Zawada et al., 2017

Volume 3 Issue 2, pp. 716 - 729

Date of Publication: 18th September, 2017

DOI-https://dx.doi.org/10.20319/pijss.2017.32.716729

This paper can be cited as: Zawada, M., Kowalik, J., & Kucęba, R. (2017). Biogas Plants as an Element of Prosumer Energy Development in the European Union. PEOPLE: International Journal of Social Sciences, 3(2), 716-729.

BIOGAS PLANTS AS AN ELEMENT OF PROSUMER ENERGY DEVELOPMENT IN THE EUROPEAN UNION

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Abstract

The aim of this study is to assess the situation on the market for biogas plants in the EU, an analysis of the environmental benefits of the construction of agricultural biogas plants and the prospects for the development of this industry in the context of the prosumer energy. In the first part of this article the Authors provide basic information about agricultural production of gas in the European Union (total installed capacity, the number of biogas plants, different types of biogas plants, types of substrates used to feed the Biogas plants). The second part of the study provides an overview of the legislation governing prosumer energy and development of this element of the energy market which is an important and permanent part of the EU energy policy.

In the third part of this paper the conducted SWOT analysis shows the strengths and weaknesses of the biogas energy, as well as the opportunities and threats of its further development. The scope of the research covers the period 2007-2015. In order to assess biogas plants market development, the Authors have used elements of multivariate statistical analysis and applied Herfindahl-Hirschman Index assessing the degree of concentration in this market.

Keywords

Agricultural Biogas, Renewable Energy, Prosumer, HHI index, SWOT Analysis

1. Introduction

Many countries in Europe and in the world are restructuring their energy systems influenced by the strong impact of so called megatrends. Megatrends are large and permanent social, economic, technological or political changes, which influence societies, governments and economies of particular countries. They formulate slowly, but once they become dynamic, they are irreversible. The most important megatrends in the European energy industry include first of all decreasing costs of energy production in renewable sources, limited impact of this industry on health, a decreasing share of coal in the energy and fuel balance, emerging new business models in the energy industry (Forum, 2016). The undergoing changes reflect the main assumption of the European Union's (EU) energy policy, which comprises: an increase in the use of renewable energy sources (RES), reduction of carbon dioxide emission and growth of energy efficiency until the year 2020 (commonly known as 3x20), as well as a full decarbonisation of the energy sector until 2050 (Malko, 2014).

For the last few years the energy sector has been undergoing a deep transformation connected with a decrease in the share of conventional coal-based energy in favour of new energy production technologies and a significant share of renewable energy (Charan, 2017). From the centralised production towards dispersed technologies and form providing only energy for final recipients towards combining innovative products and services connected with it. Consumers are slowly becoming prosumers, connected to the network and producing more and more energy.

Agricultural biogas and agricultural biogas plants belong to the fastest developing segments of renewable energy sector in Europe, especially in Germany. Human beings have been interested in producing biogas for ages: the earliest records about the use of biogas come from Assyria from the 10th century B.C. The first biogas installation was built in Bombay (India) in the leper colony, and in 1895 in Exeter biogas was used to light the streets. Biogas as a transport fuel was used for the first time by the German army during the Second World War (Bond & Templeton, 2015).

Biogas plants, although known and used successfully already in the 19th century as an excellent energy source in Europe, was only appreciated in the 1980s of the previous century. Presently, they experience a revival of their application. This is connected on the one hand with the guaranteed supply of the source to produce it, and on the other hand with improved technological and economic parameters of its acquisition and use (Deublein & Steinhauser, 2011).

A biogas plant is a complex system of devices created to produce biogas from animal biomass (faeces), plant biomass, organic waste and sewage. In cogeneration, aggregate biogas is used to produce electricity and heat. The location of the biogas plant and the type of biomass used determine their division into the agricultural ones, biogas plants at rubbish dumps and biogas plants at water treatment stations (Simbolon, 2015).

Biogas is used to produce electricity, usually in cogeneration with production of heat or cool, and also, enriched, constitutes an alternative fuel for transport. Vehicles powered with biomethane generate lower emission of fumes, as methane combusts entirely and its calorific value is higher (55,5 MJ/kg) than this of petrol (43–45 MJ/kg), diesel oil (43 MJ/kg) or LPG (50,4 MJ/kg), and is also characterized by a lower level of noise, as the combustion process is smoother than in petrol or diesel oil powered vehicles (Kochańska, 2012).

The level of biogas energy in the world is very differentiated, both with reference to the number of installations as well as the level of their complexity. The largest number of installations can be found in Asia. It is estimated that in China itself function about 6-7 million of them, in India about 1 million. Other countries where they are popular are Vietnam and Thailand. However, these are simple household installations of very simple construction, small sizes and built using home-grown methods. Main resource used in the anaerobic digestion is livestock manure and organic waste from households (Biogazownie na świecie, 2016).

The opposite are biogas plants functioning in some European countries. Despite the fact that the history of contemporary turnkey constructions has been just 10-15 years long, these are large installations of large level of technological advancement. The world leader in this industry is Germany, where functions over 10 000 of biogas plants, and the total power amounts about 900 MW. The upwards trend still remains at a high level. Other countries of high level of biogas energy development are Denmark, Sweden, Austria and Switzerland. In Spain, England, Ireland, Poland, Lithuania and Hungary a growing interest in installations of this type can be observed. These are countries characterized by a high dynamism of biogas sector development (Torrijos, 2016).

2. Biogas Production in Europe

According to data by the European Biogas Association (European Biogas Association, 2016) in 2015, the total number of biogas plants in Europe was 17 358 (Figure 1). An indisputable leader in the number of active biogas plants is Germany, where there are 10 846 of them. Italy is in the second place with 1555 biogas plants. The top ten countries include: France (717), Switzerland (638), Czech Republic (554) and Great Britain (523), Austria (444), Sweden (282), Poland (277) and the Netherlands (268). The last positions in the rank occupy Romania (11) and Serbia (7) and Iceland (4). The number of biogas plants in Europe increased by 3 percent, or by 542 plants, in 2015. Significant increases were achieved in some countries, such as the U.K. adding 77 plants, representing 17 percent growth; Belgium growing by 11 percent, or by 20 plants; and the Netherlands adding 16 plants, a growth rate of 6 percent.

The total installed capacity of European biogas plants grew in the years 2010-2014 from 4136 to 8339 MWel.

The number of biomethane plants in 2014 was 367 with a strong domination of Germany (178 plants) followed by Sweden (59 plants) and Great Britain (27 plants). Biomethane industry is still at a very early stage in Hungary (2 plants) and Spain (1 plant).

The European Commission indicates in the report "Optimal use of biogas from waste streams - An assessment of the potential of biogas from digestion in the EU beyond 2020" (Optimal use, 2016), that in 2014 as much as 77% of biogas production in the European Union belonged to Germany, Great Britain and Italy, where Germany produced impressive 7,4 Mtoe (311 PJ).The biogas produced in the European Union is dominated by the organic substrate generation (72%), carried out mainly in agricultural biogas plants, and a smaller share belongs to the biogas produced at rubbish dumps (18%) and at water treatment plants (9%). The produced in the European Union biogas is used mainly to produce electricity (62%), and to a smaller extent heat (27%). The remaining 11% is biogas used in transport or directly fed to the gas network.

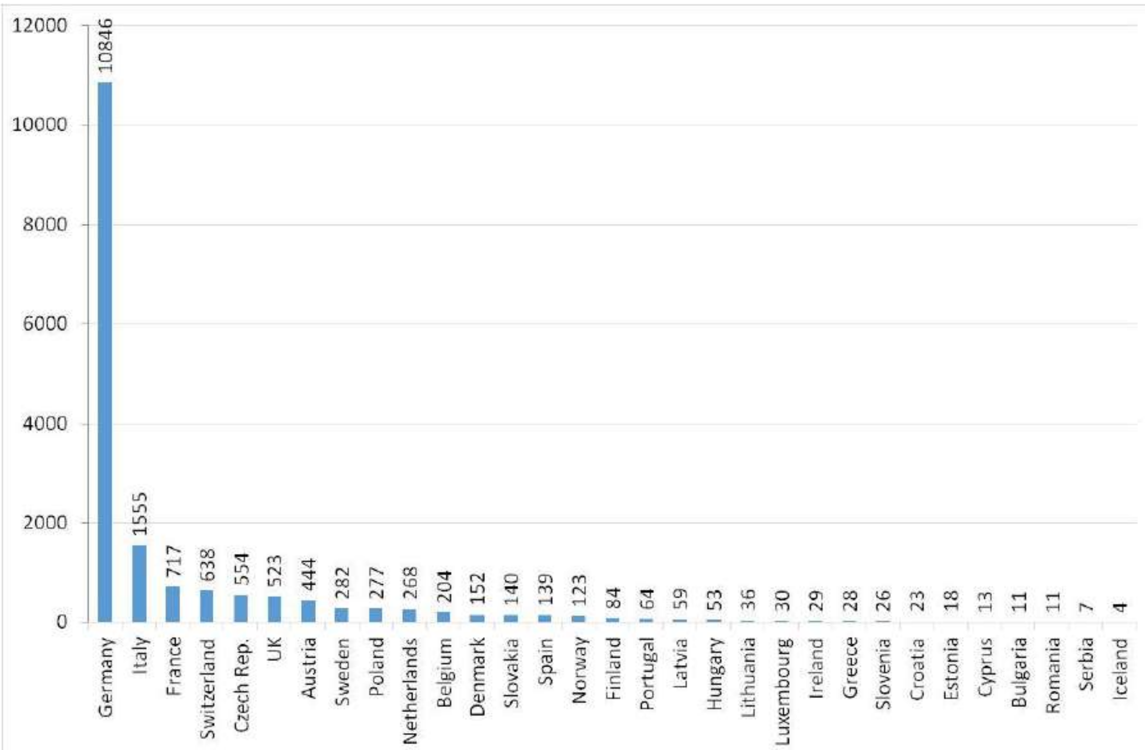

Figure 1: *Biogas plants in Europa (31.12.2015), Source: European Biogas Association*

3. Concentration on the Biogas Plants Market in the Eu

Concentration measures are numerical characteristics which are used to determine the irregularity level of a tested feature. The concentration phenomenon is expressed by a concentration of a significant percentage of the tested feature value in a relatively small percentage of the units of the collective. Lack of concentration happens if all the units possess identical value of the feature. Studying the competition state consists in a search for a comprehensive concentration ratio, which would reflect not only the ultimate number of entities functioning on the market, but also their relative size. So far, one, best concentration measure has not been developed. Depending on the needs and availability of data mainly concentration ratio is used (CR), Herfindahl- Hirschman average market concentration index, Grossack concentration dynamism index, and Gini concentration coefficient most frequently illustrated by the Lorenz curve (Yang & Dong, 2016; Devereux et al., 2004).

Table 1: *Installed capacity (MW) in biogas plants in Europe in the years 2007-2015 and HHI concentration index*

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015
HHI	0,2465	0,2493	0,2608	0,2692	0,2722	0,2546	0,2658	0,2794	0,2770
Austria	289	285	335	330	372	377	194	192	206
Belgium	68	88	105	115	129	141	151	172	183
Bulgaria	0	0	3	4	5	5	4	10	10
Croatia	2	4	5	6	8	11	17	17	26
Cyprus	1	7	8	8	9	9	10	10	10
Czech Republic	50	71	96	118	177	300	361	384	384
Denmark	59	74	77	80	77	80	84	95	95
Estonia	2	2	2	4	4	4	6	8	8
Finland	2	2	3	18	18	18	18	18	18
France	107	127	159	171	206	247	273	320	363
Germany	1676	1913	2360	2840	3501	3911	4210	4820	4976
Greece	39	40	40	41	45	45	46	47	52
Hungary	19	19	24	24	45	53	63	63	63
Ireland	27	29	30	31	34	40	40	53	57
Italy	329	349	359	480	732	1274	1317	1336	1390
Latvia	7	7	8	11	25	43	53	58	58
Lithuania	6	8	8	13	15	15	16	19	23
Luxemburg	6	8	9	9	10	10	10	10	10
Netherlands	124	167	186	200	217	220	230	237	237
Poland	40	52	68	81	102	128	153	187	211
Portugal	13	13	20	25	44	51	55	66	67
Romania	0	0	0	1	4	5	11	15	15
Slovenia	8	9	12	14	21	29	29	37	38
Slovakia	3	4	4	9	21	41	35	78	78
Spain	165	149	177	205	209	218	220	223	225
Sweden	24	24	17	22	4	5	5	2	5
United Kingdom	1082	1084	1226	1353	1442	1489	1528	1476	1519

Source: Own calculations based on International Renewable Energy Agency 2016

The Herfindahl-Hirschman index (HHI) is the most frequently applied market concentration measure on the energy market (Chuang & Ma, 2013). It is defined as a sum of market share squares and calculated according to the formula:

$$HHI = \sum_{i=1}^{n} {u_i}^2 \qquad (1)$$

where u_i means the value of the tested feature for the i-th object in the total value of the tested feature for all n analysed units.

The HHI index takes values from the range (1/n; 1), while the higher its value, the higher the concentration. According to the recommendations by FERC (Federal Energy Regulatory Commission) in the USA the index value:

- below 0,10 indicates lack of concentration,
- from 0,10 to 0,18 indicates a fairly high concentration,
- above 0,18 indicates a very high concentration.

However, the use of concentration measures does not provide a full picture of the energy market functioning, as these risk measures do not consider all the information necessary for full market analysis (Zawada, 2009).

While analysing information included in tab. 1 one can notice that the largest installed capacity in biogas plants is in Germany, Great Britain and Italy. The smallest one is in Sweden, Estonia and Cyprus. The HHI concentration index during the analysed years takes the values above 0,18, which indicates a high concentration of the biogas plants market and means that there are countries, which due to the installed capacity reach leading positions in the European Union. This situation will probably not change soon. The leading countries will still build new biogas plants in their territories, the countries with a small potential will not enlarge their market share soon.

4. Prosumer Energy Development in the Context of Biogas Plants Market

Prosumption is not a new phenomenon. Production and following it consumption of goods and services by the producer was characteristic for a very early stage of human civilisation development. Presently, it takes new forms, the emergence of which was possible thanks to the development of new techniques and technologies. Prosumers can produce electricity (and/or heat) either to satisfy their own needs, or to make the surpluses of production available to other users. In the first case, it is off grid presumption (outside the network) and in the second case it is on grid presumption (within the network). The biggest chances of becoming a prosumer on the electricity market are connected with installation of photovoltaic panels, wind generators, small hydro-energy and biogas production (Burchard-Dziubińska, 2015).

The use of renewable energy sources (RES) is one of the key actions of the EU horizontal policy in the scope of climate protection, energy security and environmental protection. Reducing the emission of harmful substances (mainly greenhouse gases), a positive influence on the security of energy supplies and effective energy use, are the factors vital for the development of household energy systems. Thus, energy industry closely connected with environmental protection requires a new approach to the efficiency in the economy and building a strong position of social energy industry, which will implement social goals through creation and activation of prosumer movement. The basic barriers of prosumer energy model development include first of all lack of sufficient information for enterprises and households, and also problems with acquiring necessary capital. The idea of prosumer energy is a relatively new one, but it has already been implemented in many countries.

A promising solution of the prosumer energy in the context of renewable energy may become biogas installations, in which electricity is produced as a result of combusting gas which is created in the process of waste digestion. These plants are not dependent on weather conditions, thanks to which they can produce energy during the whole year. Another advantage of biogas plants is also operation in cogeneration systems, where electricity and heat are produced simultaneously. Contrary to energy acquired from sunlight or wind, production of agricultural biogas offers a series of additional advantages. The ones that can be indicated include organic waste utilization (instead of purposeful biomass acquisition on arable land), or additional reduction of methane, ammonium and nitrogen oxides emission, which in case of lack of organic matter utilization, being a side-effect of agricultural production, would be emitted into the atmosphere. Especially predisposed to produce biogas are farms where animal production takes place, which due to the type of activity possess a proper substrate (Sulewski et al., 2016).

The European Union's directive 2009/28/WE in force, which concerns promoting the use of energy coming from renewable sources does not refer directly to the prosumer generation. What is more, in almost the entire climate and energy package of the EU there are currently no regulations which would support an active participation of citizens on the energy market. It is also worth stressing that the electro-energy directive does not use the term of consumer, but “recipients” of energy. As a result, the level of the guaranteed by law rights for prosumers in particular member states differs significantly. Therefore, it is postulated that the European law should include at least general framework, which would harmonise regulations concerning the rules according to which the citizens can participate in the energy market. In particular, the term prosumer has to be defined in the European Union’s law. The most suitable place to do so seems to be the future, general electro-energy directive (the successor to the 2009/72/WE directive). The prosumer should be defined in the EU law as an active energy recipient, who – individually or collectively – participates in at least one area (Bator & Kukuła, 2016):

- Producing energy from renewable sources or introducing this energy into the network;
- Storing energy
- Energy consumption management (DSM).

5. SWOT Analysis

SWOT is a comprehensive method of strategic analysis, which considers both testing the inside of the venture/organization as well as its external environment. It consists identifying key advantages and weaknesses and confronting them with present and future opportunities and threats (Chen et al., 2014). The SWOT analysis is one of the most frequently applied tools of strategic analysis. On the basis of SWOT it is possible to receive a set of:

- S (Strengths) –strong sides, which need to be strengthened,
- W(Weaknesses) –weak sides, which need to be eliminated/reduced,
- O(Opportunities) –opportunities, which need to be used,
- T(Threats) –threats, which need to be avoided

The SWOT analysis allows to systematize the knowledge, notice new possibilities or threats, sensitizes to certain issues. This is a good opportunity to recognize the market/environment, verify the project assumptions, test the trends.

The literature on the subject includes numerous examples of SWOT analysis application for the needs of energy market. This concerns mainly renewable energy sources (Brzezińska-Rawa & Goździewicz-Biechońska, 2014; Aydin, 2014), use of nuclear energy (Martinez-Alegria et al., 2014) and energy sources use in the aspect of climate changes (Wang & Li, 2016) and pollutant emission reduction.

Table 1.2 *SWOT analysis for biogas plants development in Poland*

Strong sides	**Weak sides**
• Additional source of income • Utilization of available resources • Reduced energy costs through self -provision • Recovery of fermentation residuals in agriculture • Development of municipal anaerobic digestion plants to handle municipal organic wastes	• Low financial strength • Potential underutilization of plant capacity • Lack of use for heat generated • Lack of technology know-how • Local community resistance
Opportunities	**Threats**
• Fast development of biogas technology • Climate change • Reduced dependency on energy imports • Multifunctionality of biogas • Development projects for rural areas • Large potential for energy crops and other 'new' substrates • Rural areas development, programme of new work posts creation, improved incomes of rural population • A move towards creating energy self-sufficiency – regional and local one.	• Feed-in-tariff depends on policy • Food vs. fuel dilemma • Low acceptance rate among neighbours • Small- scale agriculture • Large investment costs

Source: Own Elaboration

On the basis of the literature review (Igliński et al., 2015; Brudermann et al., 2015; Martin, 2015) in the scope of biogas plants functioning as well as own conclusions, the following SWOT analysis for biogas plants development in Europe has been created:

The presented summary shows that the number of strong sides and opportunities is much higher than the number of weaknesses and threats which emerge on the path of investments and biogas plants development in Europe. Undoubtedly, the most important thing turns out to be creating a good political climate for their development.

6. Conclusions

The electro-energy system in Europe is presently experiencing serious transformations. The most important goals of these transformations are: development towards a unified energy market, improved cross-border flows of transmission capability allocations. Efficient and competitive wholesale markets and increased energy efficiency and the importance of demand management. On the other hand, in Europe, as well as in the whole world one can observe a significant growth of investments into renewable energy sources, in this biogas production, and quick development of transport connected with the use of electric cars.

An advantage of biogas production is that it combines two EU's policies: the one concerning renewable energy and the other one in the scope of organic waste management. The goal of both these policies is to increase efficiency of waste management; on the one hand this concerns an increase in the amount of biodegradable waste, transported to rubbish dumps, waste recycling and retrieval, and on the other hand – an increase in the share of energy coming from sources other than fossil fuels in the energy balance of member states.

Apart from the possibility to successfully manage the troublesome waste biomass and produce energy qualified as renewable one, agricultural biogas plants are also a source of other environmental benefits. For farms, they also result from creation in the technological process used in biogas plants production material (digested slurry – so called digestate), which constitutes a high-quality fertiliser. 1 MWh of electricity produced from agricultural biogas is the carrier of even several Times lower amounts of basic air pollutants (mainly sulphur dioxide and nitrogen oxides), than the same amount of fossil fuels (Olbrycka, 2014).

The profitability of agricultural biogas plants is influenced by numerous factors, which if controlled properly ensure cost and incomes profitability and the venture profitability. The factors which influence profitability of agricultural biogas plants, or rather can be to a large extent controlled by the investor include: guaranteed supplies for many years, purchase price of substrates, using the resources of high biogas productivity as a feed, reducing to minimum the distance of transporting the feed material to biogas plants, the possibility to manage the post-digestate pulp on own fields or the guarantee of reception by other entities, a possibility of acquiring support for highly effective cogeneration, proper infrastructure, limiting the size of tanks (digestion chambers, lagoons), production level guaranteed for many years by the technology provider.

Energy production in biogas plants supplements very well production in system sources, enabling a decrease in the demand for peak capacity and network losses. Moreover, by building agricultural biogas plants a new branch of business activity is created in local conditions. Biogas plants also contribute to an increase in social effects, thanks to generating by them new work posts. Thus, building such installations is desirable and in the years to come it can be expected that they will still dynamically develop.

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