STOWARZYSZENIE EKONOMISTÓW ROLNICTWA I AGROBIZNESU
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ECONOMIC EFFICIENCY OF THE UTILIZATION OF LOCAL BIOMASS FOR ENERGY PURPOSES

EFEKTYWNOŚĆ EKONOMICZNA WYKORZYSTANIA LOKALNEJ BIOMASY DO CELÓW ENERGETYCZNYCH

Key words: biomass, resource potential, economical, efficiency
Słowa kluczowe: biomasa, potencjał, efektywność ekonomiczna surowców
JEL codes: Q42

Abstract. The utilization of local biomass should aim at increasing the regional competitiveness based on the endogenous regional potential. A justification was presented of the utilization of biomass from agriculture for energy purposes. This is to serve the fulfilment of the objectives by Poland in accordance with the National Indicative Target by the year 2020. Particular attention was drawn to the need of the production of thermal and electrical energy (CHP) in a distributed system in small local heat and power stations. Poland is a country with a high biomass potential. The study presents the current development status of the biogas sector and of the resources in use. The condition of the development of this sector is continuous efforts aimed at obtaining a high economic efficiency of the production of energy from biogas to permit in the future competition with conventional fuels.

Introduction

Considering its form, biomass constitutes a diversified group that allows the production of electrical energy, thermal energy and liquid fuels. Its chief advantage as compared to fossil fuels is a smaller negative environmental impact including above of all reduced emissions of carbon dioxide and other greenhouse gases whose effect is the global warming. These results are not always taken into consideration in economic accounts and, in this respect, their price competitiveness at the current level of technological development does not allow its wider applications. Furthermore, coal is the Polish national fuel, and for this very reason, the policy in relation to renewable energy resources pursued by Polish policy-makers is limited merely to the fulfilment of the international obligations following the EU directives. In these circumstances, the measures that are undertaken to increase the share of renewable energy resources including biomass in the energy balance of Poland should focus to a significant extent on an improvement of the economic efficiency, an increase of the desirable effects and a limitation of a part of the costs.

One of the desirable measures in this area should be the use of new technologies based on innovative solutions that allow a better utilization of the resources in use and of energy obtained [Rosch et al. 2009]. The research and analyses that were carried out for the needs of this study demonstrate that there is a huge potential of innovative biomass processing technologies and of those agricultural biogas plants that possess functional connections with other food-processing plants in agricultural and food processing industry. An improvement of the energy production efficiency should result in the future in the fact that biomass processing installations will function in every commune, and these will become an element of the energy mix and a part of the labour market; in this way, they will contribute to the regional and local development. The weaknesses of biomass include its high cubic volume and a significant local dispersion. These features may at the same time constitute its strength should we opt for distributed power industry. Energy should be effectively generated where there is a demand for it, and it should be economically used by local consumers. By adapting the technology and the scale of production to cover the local demand, we are able to effectively generate energy from local biomass resources.

Notion of efficiency and cost level

The notion of efficiency refers most frequently to the principles of rational management formulated in two variants: a productivity variant (a maximization of the effect) and an economical variant (a minimization of the expenditure) [Matwiejczuk 2000]. Efficiency understood as mutual relations between expenditures and effects can be presented based on three principal formulas:

1) efficiency as the difference between effects and expenditures (gainfulness): the desired result ought to be greater than zero: this means that the effects obtained are greater than the expenditures incurred;
2) efficiency as the quotient of effects in relation to the expenditures incurred (cost-efficiency): the result desired should be greater than 1: this means that the expenditures incurred are lower than the effects obtained;
3) efficiency as the quotient of the difference between effects and expenditures to the expenditures incurred: this formula is defined as the return on investment (ROI), and it is expressed in percent.

The use of renewable resources is strongly diversified in the individual EU and in Poland. The historical economic and environmental determinants are the main causes of the current renewables acquisition structure. In the year 2011, the share of energy from renewable resources in the acquisition of primary energy in the European Union totalled 20.3% and 10.9% in Poland. The highest share was reported in Latvia, and it amounted to 99.8%.

In Poland, it is biomass that dominates in the acquisition structure of renewable energy. It is primarily used in the production of heat. In the production of electrical energy, the share of wind energy has been dynamically growing in the recent years; as a result, it took the first position [Gostomczyk 2014].

The overall biomass potential in Poland is high and it amounts to ca. 895 PJ [Jasiulewicz 2010]. This offers many possibilities of regional activation both in rural areas and in towns. The development of bio-energetics is connected with an increase of agricultural production and the growing surplus of the supply of consumer resources over the possibilities of their absorption by the market. On the other hand, the increased consumption of electrical energy and liquid fuels creates the possibility to use renewable energy resources from the national resource,s especially in the local system. Taking into consideration the regional and local diversity of the use of renewable energy resources for energy purposes, an increase of their diversification and distribution should be accepted in every region [Jasiulewicz 2013].

Table 1. Share of individual renewable energy carriers in the total production of energy from renewable energy resources in Poland in the years 2007-2012

Tabela 1. Udział poszczególnych nośników energii odnawialnej w łącznym pozyskiwaniu energii ze źródeł odnawialnych w Polsce w latach 2007-2012

Specification/*Wyszczególnienie*	Share of renewable energy carries/*Udział poszczególnych nośników energii odnawialnej [%]*					
	2007	2008	2009	2010	2011	2012
Solid biofuels/*Biopaliwa stałe*	91.03	87.48	85.77	85.29	84.99	82.16
Solar energy/*Energia słoneczna*	0.01	0.02	0.11	0.12	0.14	0.15
Energy of water/*Energia wodna*	4.17	3.42	3.37	3.65	2.68	2.06
Wind energy/*Energia wiatru*	0.92	1.33	1.53	2.08	3.69	4.80
Biogas/*Biogaz*	1.33	1.78	1.62	1.67	1.83	1.98
Liquid biofuels/*Biopaliwa ciekłe*	2.27	5.47	7.04	6.64	5.76	7.97
Geothermal energy/*Energia geotermiczna*	0.22	0.23	0.24	0.20	0.17	0.19
Municipal waste/*Odpady komunalne*	0.02	0.00	0.01	0.04	0.43	0.38
Heat pumps/*Pompy ciepła*	0.03	0.27	0.30	0.31	0.30	0.31

Source: own study based on [GUS 2013]

Źródło: opracowanie własne na podstawie [GUS 2013]

Table 2. Amount of investment expenditures per peak power unit and medium power unit in selected types of renewable energy resources.
Tabela 2. Wysokość nakładów inwestycyjnych na jednostkę mocy szczytowej i mocy średniej w wybranych rodzajach OZE

Type/*Rodzaj*	Units/*Jedn.*	Amount of investment expenditures/*Wysokość nakładów inwestycyjnych*							
		land wind farms/*lądowe farmy wiatrowe*	maritime wind farms/*morskie farmy wiatrowe*	biomass/*biomasa [EC]*	biogas/*biogaz [EC]*	hydroelectric power stations/*elektrownie wodne*	distributed biomass power industry/*biomasa energetyka rozproszona*	solar cells/*fotowoltanika*	nuclear energy/*energia jądrowa*
CAPEX on MWof peak power/*CAPEX na MW mocy szczytowej*	mln PLN MW/ *mln zł/MW*	6.6	13.6	10.7	14.4	18.5	10.3	7.8	14.4
Use time of installed power/*Czas wykorzystania mocy zainstalowanej*	h/*godz.*	2300	3100	8000	6000	4000	7000	900	8000
CAPEX on MW of medium power/*CAPEX na MW mocy średniej*	mln PLN/MW medium power/ *mln zł/MW średniej mocy*	25.1	38.4	11.7	21.0	40.5	12.9	75.9	15.8

Source: own study based on [EY 2012]
Źródło: opracowanie własne na podstawie [EY 2012]

Those factors that are formed both during the investment process and during the operation, production and sales of energy produced exert an influence on the efficiency of biomass utilization. A more detailed characterization should also include the following:
– type of resources used,
– electrical energy and heat production technologies,
– production scale,
– economic and legal environment that forms the support system for renewable energy resources,
– the value of green certificates, prices of energy, income gained.

It is evident from the statement presented that biomass, due to a high index of the production power use time, possesses one of the lowest levels of investment costs in per one MW of medium power. This translates directly into a high level of energy safety, stability of energy supplies and competitiveness in relation to other sources.

When determining costs, it is not only direct expenditures that should be taken into consideration in calculations but also efficiency, the time of construction and operation and the annual production capacity utilization rate of the installation (load factor – LF). This is an equivalent of the annual relative utilization time of the installed power. For biomass, LF is 0.85, and for other renewable technologies it is as follows [Paska 2010]:
– photovoltaic systems – 0.11,
– heliothermal systems – 0.41,
– land wind power stations – 0.23,
– maritime wind power stations – 0.39,
– big hydroelectric power stations – 0.5,
– small hydroelectric power stations – 0.57
– biogas plants – 0.9

The current development of renewable energy resources in Poland was supported by the system of "colour" certificates. As a result, the producers of renewable energy gained profits from sales at the prices of "black energy" and the sale of property rights of those certificates that differed depending on the production technology used. "Black energy" itself did not cover the production costs. The growing production of renewable energy lead to a situation where the costs of

Table 3. Prices of green certificates in Poland
Tabela 3. Ceny zielonych certyfikatów w Polsce

Prices of green certificates [zł/MW]/*Ceny zielonych certyfikatów [PLN/MW]*							
2007	2008	2009	2010	2011	2012	14.02.2013	2.09.2014
242	248	259	268	275	280	100	177

Source: own study on the basis of data from the Energy Regulatory Authority
Źródło: opracowanie własne na podstawie danych Urzędu Regulacji Energetyki

Table 4. Prices of electricity in Poland per 1 kWh including distribution fee: average in the years 2001-2014
Tabela 4. Ceny prądu w Polsce za 1 KWh wraz z opłatą dystrybucyjną – średnia w latach 2001-2014

Prices of electricity [zł/kWh]/*Ceny prądu [PLN/kWh]*													
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0.36	0.38	0.40	0.41	0.42	0.44	0.45	0.50	0.53	0.55	0.56	0.57	0.58	0.56

Source: see tab. 3
Źródło: jak w tab. 3

support were systematically increasing year after year, and they were becoming a growing burden to the state budget.

An excessive quantity of green certificates at the turn of the years 2012 and 2013 caused a significant decrease of their values and a collapse the current support system. A drop of prices and demand for wood chips, briquettes and pellets contributed to losses on the part of green energy producers and, consequently, a limitation of the production.

One of the goals of this article is to demonstrate the influence of primary external factors (the price of biomass, electrical and thermal energy and the price of green certificates) on the economic efficiency of a small power cogeneration installation (2 MW) that uses solid agro-biomass. The proper utilization of local agro-biomass with the use of the latest technologies in a cogeneration system, e.g. ORC, offers an effective solution both to farmers and the producers of thermal and electrical energy (local heat and power stations located in small and medium sized towns (currently, municipal thermal power stations).

An installation of a cogeneration boiler (ORC) heated with agro-biomass is fully justified in those cases where there is a central heating installation with a boiler heated with hard bituminous coal, especially after its depreciation as a result of long-term operation, and a replacement of the heating equipment is required. A decision to start an investment related to a heat and power station based on the local resources of solid biomass will bring benefits to heating companies, and it will also contribute to an improvement condition of the environment. The security is required of the permanent supplies of biomass (long-term contracts with local farmers) ensuring the delivery of resources over the whole year as demanded. Appropriate logistic solutions connected with biomass deliveries and storage are required. What needs to be guaranteed is cooperation with the energy grid operator and the collection of heat or cold (in summer).

Econometric model of cogeneration investment

Activities connected with the realization of a cogeneration investment require a well-prepared design, technical and organizational expertise and determination. The project of an ORC type investment is characterized by low investment costs and operation costs, and it demonstrates a high economic efficiency. These investments can be realized in the different variants of financial montage, which finally has an influences on the return time of the expenditures incurred. According to the analyses carried out, the following variant: 10% – own capital, 40% – subsidy, 50% – credit, is the one that is the most attractive to the investor [Jasiulewicz 2012].

In accordance with the parameters accepted, an estimation was performed of the economic efficiency from the investment. The following factors were accepted that exert an influence on the final economic effect: X_{11} – the biomass purchase price (PLN 300-500/tone of dry mass), X_{12} – the price of electrical energy (PLN 230 – 280/MWh), the price of the green certificate X_{13} – (from PLN 240 to PLN 290/MWh), X_{14} – the market price of thermal energy (PLN 35.00 – 55.00/GJ), whereas in the majority of cases, the sale value was accepted on the average level, i.e. PLN 45.00/1 GJ.

After an assessment of the structural parameters, the model takes the following form:

276,960 – 4,117x i 1 + 2,560x i 2 + 2,560x i 3 + 40,896x i 4 = {1,2,….14)

– a1 = –4117: Interpretation of the parameters of the models. An increase of the purchase price of biomass by 1 PPS with the assumption that the price of electrical energy, the price of the "green certificate" and the market price of thermal energy remain unchanged, will cause a decrease of the annual economic effect by 4117 units of value;
– a2 = 2560: An increase of the price of electrical energy by 1% with the assumption that the purchase price of biomass, the price of the "green certificate" and the market price of thermal energy will remain unchanged, will cause a decrease in the quantity of the annual economic effect by 2,560 units;
– a3 = 2560: An increase of the price of the "green certificate" by 1% with the assumption that the purchase price of biomass, the price of electrical energy and the market price of thermal energy will remain unchanged, will cause a decrease in the quantity of the annual economic effect by 2,560 units;
– a4 = 40896: An increase of the market price of electrical energy by 1% with the assumption that the purchase price of biomass, the price of electrical energy and the price of the "green certificate" will remain unchanged, will cause a decrease in the quantity of the annual economic effect by 40,896 units.

The econometric model described follows from multiple regression calculations. An extremely important element of economic efficiency is aiming at an optimization of economic effects with the assumption of changes to the values of the individual components. The calculation accepted provided for 8,000 hours of the operation of the installation annually, the biomass purchase price of PLN 300.00/tone of dry matter, the selling price of electrical energy of PLN 200.00/MWh, the price of the "green certificate" of PLN 200.00/MWh, the market price of thermal energy at an exceptionally low level, i.e. PLN 20.00/GJ with the assumed level of the production of electrical energy of 2,560 MWh, the production of thermal energy of 11,360 Mwh, i.e. 40,893 GJ. This creates the annual economic effect on the level of PLN 330,057.14 per year.

Accepting the maximum number of hours of the nominal work of the installation over a year, i.e. 8,760 hours at the purchase price of biomass on the level of PLN 300.00/tone of dry matter, with the selling price of electrical energy on the level of PLN 600.00/MWh, the price of the "green certificate" of PLN 200.00/MW and the sale volumes of thermal energy, the annual economic effect will amount to PLN 5,260,736.50. The parameters accepted should be treated as an optimization which can be achieved in ca. 10 years. This offers an interesting perspective in the development of renewable energy resources, especially in the use of biomass in distributed systems based on cogeneration installations. Therefore, there is a complete argumentation for the use of an ORC type cogeneration investment in small distributed heat and power stations, which justifies the flow of accumulated funds and NCFt. A creation of a distributed network of small heat and power stations based on the combustion of local biomass is a fully justified undertaking [Jasiulewicz 2012].

Biogas plants constitute another element of distributed power industry where biomass is used. These are facilities and installations which produce biogas as a result of biological and biochemical processes in methane fermentation. Resources include only organic products that undergo a decomposition into gases: carriers of energy, and liquid digestate pulp. The use of resources with a high energy productivity would be an optimal solution from the perspective of production. Their quantity and availability is limited and prices are high. In the past, liquid manure, which was supplemented with high-energy maize silage, constituted the basic resource. Depending on the size of a biogas plant, resources constitute from 70 to 90% of operation costs. Therefore, the current biogas production model is undergoing changes towards the use of cheaper and commonly available resources (including waste). At present, the structure of resources used in biogas plants is being extended to include by-products and waste products. This allows one to state that biogas plants are of an agricultural and utilization nature.

The resources used have an influence both on investment and operation costs. When planning the use of liquid and volumetric resources, we incur higher costs connected with the construction of larger fermentation and post-fermentation tanks. The operation costs increase because of the transport costs of large masses of the material of a low biogas productivity from 1 tone of substrate that undergoes fermentation [Reinhardt, Gaertner2007].

Location constitutes an extremely important factor for efficiency. Location is determined by the availability of grounds, possibilities to obtain the material and to utilize the products of the biogas production. Currently, most biogas plants are situated near farm facilities as it is liquid manure that is the primary resource. It is fed both through pipelines and slurry transfer vehicles. Much more space is required to enrich the feedstock to include substrates with a high gasification efficiency. A biogas plant where maize silage constitutes half of the feedstock requires ca. 300 ha for maize cultivation per 1 MW [*Handreichung*... 2008].

The location is also essential for the utilization of heat produced by biogas plants. Those farm facilities where a significant number of biogas plants are located are at a great distance from residential building. This is dictated by the possibility of a penetration of oppressive odours that are produced on farms. The transport costs of heat over a distance of several kilometres might be too high and unprofitable. Lack of heat or partial use of heat reduces the efficiency of a biogas plant [Blanco, Azqueta 2007]. This problem can be limited by dividing the production of resources, biogas and energy in the space. The following variants are possible:

– transport of manure through a pipeline from the farm to the biogas plant located on the outskirts of a town or a village. Electric energy and heat are produced in a generator located in a close neighbourhood to its consumers;
– production of biogas in a biogas plant located by a farm and transport of biogas by a pipeline to a generator situated in a housing estate. Such a location is more acceptable to the local community due to a reduction of odours produced in farm facilities owing to an increased distance from populated areas. Owing to the separation of costs into electricity and heat produced and sold completely, production unit costs are reduced;
– pumping biogas produced into the national gas grid. This variant is rarely used because the compression of biogas and its purification to obtain the parameters of natural gas is expensive, and for this reason, this is possible only when there is a gas grid in the direct neighbourhood;
– compression and liquefying of biogas to a liquid form and its use to drive transport vehicles, e.g. municipal buses [Gostomczyk 2012, Scarlat et al. 2010].

Those factors that are responsible for the economic effectiveness of the operation of agricultural biogas plants include both their structures and biogas production technologies used.

At present, there is a tendency to increase the sizes of biogas plants and to unify them. Modern biogas plants can process both single substrates in the process of the so-called mono-fermentation and mixtures of several substrates. We then deal with co-fermentation. This increases the security of resource supplies to the biogas plant, but it requires a strict observance of the technological regime. Substrates for the production of biogas should be selected bearing in mind a maximization of the biogas yield, the availability of resources and their prices, the stability of the fermentation process and the possibility to use the digestate mass produced. Due to economic determinants, the location of the biogas plant is optimal within a range of 10 kilometres from the source of supplies. Transport costs and the condition and quality of roads, i.e. logistic determinants, are decisive here. In the case of the sale of heat, which should currently be a standard, the distance of the hot water pipeline from the cogeneration aggregate and the heat collection point (flats, public buildings, those plants that use heat in production) is of a great significance.

Conclusions

Poland possesses a high potential of biomass which can be used for energy purposes. The biomass potential that exists in the region constitutes an opportunity which may or not be taken an advantage of. This offers a great opportunity of an activation of rural areas and utilization of all organic waste from plants and animals and building energy safety. The volume of the biomass potential constitutes merely a determinant of the possibilities related to the development of bioenergetics in the aspect of sustainable development. It is important to consider the possibility to introduce a cogeneration system (where electricity and heat are produced) and to use modern and highly efficient technologies, ones that are justified by cost efficiency [Gaczek 2009, IBMER 2008]. In this context, with an optimal use of the biomass potential in regions, Poland will cover its own demands in accordance with the National Indicative Target; what it more, it may become an exporter of biofuels and surpluses in the CO_2 emission trade. On the grounds of the analyses and calculations performed, the following conclusions can be formulated:

1. Many of those installations that use renewable resources are at an initial stage of technological development; without any additional financial support, they are unable to compete with conventional fuels.
2. Owing to the technological progress, both investment and operational costs are being systematically reduced.
3. In order to guarantee the competitiveness of energy produced from biomass, the creation of hybrid installations is recommended: ones that guarantee the use of resources and energy in closed and complementary systems.
4. Processing of biomass in biogas plants, and processing of by-products and waste products in particular, constitutes a form of their utilization; for this very reason, their environmental impact is very positive.
5. Important factors that contribute to an effective utilization of biomass include the prices of energy and green certificates, the technologies used and the selection of the material used in a given technology.
6. Seeking and introducing hybrid technologies based on waste products, owing to a high economic effectiveness, will allow one to compete with traditional fuels in the future, without any need of additional subsidies.

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Streszczenie

Celem pracy jest przedstawienie uzasadnienia wykorzystania biomasy z rolnictwa do celów energetycznych. Powinno to służyć wypełnieniu przez Polskę zadań zgodnie z Narodowym Celem Wskaźnikowym (NCW) w 2020 roku. Wykorzystanie lokalnej biomasy powinno zmierzać do podnoszenia konkurencyjności regionalnej w oparciu o endogeniczny, regionalny potencjał. Szczególną uwagę zwrócono na konieczność produkcji energii cieplnej i elektrycznej (CHP) w systemie rozproszonym w niewielkich lokalnych elektrociepłowniach. Polska jest krajem o wysokim potencjale biomasy. Przedstawiono również aktualny stan rozwoju sektora biogazowego oraz wykorzystywanych surowców. Warunkiem rozwoju tego sektora jest ciągłe dążenie do uzyskania wysokiej efektywności ekonomicznej produkcji energii z biogazu, pozwalającej w przyszłości konkurować z paliwami konwencjonalnymi.

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