УДК 620.95:631.16 doi: 10.30766/2072-9081.2019.20.1.76-83

BIOGAS PRODUCTION AS AN ELEMENT OF SUSTAINABLE DEVELOPMENT OF RURAL AREAS IN EU AND POLAND*

© 2019. Witold Jan Wardal, Jan Barwicki, Kinga Borek, Kamila Mazur
Institute of Technology and Life Sciences in Falenty, Branch in Warsaw, Poland

The article is devoted to the issue of sustainable rural development, with particular focus on biogas. It presents legal regulations in this area used in the European Union, including Poland. Additionally, the article provides the results of operational tests (conducted in 2011-2012) of a small biogas plant with total capacity of two reactors 411 m^3. The cost of electricity production was on the level of 113.76 PLN·MWh^{-1} and heat production costs - 206.06 PLN·MWh^{-1}. The construction cost of biogas plant was equal 1100 PLN per cubic meter. The exploitation costs of biogas plant were 42450 PLN·year^{-1} as the cumulative costs: the annual cost of installation maintaining 27 000 PLN·year^{-1} and cost of use of the biogas plant was 5450 PLN·year^{-1}. The calculated profit from the sale of produced electricity was 100622 PLN·year^{-1}. The calculation has been prepared in accordance with the level of prices in Poland in the years 2011-2012.

Key words: *sustainable development, RES (renewable energy sources), rural areas, biogas*

For citation: Witold Jan Wardal, Jan Barwicki, Kinga Borek, Kamila Mazur. Biogas production as an element of sustainable development of rural areas in EU and Poland. *Agrarnaya nauka Evro-Severo-Vostoka = Agricultural Science Euro-North-East.* 2019; 20(1):76-83. DOI: 10.30766/2072-9081.2019.20.1.76-83.

Производство биогаза как элемент устойчивого развития сельских территорий в ЕС и Польше

© 2019. Витольд Ян Вардал*, Ян Барвицкий, Кинга Борек, Камила Мазур
Технолого-природоведческий институт Фаленты, г. Варшава, Республика Польша

Статья посвящена проблеме устойчивого развития сельских территорий, при этом особое внимание уделяется роли биогаза. Представлены правовые нормы в этой сфере, принятые в Европейском Союзе, включая Польшу. Кроме того, статья содержит результаты проведенных в 2011-2012 годах производственных испытаний небольшой установки для получения биогаза общей емкостью двух реакторов 411 м^3. Стоимость производства одного мегаватт-часа электрической энергии была на уровне 113,76 польских злотых, а стоимость выработки тепловой энергии – 206,06 польских злотых. Удельные затраты на монтаж биогазовой установки составили 1100 польских злотых/ м^3 биогаза. Эксплуатационные расходы данной установки составили 42450 польских злотых в год, в том числе затраты на техническое обслуживание установки – 27000 польских злотых и стоимость эксплуатации установки 5450 польских злотых. Расчетная прибыль от продажи выработанной электрической энергии составила 100622 польских злотых в год. Расчеты были проведены в соответствии с уровнем цен в Польше на 2011-2012 годы.

Ключевые слова: *устойчивое развитие, ВИЭ (возобновляемые источники энергии), сельские территории, биогаз*

Для цитирования: Witold Jan Wardal, Jan Barwicki, Kinga Borek, Kamila Mazur. Производство биогаза как элемент устойчивого развития сельских территорий в ЕС и Польше. Аграрная наука Евро-Северо-Востока. 2019; 20(1):76-83. DOI: 10.30766/2072-9081.20.1.76-83.

Sustainable development is the socio-economic development, in which political, economic and social activities are integrated, which preserves the natural balance and permanence of basic natural processes in order to guarantee the possibility of satisfying the basic needs of individual communities or citizens in both the present generation and future generations[1].

The idea of sustainable development requires: 1) global environmental protection; 2) solidarity in relations between countries, especially between rich and poor ones, and solidarity with future generations; 3) treatment of economic, political, social and environmental factors as dependent on each other.

The term "sustainable development" was introduced and defined in 1987 by G. Brudtland in the report "Our Common Future" by the World Commission on Environment and Development. The concept of sustainable development is clarified by two documents adopted in 1992 at the UN Conference "Environment and Development" in Rio de Janeiro Declaration on Environment and Development and Agenda 21 (Earth Summit Conference).

* Опубликована по материалам доклада на Международной научной конференции «Энергосберегающие агротехнологии и техника для северного земледелия и животноводства» (г. Киров, 2018 г.).

[1]Environmental Protection Law, 2001. PL: Ustawa z dnia 27 kwietnia 2001 r. Prawo ochrony środowiska. Dz.U. 2001 Nr 62 poz. 627.

The first document contains 27 principles defining the rights and obligations of the signatory countries in pursuit of sustainable development, the second consisting of 4 parts (specific social and economic, natural resource conservation and management, strengthening the role of major groups and organizations, ways of achieving development sustainability) is an extension of the Declaration and makes recommendations to states and organizations on specific issues that must be resolved in the implementation of sustainable development (among others: the fight against poverty, demographic dynamics, protection of the human health, environmental protection, management of the Earth's surface, wastes management).

These documents are the basis of international legal instruments, global and regional (cross-border) setting out the strategy of sustainable development in a given location (country, region, sector, institution). Feasibility of sustainable development depends on the situation and the level of development of individual countries and regions of the world. To assess the degree of implementation of sustainable development projects or compliance with the principles of sustainable development are both quantitative and qualitative measures of sustainable development, different from the existing and traditional (used for example for statistical purposes) or assessments of economic indicators and environmental standards.

Polish and EU actions for the sustainable development. Since 1993, when the European Union adopted a V Program for Environmental Protection and Sustainable Development in the EU member states, a number of programs of sustainable development (for all countries, municipalities, businesses and others) have appeared. In 1998 the Council of Baltic Sea States adopted the Agenda Baltic 21, covering 7 sectors of key importance for the sustainable development of the region: agriculture, energy, fisheries, forestry, industry, tourism and transport. The initiative is supported by: Union of the Baltic Cities and the Baltic Local Agenda 21 Forum. In 2000 eleven education ministers of the Baltic states adopted The Hague Declaration - Agenda 21 on education for sustainable development in the Baltic Sea Region. In 2001 the European Commission presented a Communication "A Sustainable Europe for a Better World: A strategy for the sustainable development of the European Union", containing a list of the main threats to the sustainable development of European societies, among others: global warming caused by emissions of greenhouse gases; multigenerational poverty; marginalization and exclusion of certain social groups; aging of population; dramatic rise of biodiversity loss; rapid increase in the quantity of waste; destruction of soils; traffic congestion. On the basis of this document, in 2001 in Gothenburg the Council of Europe adopted EU strategy for sustainable development. In 2002 the "Earth Summit" conference in Johannesburg rated the achievements in implementing the principles of sustainable development and the adoption of a declaration which is the obligation of States to comply with them with particular attention to the situation in developing countries. In 2004 the European Commission presented a Communication "Stimulating of Technologies for Sustainable Development: European Union action plan on environmental technologies" [1].

Europe Agreements of 1991 fixing Polish association with the European Communities, contain a provision (Article 71, paragraph 2) that the execution policy of economic and social development of Poland should be guided by the principle of sustainable development. Since 1993 Poland cooperates with the United Nations Commission on Sustainable Development and submits its annual reports on the implementation of Agenda 21. The Law on Spatial Development (1994) recognized sustainable development as the basis "of actions in matters of destination sites for specific purposes and establish rules for their development".

The principle of sustainable development was also recorded in the Constitution of 1997 (Article 5). In 2000 the Parliament adopted, and the Polish government decided to launch the document "Long-term Strategy for Sustainable Development - Poland 2025". On the 27th of April 2001 Environmental Protection Law was passed, it defined the principles of the environment protection and conditions for the use of its resources, taking into account the requirements of sustainable development (Article 3, paragraph 50 introduced Polish-language official definition of sustainable development). In September 2002 the Prime Minister's Office established a Council for Sustainable Development.

The Law of 27 III 2003 for planning and spatial development adopted sustainable development (in addition to spatial order) as a basis: 1) spatial policy by local authorities and government bodies; 2) proceedings in cases of destination areas for specific purposes and establishing rules for land and buildings use on these sites[2].

[2]Planning and Spatial Development Law, 2003. [Ustawa z dnia 27 marca 2003 r. o planowaniu i zagospodarowaniu przestrzennym. Dz.U. 2003 Nr 80 poz. 717].

The idea of sustainable development can be presented as an evolution of the idea of progress, from technocratic conceived economic growth (production, consumption, technical progress), through sustainable development (development planned and implemented taking into account the possibilities and environmental effects) to contemporary multidisciplinary and humanitarian concept (Universal Declaration of Human Rights), where the subject is the human person, and especially his right to a healthy and productive life in harmony with nature, the well-being of the global community of people of intergenerational justice, self-realization. Sustainable development can be seen as an alternative to globalization.

The concept of sustainable development in Polish law is defined in the Environment Protection Law of the 27th of April 2001 (Art. 3 pt. 50). It means the socio-economic development in which political, economic and social activities are integrated, preserving the natural balance and permanence of basic natural processes in order to guarantee the possibility of satisfying the basic needs of individual communities or citizens in both the present generation and future generations [1].

Directive 2009/28/EC[3] of the European Parliament and of the Council (23 April 2009) on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, called the Renewable Energy Directive, establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the achievement of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels will have come from renewable sources by 2020.

Cooperation mechanisms in eu for sustainable development. The Directive promotes cooperation amongst EU countries (and with countries outside the EU) to help them meet their renewable energy targets. This cooperation can take the form of:

- statistical transfers of renewable energy;
- joint renewable energy projects;
- joint renewable energy support schemes.

Biofuels and bioliquids are instrumental in helping EU countries meet their 10% renewables target in transport. The Renewable Energy Directive sets out biofuels sustainability criteria for all biofuels produced or consumed in the EU to ensure that they are produced in a sustainable and environmentally friendly manner.

Companies can show they comply with the sustainability criteria through national systems or so-called voluntary schemes recognized by the European Commission.

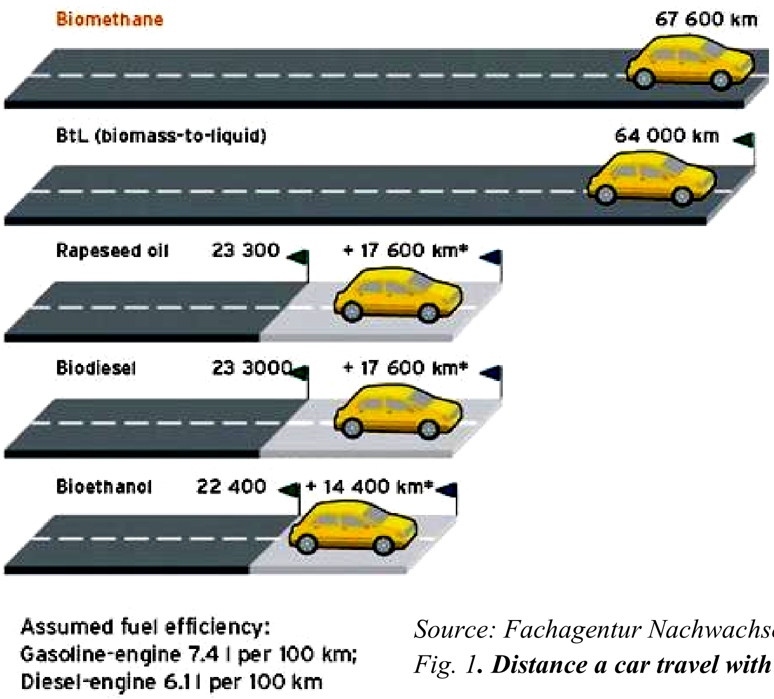
The Renewable Energy Directive 2009/28/EC[3] prompts the Commission to report on requirements for a sustainability scheme for energy uses of biomass and biogas other than biofuels and bioliquids, and to provide analysis on biofuel sustainability with respect to indirect land use change (ILUC). The ILUC corresponds to the carbon stock release from the conversion of natural land such as rainforest or grassland into cropland that can result from an increased production of biofuels/bioenergy in Europe. For the transport sector, the current sustainability criteria aim at ensuring minimum greenhouse gas (GHG) savings when compared to fossil fuels as well as defining land criteria, e.g. avoid high biodiversity areas for raw material production. In October 2012, the Commission additionally introduced a proposal to further minimize the climate impact of biofuel production, including a 5% cap on 1st generation biofuels (crop-based) and reporting requirements on estimated ILUC emissions.

Biogas can be produced from a variety of feedstock and used for different purposes: electricity, heat and transport. Thus, the sustainability schemes for biomass and the GHG calculation of biogas pathways would need to take this into consideration. For instance, anaerobic digestion of manure greatly reduces the amount of methane that would otherwise be released into the atmosphere and therefore enable significant GHG savings. Biogas production also closes the nutrient cycle when the produced digestate is an excellent bio-fertilizer, replaces and thereby prevents the CO_2 emissions from the production and use of mineral fertilizer. As for biofuels, the co-digestion of energy crops and manure has proved to be the most energy-efficient: one hectare of land used for biomethane production allows a longer running distance than with any other biofuel.

The Waste Framework Directive 2008/98/EC[4] entitles the European Commission to set criteria under which certain specified waste shall cease to be waste. This mechanism was introduced to further encourage recycling in the EU by creating legal certainty and a level playing field as well as removing unnecessary administrative burdens. The Joint Research Centre of the

[3] Renewable Energy Directive 2009/28/EC.
[4] Waste Framework Directive 2008/98/EC.

Commission will conduct a study on the material prepared by experts to compile technical proposals for the end of waste criteria. This work will be accompanied by a technical working group with experts from Member States, relevant industry and other stakeholders including EBA. Digestate is an excellent organic fertilizer which contains nearly all nutrients from used feedstock. The EU wants to become sustainable and independent from foreign raw materials.



Source: Fachagentur Nachwachsende Rohstoffe e.V.
Fig. 1. ***Distance a car travel with biofuels from 1 hectare of cropland***

Economic aspects of energy production from renewable sources. The EC proposal published on 13 April 2011 aims to revise the Energy Taxation Directive 2003/96/EC[5], which introduced a tax for energy products at EU level. This current energy tax, in the EC proposal, is split into an energy consumption tax (min rate = €9,6/GJ for motor fuels, and €0,15/GJ for heating fuels) and a CO_2 tax (€20 per ton of CO_2). At the moment renewables are taxed (mainly based on volume) at the same rate as the energy sources they are intended to be replaced, i.e. biodiesel is taxed at the same rate as diesel. Due to the taxation based on volume rather than energy content, products with lower energy content, particularly liquid biofuels, carry a heavier tax burden compared to the fuels they are competing with.

In 2009 the EU-27 emitted more than 4,600 million tons of CO_2. Roughly half of EU emissions are already covered by the Emissions Trading Scheme (ETS) for plants above 20 MW. The EC proposal to revise the Energy Taxation Directive aims to cover the other half of CO_2 emissions by introducing a carbon tax for energy applications below 20 MW. However, the proposed revision would unfairly weaken the use of biogas in the transport sector since the CO_2 tax in this sector weighs only around 10%. Therefore, biogas will bear, in spite of the CO_2 tax exemption guaranteed for biogas, a tax that is almost equivalent to the overall tax for one of the fossil fuels, i.e. natural gas. On April 19th, 2012, the Members of the European Parliament voted 374-217, with 73 abstentions against the proposal. Rapporteur MEP Lulling from Luxembourg argued that the revised Directive would have a direct social impact due to higher prices for coal, natural gas, heating oil and diesel oil. As far as taxes are concerned, the Parliament has however no decision power in the legislative procedure; it is merely consulted. The decision is up to the Council and thus to the Member States. EBA keeps its members up-to date on the progress within the Council.

The member states of the European Union, including Poland, have set up special institutions to coordinate activities in the field of renewable energy sources, especially for development of sustainable technologies and knowledge in the field of energy efficiency, enabling industrial processes to be used more efficiently. The European

[5]Energy Taxation Directive 2003/96/EC.

Energy Efficiency Directive aims to achieve energy savings of 20 percent in 2020 in Europe. For each member state this objective is translated into a national objective (for example the target for the Netherlands amounts to a cumulative energy saving in final consumption of 480 PJ in the period of 2014-2020).

To be able to meet these targets, innovations in energy efficiency are necessary, with taking into account the following aspects: research and technology, strategy and advice, products and services, implementation of international projects. For implementation of these solutions, every works must be coordinated closely with suppliers of raw materials, equipment manufacturers, contractors, engineering companies, machine manufacturers, installation contractors and a range of major end users.

Technological innovations can help investors to make process more energy efficient, with reduced energy consumption and lower operating costs. Modern methods for realization this purpose should contain:

– Developing more efficient separation processes of by-products.
– Reducing undesirable by-products.
– Improving final product yield and quality.
– Switching to sustainable products.

The works of research centers on generating energy from renewable sources, especially biogas (biomethane) are focused on:

– using heat technology to reduce energy costs (energy efficiency research to develop technologies and services for heat pumps and heat integration and storage. These technologies reduce the demand for heat and produce, enabling to use less energy, leading to lower energy costs and reduced carbon emissions;
– using process technology to improve operating processes;
– separation processes;
– biogas treating and upgrading for biomethane (developing of technology for various scale of production);
– intensifying chemical processes (combining process steps and reduce the scale of processes, resulting in more compact and efficient plants and systems;
– CO_2 capture.

Residues from preparation and processing of animal food products. The use of animals for slaughter indicates that remains for utilization account for 27% of their weight. In Poland, collected residues from preparation and processing of animal food products consist mainly of swine remains (62%), poultry remains (13%), feathers (13%) and blood (10%). Since 1997, these remains cannot be used in form of meat-and-bone meal in feeding animals for slaughter. Therefore, their use for energy production is highly recommended and possible (e.g. in biogas plants). Animal fat is one of the most valuable remains from processing. In general, in the Polish market there is a deficit of animal fat in food production and this valuable group of products cannot be considered meaningful as components of energy biomass. Consequently, waste fats (not used for food purposes), related to utilization of animal waste in high temperature, could be used for energy production. The volume of waste fat produced in such way in Poland is estimated at about 80-100 thousand cubic meters.

Directive 2009/28/EC[3] of The European Parliament and of The Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, stated that the use of agricultural material such as manure, slurry and other animal and organic waste for biogas production has, in view of the high greenhouse gas emission saving potential, significant environmental advantages in terms of heat and power production and its use as biofuel. Biogas installations can, as a result of their decentralized nature and the regional investment structure, contribute significantly to sustainable development in rural areas and offer farmers new income opportunities.

Reduction of greenhouse gas emissions. Rules for calculating the greenhouse gas impact of biofuels, bioliquids and their fossil fuel comparators are given below (tab. 1).

Research works of the institute of technology and life sciences. The answer to the growing demand for expertise in the area of biogas can be found in publications of various research institutes and technical centers, including The Institute of Technology and Life Science, Branch in Warsaw and Poznan [3, 4, 5, 6, 7].

Objective of the studies and methodology. The aim of the study was to present the technical and economic aspects of biogas production from agricultural sources including Polish conditions, having an impact on implementation of the Directive 2009/28/EC[3] of the European Parliament and of the Council on the promotion of the use of energy from renewable sources.

Table 1
Typical and default values for biofuels if produced with no net carbon emissions from land-use change, %

Biofuel production pathway	*Greenhouse gas emission saving*	
	typical	*default*
Sugar beet ethanol	61	52
Wheat ethanol **(process** fuel not specified)	32	16
Wheat ethanol (lignite as process fuel in CHP plant)	32	16
Wheat ethanol (natural gas as process fuel in conventional boiler)	45	34
Wheat ethanol (natural gas as process fuel in CHP plant)	53	47
Wheat ethanol (straw as process fuel in CHP plant)	69	69
Corn (maize) ethanol, Community produced (natural gas as process fuel in CHP plant)	56	49
Sugar cane ethanol	71	71
The part from renewable sources of ethyl-tertiary-butyl-ether (ETBE)	Equal to that of the ethanol production pathway used	
The part from renewable sources of tertiary-amyl-ethyl-ether (TAEE)		
Rape seed biodiesel	45	38
Sunflower biodiesel	58	51
Soybean biodiesel	40	31
Palm oil biodiesel (process not specified)	36	19
Palm oil biodiesel (process with methane capture at oil mill)	62	56
Waste vegetable or animal oil biodiesel	88	83
Hydrotreated vegetable oil from rape seed	51	47
Hydrotreated vegetable oil from sunflower	65	62
Hydrotreated vegetable oil from palm oil (process not specified)	40	26
Hydrotreated vegetable oil from palm oil (process with methane capture at oil mill)	68	65
Pure vegetable oil from rape seed	58	57
Biogas from municipal organic waste as compressed natural gas	80	73
Biogas from wet manure as compressed natural gas	84	81
Biogas from dry manure as compressed natural gas	86	82

Source: Directive 2009/28/EC[3]

The scope of work included: the analysis of biochemical and technical problems of biogas production; the development of renewable energy resources in Poland (especially the study of the increase of biogas stations number); the economic balance of biogas station.

Investigations of agricultural biogas plant located at private farm in Studzionka village (Lubusz voivodeship) were done according to the methodology of the Institute of Technology and Life Sciences presented by Romaniuk et al. [3, 5].

The total exploitation costs *(C_e)* was specified according to the formula No. (1) - [3, 5]:

$$C_e = C_{main} + C_{use};\ (\text{PLN}\cdot\text{year}^{-1}), \qquad (1)$$

where C_{main} – the annual cost of installation maintaining, (PLN·year^{-1}); C_{use} – cost of use of the biogas plant, (PLN·year^{-1}).

Unit exploitation cost C_{ej} is equal:

$$c_{ej} = \frac{C_{main} + C_{use}}{V};\ (\text{PLN}\cdot\text{m}^{-3}), \qquad (2)$$

where V – amount of produced biogas in normal conditions, (m^3·year^{-3}).

Biogas station research was carried out in the period of 2011-2012. Costs and profits were given according to 2011-2012 prices.

Results of ITP investigations of biogas plant. Investigations of agricultural biogas plant were done according to the methodology of the Institute of Technology and Life Sciences presented in the work: "The method of assessment of agricultural biogas plants" [3]. Biogas station research was carried out in 2011-2012 and is presented below (Tab. 2). Costs and profits were given according to 2011-2012 prices.

Table 2

Results obtained during the study of biogas plants in Studzionka village (Lubusz Voivodeship)

Parameters and results	*Units*	*Values*
Number of fermentation chambers	-	2
Total capacity of fermentation chambers of biogas plant	m^3	410
Investment cost of the whole installation	PLN	450 000
The cost of building - 1 m^3 of biogas plant	PLN	1 100
The amount of biogas produced per year	m^3	112 000
Calorific value of biogas	$MJ \cdot m^{-3}$	20.75
The amount of electric energy produced from biogas	$MWh \cdot year^{-1}$	212
The amount of heat produced from biogas	$MWh \cdot year^{-1}$	246
The potential profit from the sale of produced electricity	$PLN \cdot year^{-1}$	100 622
The market price of energy sold to the grid	$PLN \cdot MWh^{-1}$	197.72
The market price of green certificates of origin	$PLN \cdot MWh^{-1}$	273.73
The annual cost of maintaining installation C_{main}	$PLN \cdot year^{-1}$	27 000
Cost of use of the biogas plant C_{use}	$PLN \cdot year^{-1}$	15 450
The exploitation costs of biogas plant C_e	$PLN \cdot year^{-1}$	42 450
The cost of electricity production in the installation	$PLN \cdot MWh^{-1}$	86.2
The cost of heat production in the installation (the calculation does not take into account 30% of the heat that is used to the biogas plant heating)	$PLN \cdot MWh^{-1}$	156.13
Annual use of slurry and poultry manure for biogas production	t	1058.5
The cost of raw material	$PLN \cdot t^{-1}$	10
Annual cost of raw material	PLN	10 585
The cost of electricity production	$PLN \cdot MWh^{-1}$	113.76
The cost of heat production	$PLN \cdot MWh^{-1}$	206.06

Conclusions. As global demand for energy continues to rise, the transition to sustainable energy cannot be put off any longer. Natural resources and fossil fuel reserves are becoming depleted and water shortages are an ever-more frequent occurrence. Our climate is changing and biodiversity is declining, while huge increase in world energy consumption is reflected in a corresponding increase in CO_2 emissions and pollution by other greenhouse gases. Sustainable energy, including renewable energy technology and energy efficiency, is the prime key to solving international issues concerning climate change and fossil fuel depletion.

Based on the bibliography study and the research which was carried out, the following conclusions have been presented:

– National policies have the greatest influence on the development of renewable energy production in different countries of the European Union.

– Use of agricultural biogas is dependent on many factors specific to location of each installation (distance from the grid, general and local demand for a particular source of energy).

– Biogas plants are the objects of stable energy when properly correspond with the technological regime. They have constant electrical performance and can be built to meet the demand for electricity.

– In Poland to build both agricultural biogas plants below 100 kW and much larger installations is warranted. The final investment decision should result from a comprehensive account of the opportunities and needs.

– Operational tests of small biogas plant with total capacity of the two reactors 411 m^3 conducted in 2011-2012 have enabled to determine the actual cost of electricity production - 113.76 PLN·MWh^{-1} and heat production costs - 206.06 PLN·MWh^{-1}. The cost of building 1 m^3 of biogas plant in the economic way was 1100 PLN. The exploitation costs of biogas plant were 42 450 PLN·$year^{-1}$ as the cumulative costs: the annual cost of installation maintaining 27 000 PLN·$year^{-1}$ and cost of use of the biogas plant was 5450 PLN·$year^{-1}$.

– The calculated profit from the sale of produced electricity was 100 622 PLN·$year^{-1}$.

References

1. Myller R. Report on the communication from the Commission to the Council and the European Parliament on Stimulating Technologies for Sustainable Development: An Environmental Technologies Action Plan for the European Union. Committee on the Environment, Public Health and Food Safety. 11 May 2005. 2004/2131(INI).

2. Czarski E. Sustainable Development Indicators for Poland. GUS Katowice, 2011. p. 195.

3. Romaniuk W., Głaszczka A., Domasiewicz T., Biskupska K., Barwicki J. *Metoda oceny biogazowni rolniczych.* [The method of assessment of agricultural biogas plants]. Romaniuk W. (Red.). *Problemy intensyfikacji produkcji zwierzęcej z uwzględnieniem struktury obszarowej gospodarstw rodzinnych, ochrony środowiska i standardów UE. Monografia*. Wydawnictwo ITP Falenty, 2011. pp. 108-114.

4. Romaniuk, W., Biskupska, K. *Rozwiązania instalacji biogazowych dla gospodarstw rodzinnych*. [Solutions of biogas plants for family farms]. *Problemy Inżynierii Rolniczej*. 2012. no. 2(76). pp. 149-159.

5. Romaniuk W., Głaszczka A., Biskupska K. *Analiza rozwiązań instalacji biogazowych dla gospodarstw rodzinnych i farmerskich. Monografia*. [The analysis of of biogas plants for family farms and farmhouses. A monograph]. Wydawnictwo ITP, 2012. 104 p. ISBN 978-83-62416-53-0.

6. Głaszczka A., Wardal W., Romaniuk W., Domasiewicz T. *Biogazownie rolnicze*. [Agricultural biogas stations] Oficyna Wydawnicza Multico. Warszawa, 2010. 76 p. ISBN 978-83-7073-432-9.

7. Myczko A., Myczko R., Kołodziejczyk T., Golimowska R., Lenarczyk J., Janas Z., Kliber A., Karłowski J., Dolska M. *Budowa i eksploatacja biogazowni rolniczych. Poradnik dla inwestorów zainteresowanych budową biogazowni rolniczych*. [Construction and operation of biogas plants. Guidance for investors interested in building biogas plants]. Wydawnictwo ITP Falenty, 2011. 142 p. ISBN 978-83-62416-23-3.

Received: 22.11.2018 Accepted for publication: 19.02.2019

Information about the authors:
Witold Jan Wardal, PhD in Engineering Institute of Technology and Life Sciences in Falenty, Branch in Warsaw, Rakowiecka 32, Warszawa, Poland, 02-532, e-mail: w.wardal@itp.edu.pl,
Jan Barwicki, PhD in Engineering Institute of Technology and Life Sciences in Falenty, Branch in Warsaw, Rakowiecka 32, Warszawa, Poland, 02-532, e-mail: j.barwicki@itp.edu.pl,
Kinga Borek, M.Sc. Engineering, Institute of Technology and Life Sciences in Falenty, Branch in Warsaw, Rakowiecka 32, Warszawa, Poland, 02-532, e-mail: k.borek@itp.edu.pi,
Kamila Mazur, PhD in Engineering Institute of Technology and Life Sciences in Falenty, Branch in Warsaw, Rakowiecka 32, Warszawa, Poland, 02-532, e-mail: k.mazur@itp.edu.pl.

Поступила: 22.11.2018 Принята к публикации: 19.02.2019

Сведения об авторах:
Витольд Ян Вардал, кандидат техн. наук Института технологии и наук о жизни в Фаленти, филиал в Варшаве, Раковецка, 32, Варшава, Польша, 02-532, e-mail: w.wardal@itp.edu.pl,
Ян Барвицкий, кандидат техн. наук Института технологии и наук о жизни в Фаленти, филиал в Варшаве, Раковецка, 32, Варшава, Польша, 02-532, e-mail: j.barwicki@itp.edu.pl,
Кинга Борек, магистр инженерных наук Института технологии и наук о жизни в Фаленти, филиал в Варшаве, Раковецка, 32, Варшава, Польша, 02-532, e-mail: k.borek@itp.edu.pi,
Камила Мазур, кандидат техн. наук Института технологии и наук о жизни в Фаленти, филиал в Варшаве, Раковецка, 32, Варшава, Польша, 02-532, e-mail: k.mazur@itp.edu.pl.