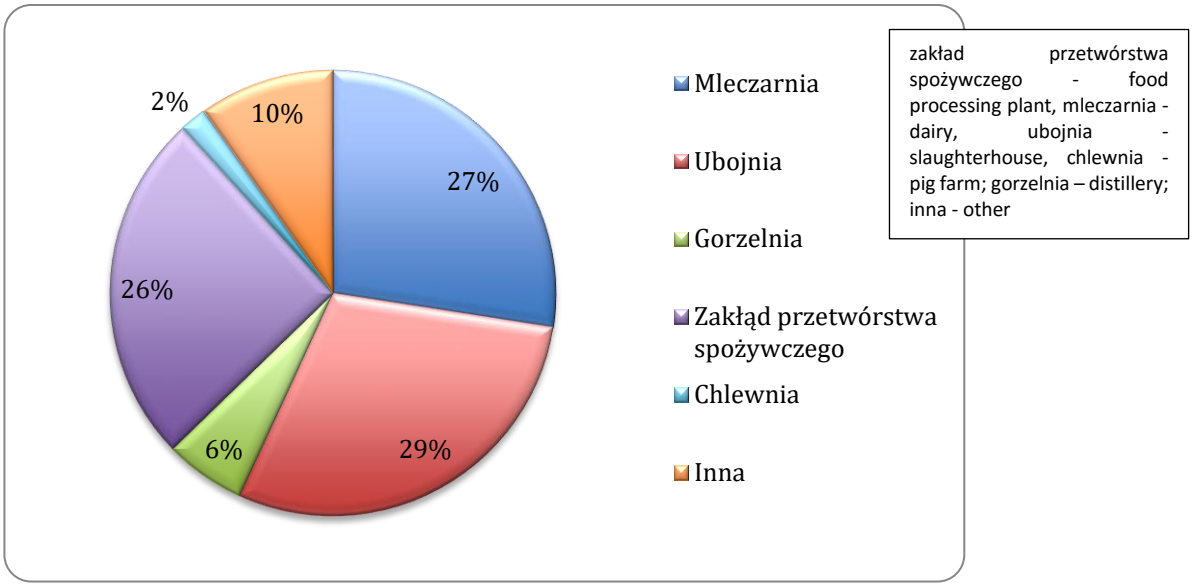
Table 2. The number of entities generating organic waste in particular counties of the Łódź region (as of December 2011).

COUNTY	FOOD PROCESSING PLANTS	DAIRIES	SLAUGHTE RHOUSES	PIG FARMS	DISTILLERIES
Łódź	7	3	1		2
Bełchatów	2	3	2		1
Brzeziny	1				1
Kutno	1	1		1	
Łask	1	1			1
Łęczyca		1			1
Łowicz	1	2		1	
Łódź East	4	2			1
Opoczno	1		1		
Pabianice	2	1	1		1
Pajęczno	1	1	1		1
Piotrków		2	6	1	2
Poddębice	1	1			
Radomsko	3	1	1		1
Rawa	4	1	2		
Sieradz	3	2		1	1
Skierniewice					
Tomaszów	5		1		1
Wieluń	1	2			
Wieruszów	1	1			4
Zduńska Wola		1			
Zgierz	3	1	5	1	1
IN TOTAL	**42**	**28**	**21**	**5**	**18**

Source: own study.

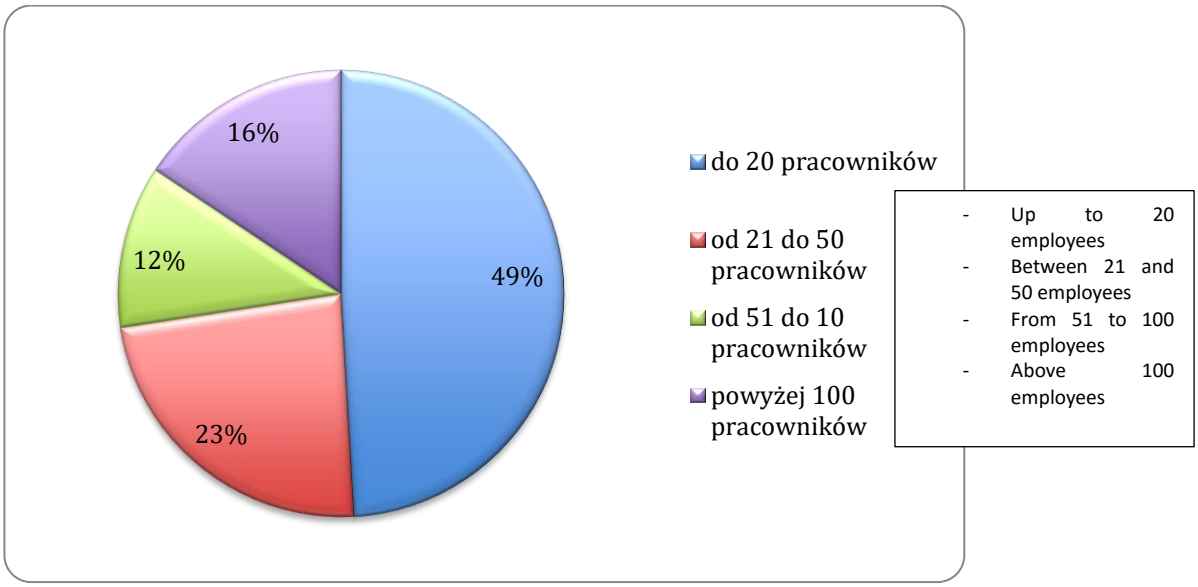
The analysis of research results indicates that there are 114 entities generating organic waste in the Łódzkie voivodeship. Among the entities that generate organic waste in the Łódzkie voivodeship are food processing plants (42), then dairies (28), slaughterhouses (21), distilleries (18) and pig farms (5). The largest number of food processing plants is located in the city of Łódź (7). Then - in the area of the Tomaszów county (5), Łódź East (4) and Rawa (4). The largest number of dairies is located in the city of Łódź (3) and in the Bełchatów county (3). Most of the slaughterhouses are located in the Piotrków county (6), and most of the distilleries - in the Wieruszów county (4).

The next stage of the research was an IDI study on a group of 51 entities: 15 slaughterhouses, 14 dairies, 13 food processing plants, 3 distilleries and 1 pig farm, as well as 2 agricultural farms, 2 dairy waste treatment plants and a meat processing plant.



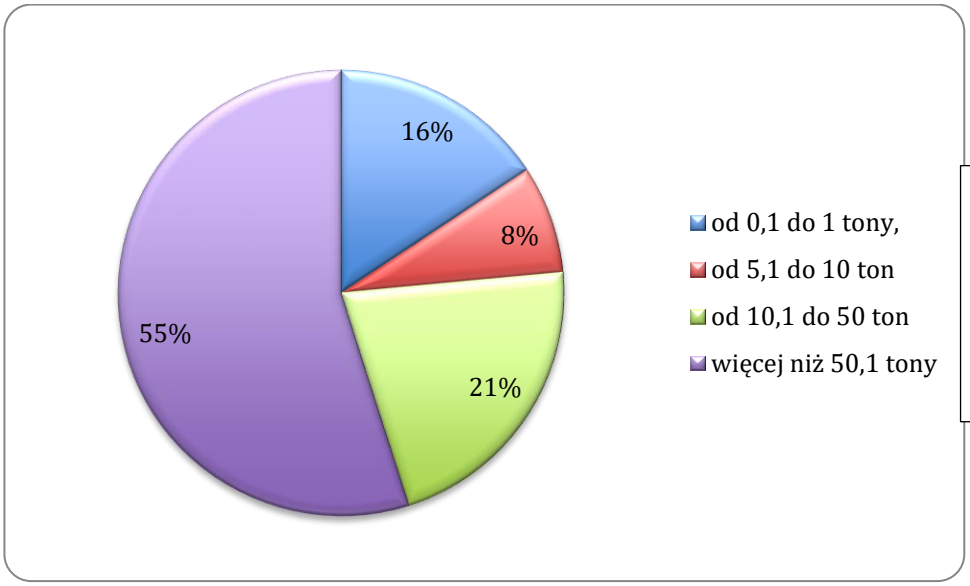
Graph 1. Type of activity.
Source: the author's own study.

Among the respondents, 49% were small companies employing up to 20 employees, 23% employing between 21 and 50 employees, 16% employing more than 100 employees, and 12% employing between 51 and 100 employees.



Graph 2. Number of persons employed in the entities (in total).
Source: the author's own study.

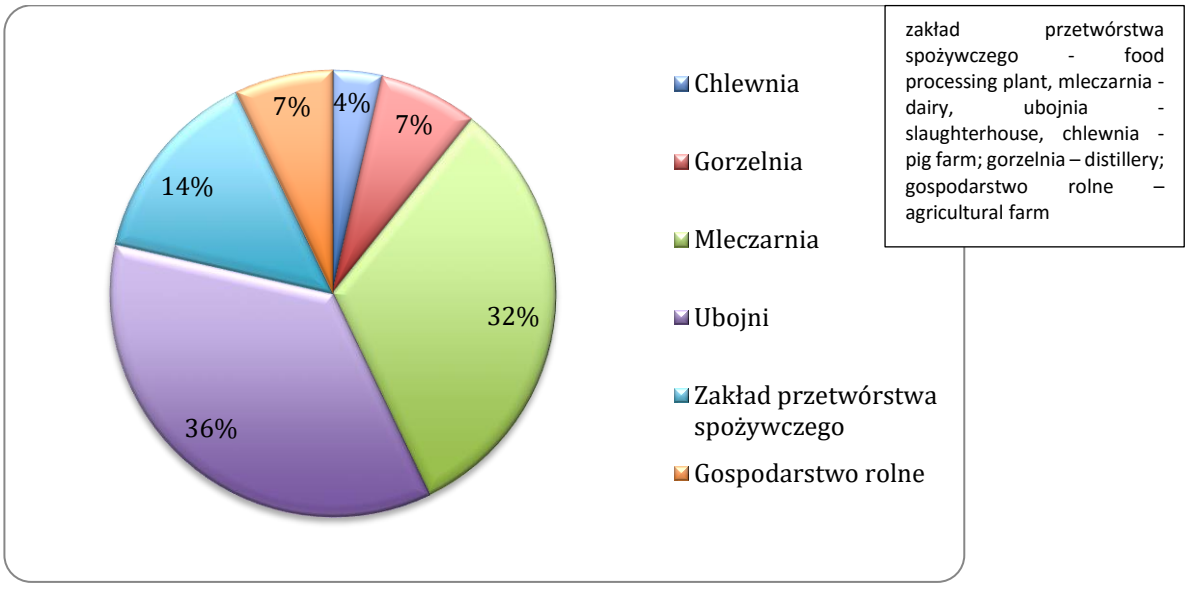
More than half of the studied companies (54.9%) generate organic waste at a level of above 50 tonnes. Over 20% (21.56%) produce organic waste in the range of 10.1 to 50 tonnes, 15.6% from 0.1 to 1 ton, 7.8% from 5.1 to 10 tonnes. None of the companies produces waste in the range of 1.1 to 5 tons.



Graph 3. Number of generated waste (annually).

Source: the author's own study.

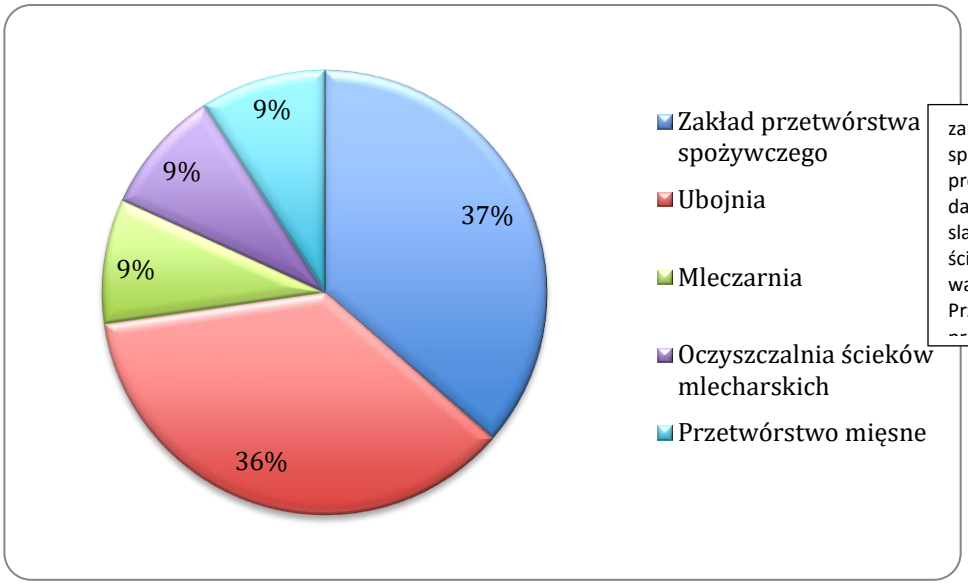
Among the companies surveyed, the most organic waste is generated by slaughterhouses and dairies: 10 slaughterhouses and 9 dairies can produce more than 50 tons of waste per year. Among the food processing plants, 4 generate waste at a level of over 50 tons. Among the other entities 2 agricultural farms, 2 distilleries and 1 pig farm produce over 50 tons of waste.



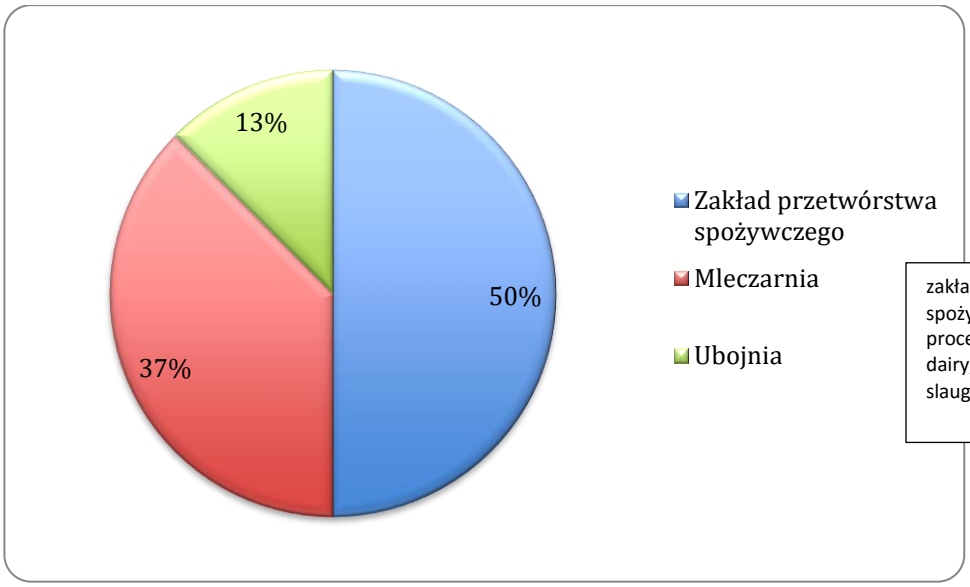
Graph 4. Type of business conducted by companies generating more than 50 tons of waste.

Source: the author's own study.

There are 4 slaughterhouses and 4 food processing plants, 1 dairy, 1 dairy waste treatment plant and 1 meat processing plant generating from 10.1 to 50 tons of waste. Production at a level from 0.1 to 1 ton can take place in 4 food processing plants, 3 dairies and one slaughterhouse.

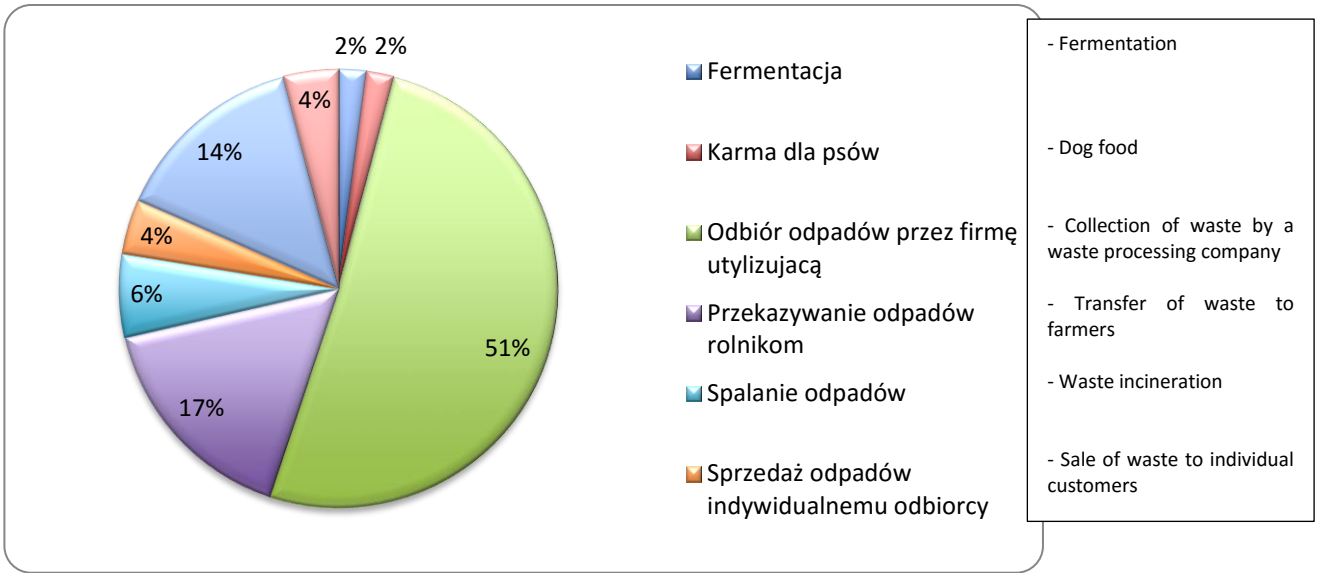


Graph 5. Type of business conducted by companies generating from 10.1 to 50 tons of waste.
Source: the author's own study.



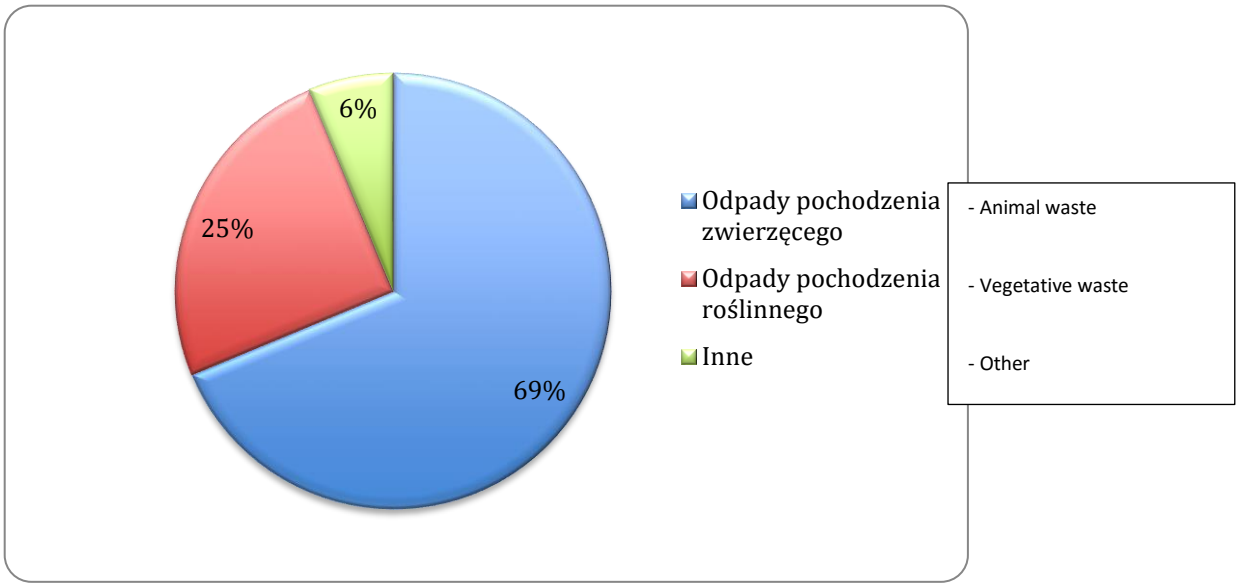
Graph 6. Type of business conducted by companies generating from 0.1 to 1.0 tons of waste.
Source: the author's own study.

More than half are clients of outside waste disposal companies. The most common method of disposal is by transferring waste to farmers (16% of the facilities). This waste is often used by farmers as animal feed. In the case of 14% of companies, waste is used as fertilizer. As few as 6% of the facilities burn waste and another 4% sell waste to individual customers or transports the waste to agricultural lands. In the case of 4 companies, there are 2 simultaneous methods of waste disposal.



Graph 7. Methods of waste disposal.
Source: the author's own study.

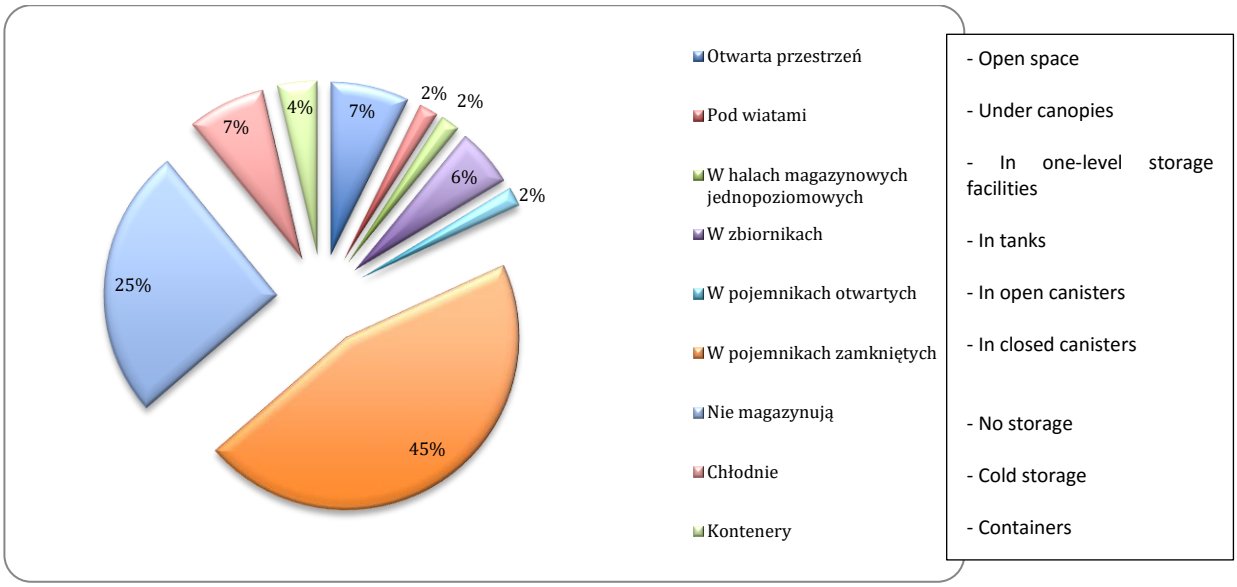
The analysis of the research results indicates that 69% of companies generate animal waste, 25% generate vegetative waste and 6% generate other waste, such as medical waste. The animal waste mainly consists of manure, liquid manure, meat, fats, animal remains and bones. Vegetative waste generated among the companies in the Łódź region is mainly whey, silage, peels and products and raw materials not suitable for consumption and processing. They are classified under code 020501 - solid and/or liquid, non-complying or expired raw materials and products not suitable for further processing. The waste mainly constitutes of milk that is non-compliant due to the high content of antibiotics, as well as cheeses and yoghurts and other dairy products past their expiry date (pressed on press, separated from packages, which can be disposed of in the methane fermentation process).



Graph 8. Organic waste generated in the Łódź voivodeship.
Source: the author's own study.

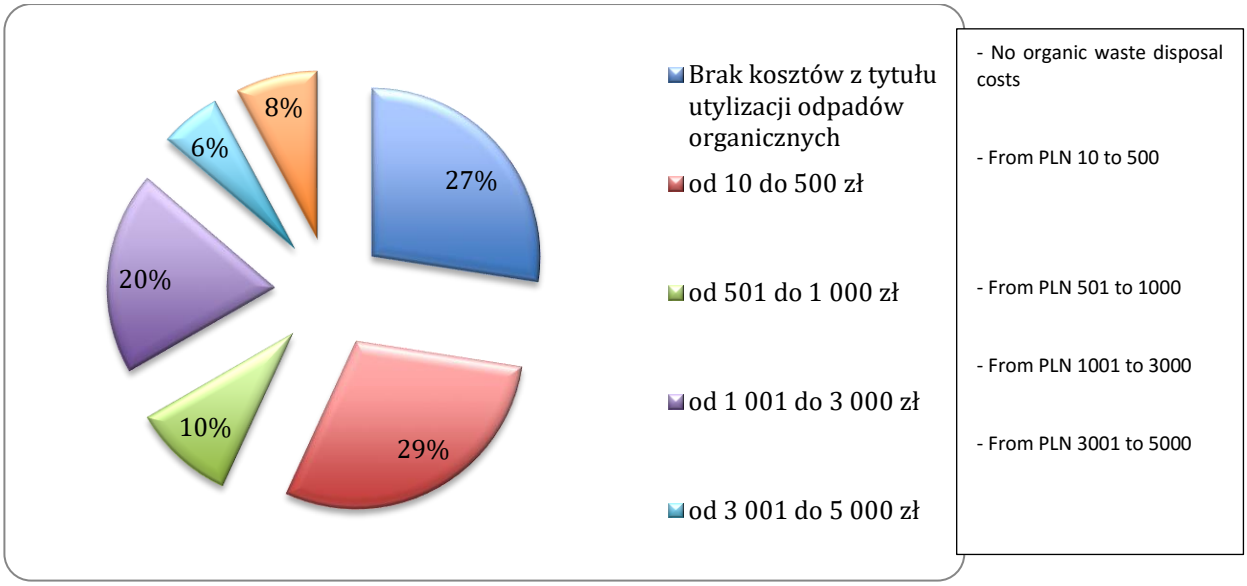
In most companies, the waste generated is kept in closed tanks. Waste is not stored, due to the 14 companies' current delivery to the recipients. Only four companies store waste in the open and four others store the waste in freezers. Other facilities collect waste in tanks, indoors or in containers.

Research has also shown that 68% of companies do not have their own containers. They are provided by the companies that handle the waste and its transport to its destination. Other companies use their own containers (closed, acid resistant, or containers).



Graph 9. Methods of storing organic waste generated by companies in the Łódzkie voivodeship.
Source: the author's own study.

Most of the companies surveyed bear low costs of waste disposal (in the range of PLN 10 to 500 per month) or do not bear them at all. Only 10 facilities bear cost from PLN 1001 to 5000, 5 companies - in the range from 501 to 1000, and 4 facilities - above PLN 5000.

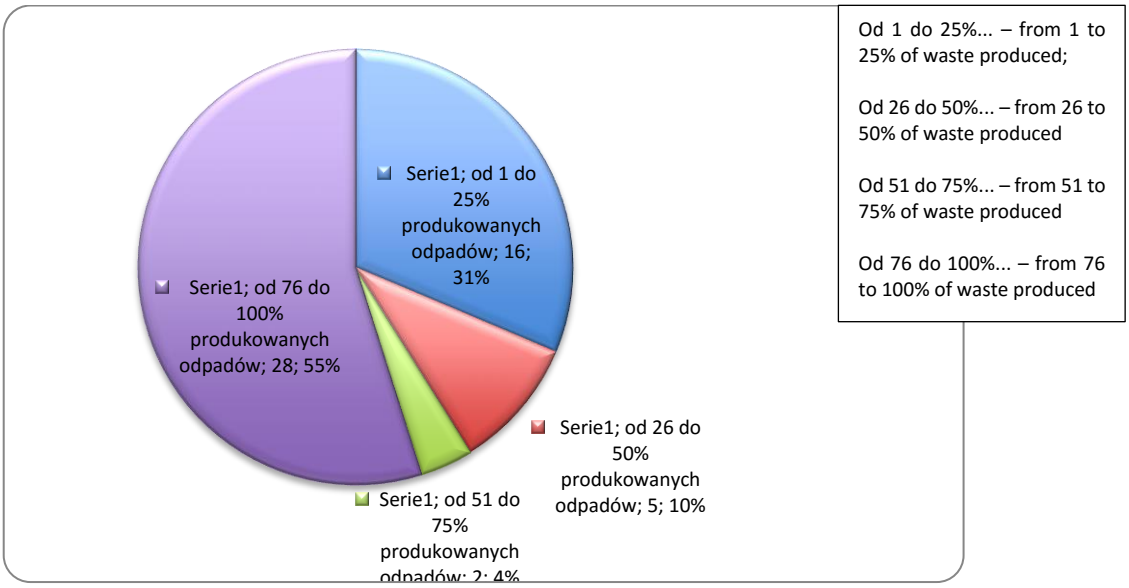


Graph 10. Monthly costs of waste disposal borne by the companies of the Łódź region.
Source: the author's own study.

A significant number of the examined companies (65%) believe that transferring waste to a biogas plant is beneficial because it reduces the cost of recycling organic waste. Companies that consider transferring waste to a biogas plant as non-beneficial are entities generating liquid manure. They express the view that liquid manure is a valuable fertilizer, usually used for their own needs.

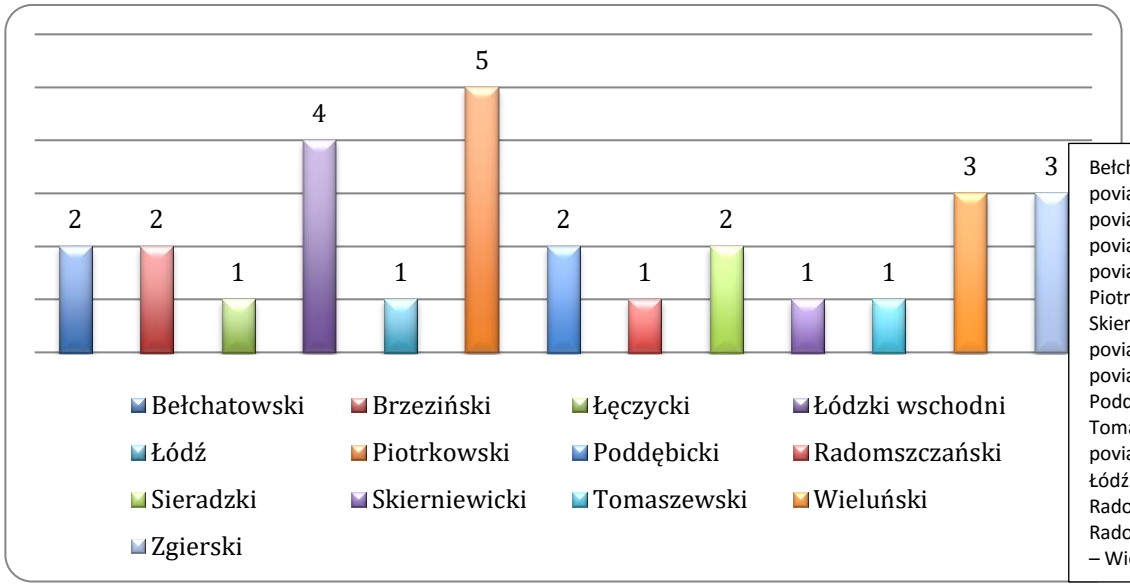
Despite the interest in transferring waste to a biogas plant, only one company has declared such a manner of waste disposal. The rest of the companies do not transfer waste to a biogas plant because there is no such facility in the near vicinity.

In the event of a biogas plant being established, 28 companies declared that they could transfer 76 to 100% of the generated waste, 16 companies - from 1 to 25%, 5 companies - from 26 to 50% and 2 companies from 51% to 75%. The vast majority (78%) of the entities could transfer waste into biogas plants once a week, and 19% of the businesses could once a month. The most favorable manner of transporting waste, in the opinion of the respondents, would be for the biogas plant to ensure the transport.



Graph 11. Potential amount of organic waste transferred to biogas plants (%).
Source: the author's own study.

The largest number of facilities generating organic waste, at a level of over 50 tons per year, is located in the counties of Piotrków and Łódź East. Three facilities are located in each of the counties of Wieluń and Zgierz. In turn, two facilities are located in each of the following counties: Bełchatów, Brzeziny, Poddębice and Sieradz.



Graph 12. Number of facilities generating organic waste in individual **poviats** of the Łódź voivodeship.
Source: the author's own study.

Tables 3 and 4 show the facilities located in the Piotrków and Łódź East poviats, taking into account the amount of generated organic waste. In the Piotrków poviat, the largest amount of waste is produced by the slaughterhouses, and in the Łódź East poviat - by the food processing plants.

Table 3. The amount of organic waste generated by plants in the Piotrków county of the Łódzkie voivodeship.

Type of activity	Production of more than 50 tons of waste per year	Production of between 10 and 50 tons of waste per year
Slaughterhouses	**2**	**3**
Distilleries	**1**	**0**
Dairies	**1**	**0**
Pig farms	**1**	**0**

Source: own study.

Table 4. The amount of organic waste generated by plants in the Łódź East county of the Łódzkie voivodeship.

Type of activity	Production of more than 50 tons of waste per year	Production of between 10 and 50 tons of waste per year
Food processing plant	**2**	**0**
Slaughterhouses	**1**	**0**
Dairies	**1**	**0**
Meat processing plant	**0**	**1**

Source: own study.

Both in the Piotrków and the Łódź East county, the most common method of utilizing waste is by transferring waste to waste disposal companies or selling them to individual consumers. In both counties, mainly animal waste is generated, including animal remains and fats that are disposed of by specialized companies, usually by incineration. In Piotrków county, two companies have estimated the monthly costs of waste disposal at PLN 1001-3000, the next two - at over PLN 5000, and the remaining three companies - from PLN 10 to PLN 500 or stated that they incur no such costs. In the Łódź East county, two companies have stated that they incur costs above PLN 5000, and the remaining three companies, depending on the circumstances, from PLN 10 up to even PLN 5000.

The companies from both counties believe that transferring waste to a biogas plant is beneficial, mainly because of the financial benefits of this type of disposal.

The table below shows the number of dairies in each county of the Łódź voivodship, depending on the amount of organic waste generated.

Table 5. Dairy plants in individual counties of the Łódź region depending on the amount of generated organic waste .

County	Over 50 tons	From 10.1 to 50 tons	From 5.1 to 10 tons	Less than 5 tons
Bełchatów	0	1	0	**0**
Łódź East	1	0	0	**0**
Łódź	0	0	0	**1**
Piotrków	0	0	0	**1**
Poddębice	2	0	0	**0**
Radomsko	1	0	0	**0**
Rawa	0	0	0	**1**
Sieradz	0	0	0	**1**
Skierniewice	1	0	0	**0**
Wieluń	2	0	0	**0**
Zgierz	**1**	**0**	**1**	**0**

Source: own study.

The analysis of the results contained in the table shows that the largest amount of dairy waste is produced in the Poddębice and Wieluń counties. Therefore, these counties constitute an optimal location for the construction of a biogas plant producing biogas from dairy waste. The border between the Poddębice and Zgierz counties is also a convenient location.

In the Łódź region, dairies produce organic waste of plant origin, mainly whey and products not suitable for consumption.

Conclusions

- In the Łódź region, companies producing organic waste are mostly small companies, generating over 50 tonnes of organic waste per year.
- In the Łódzkie Voivodship, the main producer of organic waste are slaughterhouses and dairies, which generate waste primarily of animal origin.
- The most popular way to dispose of waste by companies in the Łódź region is waste reception by outside companies or by sending it to individual recipients.
- A small number of waste generating facilities keep waste for their own use.
- Companies in the Łódź region recognize delivering waste to biogas plants as beneficial. Most companies would be willing to hand over waste to biogas plants free of charge, if it existed within a radius of 20-25 km from the place of business conducted, and it would be optimal to use transport provided by the biogas plant.
- Most companies do not have their own waste tanks, so it would be an advantage to systematically transfer most waste to biogas plants, preferably once a week. Thanks to this, companies would not have to manage additional waste storage space and would not incur additional costs for the disposal of organic waste.
- The largest amount of waste in the region is generated by companies located in the Piotrków and Łódź East counties. There are three optimal locations for biogas plant construction: Piotrków county, Łódź East county or the border between them. A potential investor could use the funds in the form of a loan or grant from the National Fund for Environmental Protection and Water Management under the Green Investment Scheme - GIS (2nd Priority Program: Agricultural Biogas Plants).
- In both counties, mainly waste from animal origin is produced and mainly transferred to outside companies. The facilities in the two counties incur quite high costs of waste disposal, which may stimulate them to seek alternative forms of waste disposal. In addition, these entities notice the financial benefits that could lead them to use biogas plants.

- The potential of organic waste is also apparent in such entities as school, university, hospital cafeterias, or the entire catering segment. This would, however, require the development of a special system for segregation and collection of waste from these units.

Recapitulation

Investing in renewable energy sources, in addition to environmental benefits, can foster the development of the local economy. Biomass production or disposal of the waste generated via biogas plants can be a significant source of revenue for the region's economic operators. The energy produced can in turn guarantee energy stability for the voivodeship and increase its investment potential.

The available resources, the amount of organic waste generated, and the nature of the region can provide significant potential for biomass-based energy production. It is therefore advisable for the energy policy of Łódzkie voivodeship to change towards stronger support for biogas investments.

Among the most important macroeconomic effects of biogas plants construction, it is important to point out that biogas eliminates conventional energy carriers - it contributes to the protection of the environment and becomes a product participating in the market game with energy tycoons. In addition, biogas production changes the hygiene and sanitary conditions, and increases the efficiency and energy independence of the economy.

Thus, a sensitivity and risk analysis should be carried out to assess the cost-effectiveness of the project when changing the input parameters of the given economic model. The analysis should include:

- A sensitivity analysis allowing to show how the calculated values of financial and economic indicators (IRRs or NPVs) change with increasing (decreasing) parameters used for determining costs and benefits.
- Examining the probability distribution of selected parameter values and calculating the expected value of the project performance indicators.

Such an analysis would determine the break-even point of the potential biogas investment.

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ANALIZA POTENCJAŁU WOJEWÓDZTWA ŁÓDZKIEGO POD KĄTEM BUDOWY BIOGAZOWNI

Abstrakt

Celem artykułu jest analiza potencjału województwa łódzkiego pod kątem budowy biogazowni, w kontekście stanowiska rządu RP w zakresie planów rozwoju energetyki zrównoważonej środowiskowo, walorów energii pochodzącej z biogazu oraz uwarunkowań ekonomicznych związanych z inwestycjami w biogazownie. W celu zdiagnozowania potencjału województwa łódzkiego, w kontekście wymienionych elementów, zaprezentowano i poddano analizie oraz interpretacji wyniki badania przeprowadzonego wśród podmiotów generujących odpady organiczne. Artykuł zamykają wnioski, rekomendacje z badania oraz analiza SWOT regionu łódzkiego pod kątem powstawania biogazowi.

Słowa kluczowe

biomasa, alternatywne źródła energii, odpady, biogazownia, odpady organiczne, utylizacja odpadów, produkowanie odpadów organicznych