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ECONOMIC AND LEGAL CONDITIONS AND PROFITABILITY OF INVESTMENTS IN AGRICULTURAL BIOGAS PLANTS IN POLAND*

Abstract

The paper analyses profitability of biogas production in livestock farms in Poland with a focus on micro-biogas plants. Due to the high value of investments a crucial issue, from the farmers' point of view, is the mechanism of financial support. The efficiency of investments has been measured assuming three variants of power of CHP plants. In addition, two scenarios of financial support have been taken into consideration: the "old" mechanism of green certificates and a forthcoming mechanism based on the new Act on Renewable Energy Resources. The new system introduces feed-in tariffs for small plants and auctions and guarantees of purchase for larger biogas plants. The results of the analyses indicate a strong dependence of the financial effects of micro-biogas plants on subsidies. It can be concluded that, under the current state of market development and financial support offered to micro-scale biogas production, investments in biogas plants are in general unprofitable.

Keywords: biogas plants, renewable energy sources, farm.

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Introduction

The issue of scarcity of resources is one of the major problems of the economy. In the context of natural assets, it does not refer only to the dimension of their scantiness with respect to human needs but also to the aspect of their depletion over time. This problem has been the subject of economic deliberations for many years[1], but it gained special significance in the second half of the 20th century, when negative effects of intensive economic growth were noted. They were linked not only to the risk of depletion of natural resources but also to a number of environmental externalities accompanying, for instance, energy generation from fossil fuels. Such effects are manifested in: immissions, emissions, landscape changes and many other forms of human impact on ecosystems (Pieńkowski, 2012) and, consequently – climate change. A breakthrough, as regards perception of mutual relations between the environment and economic activity of humans, came with the publication, by the team of Brundtland, of the report entitled *Our Common Future* (United Nations, 1987), which introduced the concept of sustainable development into the vernacular of policy and economy for good[2]. In the face of the existing problems, the general idea of sustainability started to be operationalised, seeking for dimensions and measures enabling real solution of the issues linked to the negative impact of humans on the environment (Pezzey and Toman, 2002). One of the practical measures taken in the field was the search for new energy sources, which would make it possible to replace fossil fuels and would, at the same time, be renewable and favour reduction in environmental pollution. The programme framework for the EU countries is set by the so-called energy package 3 20 of 2007, which assumes that by 2020 the emissions of greenhouse gasses will be reduced by 20% against 1990, the energy efficiency will increase by 20% and the share of renewable energy sources[3] (RES) in the total energy balance will be at 20%. Poland is obliged to obtain 15% share of RES (URE, 2012). Governmental long-term national development projects also assumed a major growth in the significance of energy from RES (Ministerstwo Gospodarki, 2015).

According to the data of the British Petroleum (BP, 2015), renewable energy sources meet the world energy demand in 9.8%, and as much as 6.8% falls to hy-

[1] At this point the Malthusian theory of 1798 could be referred to, which was an expression of care for the possibility of permanent human development at limited resources (consequently, limited food production possibilities). In the 19th century an English economist – William Jevons (Pieńkowski, 2012), tackled the issue of depleting coal resources and the impact of this phenomenon on the possibilities of further development of the British economy, to which the works of the Club of Rome referred to later on.

[2] Slightly earlier, in the 1970s, the Club of Rome published a work entitled *The Limits to Growth*, which considers the possibilities of further development of civilisation in the light of the risk of depletion natural resources (Meadows et al., 1972).

[3] Renewable energy sources are defined differently in different countries and by different authors. In Poland the definition included in the Act – Energy Law (Act, 1997) should be considered as the most relevant.

dropower. These statistics, however, fail to cover energy from traditional wood and biomass combustion, whose inclusion in the account makes the share of renewable energy sources in meeting the global energy needs reach ca. 19% (REN21, 2014). Omission of hydropower and traditional biomass combustion lowers the share of other, seen as more innovative, renewable energy sources to only ca. 2.5% in the energy mix worldwide. What needs to be highlighted are the crucial regional differences in the field, e.g. the EU average ratio reached in 2014 nearly 7.5% and in Poland it was 4.1% (BP, 2015). Although these values should still be considered as fairly low, it should be stressed that power industry based on renewable energy sources develops dynamically in the recent years. Calculated per crude oil equivalent, the amount of energy generated from renewable sources (excluding hydroelectric power plants) between 2000 and 2014 worldwide grew six-fold, over eight-fold in case of the EU countries and over five-fold in case of Poland (the low baseline level was key for such high growth in the ratio). The development largely takes place as a result of subsidising investments by governments of individual countries, since although the "fuel" is available free-of-charge, the technologies of its efficient use continue to be quite expensive, regardless of the progressing drop in their prices. This translates into much higher costs of energy unit generation than in case of energy generated from fossil fuels (AiS, 2015; Kost et al., 2013). The fact of intensive subsidisation of energy from renewable energy sources leads also to various controversies concerning economic justification of activity, which is based – according to some authors – on controversial political assumptions (Jankowski, 2014). It seems that in the current stage of the RES sector development achievement of the climate policy targets, formulated during the international forum, will not be possible without financial support for RES.

It needs to be noted that meeting the standards set, for example, by the 3 20 regulation can happen in a manner quite discordant with the principles laying at the foundation of their formulation, for instance, the practice of biomass co--firing, which in some cases should be considered as "artificial" meeting of the requirements resulting from the international arrangements. Biomass use is justified when it is fired at the place of its generation. Biomass transport at long distances is usually linked to high costs and additional emission of flue gas. This practice became popular, e.g. in Poland, due to subsidies for biomass co-firing in large power units. According to Wiśniewski (Forbes, 2012), this can lead to a situation when emissions from transport and biomass management (often delivered from distant foreign locations) are higher than emission limits resulting from replacement of fossil fuels with biomass (the so-called carbon footprint grows)[4].

Renewable energy sources, despite the basic advantage which is limitation of the use of non-renewable resources and emission reduction, are characterised by some features considerably limiting their usefulness. The basic problem is

[4] The total set of greenhouse gas emissions caused by an individual, organisation, event or product (https://pl.wikipedia.org/wiki/Ślad-węglowy).

dependence of energy production on the weather conditions, which in particular concerns energy generated in photovoltaic cells and wind power plants (Oniszk-Popławska, 2011), or major interference in the environment (e.g. hydroelectric power plants) (Zabłocki, 2013). Moreover, controversial is also the issue of biomass co-firing, which is linked to, e.g., decrease in the resources of arable land intended, up to date, for food production and a number of other negative consequences (Stankiewicz, 2012). An alternative solution, free from the aforementioned flaws, is agricultural biogas production form animal waste. Contrary to energy generated from solar radiation or wind, agricultural biogas generation brings a number of additional benefits. These include, for instance, organic waste disposal (instead of dedicated biomass production on arable lands) or additional reduction in the emission of methane, ammonia and nitrogen oxides which would have been emitted to the atmosphere if organic matter, being the by-product of agricultural production, had not been managed. At this point it should be mentioned that some part of organic matter supplied to soil is permanently bounded to it, which is termed carbon sequestration in soil. The issue of reducing emissions from agriculture is especially important taking into account the fact that agricultural production is its major source (Zieliński, 2014). Assumptions of the new political framework provide, e.g. reduction in emissions from the so-called non-ETS sector, covering the activities not included in the emission trading scheme, which includes also agriculture (Bańkowska, 2015). Apart from that the use of biogas lowers the demand for conventional energy, just like the use of other types of RES. Moreover, energy production from biogas does not depend on weather conditions and this translates into much lower fluctuations in the produced energy volume as compared to solar or wind energy. Farms running livestock production are especially predisposed to biogas generation, because the type of farming they pursue provides them with the relevant substrate. Agricultural biogas production is also a method of agricultural activity diversification. According to a government plan of 2010 (Curkowski et al., 2011), by 2020 over 2,000 agricultural biogas plants were to be created in Poland. However, only 66 agricultural biogas plants (including 8 belonging to one producer) were registered in October 2015 (ARR, 2015). Although it seems rather unlikely to execute the adopted targets by 2015, still what remains open are the questions about validity of agricultural biogas plants promotion as a modern renewable energy source and their potential usefulness from the perspective of farm activity diversification.

Methodology and key research assumptions

In the context of presented methodological and cognitive conditions, the paper aimed at assessment of profitability of investments in agricultural biogas plants, considering the changing institutional and economic conditions, resulting mainly from the entry into force of the Act on Renewable Energy Sources

(Act, 2015). Given the relatively short history of the RES sector in Poland, and the rather low level of its development, the implementation of the aforementioned aim requires adoption of a number of assumptions concerning different aspects of agricultural biogas plants' functioning.

The basic assumptions regarding support to agricultural biogas generation under the Act on RES

The Act, referred to above, introduces, e.g., the new support mechanisms for producers of energy from RES. The former support mechanism, which was based on the certification scheme[5], will be available for plants launched before 2016 (owners of these biogas plants will be able to choose whether to stay in the old scheme or transfer to the new one). Under the new support scheme, the differentiation between energy producers depending on the installed electric power is of key significance. Table 1 presents a simplified financial support scheme depending on the installed power. Taking into account the aforementioned criteria, the Act differentiates between micro-plants (up to 40 kW), small plants (from 40 to 200 kW) and plants with power at > 200 kW. Additionally, plants with power up to 3 kW and 3-10 kW were selected, which are commonly known as "prosumer plants", although in the Act such term is not used.

The new Act introduces three fundamental support mechanisms:

- auctioning – for RES plants with over 40 kW run by businesses;
- balancing, which guarantees repurchase of energy surplus, the so-called net-metering[6] – for plants with up to 40 kW run both by business operators and natural persons; energy sales under the system is to be done at a price accounting for 100% of the price from the former quarter at a competitive market (wholesale price);
- feed-in tariffs – under this mechanism micro-plants have a guaranteed energy sales price at the level of PLN 0.7 per kWh for 15 years.

[5] The certification scheme (energy certificates) consist in issuance of transferable property rights to each generated MWh of electric energy, by the Energy Regulatory Office (Polish: *Urząd Regulacji Energii, URE*) to producers of energy from renewable energy sources. Producers of energy from RES can sell the obtained certificates to large power plants which were obligated by law to reach a relevant share of RES in the structure of generated energy. An alternative to purchase of energy certificates is payment by the large energy producers of the so-called substitution fee, whose level is established by administration. Major oversupply of certificates resulted in a considerable drop in their prices in the Polish market and thereby reduction in their significance in supporting the RES sector. The basic types of energy certificates available for smaller plants are the so-called green certificates. More detailed information can be found, e.g., in the Act – Energy Law (Act, 1997) or in a Manual drawn up by the Polish Power Exchange (*Towarowa Giełda Energii, TGE*).

[6] "Net-metering" – is a service concerning an energy consumer who is also energy producer (prosument). Energy produced by the prosument at his own micro-plant and supplied to the local distribution system is settled by its deduction from the amount of energy used from the power grid.

Table 1

RES support scheme as per the Act of 20 February 2015

<table>
<tr><th colspan="2">POWER OF THE PLANT</th><th colspan="3">SUPPORT MECHANISM</th></tr>
<tr><td rowspan="3">Micro-plants (up to 40 kW)</td><td><3 kW</td><td rowspan="3">Scheme based on the obligation to buy energy surpluses – the so-called net-metering</td><td rowspan="2">Feed-in tariff scheme</td><td>price at PLN 0.75 per 1 kWh (hydropower, wind and solar energy)</td></tr>
<tr><td rowspan="2">3-10 kW
<40 kW</td><td>1) agricultural biogas – PLN 0.70 per 1 kWh
2) biogas from raw materials originating from landfill sites – PLN 0.55 per 1 kWh
3) biogas from raw materials originating from wastewater treatment plants – PLN 0.45 per 1 kWh
4) hydropower – PLN 0.65 per 1 kWh
5) wind power onshore – PLN 0.65 per 1 kWh
6) solar power – PLN 0.65 per 1 kWh</td></tr>
<tr><td colspan="2">The obligation to repurchase energy surpluses at a price amounting to 100% of price in the competitive market (natural persons and business operators)</td></tr>
<tr><td>Small plants</td><td>40-200 kW</td><td colspan="3" rowspan="2">Auction scheme (for business operators)</td></tr>
<tr><td>Other plants (large)</td><td>>200 kW</td></tr>
</table>

Source: own study based on the Act of 20 February 2015 on Renewable Energy Sources.

Under the auction scheme the suppliers of energy from RES are project owners offering the lowest energy prices (the state decides on the demand). After winning an auction they receive a guarantee of energy receipt at the offered price for 15 years (the price will be corrected by the inflation rate). A starting point for an auction are reference prices announced by the Ministry of the Economy (Ministerstwo Gospodarki), for example, for biogas the reference price for 2016 is to amount to PLN 450 per MWh (Ministerstwo Gospodarki, 2015). The reference prices announced by the Ministry of the Economy will include in respective years a possibility of using additional investment support by the investor.

Technological assumptions

The technological processes taking place in a biogas plant are based on anaerobic decomposition of organic matter by anaerobic bacteria, leading to creation of gas mixtures, including methane (biomethane), which is the expected product of the plant's operation. The obtained methane can be used for combustion in boilers to generate thermal energy or used for powering aggregates generating electric and thermal energy (cogeneration), which is the basic method of its management. An alternative solution is biogas upgrading to the natural gas parameters and its injection into the gas system or its use to power mechanical vehicles, but the popularity of these solutions is still slight. Taking into account the present scope of the study, it will omit details concerning the technical aspects of production and agricultural biogas use, which can be found in quite elaborate both national and foreign literature in the field (e.g. Curkowski et al., 2011; MAE, 2009; KTBL, 2015; Paterson et al., 2015).

A profitability analysis has been held on the example of three models of biogas plants with differentiated levels of electric power (10 kW, 40 kW and 200 kW), operating under cogeneration. Cogeneration means simultaneous generation of electric and thermal energy via biogas combustion in heat engines. Selection of the power levels resulted from differentiation in the scheme of operating support which is to be allocated to this type of facilities pursuant to the provisions of the Act on RES. An overriding assumption was taken that the analysed biogas plants are typically agricultural in character, and the basic source of substrate is cattle slurry – the number of animals was thus selected to ensure a relevant quantity of the substrate at defined parameters of the biogas plant[7].

In case of biogas combustion in CHP aggregates, apart from electric energy – constituting no more than 40% of biogas chemical energy – thermal energy is also generated, which is only partly used to support the processes taking place in the biogas plants (ca. 30%). The remaining part (after deduction of hard-to-avoid energy losses amounting to ca. 15%) can be managed and used as additional source of farmer's income. If only electric energy is managed, the other part of energy included originally in the biogas would be lost. In the conditions of a typical and relatively small farm, a part of thermal energy can without much trouble be used as a source of utility heat for households or livestock buildings. Depending on the local and individual conditions the management of heat surplus left for disposal might be the problem. The conducted analyses assumed two variants concerning thermal energy management, i.e. "only electric energy" – meaning that the energy surpluses over the demand of the internal processes and household are lost, and "electric + thermal energy", assuming that additionally 50% of thermal energy at the disposal of the farmer is managed (and is a source of income).

Assumed scenarios

The analyses were carried out with the assumption of two support schemes of biogas plants at the operating level:

- "new" one following from the provisions of the Act on RES of 2015,
- "old" one, basing on the support in the form of energy certificates.

[7] Analyses take as the basis for supply the cattle slurry (assuming that the cattle is kept all-year-long in livestock buildings) supplemented with maize silage (co-substrate). It is a wet fermentation process. It was assumed that 1 livestock unit produces 24 m^3 per year of slurry. Slurry, although it is the most often used material in the agricultural biogas plants, is characterised by too low content of dry mass as compared to the demands of a biological process taking place in the decomposition chamber. The expected content of dry mass in the substrate is ca. 11-15%, while the dry mass content in the cattle slurry is 8-11%. Therefore, the admixture of maize silage makes it possible to achieve dry mass content in the substrate at the level of 11.5%. Detailed calculations were conducted with the use of a calculator developed under the BioEnergy Fram2 project (available at: http://www.bioenergyfarm.eu/pl/).

The certificates are characterised by a considerable price volatility, thus – with reference to the "old" scheme – two scenarios were assumed (pessimistic – "PESM", and optimistic – "OPTM"), which reflect the extreme (from the perspective of operating support) conditions of agricultural biogas plant operation. The price of "green certificates" in the pessimistic scenario was taken at the level of the historic minimum (of July 2015) noted at the Polish Power Exchange (Notowania TGE, 2015), while in the optimistic scenario – at the level of substitution fee amounting in 2015 to PLN 300 per MWh[8] (URE, 2015). Support in the form of "yellow certificates" – allocated to owners of CHP plants (i.e. biogas plants processing biogas into electric and thermal energy), according to the Act of 14 March 2014, will be applied by the end of 2018. The price of "yellow certificates" was taken at the level of average quotes of this instrument in the contracts of 2015 noted at the Polish Power Exchange under a continuous mode (https://tge.pl/pl/464/rynek-praw-majatkowych). Given the short planned period of the instrument applicability, scenario solutions were disregarded in the case. The "yellow certificates", just like "green certificates", are allocated to 1 MWh of electric energy from RES (at highly efficient cogeneration). Table 2 presents a diagram of scenarios and variants considered in the paper.

Table 2

Comparison of variants and scenarios considered in the paper

RES support scheme									
new		old							
only electric energy	electric + thermal energy	only electric energy				electric + thermal energy			
		only green certificates		green + yellow certificates		only green certificates		green + yellow certificates	
		PESM[a]	OPTM[a]	PESM	OPTM	PESM	OPTM	PESM	OPTM

[a] PESM – pessimistic scenario, OPTM – optimistic scenario.

Production and organisation assumptions

Table 3 contains detailed assumptions on the plant size, demand for substrates, energy consumption by a household and energy production and prices. In the context of this information, it is expedient to note the issue of the scale of livestock production enabling operation of a biogas plant powered by slurry.

[8] The new Act provides for implementation of a mechanism preventing excessive drop in the prices of certificates. If the price of green certificates noted at the Polish Power Exchange for 3 months will be lower than 75% of the value of substitution fee, then the power plant will not be able to pay the substitution fee and they will be obligated to purchase energy certificates. This solution is to stop the excessive drop in the prices of green certificates.

For biogas plants with 10 kW power, it is ca. 30 livestock units (LU)[9], for 40 kW – 116 LU and for 200 kW plants – over 540 LU. At the assumed parameters of the slurry it is necessary to add maize silage (or other co-substrate), which at yields of 55 tonnes per ha would mean the need to allocate for its production, respectively, 2.2 ha (at 10 kW), 8.2 ha (at 40 kW) and nearly 39 ha for the largest of the considered plants. The estimated number of livestock units and area for co--substrate production are the basic organisation parameters from the perspective of a farm. However, in reality other proportions and different substrate compositions are possible (as well as other technological solutions, e.g. dry fermentation process).

Table 3

Technological assumptions concerning energy generation under individual variants

Electric power of the CHP plant	10 kW	40 kW	200 kW
Investment value[a] (PLN)	410,000	902,000,	3,400,000
Gross electric power production (kWh)[b]	69,765	291,768	1,453,529
Net electric power production (kWh)[b]	63,593	268,042	1,341,873
Gross thermal energy production (GJ)[b]	402	1,430	6,472
Net thermal energy production (to be used) (GJ)[b]	215	743	3,323
Necessary number of livestock[b] (LU)	30	116	545
Necessary admixture of maize silage (co-substrate) (tonnes per year)[c]	120	450	2,130
Price of maize silage (PLN per tonnes)[d]	106	106	106
Arable land area intended for silage (yield at 55 tonnes)	2.2	8.2	38.7
Share of electric energy from biogas plant in the energy consumed at a farm[e]	70%	80%	90%
Quantity of energy used at a farm and in a household (kWh/year)[f]	5,182	18,528	68,308
Electric power from a biogas plant to cover the demands of a farm (kWh)	3,627	14,823	61,477

[a] Estimation on the basis of an offer of companies included in the Manual prepared under the BIOGAS3 project.

[b] Calculations conducted with the use of a calculator drawn up under the BioEnergy Fram2 project (available at: http://www.bioenergyfarm.eu/pl/).

[c] Admixture of maize silage at the level ensuring 11.5% of dry mass in the substrate mass (source of calculations – as above).

[d] The production cost according to the calculations of the Mazovian Farm Advisory Centre in Warsaw was taken as the maize silage price (http://www.modr.mazowsze.pl/notowania-i-kalkulacje-cenowe).

[e] Own assumptions.

[f] Estimation based on information about energy consumption according to the record from the FADN database.

[9] Livestock unit (LU) – livestock calculation unit corresponding to an animal weighting 500 kg.

Applied analysis method

The assessment of profitability of investments in individual solutions was based on the classical methods of efficiency assessment, such as: Net Present Value (NPV), Internal Rate of Return (IRR) and simple payback period, and also the so-called Levelized Cost of Electricity (LCOE), which is usually used to compare profitability of electric energy generation, taking into account "lifetime" of the plant (Kost et al., 2013). The LCOE value was determined with the use of the following formula (Wiśniewski et al., 2013):

$$\mathrm{LCOE}=\frac{\sum_{t=0}^{N}\frac{(I_t + M_t)}{(1+r)^t}}{\sum_{t=0}^{N}\frac{E_t}{(1+r)^t}}; \qquad (1)$$

where:
LCOE – Levelized Cost of Electricity – averaged unit cost of electric energy generation during a lifetime (PLN per kWh),
I_t – investment inputs in the *t*-th year,
M_t – operating costs and financial costs of a credit in the *t*-th year,
E_t – electric energy production in the *t*-th year,
r – interest rate.

Results

The conducted analyses have the character of scenarios and refer only to an issue of the economic account held from the perspective of a potential investor – farmer, disregarding other aspects linked to a broad context of conditions of investments implementation in RES (for instance, efficiency of using public funds, implementation of climate policy targets, etc., which are the subject of vivid discussions between publicists, politicians and scientists). At the same time, it needs to be emphasised that the adopted assumptions significantly determine the observed results, thus the presented calculations should be treated as averaged solutions based on average values indicated in the used sources. Considering the differentiation in the possibilities of technical solutions and the impact of local conditions, both the investment inputs and costs of and incomes from the conducted biogas plants can, in individual cases, deviate from the presented calculations.

Table 4 includes a comparison of annual production costs, while Tables 5 and 6 cover a comparison of incomes in respective variants of the biogas plant, which refer to the "new" and "old" support schemes, respectively. Incomes cover benefits from elimination of costs of energy purchase from grid operators. It needs to be noted that given the assumed uncomplete time of operation of the generator, some part of the energy demand of farms and households is covered by energy from the power grid, despite the general surplus of generated energy.

Table 4

Estimated costs of energy production in biogas plants of different power level (identical costs regardless of the support scenario)

Specification	Electric power of the biogas plant		
	10 kW	40 kW	200 kW
Costs of the co-substrate (maize silage) (PLN per year)	12,720	47,700	225,780
Operating costs (3.5%)[a] of investment value (PLN per year)	14,350	31,570	119,000
Total operating costs (PLN per year)	27,070	79,270	344,780

[a] Including the costs of additional hired employment; own assumption on the basis of the estimation following from an analysis of offers of companies presented in the Manual drawn up under the BIOGAS3 project.

Source: own calculations.

Table 7 includes estimations of the "operating result" per 1 MWh of energy for respective variants and scenarios. The term "operating result" is contractual and means a difference between the value of incomes and costs of operation, covering the costs of co-substrate and operating costs (excluding costs of depreciation and possible debts). The presented values constituted basis for the account of the Net Present Value (NPV) and designation of the Internal Rate of Return (IRR) at subsequent stages of the analysis. The obtained results enable to compare production profitability at the operating level between the considered facilities over one year. Given the new RES support scheme, it may be noted that the best result is typical of the smallest biogas plant, which is a consequence of a guarantee of high sales prices. The worst, in this aspect, is a biogas plant with 40 kW power, which follows from sales of energy (guaranteed) at wholesale prices. At the same time, it needs to be kept in mind that the paper assumes biogas plant power output to be adjusted to the number of livestock units – "operating results" would be higher if the scale of the agricultural production of a farm was higher than it results from the needs of a biogas plant. Larger production scale would mean greater demand for energy, which for own needs is valued by retail prices ("avoided purchase") which are considerably higher than "wholesale" prices for which the farmer will be able to sell energy. In case of 10 kW biogas plants, increasing the number of livestock units over the demand of a biogas plant would not have a major significance (assuming that other parameters remain the same) because the feed-in tariffs for sales of energy and retail prices (of energy purchase) are similar to each other (0.70 and 0.60 PLN per kWh, respectively).

Table 5

Calculation of income from energy production in biogas plants of varied power level according to the principles of support compliant with the system based on energy certificates ("old" system)[a]

Specification	Electric power of the CHP plant		
	10 kW	40 kW	200 kW
Incomes form energy production			
Amount of electric energy for sales (kWh)	59,240	251,581	1,279,495
Time of sales (PLN per kWh) (in a "competitive market")	0.17239	0.17239	0.17239
Sales value (PLN)	10,212	43,370	220,572
Value of energy from biogas plant used for own needs of a farm (assumed retail price is PLN 0.60 per kWh[b])	2,612	9,877	37,426
Sales of green certificates			
Price of green certificates – pessimistic variant (PLN per MWh)	99	99	99
Price of green certificates – optimistic variant (PLN per MWh)	300	300	300
Support value for green certificates – pessimistic variant	6,907	28,885	143,899
Support value for green certificates – optimistic variant	20,930	87,530	43,6059
Sales of yellow certificates			
Price of yellow certificates	110	110	110
Support value for yellow certificates	7,674.15	32,094.48	159,888.19
Total incomes (PLN), excluding thermal energy			
Only green certificates_PESM	19,731	82,132	401,898
Only green certificates_OPTM	33,754	140,777	694,057
Green + yellow certificates_PESM	27,405	114,226	561,786
Green + yellow certificates_OPTM	41,428	172,872	853,945
Total incomes (PLN), including thermal energy			
Only green certificates_PESM	25,444	101,852	490,125
Only green certificates_OPTM	39,467	160,497	782,284
Green + yellow certificates_PESM	33,119	133,946	650,013
Green + yellow certificates_OPTM	47,141	192,591	942,172

[a] Assumed value of costs is identical as for the "new" scheme, thus they were omitted in the presented Table.

[b] It needs to be noted that the farm use of energy, which comes from biogas plant, does not affect the level of fixed fees (which do not depend on the quantity of purchased energy). The adopted price should refer only to the costs of energy purchase linked to variable components. The differences in the level of payment rates for different tariffs at different operators make the assumption a sort of a simplification.

Source: own study.

Table 6

Calculation of incomes from energy produced at biogas plants with varied power level according to the support principles compliant with the Act on RES of 2015 ("new" scheme)

Specification	Electric power of the CHP plant (kW)		
	10	40	200
Incomes form energy production			
Sales of electric energy (kWh)	59,240	251,581	1,279,495
Sales price (PLN per kWh)	0.70[a]	0.17239[b]	0.3825[c]
Sales value (PLN)	41,468	43,370	489,407
Value of energy use for own needs of a farm (assumed retail price PLN 0.64 per kWh) (PLN per farm)	2,612	9,877	37,426
Incomes – total electric energy (PLN per farm)	**44,080**	**53,247**	**526,833**
Incomes form energy production			
Managed thermal energy (75% at the disposal) (GJ)	161	557	2,492
Price of thermal energy (PLN per GJ)[d]	35.4	35.4	35.4
Income – thermal energy (PLN per farm)	**5,714**	**19,720**	**88,227**
Total incomes (PLN), including thermal energy use (PLN per year)	**49,794**	**72,967**	**615,060**

[a] Feed-in tariff as per the Act on RES (Act, 2015).

[b] Wholesale prices (prices in a competitive market) as per the Energy Regulatory Office.

[c] Assumption on the basis of reference prices set by the Ministry of the Economy (Ministerstwo Gospodarki, 2015) for auctions for 2016 (it was assumed that the auction price is by 15% lower than the reference price).

[d] The heat price was set as the equivalent of heating costs, assuming the use of coal boiler with 50% efficiency and coal price with calorific value at 23 GJ per tonne at the level of PLN 700 per tonne.

Source: own study.

The estimated value of the "operating result", after considering investment inputs, formed grounds for estimation of the NPV and IRR. Additionally, the analyses contain information on the simple payback period. Table 7 contains results of the calculations. It needs to be emphasised that the system basing on certificates will be "supressed", thus, discussions on the issue are mainly hypothetical.

From the conducted analyses it follows that none of the variants of the biogas plant with the assumptions taken generates positive value of NPV under the conditions of the "new" RES support scheme. In case of the smallest biogas plants, also in all of the scenarios of the "old" scheme, negative NPV values were obtained. In case of biogas plants with 40 kW power, positive flows appeared only when optimistic scenario was taken for the prices of "energy certificates" and thermal energy produced in the installation was simultaneously managed. In the variant of a biogas plant with 200 kW power, negative NPV results in the conditions of the "old" support scheme would appear only in the pessimistic scenario. The NPV values observed in most of the considered cases, correspond to the absolutely low level of the Internal Rate of Return. Bearing in mind that the Internal Rate of Return means maximum interest rate on a loan ensuring NPV at zero level, it can be stated that in case of RES support according to the "new" principles, none of the investment variants would result in an interest rate higher than the assumed 5% level (in most of the cases it was lower than zero).

In the "old" scheme the IRR at the level exceeding 5% was noted only for the optimistic scenario (in case of one variant of 40 kW plant and all variants of 200 kW plants).

The estimate of the simple payback period also shows rather pessimistic perspectives. In some part of variants, given the negative value of the "operating result" it was not possible at all to determine the payback period, and in some part – it exceeded the limits of rationally justified considerations (Table 8 shows results not exceeding 30 years).

Table 7

Estimated "operating result" for considered scenarios and variants of agricultural biogas plants (PLN per MWh)

Specification	RES support scheme									
	new		old							
	only electric energy	electric + thermal energy	only electric energy				electric + thermal energy			
			only green certificates		green + yellow certificates		only green certificates		green + yellow certificates	
			PESM	OPTM	PESM	OPTM	PESM	OPTM	PESM	OPTM
10 kW	0.27	0.36	-0.12	0.11	0.01	0.23	-0.03	0.19	0.10	0.32
40 kW	-0.10	-0.02	0.01	0.23	0.13	0.35	0.08	0.30	0.20	0.42
200 kW	0.14	0.20	0.04	0.26	0.16	0.38	0.11	0.33	0.23	0.45

Source: own calculations.

Table 8

Net Present Value (NPV), Internal Rate of Return (IRR) and simple payback period for the considered scenarios and variants of agricultural biogas plant operation

Assessment parameters	Electric power of the installation	RES support scheme									
		new		old							
		Energy management variant									
		only electric energy	electric + thermal energy	only electric energy				electric + thermal energy			
				Scenarios							
				only green certificates		green + yellow certificates		only green certificates		green + yellow certificates	
				PESM	OPTM	PESM	OPTM	PESM	OPTM	PESM	OPTM
NPV[a] (PLN thousand)	10 kW	-222	-166	-463	-324	-443	-305	-407	-268	-387	-248
	40 kW	-1,116	-921	-831	-251	-748	-168	-636	-56	-553	27
	200 kW	-1,438	-566	-2,673	215	-2,259	629	-1,801	1,087	-1,387	1,501
IRR (%)[a]	10 kW	<0	<0	<0	<0	<0	<0	<0	<0	<0	<0
	40 kW	<0	<0	<0	0.3	<0	1.7	<0	4.0	<0	5.5
	200 kW	<0	2.3	<0	6.0	<0	8.0	<0	9.6	<0	11.8
Simple payback period (years)[b]	10 kW	24	18	-	-	-	-	-	-	-	29
	40 kW	-	-	-	15	-	13	-	11	-	10
	200 kW	19	13	-	10	-	9	23	8	19	7

[a] At interest rate equalling 5%; operation period – 15 years.

[b] In case of negative flows, simple payback period calculation was impossible; the Table includes only cases with payback period < 30 years.

Source: own study.

The presented analyses of investment efficiency pointing to a very low profitability (or lack thereof) were supplemented with a calculation of the Levelized Cost of Electricity (LCOE). This cost shows, at the same time, the electric energy price that needs to be collected throughout the time of investment operation to cover the investment inputs and operation and financial costs. This cost is also determined by the averaged costs of energy production in a lifecycle (Wiśniewski et al., 2013). It points to a price at which NPV reaches zero. The LCOE index is usually used for comparing energy production costs form different sources. In the approach presented in the paper, it was used to compare energy production costs at different variants of agricultural biogas plants, and to compare them with the energy price paid by farmers for energy supplied from the power grid (Fig. 1). As compared to earlier analyses, the Figure contains additional results of a simulation, which assumes that financial costs are taken into account if the investment is funded in 60% by a loan with interest rate of 5% per annum. Moreover, the Figure presents information on the prices of energy sold under individual variants of the installation (this is possible due to comparison of the production costs with price at which electric energy can be bought). It needs to be noted that the LCOE index is basically applied to determine the electric energy production costs, but due to a significant share of thermal energy generated as a result of biogas combustion in the CHP plant, the analysis was supplemented with a variant involving a modified LCOE index (variant: electric + thermal energy), in which the sum of discounted investment inputs and costs were reduced by savings resulting from heat production (O_c), in line with the formula:

$$\mathrm{LCOE}=\frac{\sum_{t=0}^{N}\frac{(I_t\ +M_t-Oc)}{(1+r)^t}}{\sum_{t=0}^{N}\frac{E_t}{(1+r)^t}}; \qquad (2)$$

where:

O_c – annual savings resulting from use/sales of heat (PLN per year), other markings as in formula (1).

From the presented comparison it follows that definitely the lowest costs are typical of biogas plants with 200 kW power. In each of the considered variants the costs would be at a level below the retail price of electric energy obtained from the grid. This means that energy production would be in this case profitable if it was to be used for replacement of energy taken by framers from the power grid. However, assuming that most of the energy will be sold with the auction price at the level of PLN 0.382 per kWh, in all the scenarios for 200 kW plants the "levelized costs" would be higher than the obtained price, thus pointing to a lack of an economic validity of the venture. The case for biogas plants with 40 kW power is much worse. The point of reference is the wholesale price, which is much lower than the production costs in all of the considered variants for plants with this power output. At the same time, the estimated "levelized costs" are lower or similar to the retail price, which suggests that energy generation in a biogas plant with 40 kW power output can be economically justified, mainly if it is managed for own needs. The smallest biogas plant with 10 kW power has absolutely the highest costs as it comes to the LCOE methodology. The production costs in this case exceed both the retail prices (PLN 0.60 per kWh) and the feed-in tariff provided in the Act on RES (PLN 0.70 per kWh).

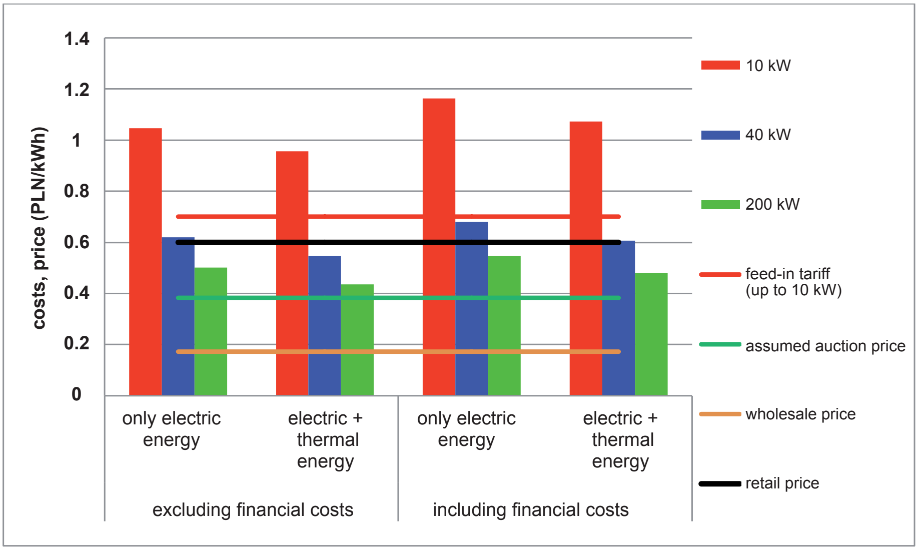

Fig. 1. Value of "Levelized Costs of Electricity" (LCOE) by biogas plant variants.
Source: own study.

The conducted analyses show that at the assumed level of costs and inputs, investments in agricultural biogas plants, in most of the cases, fail to ensure return on the invested funds. This means that investment profitability from the perspective of a potential investor (farmer) can be achieved only in case of additional investment support (disregarding the issue of economic profitability from the perspective of the society, because the subsidy system is justified by non-economic reasons). However, it needs to be remembered that in reality simultaneous use of operational support and investment support is limited by the provisions included in Article 39 of the Act on Renewable Energy Sources, which assumes restriction of the maximum total sum of state aid available to a producer participating in the auction (and a producer earning income on sales of certificates). In practice, this means that the possibilities of additional co-financing for investments in biogas plants will be very much limited, thus the presented analyses are only hypothetical.

Taking into account the previously taken assumptions, simulations were conducted which indicate the share of support at the stage of incurring investment expenditures by a farmer, which would ensure NPV at zero. Table 9 contains results of the calculations. What is evident is a significant differentiation between individual scenarios and variants (presented simulations fail to consider any possible financial costs). Considering the variants of the simulation referring to the regulations of the "new scheme", it can be stated that the highest level of co-financing of investment inputs enabling to reach NPV at zero would be required in case of biogas plants with 40 kW power and it would exceed 100% (which is linked to losses at the operational level). In case of the smallest of the considered installations, the required share of external funds in investment inputs would be at the level of 45%, assuming sales of electricity and thermal energy, and at almost 60% if only electric energy would earn income. In case of the "old scheme" additional investment support would be unnecessary only in case of plants with 200 kW power in the optimistic scenario.

Table 9

Share of external support provided to investors at the investment level ensuring NPV at zero (% of investment value)

Electric power of the installation	RES support scheme									
	new		old							
	Energy management variant									
			only electric energy				electric + thermal energy			
			Scenarios							
	only electric energy	electric + thermal energy	only green certificates		green + yellow certificates		only green certificates		green + yellow certificates	
			PESM	OPTM	PESM	OPTM	PESM	OPTM	PESM	OPTM
10 kW	59	45	118	84	113	79	104	70	99	65
40 kW	129	107	97	33	88	23	75	11	66	1.8
200 kW	47	21	83,4	un[a]	71	un[a]	58	un[a]	45	un[a]

[a] Unnecessary.

Source: own study.

Conclusions

Bearing in mind the above signalled problems, it needs to be assumed that efficient climate policy-making of the state will be possible only in case of a positive assessment of the energy projects by investors. The assessment can be reduced to the issues of profitability of planned investments and risk related thereto. Given a low level of the RES sector development in Poland, risk assessment in the categories of volatility is difficult to be estimated in quantitative terms. In the categories of a classical division, introduced to the language of the economy by Knight (1921), it can be referred rather to uncertainty than classical understanding of risk, whose vital attribute is objective probability. Depending on the level of risk aversion and subjective risk valuation, the investor will expect various levels of "risk premiums" constituting a "prize" for involvement in the measures of uncertain nature. A key factor influencing the assessment is the potential profitability of investments in RES – the higher the profitability, the larger the risk-taking "prize". Aiming at execution of climate policy targets, states implement different mechanisms encouraging, e.g., farmers to create renewable energy sources. Unfortunately, the implemented support mechanisms not always guarantee investment profitability from the perspective of a business operator. This refers also to agricultural biogas plants. The following arrangements follow from the conducted research:

1. With the assumptions taken, all variants of a biogas plant generate negative NPV for the scenario following from the new support scheme. In case of the "old" scheme, the situation depends on the price of "green certificates" and is subject to greater fluctuations. Thus, it can be concluded that the "new" scheme ensures greater stability of results, but with the adopted parameters the investment would be unprofitable. The "old" scheme involves higher risk resulting from the market character of the support instruments, but it gives a chance for a positive result. The certificate scheme may thus turn out to be more profitable for investors than participation in auctions, on condition that the price of certificates will be close to assumptions of the optimistic scenario. A probability of such a scenario grows along with the introduction, by way of the Act on RES, of the provision on the ban to pay the substitution fee by power plants in case of a low price for "green certificates". However, considering the small number of the existing agricultural biogas plants, this will not have a greater impact on the sector development, since the newly-created biogas plants will not be able to benefit from the support under the energy certificates scheme. It should be noted that implementation of such restrictions in earlier regulations, would have probably prevented the RES market crisis in Poland, which started in 2012. It should be also emphasised that the "new" scheme, although it increases the stability of functioning, it starts to be the source of institutional risk itself, which is linked to the possibility of changes in the principles of support provided by the state. It is all the more important that the legal analyses point to numerous errors and shortcomings (Motylewski, 2015), which seems to preordain the need for amendment of the Act on RES. An open issue in this context remains the question about the shape of the future changes and their impact on the essential elements of the RES support scheme.
2. With the assumptions taken, positive NPV would require not only support at the operational but also investment level. The possibility of its use, given the principles of state aid in the EU, will be strongly restricted, though. Especially significant share of external funds would be required in case of plants with the 40 kW electric power. This results from a fact that the basic manner of operating support, the so-called net-metering (the term does not appear in

the Act), is to be settled with the use of the wholesale price of electric energy, which is definitely lower than the retail price at which the farmer buys energy from the grid. It seems that the mechanism cannot be used as an efficient incentive to launch new biogas plants targeted at energy sales. In this case the main alternative still is electric and thermal energy management for own needs of a farm, which – as it seems – was the intention of the legislator. The benefits on account of "saved up costs" would be much higher in this case than in the case of energy sales to the grid at wholesale prices. However, this is preconditioned by running activity at a farm which would enable the use of the total generated energy.

3. The conclusions for the smallest of the above-considered plants (10 kW) are slightly different. The feed-in tariffs correspond to approximated current retail prices of energy, which means that the lack of profitability is linked to high level of unit costs related, mainly, to the investment implementation. This observation is confirmed by the level of LCOE, which is much higher than in the two other variants of biogas plants. Increasing the profitability of investments in this situation is possible only for a drop in investment inputs. On the basis of experiences of other countries, it can be expected that the development of the RES sector will contribute to a quite significant decrease in investment costs (Kost et al., 2013) and thereby better profitability of the smallest biogas plants.
4. As regards the largest of the considered biogas plants, it can be stated that the issue of auction price will actually be decisive. If it will be lower by 15% from the reference prices settled by the Ministry of the Economy, the investment in the biogas plant of this scale becomes profitable with additional investment support at the level of slightly over 20% (in the thermal power management variant). Given the restrictions in the state aid use, it needs to be highlighted that the designated share of investment support determine, at the same time, the level by which the investment inputs should be cut to ensure positive flows.
5. An important element that can precondition the profitability of investments in agricultural biogas plants is the possibility of management (sales or use at a farm) of thermal energy generated in the CHP plants. In typical livestock farms, possibilities within this scope are usually limited (e.g. mainly to the needs of a household), which has a negative impact on the assessment of a potential project. An important element are thus also organisational factors linked to the localisation that enables a relatively easy sales of heat surpluses or its use for the needs of a farm.
6. Bearing in mind the high investment inputs and in particular the fact that their unit value drops more than proportional value along with a growth in the investment scale, it seems justified to promote solutions basing on the cooperation between farmers in case of biogas plants with power at >10 kW.

Joint projects are especially justified for commercial direction of energy production, because – as it follows from the conducted analyses – net-metering settlement targeted at small plants will generate losses. Therefore, it seems to be rational to either produce energy for own needs of a farm or invest in biogas plants of a scale justifying the participation in the auction scheme. An additional argument for a solution based on cooperation is the need to ensure a relevant amount of substrate in the form of slurry and manure, which is especially important in case of fragmented agricultural structure.

7. The presented publication focuses on economic aspects, but in the assessment of the justification for agricultural biogas plant launching also other benefits (e.g. environmental) can be important. It needs to be stressed that, although in a short term the non-economic consideration can justify stimulation of the development of projects which are economically unfeasible, in the long term – sustainable development and RES sector functioning will be possible when economic and environmental targets are sustainable. In the present situation what seems to be especially important are the measures extending availability of technological solutions and competitiveness among their suppliers, which would allow lowering the investment inputs. In the long term, two possible directions of development can be indicated, namely a drop in costs of energy production from RES, mainly as a result of a drop in prices of investment inputs (it can be assumed that it is a direction required from social reasons) or increase in costs of energy obtained from conventional sources, which will influence the relative attractiveness of RES (such direction of development is possible, e.g., as a result of changes in the situation in the market of energy raw materials or in the effects of administrative decisions). In both cases it is difficult, however, to expect social acceptance.

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UWARUNKOWANIA EKONOMICZNO-PRAWNE I OPŁACALNOŚĆ INWESTYCJI W BIOGAZOWNIE ROLNICZE W POLSCE

Abstrakt

W artykule przeanalizowano opłacalność biogazowni rolniczych, które mogą być uruchamiane w polskich gospodarstwach prowadzących produkcję zwierzęcą. Ze względu na wysokie nakłady inwestycyjne, kluczową – z perspektywy rolników – jest kwestia mechanizmu wsparcia finansowego. Analizę efektywności inwestycji przeprowadzono przy założeniu trzech wariantów mocy jednostki kogeneracyjnej zainstalowanej w biogazowni. Dodatkowo rozpatrzono dwa scenariusze wsparcia finansowego odnoszące się do starego „systemu zielonych certyfikatów" oraz nowego mechanizmu wynikającego z „Ustawy o odnawialnych źródłach energii". Nowy mechanizm, który powinien obowiązywać od 2016 r., zakłada wsparcie odnawialnych źródeł energii poprzez ceny gwarantowane (najmniejsze instalacje) oraz system akcji i gwarancje odkupu energii (większe instalacje). Wyniki analiz wskazują na silną zależność efektów finansowych od mechanizmu wsparcia. Przy przyjętych założeniach można stwierdzić, że inwestycje w biogazownie rolnicze na obecnym etapie rozwoju rynku charakteryzują się w zasadzie brakiem opłacalności.

Słowa kluczowe: biogazownie, odnawialne źródła energii, gospodarstwo rolne.

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