DOI: 10.1515/jwld-2017-0064

JOURNAL OF WATER AND LAND DEVELOPMENT
2017, No. 35 (X–XII): 19–25
PL ISSN 1429–7426

Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld

Received 12.06.2017
Reviewed 24.08.2017
Accepted 12.09.2017

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

The possibility of functioning micro-scale biogas plant in selected farm

Wojciech CZEKAŁA ABCDEF ✉, **Karolina GAWRYCH** ABCDEF, **Anna SMURZYŃSKA** DEF, **Jakub MAZURKIEWICZ** B, **Artur PAWLISIAK** E, **Dawid CHEŁKOWSKI** F, **Michał BRZOSKI** F

Poznań University of Life Sciences, Faculty of Agronomy and Bioengineering, ul. Wojska Polskiego 28, 60-637 Poznań, Poland; e-mail: wojciech@up.poznan.pl

For citation: Czekała W., Gawrych K., Smurzyńska A., Mazurkiewicz J., Pawlisiak A., Chełkowski D., Brzoski M. 2017. The possibility of functioning microbiogas plant in selected farm. Journal of Water and Land Development. No. 35 p. 19–25. DOI: 10.1515/jwld-2017-0064.

Abstract

Renewable energy sources (RES) become more and more popular. In Poland, biomass has the highest energy potential among all RES. Methane fermentation is one of possible ways to use it. The aim of the study was to perform energy and economic calculations for the biogas plant installation project in an existing farm situated in the Wielkopolska voivodeship. Because of the small area of the farm and the type of production, the calculations were carried out for micro-installation biogas plants. During the preparation of the project the production potential of the substrates was determined, allowing for further analyses. It was calculated that the electrical power of the designed biogas plant was 8.10 kW, with a total annual production of biogas at 29 471 m^3. The obtained amount allows to generate in the cogeneration system 66 450 kWh of electricity and 71 190 kWh of heat energy. Some of the energy produced can be used on the farm and its surplus sold to the grid, which will allow for financial and environmental benefits.

Key words: *agricultural land, biogas production, energy production, renewable energy sources, waste management*

INTRODUCTION

It is apparent that energy consumption worldwide is still increasing [BAHRAMI, AMINI 2017]. This is due not only to scientific and technical progress, but also to the socio-economic development of civilization. This phenomenon is also compounded by the following increase in the population, and with it the pursuit of ever higher comfort of life. Most of today's power generation is based on conventional sources of energy such as coal, oil or natural gas, resources of which are limited and insufficient to cover rising energy consumption [PULTOWICZ 2009]. It should also be stressed that their use particularly affects the environment, among others by increasing the emission of gases, dusts and the generation of large quantities of waste [AKELLA *et al.* 2009].

The solution to the problem of energy shortage and environmental risks is the use of renewable energy sources such as sun, water, wind, geothermal and biomass [MATHIESEN *et al.* 2011]. Particularly the last of the aforementioned sources creates in Poland prospects and opportunities for development. The biomass can be sourced from forestry, agriculture and various other industries. Because of its diversity, it can be converted to energy using multiple technologies [CZEKAŁA *et al.* 2016]. Should be replaced the production of solid fuels (e.g. briquettes, pellets), liquid fuels (e.g. bioethanol from potatoes, cereal grains, beet) and gas fuels (biogas).

Acquisition of biomass for energy production generates special growth prospects for agriculture, which still remains a key branch of the Polish economy [RASHEED *et al.* 2016]. So far, farms have been focused on the production of consumer raw materials and the technologies available today provide the opportunity to become energy producers [HIJAZI *et al.* 2016]. Examples are biogas plants, where biogas is produced during methane fermentation [CZEKAŁA *et al.* 2017; ERIKSSON *et al.* 2014].

Biogas plants are one of the fastest growing segments of renewable energy and their role in energy production is becoming increasingly noticeable [PAWLAK 2013]. Thanks to them, farms can produce energy resources in targeted crops while managing waste [ROMANIUK, BISKUPSKA 2012; SMURZYŃSKA *et al.* 2016]. In addition, these installations allow for the generation and consumption of energy produced [IGLIŃSKI *et al.* 2015; MIRZA *et al.* 2009]. The aim of the study was to perform an energy and economic analysis for the agricultural biogas plant for a selected farm located in the Wielkopolska voivodeship.

MATERIALS AND METODS

CHARACTERISTICS OF THE FARM

The design of the biogas plant was made for a functioning farm located in the Wielkopolskie voivodeship, the Czarnków–Trzcianka region. The area of the selected farm occupies 35 ha of agricultural land, which are planned as follows: 15 ha of cereals, 4 ha of potatoes, 4 ha of maize, 12 ha of meadows. In addition to growing plants on the farm, animal production is also carried out. The Table 1 shows the number of animals kept.

Table 1. Animals kept on the farm

Type of animals	Number of animals, pcs.
Cattle	
Cows	25
Gestating heifers	4
Heifers above 1 year	4
Heifers between 6 and 12 months	6
Calves till 6 months	5
Swine	
Sows	5
Weaners between 2 to 4 months	20
Piglets till 2 months	15
Finishers	15
Poultry	
Hens	18

Source: own elaboration.

CALCULATING METHODS

A computational analysis was performed to estimate the energy and economic efficiency of the designed micro biogas plant. The type and weight of substrates to be used in the methane fermentation process were determined. The volume of biogas and methane produced was calculated. The amount of energy produced and the power of the installation was determined. This paper uses the methodology of calculations presented by SZULC and DACH [2014] described by CIEŚLIK *et al.* [2016].

RESULTS AND DISCUSSION

AMOUNT OF AVAILABLE SUBSTRATES ON THE FARM

It was assumed that the basis of the fermentation mixture into the biogas plant was manure and slurry generated when livestock in large quantities is kept. Natural fertilizers play a number of functions in the process of anaerobic decomposition [SMURZYŃSKA *et al.* 2016]. Table 2 shows the amount of manure produced in the selected farm.

Table 2. Produced on the farm of natural fertilizers

Kind of animal	Number of animals	Unit manure production Mg·(year·pcs.)$^{-1}$	Slurry production unit, m^3·(year·pcs.)$^{-1}$	Total manure production, Mg·year^{-1}	Total slurry production, m^3·year^{-1}
Cattle					
Cows	25	10	6.2	250	155
Gestating heifers	4	8.5	5.4	34	21.6
Heifers above 1 year	4	7.5	2.8	30	11.2
Heifers between 6 and 12 months	6	6	1.8	36	10.8
Calves till 6 months	5	2	0.9	10	4.5
Total production				360	203.1
Swine					
Sows	5	3.7	3.6	18.5	18
Weaners between 2 to 4 months	20	0.1	1.1	2	22
Piglets till 2 months	15	0.2	0.9	3	13.5
Finishers	15	2.5	2.2	37.5	33
Total production				60	86.5
Poultry					
Hens	18	0.045	–	0.81	–
Total production				0.81	–

Source: own elaboration based on Agency for Restructuring and Modernization of Agriculture [ARiMR 2015] data.

As can be seen in Table 2, approximately 360 Mg of manure and 203.1 Mg of slurry and 60 Mg of manure and 86.5 Mg of pig slurry and 0.81 kg of chicken manure per year are produced in the farm. Each of these substrates can be taken from the farm and use to biogas production. Maize silage is proposed as a substrate for biogas plants, which is most often used in fermentation mixtures [CIEŚLIK *et al.* 2016; FUGOL, PRASK 2011; SZLACHTA, FUGOL 2009]. 28 Mg of this substrate can be used for the production of biogas annually. This solution raises the efficiency of the installation, ensuring a significant amount of biogas with high methane content [CIEŚLIK *et al.* 2016; PILARSKA *et al.* 2014].

Cattle is predominant among the animals being kept and when they are fed, the so-called not eaten particles, that is feed residue, which for various taste and qualitative reasons was not consumed by animals. Cows are rearing in cowsheds all year. In the analysed farm, the not eaten particles is primarily grass silage, whose production is about 10 kg·day^{-1}, which gives about 3.7 Mg of substrate per year.

On a farm of 4 ha potatoes are grown for sale and for industrial purposes. At the time of its sorting and storage, organic waste, including sprouts and potatoes, are produced and their quality deteriorates. It is also proposed to use such materials as a substrate for biogas. In addition. about 6 Mg potatoes of lower quality are produced in the farm, and about 200 kg of germination during the spring sorting.

Also various types of kitchen waste arising in the household are the next substrate for biogas plant. It is assumed that an adult person produces 70 kg of this type of waste per year. This quantity is considered minimal. In case of production more waste, it could be used as an additional substrate. In the household there are 7 people, so the annual production of this type of material is about 490 kg. A quantitative summary of all available substrates is provided in Table 3.

Table 3. Available substrates on the farm

Type of substrate	Weight of fresh substrate Mg
Cattle manure	360
Pig manure	61
Hen manure	0.81
Slurry	289.6
Maize silage	28
Uneaten particles (grass silage)	3.7
Rejected potatoes	6
Potato sprouts	0.2
Kitchen waste	0.49
Total	749.8

Source: own study.

Analyses of the efficiency of the three substrates available on the farm: silage from maize, manure and potato sprouts were carried out at the Ecotechnology Laboratory of the Institute of Biosystems Engineering, Poznań University of Life Sciences (PULS, Pol. Uniwersytet Przyrodniczy w Poznaniu). The research was carried out according to the modified German standard DIN 38414–S8. The biogas production was analyzed using a gas analyser from GEOtech GA5000. The results of the biogas and methane yields of all the proposed substrates that can be used in the micro biogas from the selected farm are summarized in Table 4 [MYCZKO *et al.* 2011; SCHATTAUER, WEILAND 2005].

It has been shown that high hydration of the slurry which acts as a diluents of the fermentation mixture is insufficient because after its application the dry matter content of the feed is 16.03%. 270 Mg of water need to be added, which is 11.78% of load. As shown in Table 5, the mass of all substrates is 1 019.8 Mg per year and the daily dose (for 342 days) is 2.98 Mg.

Table 4. Summary of substrates available on the farm, subjected to microbial fermentation

Type of substrate	Weight of fresh substrate, Mg	Dry mass content, % DM	Mass of dry substrate, Mg	Biogas efficiency m^3·Mg^{-1} FM	Biogas efficiency m^3·Mg^{-1} DM	Methane content %
Cattle manure	360.0	24.0	86.40	48.0	200.0	60
Pig manure	61.0	24.0	14.64	47.0	195.8	60
Hen manure	0.8	70.0	0.57	80.0	114.3	60
Slurry	289.6	2.5	7.10	6.5	267.7	64
Maize silage	28.0	31.1	8.70	200.1	644.4	54
Uneaten particles (grass silage)	3.7	35.0	1.30	180.0	514.3	55
Rejected potatoes	6.0	22.4	1.34	170.0	758.9	47
Potato sprouts	0.2	11.9	0.02	53.5	450.4	47
Kitchen waste	0.5	18.0	0.09	125.0	694.4	55

Source: own elaboration based on the Ekotechnology Laboratory in Poznań (PULS) data, MYCZKO *et al.* [2011], SCHATTAUER and WEILAND [2005].

Table 5. Content of dry matter depending on the application of water

Mass of fresh substrates Mg	Mass of dry matter in all substrates Mg	Dry matter is total load % FM
Without adding water		
749.8	120.16	16.03
With adding water		
1 019.8	120.16	11.78

Source: own study.

ENERGY ANALYSIS

For calculating the amount of energy and power of installation, the biogas plant operating time is assumed to be t = 8 200 h. The results of calculations of biogas and methane volumes for individual substrates are presented in Table 6.

Table 6. Calculation of biogas and methane volumes for individual substrates and their combined values

Substrate	Volume of produced biogas m^3	Volume of produced methane m^3
Cattle manure	17 280	10 368
Pig manure	2 867	1 720.2
Hen manure	64.8	38.88
Slurry	1 899.78	1 215.86
Maize silage	5 601.96	3 025.06
Uneaten particles (grass silage)	666	366.3
Rejected potatoes	1 020	479.4
Potato sprouts	10.7	5.03
Kitchen waste	61.25	33.69

Source: own study.

The calculations in Table 6 show that the total volume of biogas produced is 29 471.49 m^3 and that of methane is 17 252.41 m^3. Results of energy production, power and volume of tanks are presented in Table 7.

Table 7. Summary of results of generated biogas, methane, energy and power

Feature	Unit	Value
Amount of electricity	kWh	66 450
Amount of heat energy	Wh/GJ	71 190/ 259.82
Electric power of the aggregate	kW	8.10
Thermal power of the aggregate	kW	8.68
Mass of pulp	Mg	948.41
Volume of the fermentation chamber	m^3	106.31
Volume of biogas tank	m^3	15
Volume of the digestive pulp tank	m^3	797.35

Source: own study.

The volume of the biogas tank can be estimated at 15 m^3. This means that it is unable to accumulate daily average production. Some of the biogas can be accumulated in the upper part of the fermentation tank. In addition, it is continuously burned in the cogeneration unit.

ECONOMIC ANALYSIS

In order to estimate the profitability of the investment. an analysis of the investment costs and the costs and annual revenues is presented in Table 8. According to the data presented to the highest investment costs, it is necessary to purchase a fermentation chamber and a cogeneration unit. The high price of the tank results from its necessary appropriate parameters ,adapted to the needs of the farm. The cogeneration unit is a high-performance machine. providing very favourable cost-effectiveness ratios, therefore its high price is justified. It was assumed that the biogas plant was purchased for cash and without subsidies.

Table 8. Capital expenditures

Type of costs	Cost, PLN
Cogeneration module	123 304
Fermentation chamber	200 000
Digestion pulp tank	17 430
Biogas tank	6 000
Automation and control systems	20 000
Measurement systems and electrical connection	10 000
Documentation, technical design, supervision	10 000
Other	5 000
Total	391 734

Source: own elaboration based on LATOCHA *et al.* [2011].

Analysis of annual revenues and costs requires some assumptions to allow the profit to be estimated under certain microbiogas plant operating conditions. The amount of electricity produced is 66 440 kWh and the heat energy is 71 190 kWh. On the basis of the review of electricity bills, the annual consumption of electricity on the farm was 18 500 kWh. 65% of this demand can be covered by work of the cogeneration unit, i.e. it is 12 025 kWh. This is due to the fact that the microbiogas plant is not working all year round, and the temporary production of electricity may be insufficient to cover the temporary needs of the farm. It is assumed that the biogas plant consumes about 10% of electricity produced for its own needs, like supplying control or measuring system. The remaining part of electricity, 47 771 kWh is proposed to be sold to the power grid. 30% of the heat is used to maintain the correct temperature of the fermentation, while the remaining part can be used on the farm. There are different ways to manage it, among which the most important are: heating the house, livestock buildings in winter or preparing hot water and drying summer crops. All assumptions used in the subsequent calculations are listed in Table 9.

Table 9. Assumptions used for calculations

Parameter	Value
Amount of electricity	66 450 kWh
Amount of heat energy	71 190 kWh
Annual electricity consumption on the farm estimated on the basis of the annual amount of accounts	18 500 kWh
The possibility of using electricity produced in a cogeneration unit to cover 65% of the needs of a farm	12 025 kWh
Electricity for own needs of the microbiogas plant – 10%	6 645 kWh
Electricity sold to the grid	47 780 kWh
Heat energy for use on the farm – 70%	49 833 kWh/181.87 GJ
Heat energy for own needs of microbiogas plant – 30%	21 357 kWh/77.95 GJ

Source: own elaboration based on LATOCHA *et al.* [2011].

Based on the previously agreed assumptions, 47 780 kWh of electricity will be sold to the grid. According to the Act on Renewable Energy Sources of 20. February 2015, the energy seller is obliged to purchase electricity from a generator of 3 to 10 kW, at a price that is 0.70 PLN·kWh^{-1} for agricultural biogas [Ustawa… 2015]. Assuming this value, the annual profit for the biogas plant is 33 446 PLN. Some electricity will be used for the farm. The revenue is therefore worth to buy the amount of electricity from the grid at the price of 0.55 PLN·kWh^{-1}, which is worth about 6 613.75 PLN. On the farm heat energy will also be used, that for unit price of 35 PLN·GJ^{-1} is worth 6 365.45 PLN.

The design of the biogas plant should also adequately consider economy of the resulting fermentation pulp. Digestate is a valuable fertilizer spread into the fields [BAUZA-KASZEWSKA *et al.* 2017; CZEKAŁA *et al.* 2012]. It contains macro elements and micronutrients whose availability for plants is higher than in natural agricultural residues [SZYMAŃSKA 2015]. The concentration of nutrients in the grout is mainly determined by the type of feedstock used for biogas production. Table 10 shows the content of nitrogen, phosphorus and potassium in the fermentation pulp produced from maize silage mixture and pig slurry.

Considering the price of one-component mineral fertilizers [polifoska.pl undated] one can determine the fertilizer value of 1 Mg of the post-fermentation. The calculations in Table 10 show that it amounts to 43.78 PLN·Mg^{-1}.

Table 10. Concentration and price of nutrients contained in the digested pulp, unit price of digested pulp

Substrate	Share of substrates %	DM content %	Concentration of contents in the digestate kg·Mg^{-1} FM		
			N_{total}	P_2O_5	K_2O
Maize silage (35% DM)	40	6.30	5.50	2.60	5.20
Pig slurry (6% DM)	60				
Unit price of nutrients, PLN·kg^{-1}			3.52	4.41	2.49
Value of nutrients contained in 1 Mg of digestate, PLN·Mg^{-1}			19.36	11.47	12.95
Value of digestate, PLN·Mg^{-1}			43.78		

Source: own elaboration based on SZYMAŃSKA [2015], polifoska.pl [undated].

It should be noted that digestive pulp takes up more storage space and is more difficult to apply compared to mineral fertilizers. Therefore, its value was reduced to 25 PLN·Mg^{-1}. With this assumption, the annual profit of post-fermentation on fields is 23 710.25 PLN.

The annual operating costs mainly include obtaining substrates, all of which are produced on the farm. Corn silage is the most efficient and at the same time the most expensive to produce. By accepting the unit cost of production at the level of 80 PLN·Mg^{-1}, the annual production of 28 Mg should be 2 240 PLN. Potato waste used in biogas is usually used on the farm as animal feed. Due to reduced quality the unit cost of their production was 60 PLN·Mg^{-1}. All other substrates are residues from agricultural production, so the cost of harvesting is zero. The operating costs should also include the purchase of water, which is used to ensure the appropriate content of DM in the batch. Annual demand for water is 270 m^3, which at the price of 2.48 PLN·m^{-3}, gives the value of about 670 PLN.

Substrates for micro biogas plant should always be adequately supplied and loaded. Since all of them are produced on the farm, it is not necessary to carry them over long distances. Dosing will be done by means of transport available on the farm. The annual cost is estimated at 150 PLN. Everyday supervision over the microbiogas operation will be carried out by the farm workers, so there is no need to hire additional staff to do this. A biogas plant, like any technical facility, also requires a technical maintenance with an annual cost of about 1 500 PLN.

When analyzing the annual operating costs, one should consider tax issues related to the use of micro-installations. In the case of energy sales, the VAT rate is 23%. In addition, the income from the sale of surplus electricity is subject to income tax [Ministerstwo Finansów 2015]. Taking into account the dismissal of farmers from PIT and assuming that this also applies to energy production, only VAT is included in the calculation. The annual tax charge was set at 7 692.58 PLN. An approximate analysis of revenues, operating costs and annual profit is presented in Table 11.

As shown in Table 11, the annual revenue of the micro biogas plant is 70 135.45 PLN, which at various operating costs of 12 612.58 PLN gives a profit of 57 522.87 PLN. Taking into account the size of the investment, the time of investment return is 6.8 years.

Table 11. Approximate annual revenues, operating costs and profit

Specification	Quantity	Price	Value PLN
Income			
Electricity sold to the operator. Electricity network (tariff system FiT guaranteed)	47 780 kWh	0.70 PLN·kWh^{-1}	33 446
Electricity for the needs of the farm	12 025 kWh	0.55 PLN·kWh^{-1}	6 613.75
Heat energy used in the farm	181.87 GJ	35 PLN·GJ^{-1}	6 365.45
Digestion pulp	948.41 Mg	25 PLN·Mg^{-1}	23 710.25
Total income			70 135.45
Costs			
Maize silage	28 Mg	80 PLN·Mg^{-1}	2 240
Potato waste	6 Mg	60 PLN·Mg^{-1}	360
Other substrates	991.8 Mg	0 PLN·Mg^{-1}	0
Water	270 m^3	2.48 PLN·m^{-3}	670
Transport of substrates	–	–	150
Staff	–	–	0
Maintenance services	–	–	1 500
Income tax	–	–	7 692.58
Total costs			12 612.58
Annual profit			57 522.87

Source: own elaboration based on LATOCHA *et al.* [2011].

CONCLUSIONS

Production of biogas in the micro biogas plant is done using substrates present in the analyzed farm. Biodegradable materials from the outside are not included, which reduces the cost. In addition, the plant enables the disposal of the resulting natural fertilizers and other residues from agricultural and household production, while producing energy. The electrical power of the biogas plant on the basis of available substrates in the selected farm is 8.10 kW, so it can be classified as micro-installations. The total annual production of biogas estimated at 29 291.49 m^3 produces in the co-generation system 66 450 kWh of electricity and 71 190 kWh of heat. The energy produced in the micro biogas plant is partly used on the farm and its surplus sold to the grid, so that the designed installation gives tangible financial benefits. The micro biogas plant produces 948.41 Mg of digested pulp, which is a good quality fertilizer. With capital expenditures of 391 734 PLN and annual profit of micro-scale biogas plant of 57 552.87 PLN the estimated return on investment is 6.8 years, which proves the profitability of the investment.

Acknowledgement

Dofinansowano ze środków
Wojewódzkiego Funduszu
Ochrony Środowiska
i Gospodarki Wodnej w Lublinie
Cofinanced by Voivodeship Fund
for Environmental Protection
and Water Management in Lublin

REFERENCES

Akella A.K., Saini R.P., Sharma M.P. 2009. Social economic and environmental impacts of renewable energy system. Renewable Energy. Vol. 34 p. 390–396.

ARiMR 2012. [online]. [Access 18.11.2015]. Available at: http://www.arimr.gov.pl/fileadmin/pliki/kontrole/dll/broszura_1t.pdf

Bahrami S., Amini M.H. 2017. A decentralized framework for real-time energy trading in distribution networks with load and generation uncertainty. arXiv: 1705.02575.

Bauza-Kaszewska J., Szala B., Breza-Boruta B., Ligocka A., Kroplewska M. 2017. Wpływ nawożenia pofermentem z biogazowni na kształtowanie liczebności wybranych grup drobnoustrojów w glebie płowej [Effect of digestate from biogas plant on the numer of selected groups of soil microorganism]. Woda-Środowisko-Obszary Wiejskie. T. 17. Z. 2(58) p. 15–26.

Cieślik M., Dach J., Lewicki A., Smurzyńska A., Janczak D., Pawlicka-Kaczorowska J., Boniecki P., Cyplik P., Czekała W., Jóźwiakowski K., 2016. Methane fermentation of the maize straw silage under meso- and thermophilic conditions. Energy. Vol. 115 p. 1495–1502.

Czekała W., Dach J., Janczak D., Smurzyńska A., Kwiatkowska A., Kozłowski K. 2016. Influence of maize straw content with sewage sludge on composting process. Journal of Water and Land Development. No. 30 p. 43–49. DOI 10.1515/jwld-2016-0020.

Czekała W., Pilarski K., Dach J., Janczak D. 2012. Analiza możliwości zagospodarowania pofermentu z biogazowni [Analysis of management possibilities for digestate from biogas plant]. Technika Rolnicza Ogrodnicza Leśna. Nr 4 p. 13–15.

Czekała W., Smurzyńska A., Kozłowski K., Brzoski M., Chełkowski D., Gajewska K. 2017. Kofermentacja osadów ściekowych sposobem na ich zagospodarowanie oraz produkcję energii [Sewage sludge co-digestion as a way of recycling waste and producing energy]. Problemy Inżynierii Rolniczej. Nr 1(95) p. 5–14.

DIN 38414–S8. 1985. German standard methods for the examination of water, waste water and sludge; sludge and sediments (group S); determination of the amenability to anaerobic digestion (S 8).

Eriksson O., Bisaillon M., Haraldsson M., Sundberg J. 2014. Integrated waste management as a mean to promote renewable energy. Renewable Energy. Vol. 61 p. 38–42.

Fugol M., Prask H. 2011. Porównanie uzysku biogazu z trzech rodzajów kiszonek: z kukurydzy, lucerny i trawy [Comparison of biogas yield from three types of silage: maize, lucerne and grass silage]. Inżynieria Rolnicza. Vol. 9(134) p. 31–39.

Hijazi O., Munro S., Zerhusen B., Effenberger M. 2016. Review of life cycle assessment for biogas production in Europe. Renewable Sustainable Energy Review. Vol. 54 p. 1291–1300.

Igliński B., Buczkowski R., Cichosz M. 2015. Biogas production in Poland – current state. potential and perspectives. Renewable Sustainable Energy Review. Vol. 50 p. 686–695.

Latocha L., Wereszczyński D., Jurkiewicz A. 2011. Innowacyjne technologie OZE w gminach wiejskich województwa mazowieckiego [Innovative technologies of RES in rural areas of the Mazowieckie Voivodship]. Warszawa. WFOS, GW p. 13–18.

Mathiesen B.V., Lund H., Karlsson K. 2011. 100% renewable energy systems, climate mitigation and economic growth. Applied Energy. Vol. 88 p. 488–501.

Ministerstwo Finansów 2015. Odpowiedź na interpelację nr 33336 w sprawie kwestii podatkowych zawartych w ustawie o odnawialnych źródłach energii [Answer to interpellation no. 33336 about tax issues contained in the Act on Renewable Energy Sources] [online] pp. 6. [Access 5.05.2017]. Available at: http://orka2.sejm.gov.pl/INT7.nsf/klucz/088552EF/%24FILE/i33336-o1.pdf

Mirza U.K., Ahmad N., Harijan K., Majeed T. 2009. Identifying and addressing barriers to renewable energy development in Pakistan. Renewable Sustainable Energy Review. Vol. 13(4) p. 927–931.

Myczko A., Myczko R., Kołodziejczyk T., Golimowska R., Lenarczyk J., Janas Z., Kliber A., Karłowski J., Dolska M. 2011. Budowa i eksploatacja biogazowni rolniczych. Poradnik dla inwestorów zainteresowanych budową biogazowni rolniczych [A guide for investors interested in the construction of agricultural biogas plants]. Ed. A. Myczko. Falenty–Poznań. Wydaw. ITP. ISBN 978-83-62416-23-3 pp. 140.

Pawlak J. 2013. Biogaz z rolnictwa – korzyści i bariery [Biogas from the agriculture – benefits and barriers]. Problemy Inżynierii Rolniczej. Nr 3(81) p. 99–108.

Pilarska A., Pilarski K., Dach J., Boniecki P., Dobrzański K. 2014. Nowoczesne metody oraz perspektywy zagospodarowania nawozów naturalnych [Modern methods and perspectives for management of manures]. Technika Rolnicza i Leśna. Nr 2 p. 9–11.

polifoska.pl niedatowane. Kalkulator nawozowy [Calculator for fertilizer calculations] [online]. [Access 18.11.2015]. Available at: https://polifoska.pl/kalkulator-nawozowy

Pultowicz A. 2009. Przesłanki rozwoju rynku odnawialnych źródeł energii w Polsce w świetle idei zrównoważonego rozwoju [The premises of renewable energy sources market development in Poland in the light of sustainable development idea]. Problemy Ekorozwoju – Problems of Sustainable Development. Vol. 4. No 1. p. 109–115.

Rasheed R., Khan M., Yasar A., Su Y., Tabinda A.B. 2016. Design and cost-benefit analysis of a novel anaerobic industrial bioenergy plant in Pakistan. Renewable Energy. Vol. 90 p. 242–247.

Romaniuk W., Biskupska K. 2012. Rozwiązania instalacji biogazowych dla gospodarstw rodzinnych [Innovative solutions of biogas installations for the agricultural family farms]. Problemy Inżynierii Rolniczej. Nr 2(76) p. 149–159.

Schattauer A., Weiland P. 2005. Biogaz. Produkcja. Wykorzystywanie [Biogas – production and use]. Leipzig. Institut für Energetik und Umwelt GmbH pp. 176.

SMURZYŃSKA A., CZEKAŁA W., KUPRYANIUK K., CIEŚLIK M., KWIATKOWSKA A. 2016. Typy i właściwości gnojowicy oraz możliwości jej zagospodarowania [Types and properties of the slurry and the possibility of its management]. Problemy Inżynierii Rolniczej. Nr 4(94) p. 117–127.

SZLACHTA J., FUGOL M. 2009. Analiza możliwości produkcji biogazu na bazie gnojowicy oraz kiszonki z kukurydzy [Analysis of potential for production of biogas based on liquid manure and corn ensilage]. Inżynieria Rolnicza. Nr 5 p. 169–174.

SZULC R., DACH J. (ed.) 2014. Kierunki rozwoju ekoenergetyki w polskim rolnictwie [Directions of development for renewable energy in Polish agriculture]. Kraków. PTIR p. 72–79.

SZYMAŃSKA M. 2015. Skład pofermentu – właściwości nawozowe. W: Poferment nawozem dla rolnictwa [Digestate composition – fertilizer properties. In: Digestate as a fertilizer for agriculture]. Ed. A. Kowalczyk-Juśko, M. Szymańska. Warszawa. Fundacja Instytut na rzecz Rozwoju Polskiego Rolnictwa p. 16–17.

Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii [Act of February 20, 2015 – Renewable Energy Sources]. Dz.U. 2015. Nr 87 poz. 478.

Wojciech CZEKAŁA, Karolina GAWRYCH, Anna SMURZYŃSKA, Jakub MAZURKIEWICZ, Artur PAWLISIAK, Dawid CHEŁKOWSKI, Michał BRZOSKI

Możliwość funkcjonowania mikrobiogazowni w wybranym gospodarstwie rolnym

STRESZCZENIE

Odnawialne źródła energii stają się coraz to popularniejsze. W Polsce największym potencjałem energetycznym spośród wszystkich OZE charakteryzuje się biomasa. Jednym z możliwych sposobów jej wykorzystania jest proces fermentacji metanowej. Celem pracy było dokonanie obliczeń energetycznych i ekonomicznych dla projektu instalacji biogazowni w realnie istniejącym gospodarstwie rolnym położonym w województwie wielkopolskim. Z racji na niewielką powierzchnię gospodarstwa i typ produkcji w nim prowadzony wybrano biogazownie o charakterze mikroinstalacji. W trakcie przygotowywania projektu określono potencjał produkcyjny substratów co umożliwiło przeprowadzenie dalszych analiz. Dokonano obliczeń według których moc elektryczna zaprojektowanej biogazowni wynosi 8,10 kW, przy całkowitej rocznej produkcji biogazu na poziomie 29 471 m^3. Uzyskana ilość pozwala na wytworzenie w układzie kogeneracyjnym 66 450 kWh energii elektrycznej oraz 71 190 kWh energii cieplnej. Część wyprodukowanej energii może zostać wykorzystana w gospodarstwie, a jej nadwyżka sprzedana do sieci, co pozwoli na uzyskanie korzyści finansowych i środowiskowych.

Słowa kluczowe: *energia odnawialna, gospodarka odpadami, obszary rolnicze, produkcja biogazu, produkcja energii*