

## Anomalies in energy production in Polish biogas plants

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**Abstract:** *Anomalies in energy production in Polish biogas plants.* The production of agricultural biogas in Poland becomes increasingly common year by year. Owing to the quarterly reporting obligation imposed on operators of the installations by applicable provisions of law, we are able to analyse the presented data. This paper is based on official information provided by the Agricultural Market Agency, which casts doubt on the effectiveness of operation of Polish agricultural biogas plants.

*Key words:* biogas production, biogas quality, process efficiency

### INTRODUCTION

Essentially, the amount of biogas produced depends on the composition of the substrates used. In practice, an exact calculation is virtually impossible, because of the lack of knowledge on concentration of individual nutrients included in the majority of the substrates mixed [Stejskal 2008]. Moreover, all such computations should assume a 100% decomposition of organic matter, which is in fact impossible [Klinski 2016]. The processes of decomposition in a biogas plant and the processes of digestion in ruminants have several common features, depending on the nutritional content and digestibility of animal organisms, wherefore it is only possible to calculate the theoretical yield of biogas [Weiland 2003]. Nevertheless, if the amount of the biogas produced is

already known, further computations become easier.

The majority of Polish agricultural biogas plants operate in a direct vicinity of large animal farms or industrial plants, i.e. close to the sources of substrates. Currently, there are 81 agricultural biogas plants in Poland with total electric capacity of 88.4 MW and average installed electric capacity of about 1.2 MWe. The annual productivity of all installations exceeds 340 million m<sup>3</sup>, which is almost twice the production from 2014.

As shown on Figure 1, total annual biogas production in Poland rose significantly from 2011 to 2014 and an overall upward trend can be noticed. It needs to be highlighted that all agricultural biogas plants in Poland are equipped with Combined Heat and Power (CHP) units, which ensures simultaneous production of electricity and heat from a single fuel source, such as natural gas, biomass, biogas, coal or oil. The CHP systems and biogas treatment technologies used have improved significantly [Zuza et al. 2015], which in turn enhanced the efficiency of the energy generation process.

The annual efficiency of the installations should be determined by the installed capacity of agricultural biogas plants in Poland and can be divided in three main groups: 0.6–2.5, 2.6–6.2 and

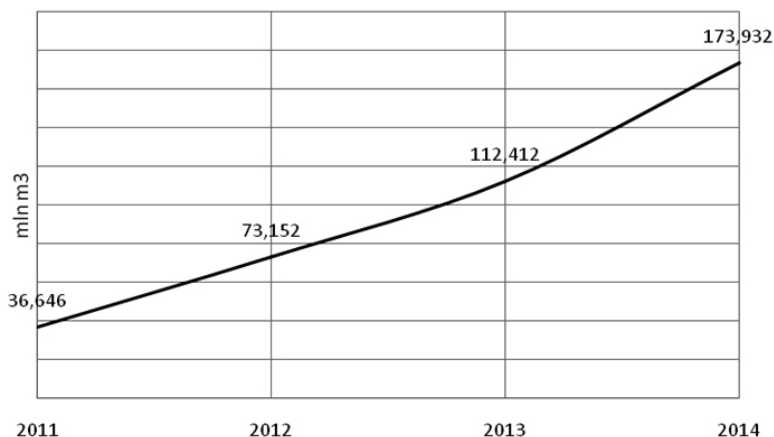


FIGURE 1. Total annual production of biogas from Polish biogas plants in 2011–2014 [ARR 2016]

6.3–8.3 million m<sup>3</sup> · year<sup>-1</sup> [Chodkowska-Miszczuk, Szymańska 2013]. The analysis of the data related to annual biogas production from installations in Poland seems correct without any restrictions. The variable element is the amount of electricity and heat produced from the declared biogas volume.

## MATERIALS AND METHODS

According to the Polish RES Act, entrepreneurs whose business activity involves production of agricultural biogas or electricity generation from agricultural biogas are required to register in the registry kept by the President of the Agricultural Market Agency (ARR),

providing the following data (available on the ARR website):

- the amount and type of raw materials used to produce agricultural biogas or to generate electricity from biogas;
- the amount of produced biogas, with specification of agricultural biogas entered into the gas distribution network, used for electricity generation in a separated or co-generation system or in a different manner;
- the amount of heat and electricity generated from agricultural biogas in a separated or co-generation system.

The analysis of official data reveals low effectiveness of the biogas conversion process and raises significant doubt related to biogas production and management on the Polish market (Table 1).

TABLE 1. Annual production from Polish biogas plants [ARR 2016]

Year	Annual biogas production	Annual electricity production	Annual heat production
	M m <sup>3</sup>	GWh	
2011	3 665	73.43	82.64
2012	73.15	141.80	160.13
2013	112.41	227.88	246.56
2014	173.93	354.92	373.70

Any commercially profitable biogas plant must operate with maximum efficiency in order to obtain maximum output over the long haul. Any inefficient or interrupted process can seriously affect the final results. Even at small plants with a capacity of 500 kW or less, any downtime easily brings about losses of several thousand euros a day [ABB 2011].

The efficiency of the process of energy production from biogas can be defined by practical efficiency limits of CHP unit mating with the specific biogas plant. However, such data are unavailable and verification was performed by means of theoretical calculation.

According to various estimates, the content of chemical energy in of biogas equals about 6.1 kWh [Banks 2009]. Based on standards for high-efficiency cogeneration, the author assumes that about 40% of electric energy (2.44 kWh) and 43% (2.62 kWh) of heat is produced in a conversion process. The remaining 17% of the energy (1.04 kWh) is lost. In the subsequent parts of the present paper, these rates shall be called efficiency ratios.

As the total biogas production expressed in million m<sup>3</sup> is known, and so is the average electrical efficiency of the CHP motor, the theoretical electricity production was calculated by simple multiplication. The theoretical heat production was calculated in a similar way.

electricity production = biogas volume ×  
× electricity efficiency ratio

heat production = biogas volume ×  
× heat efficiency ratio

The next step involved comparison of the factual and theoretical (calculated) values and combined percentage efficiency of the factual amounts from ARR's data.

## RESULTS AND DISCUSSION

The results of the calculations supported the hypothesis that the effectiveness of the biogas conversion process is surprisingly low. As seen on the line graph (Fig. 2), the energy lost in generation

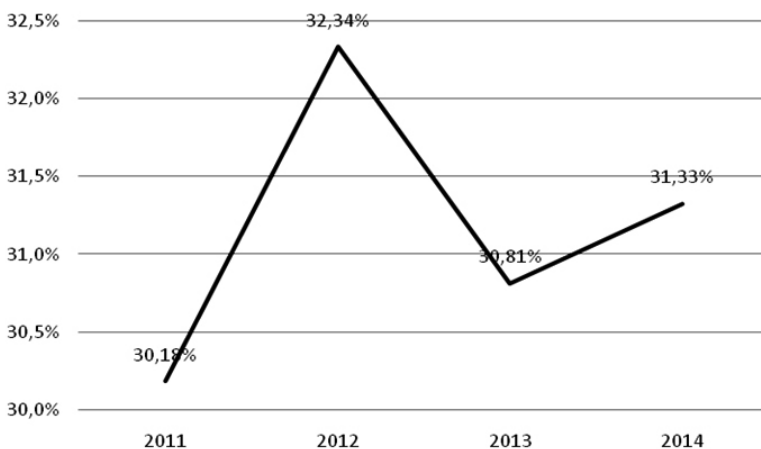


FIGURE 2. Loss of energy [%] in the process of production of energy from Polish biogas plants in 2011–2014

process amounts to about 30%. Although this was understandable in 2012, when the Polish government held back the support scheme for the “yellow certificates”<sup>1</sup>, in other years the results presented are unacceptable.

The difference between the factual amounts of energy production and the calculated values is significant. The thermal and electrical efficiencies of the CHP unit are directly related to the power outputs, and the thermal efficiency is much higher than the electrical efficiency (Table 2).

(Mtoe) of biogas primary energy were produced during 2013, which was by 1.2 mtoe more than in 2012 (a growth of 10.2%). Based on the information above it can be assumed that biogas plants in the EU are effective in energy generation and maintain economic balance. Figure 5 shows the level of energy lost in the generation process in several EU members (as a sum of all biogas plants, in percentage, between 2011 and 2014). As shown on the graph, most of the countries analysed have a transformation input lower than 25%.

TABLE 2. Calculated production from Polish biogas plants [ARR 2016]

Year	Annual biogas production	Annual electricity production	Annual heat production
	M m <sup>3</sup>	GWh	
2011	36.65	89.42	96.12
2012	73.15	178.49	191.88
2013	112.41	274.29	294.86
2014	173.93	424.39	456.22

The bar charts (Figs 3, 4) illustrate a comparison between factual and calculated amounts of heat and electricity. Even though the trend in both cases is increasing, a lot of energy seems to be wasted each year.

To get a wider perspective of the presented anomaly, the author collected available data from selected European countries. The expansion of biogas energy usage has continued across the European Union. According to [EurObservER 2014], about 13.4 million t oil equivalent

The estimation of energy production in Polish biogas plants constitutes an element of broader discussions on the perspectives of energy production from biomass [Bloch-Michalik and Gaworski 2015].

## CONCLUSIONS

Firstly, it can be concluded that the volumes of electricity produced in Polish biogas plants differ significantly from the desirable amounts. The same applies to heat. Secondly, when compared to other European countries, the efficiency of Polish biogas energy efficiency does not look well. In the next step, the reasons for such a state of affairs should be analysed.

<sup>1</sup>Yellow certificates have been targeted at the entities that generate electricity in highly efficient cogeneration system fired by gaseous fuels (irrespective of the capacity installed) or with total electrical capacity installed at the source below 1 MW.

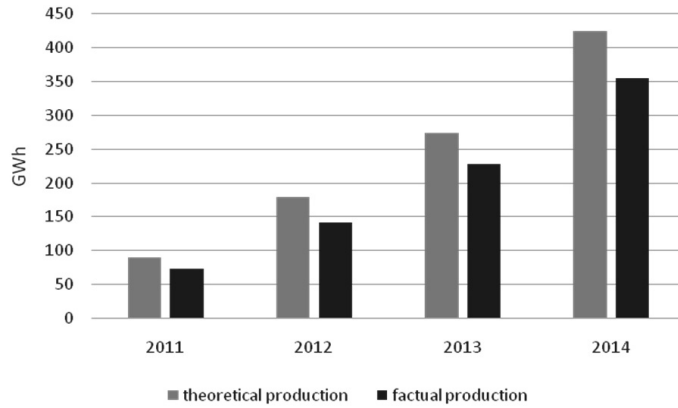


FIGURE 3. Comparison of theoretical and factual electricity production in 2011–2014

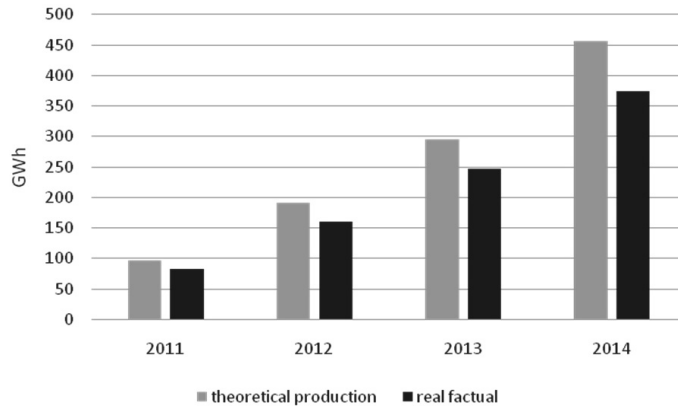


FIGURE 4. Comparison of theoretical and factual heat production in 2011–2014

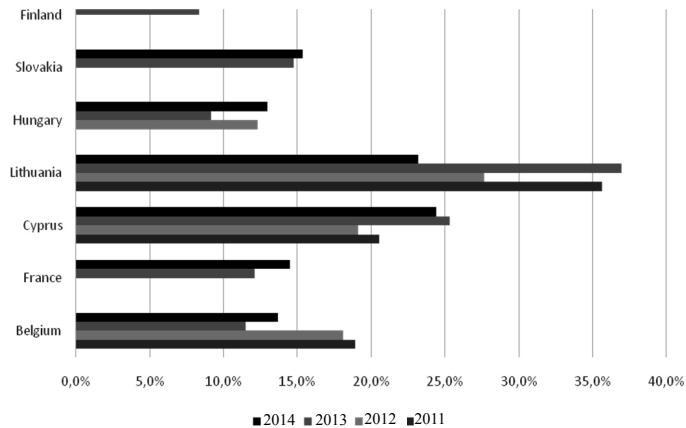


FIGURE 5. Transformation input used to produce energy in CHP biogas plants in selected EU Member States in 2011–2014 [<http://ec.europa.eu/eurostat/data/database>, accessed: March 2016]

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**Streszczenie:** *Anomalie produkcji energii w polskich biogazowniach.* Produkcja biogazu rolniczego w Polsce staje się coraz bardziej rozpowszechniona. Dzięki prawnemu zobligowaniu operatorów instalacji biogazowych do kwartalnej sprawozdawczości istnieje możliwość poddania analizie zbioru przedstawianych przez operatorów danych. W artykule, bazując na oficjalnych informacjach publikowanych przez Agencję Rynku Rolnego, poddano krytycznej ocenie efektywność pracy polskich biogazowni rolniczych.

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