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# Practical usage of additional heat from biogas plant

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**Abstract.** Biogas plants are one of the most stable and cost-effective energy sources. The better volume of produced biogas is used for parallel electricity and heat production in CHP gas engines. The heat from the engine is conveniently used for heating the digester but the additional amount causes lot of problems and is wasted despite its large potential. The inefficiency in energy use is a bottleneck in current biogas production, causing macroeconomic and microeconomic losses and challenges in the context of increasing land use competition. As a major output of the biogas management process research provide by authors, this article was elaborated in order to introduce the results of theoretical heating system analysis.

**Key words:** biogas, heat balance, CHP.

## INTRODUCTION

In order to management the heat produced additionally in the process of electricity generation it is necessary to consider its usage instead of release into the environment. Biogas heat and power plant driven by a combustion engine produces heat at different temperatures (Borowski et al., 2014; Żak et al., 2014). The largest amount of heat can be recovered by a cooling engine. Due to its temperature, this heat can be used to provide heating energy, or the energy for the biogas production process (i.e. fermentation).

The highest and usually only demand for heat occurs in winter time whereas lost in other months of year.

Average demand for heat use to provide constant fermentation process covers about 25–40% of produced heat (Jäkel, 2002).

The so called waste heat from biogas plants, like any kind of heat is characterized by the temperature level and by the quantity. For the development of waste heat concepts, the temperature and the amount of heat are important, since the heat user always needs a certain minimum level of both figures. The temperature of the waste heat source needs to be always higher than the temperature of the heat sink. The magnitude of the temperature difference between the heat source and sink is an important determinant of the quality of waste heat.

With higher waste heat temperatures, more opportunities for its use exist. Examples typical for the use of waste heat from biogas plants can be divided by minimum temperatures needed in different uses areas like (Ramanauskaire et al., 2012):

- hot water supply: 50–80 °C;
- residential heating: 50–80 °C;

- rankine cycles (ORC, CRC): 60–565 °C;
- dryer for agricultural products: 60–150 °C.

As the exhaust gas temperature of CHP units in biogas plants is typically about 450–520 °C, the use of waste heat from biogas plants is limited.

Calculations contained in this paper base on case study object and due to that authors have assumed that the best solution for heat management in existing biogas units is to enable distribution of heating to own edifices or to third parties. This seems well-grounded for the biogas plants cooperating with sewage treatment plants, because of their characteristic:

- permanent supply of feedstock (sewage sludge);
- suitable for media distribution infrastructure;
- (frequently) the optimum location – urban periphery, where is demand for cost competitive network heating.

Therefore, paper will present the methodology of the tests performed on typical sewage biogas plant containing heat and economic balances, as well as comparison of the development concept for manage surplus heat for own non-processing needs (i.e. heating social accommodation) and external sales.

## MATERIALS AND METHODS

Not utilising heat from incineration amounts to wasting the energy. Wasting heat is not just illogical as it wastes energy, but also results in macroeconomic and microeconomic losses. European countries, likewise Poland are heavily dependent on energy imports, climate change is forcing the EU to decrease its $CO_2$ emissions, and climate change policies highlight the need for renewable resources. Biogas represents a renewable and domestic resource that plays a role in all these fields. Its potential for efficient use, i.e. utilising the surplus heat, brings major benefits as it results in a decreased primary energy demand.

### Overlook of heat from biogas production in Poland

On Polish biogas market we can identify three main types of biogas plants differentiate between main substrates (Bloch-Michalik & Gaworski, 2015):

- landfill biogas plant, which are 'running on' organic wastes;

  Organic wastes mean separate collected fruit and vegetable wastes, flower soil, flowers, eggshells, coffee and tea filters and other organic leftovers also leftovers from cutting gardens or parks which do not contain woody matter – due to the Polish practice all organic wastes find its way into landfill;
- sewage biogas plants use communal sludge;

  Communal sewage sludge with percentage of dry matter varies between 20 and 30%;
- agricultural biogas plants that's producing biogas from different wastes from a wide-mean agriculture and farming.

  Farming wastes implied as liquid or solid manure from animal farming, energy crops and industrial food waste from vegetable, fruit or meat production sites or process.

As a number of biogas plants in Poland increases as well heat production become more significant (Fig. 1).

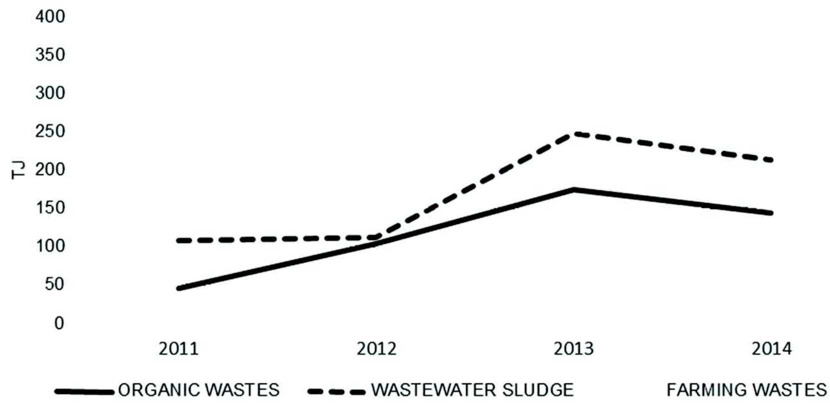


**Figure 1.** Heat produced from different types of biogas in Poland; 2011–2014 (GUS, 2015).

In Polish circumstances produced biogas is converted into energy in three ways:

- spark ignition engines or turbines;
- adapted gas boilers;
- CHP units.

The most common technical equipment comprises boilers use first and foremost on wastewater treatment biogas plants and landfill biogas plants. However, from over 170 landfill biogas plants in Poland less than a half use produced biogas for energetic reason.

Even so all farming biogas plants (nearly 80) are equipped with CHP units (ARR, 2016) and farming wastes generate the greatest amount of heat from all the types of biogas plants (Table 1).

**Table 1.** Production of heat from different biogas types in Poland in 2014 (GUS, 2015)

| Substrates categories | Annual heat production TJ |
|---|---|
| Organic wastes | 69 |
| Communal sewage sludge | 86 |
| Farming wastes | 144 |

Polish biogas heat has a great and untapped potential. There are various technical options when it comes to utilising heat. A one-size-fits-all recommendation does not exist. The way to optimally use heat depends very much on the specifications and capacity of the biogas plant, the location of the plant and offset markets, and the legal framework.

**Study case**

The subject of research in the following thesis is sewage treatment plant covers an area of about 8 hectares. The property is designed for an average amount of treated wastewater in quantities of 38,000. Sewage treatment plant is equipped with a mechanical-biological technology purification. Obtained in the process of wastewater treatment sludge is subjected to mesophilic methane fermentation process in a separate digester. The biogas, which is produced by sludge fermentation composed mainly of methane (approx. 66%) and carbon dioxide. Annual production of biogas is determined on average level of 990,000 $m^3$. Its calorific value is 26 MJ $m^{-3}$. For the studying wastewater treatment plant was proposed (Michalik, 2013) an individual CHP unit which manage to generate on average 2,2 TWh of net thermal energy per year.

To balance heat demand with its production it was necessary to inspect the energy audit for buildings are part of treatment plant infrastructure. Energy audit is an expert appraisement make and implement in terms of reducing heating costs. Results of audit calculations also helps to find solutions for reducing the environmental impacts associated with the utilization of conventional energy resources, energy conservation and energy efficiency offer attractive solutions (Krarti, 2011). All characteristics in audit were calculated for the common conditions (Hasanbeigi & Price, 2010; Krzemień, 2012) according to the methodology describes in Polish law (MoT, 2008; Michalik, 2013).

**Theory and modelling**

Theoretical support for suggested solutions underline calculations base on heat balance for case study. At the beginning it was important to estimate whole heat production possible to gain.

Gross heat production:

$$Q_{th} = P_{th} \cdot t \tag{1}$$

where: $P_{th}$ – CHP heat power; $t$ – working time for CHP

Second step was to define an amount of additional heat and its purpose as it was said before for own needs:

Annual heat demand for social buildings:

$$Q_{H,nd} = S_{th} \cdot (H_{tr} + H_{ve}) - \eta_{H,s} \cdot (Q_{\text{int}} + Q_{sol}) \tag{2}$$

where: $S_{th}$ – heating degree days; $H_{tr}$ – infiltration heat loss; $H_{ve}$ – ventilation heat loss; $\eta_{H,s}$ – coefficient of heat gain; $Q_{int}$ – annual internal energy gain; $Q_{sol}$ – annual solar heat gain; or external sale.

Method used for annual heat demand calculation is applicable for existing buildings that are not retrofitted, with an average heat transfer coefficient of the building envelope greater than $0.8\ W \cdot (m^2\ K)^{-1}$ with natural ventilation.

## RESULTS AND DISCUSSION

Total heat consumption was defined for amount of 3 078 147 kWh (11 081 GJ). From case study calculation comes out biogas plant heat demand – 967,200 kWh (3,481 GJ) (Table 2) and social building heat demand – 104,880 kWh (377 GJ) (Table 3). To calculate treatment plant heat demand, it is necessary to carry out few simple computes.

**Table 2.** Heat balance for studying object in scenario without social buildings demand (own elaboration)

| Month | Working time | CHP heat production | Heat demand | | Difference | |
|---|---|---|---|---|---|---|
| | | | Biogas plant | Wastewater treatment plant | | |
| | hours | | | MWh | | GJ |
| January | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |
| February | 612 | 246.44 | 73.93 | 153.89 | 18.62 | 67.03 |
| March | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |
| April | 655 | 264.04 | 79.21 | 164.88 | 19.95 | 71.82 |
| May | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |
| June | 655 | 264.04 | 79.21 | 164.88 | 19.95 | 71.82 |
| July | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |
| August | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |
| September | 655 | 264.04 | 79.21 | 164.88 | 19.95 | 71.82 |
| October | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |
| Noveber | 655 | 264.04 | 79.21 | 164.88 | 19.95 | 71.82 |
| December | 677 | 272.85 | 81.85 | 170.34 | 20.66 | 74.38 |

In order to use the heat from the biogas plant, the plant operator is always allowed to sing long-term contract with the potential consumers or offer warm water supplied by the biogas plant.

**Table 3.** Heat balance for studying object in scenario with social buildings demand (own elaboration)

| Month | Working time | CHP heat production | Heat demand | | | D ifference | |
|---|---|---|---|---|---|---|---|
| | | | Biogas plant | Wastewater treatment plant | Social buildings | | |
| | hours | | | MWh | | | G J |
| January | 677 | 272.85 | 81.85 | 170.34 | 20.19 | 0.47 | 1.69 |
| February | 612 | 246.44 | 73.93 | 153.89 | 15.88 | 2.74 | 9.86 |
| March | 677 | 272.85 | 81.85 | 170.34 | 4,.36 | 16.30 | 58.68 |
| April | 655 | 264.04 | 79.21 | 164.88 | 3.68 | 16.27 | 58.57 |
| May | 677 | 272.85 | 81.85 | 170.34 | 0.12 | 20.54 | 73.94 |
| June | 655 | 264.04 | 79.21 | 164.88 | 0 | 19.95 | 71.82 |
| July | 677 | 272.85 | 81.85 | 170.34 | 0 | 20.66 | 74.38 |
| August | 677 | 272.85 | 81.85 | 170.34 | 0 | 20.66 | 74.38 |
| September | 655 | 264.04 | 79.21 | 164.,88 | 9.35 | 10.60 | 38.16 |
| October | 677 | 272.85 | 81.85 | 170.34 | 14.74 | 5.92 | 21.31 |
| Noveber | 655 | 264.04 | 79.21 | 164.88 | 22.23 | -2.28 | -8.21 |
| December | 677 | 272.85 | 81.85 | 170.34 | 23.69 | -3.03 | -10.91 |

The benefits for the owners of wastewater treatment plant could be significant as they did not have to take care about the heating installation system.

The monetary value of the heat depends first of all on the end-use of the heat, regional infrastructure and national policies.

Spatially, heat from biogas plants can be used for industry or in houses or buildings in the area of the production plant. The heat energy is transferred through (underground) pipe connections. For heat as a final product, experience indicates that reasonable distances can be 1 to 5 kilometres away from the plant (Ramanauskaire et al., 2012), depending on the local circumstances.

## CONCLUSIONS

Great potential for heat use are purifying and draining processes which require large amount of this medium. Other alternative for heat used is coupling of heating, power and cooling. Nowadays is considered a great potential in further use of the heat which should provide economic reliability. However, so far projects and solutions possible to implementation are questionable from an economic point of view but it seems to sales of thermal energy can create additional sources of income that can significantly contribute to the profitability of the entire biogas plant.

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