

# Practical experience with electricity production from unused energy at the water management company

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**Abstract.** The paper deals with electricity production from unused energy at the water management company. We have practical experience with using biogas produced by wastewater treatment plants for the production of electricity and with using drinking water stored in reservoirs for the production of electricity. In the first part, technology of the biogas production in a waste water treatment plant is described, technology of the water storage and pipelines is described and then production of electricity and bargain redemption price are discussed.

## Key words

Biogas, wastewater treatment plants, hydroelectric, water supply structure, small hydropower station, electricity production.

## 1. Introduction

The paper deals with the use of biogas produced in municipal wastewater treatment plants (WWTP) for generating electricity. Firstly, the technology of production is described and later the production of electricity and bargain redemption price are discussed.

The second part of the paper deals with utilization of hydraulic potential of potable water in water supply structure for electricity production with help of small hydropower station (SHS). There is also mentioned bargain redemption price of electricity produced by SHS in the Czech Republic (CR).

## 2. Biogas Production in WWTP

The beginning of production and use of biogas in the CR, as in other countries, is connected with anaerobic sludge stabilization. The first wastewater treatment plants using this technology were operating as early as the 1950s and nowadays, in effect, every plant with over 50 000 equivalent inhabitants (EI) uses it.

Biogas is a gas mixture of mainly methane (60 – 75%), carbon dioxide (25 – 40%) and small amounts of other gases, such as hydrogen, nitrogen and sulphone. It is created by anaerobic bacterial decomposition of organic mass. This process is called anaerobic fermentation. The main holder of energy is methane and small amount of hydrogen; carbon dioxide and other gases are ballast.

Wastewater treatment plants work on the principle of mechanical biological treatment. The wastewater treatment process starts with primary pre-treatment by grift removal and screen, then the water is pumped over to settling tanks. The settling tanks are the final mechanical level where the primary sludge sediments, and along with the redundant aeration sludge, constitutes the untreated sludge which is further processed by methanation. Prior to the methanation the sludge is concentrated – the sludge is pumped into heating fermentation tanks where anaerobic methanation takes place while biogas accumulating in the upper part of the tanks is collected by gasholders.

External indicators must be taken into consideration when checking the correctness of the fermentation process. The correct process manifests itself by high gas capacity and gas outputs with small daily fluctuations with dry residue decomposition of about 50%.

Treatment and disposal of municipal and industrial wastewater sludge has become a topical and critical issue. In municipal plants, the sludge constitute approximately 1 – 2% of the wastewater capacity with the concentration of 50 – 80% of the original contamination.

Production of sludge in the CR in the years 2002 – 2008 is shown in Table I.

Table I. - Annual Production of Sludge by municipal WWTP in the Czech Republic

Year	2002	2003	2004	2005	2006	2007	2008
Sludge (1,000 t of dry matter)	211	180	178	171	175	172	175

Biogas as a source of energy can be used for:

- Gas boilers – heating
- Piston gas engines – driving electricity generators including the cogenerating engines providing use of the lost heat
- Gas turbines and microturbines
- Gas engines driving compressors of cooling systems
- Gas boilers heating the medium of absorption cooling systems
- Immersion gas burners (evaporation, concretion of e.g. wastewater)

- Refining of biogas to SNG quality and its impression into a network
- Biogas compression and/or its purification for driving vehicles
- Electricity production by fuel cell.

Biogas is mostly produced in the process of cogeneration, the combination of the production of the electricity and heating. Minor/small cogeneration uses mainly piston combustion engines with water being the heat-carrying agent.

A cogeneration unit produces electricity which may be sold and which may bring considerable revenue to the biogas plant. With respect to the operation of 8,000 hours a year, the cogeneration units are the busiest parts of the facility. To ensure efficient running of the plant it is necessary to procure the units complying with the legislative requirements, with top technical parameters, and high-quality service.

Options of usage:

- Selling all the produced electricity into a network
- Electricity production for self-consumption
- Selling surplus electricity into a network of distribution or other company for a negotiated price
- Island / emergency operation for preserving the plant activity
- Using the cogeneration heat for heating the plant or other facilities
- CO<sub>2</sub> emissions trading.

Operating reliability is the most important feature to be considered when choosing the cogeneration unit. In case of failure not only profit from electricity sales is lost, but also service and spare parts must be paid for.

Operating the cogeneration unit under its maximum rated capacity means lower efficiency. As production of biogas is a live process, its sufficient amounts for full employment of a cogeneration unit may not always be available. The practice shows that larger units have larger efficiency and also that they may not be operated under 50% of their capacity on a long-term basis. With respect to these facts it is more efficient to have more small-size units, which is also advantageous in case of failure or maintenance shutdown.

### 3. Energy Balance of Biogas in WWTPs

The heat is used for heating and produced kWh may be used to “subsidize” the plant network. The total efficiency of energy conversion is stated to be around 85% (electricity 35% and heat 50%). Energy production from biogas cogenerating electricity and heating is subsidized under the Act 180/2005 with bargain redemption prices and green bonuses for electricity buyout.

When gasholders are full, the redundant biogas may be burnt on burners.

Until recently the anaerobic sludge stabilization, i.e. lowering of the content of organic substances, was

considered a necessary evil connected with wastewater treatment, using up to 50% of operating costs and producing biogas heating chambers or facilities. However, increasing the bargain redemption prices of electricity generated from the renewable sources has made such business activities favourable.

Currently, more than 50% of the total biogas production for energy purposes comes from municipal wastewater treatment plants with anaerobic sludge stabilization. As the statistics of the Ministry of Industry and Trade show – in 2007 56.93 mil. m<sup>3</sup> biogas of which 74.4 GWh of electricity were produced. A rather substantial share of self-consumption is due to demanding electricity consumption for the aerobic wastewater treatment. The situation is similar to heat, where 100% of heat is used by the plant itself for heating sludge.

The Ministry of Industry and Trade energy statistics keep records of all the plants using this technology. Energy production in cogeneration units is recorded separately and it is differentiated where the biogas comes from, whether from municipal, industrial, or agricultural WWTP, or it is landfill gas. It must be noted that data on biogas electricity production published in the Energy Regulatory Office is only for licensed subjects, and hence is lower than the actual numbers (many WWTP do not supply into network).

Location of municipal WWTPs with anaerobic sludge stabilization within the CR is illustrated in Fig. 1. WWTPs are marked according to the yearly biogas production: the biggest points are WWTPs with over 1 mil. m<sup>3</sup>, medium-sized points are WWTPs with production of 0.5-1 mil. m<sup>3</sup> and the smallest points are WWTPs with 0.5 mil. m<sup>3</sup> biogas production.

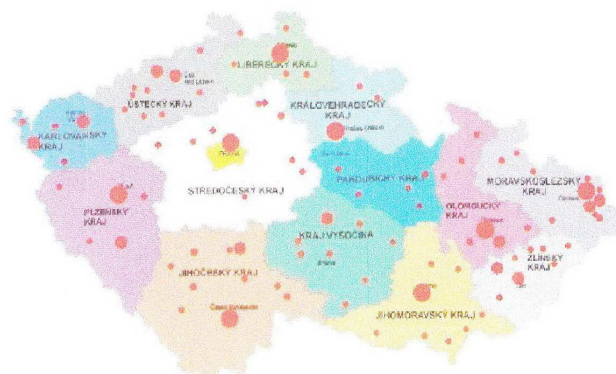


Fig. 1. Location of municipal WWTPs with anaerobic sludge stabilization within the CR

It is also possible to intensify methane production in municipal WWTPs by adding waste organic compounds into the untreated sludge – namely waste from the food processing industry or green plant residue. Adjustments of the production process – grinding and mixing the materials with untreated sludge – would not be demanding.

According to the structure of gross electricity production in electricity system of the CR it is evident that biogas electricity production is not important for the system operator; however, it is essential for the operators and owners of WWTPs, especially because of the Act 180/2005 on the support of electricity production from renewable sources of energy.

In this act we see a model of bargain redemption price determined by the Energy Regulatory Office for the sale of electricity into the network. The price must conform to the condition of guaranteed investment recovery period within 15 years. However, if produced electricity is used only for self-consumption, the price-support is in the form of a so called "green bonus" (i.e. the market price is increased and covered by the operator of the local distribution network or transmission network for the benefit of the owner/operator of the WWTP). The above stated forms of support cannot be combined – it is necessary to choose only one alternative.

Bargain redemption prices and "green bonuses" – pricing regulation of Energy Regulatory Office Act 4/2009 from November 3th are in Table II.

Table II. - Bargain Redemption Prices and "Green Bonuses"[4]

Date of putting into operation	Bargain redemption prices EUR / MWh	Green bonuses EUR / MWh
Electricity production by burning biogas for the source put into operation before 1 January 2004	119	79
Electricity production by burning landfill gas for the source put into operation before 1 January 2005	114	74
Electricity production by burning sludge gas for the source put into operation after 1 January 2006	102	62

#### 4. Small hydropower station

Hydropower station converts the energy in flowing water into electricity. The quantity of electricity generated is determined by the volume of water flow and the amount of "head" (the height from turbines in the power plant to the water surface) created by the dam. The greater the flow and head, the more electricity produced.

The CR produces approximately 3.3 % from total production of electricity by hydropower stations. Hydropower stations (including pumped storage) represent approximately 12 % of installed capacity of Czech power stations. Most of this capacity (90 % ap.) falls on facilities with installed capacity more than 5 MW. In the CR SHS are considered facilities with installed capacity less than 10 MW but in EU less than 5 MW.

Potential of water courses for big hydropower station constructions has been already spent in the CR. But it does not go for SHS with capacity of about 10 - 1000 kW at all. Their construction anyway does not require

massive intervention in landscape nor enormous investment costs. There were more than 11 500 SHS in the CR before 2nd World War. But later Czech power supply was concentrated to big central sources. That is why SHS were, unfortunately, liquidate. On the present only 1 300 ap. SHS are in operation. Most of them use out-of-date technology. Further increase in capacity of hydropower stations is possible to reach by modernization of their technology or construction of SHS on other sites.

Such an example is utilization of hydraulic potential of potable water in water supply structure. This possibility use water supply companies in the CR.

Small hydro power uses the flow of potable water from water treatment plant to water pipeline to turn turbines that are connected to a generator for the production of electricity. Operation is automated because it simultaneously fluently controls inflow of raw water into the water treatment plant according to variable demand of supply consumption area during the day.

Together with electricity production SHS help in optimization of all raw water treatment to potable water process. Water is good aerated after going through the turbine and it contributes to better stirring of aggregation additive with treated water after distribution in whole space of contact tank.

Similar is utilizing of head during potable water flow from water reservoir to water pipeline. Example of such a SHS is in Fig. 2.



Fig. 2. SHS utilizing potable water flow from water reservoir to water pipeline

Other advantage is the possibility of electricity production during profitable time of day, i. e. during high charging area.

SHS was equipped with Pelton, Banki or Francis turbines with rectangular gear to asynchronous generators. The used system of the turbine control and the turbine bearing system guarantee the hygienic quality of potable water.

Waterworks disposal plants are facilities with high power consumption. The installation of a small hydropower station will change them into energetically self-sufficient units and will in many cases even enable sale of excess energy to the public electricity network. During

installation of a small hydropower station in drinking water systems, it is not necessary to stop the water supply to residents for a long time, and it will not get polluted.

For the operation of SHS it is necessary to obtain licence for business activities in power industry. There is necessary to keep especially conditions that specify Water Right Office in permission of water treatment during operation of SHS.

There are a lot of water management companies that use SHS in the CR. But they do not show amount of produced electricity. That is why there is not any integrated statistic showing amount of produced GWh of electricity by SHS. According to accessible data the amount of produced electricity from one SHS is more than 90 MWh/year in case of SHS installation in water reservoir and up to 2.5 GWh in case of SHS installation in water treatment plant. There are tens of SHS in water supply structure.

## 5. Electricity generation

Production of electricity in SHS as well as from biogas uses for the sale of electricity into the network the same model of bargain redemption price determined by the Energy Regulatory Office. SHS operator can supply electricity to the network with redemption price. But in case he consume it itself or sell it to another customer he can use system of so-called green bonuses.

Bargain redemption prices and “green bonuses” – pricing regulation of Energy Regulatory Office Act 4/2009 from November 3th are in Table III.

Table III. Bargain Redemption Prices and “Green Bonuses” [4]

Date of putting SHS into operation	Bargain redemption prices EUR / MWh	Green bonuses EUR / MWh
SHS putting into operation from 1 / 1 to 31 / 12 2010	123	83
SHS putting into operation from 1 / 1 2008 to 31 / 12 2009	113	67
SHS putting into operation from 1 / 1 2006 to 31 / 12 2007	106	67
SHS putting into operation after 1 / 1 2005 and reconstructed SHS	96	57
SHS putting into operation before 1 / 1 2005	75	35

The water management companies derive benefit from this support and they save hundreds of thousands EUR annually by production of electricity in SHS.

## 6. Conclusion

Production electricity from renewable sources is supported in the Czech Republic. Distribution network operators according to law have to connect every

renewable energy source. The price in this way produced electricity specify Energy Regulatory Office. Minimal redemption price is according to law guarantee for 15 years in advance with possibility of annual correction +-5%.

Biogas stations and biogas production have a wide range of positive society-wide benefits. Biogas is under the Act 180/2005 valued as a renewable source of energy, and therefore, the electricity and heat produced by its means is environmentally friendly. Concerning renewable sources, biogas is one of the biggest sources of natural energy for the Czech Republic and can help dramatically with conforming to the obligations towards the EU in the field of renewable energy sources. It can also help to decrease the dependency of the Czech Republic on fossil fuels. The result of a proper fermentation process is stabilized sludge which can find its use in agriculture as a quality organic-mineral fertilizer.

The above stated facts lead to the support of intensification of biogas production in WWTPs. Technological line adjustments do bring an increase in the biogas production, and therefore, after implementing intensification measures, yearly growth of tens of millions m<sup>3</sup> in biogas production can be anticipated.

Hydropower is a clean, domestic and renewable source of energy. Hydropower plants provide inexpensive electricity and produce no pollution. And, unlike other energy sources such as fossil fuels, water is not destroyed during the production of electricity it can be reused for other purposes. In contrast to photovoltaic or wind power stations amount of electricity produced by them do not fluctuate after change of day and night or immediate weather changes. It is possible to plan supplies better and then it does not overload power network.

SHS are very often operated in areas where the most of produced electricity is consumed. That is why losses caused by electricity distribution are eliminated.

Additionally, SHS gives a higher return on investment due to the low capital investment and operational and maintenance costs.

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