

## BIOGAS – A RENEWABLE SOURCE OF ENERGY

by

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*First part of the paper deals with biogas produced in the process of anaerobic digestion. Possibilities of biogas utilization are commented briefly. Laboratory fermentation unit that was built at the Institute of Process and Environmental Engineering is described further on. The laboratory fermentation unit is used for digestion of new types of substrate and for process optimization. Finally, the biogas plant built in Sweden is described. Biogas produced there is treated and used as a fuel for public transport vehicles.*

Key words: *biogas, fermentation*

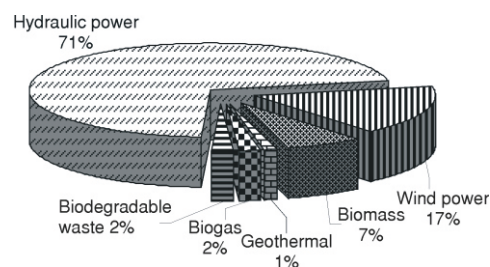
### Introduction

Biogas is produced during anaerobic digestion of organic matter. Anaerobic digestion is a process well known from nature where biogas is produced spontaneously. However, an industrial technology of anaerobic digestion has been developed as a part of waste water treatment process at the beginning of the 20<sup>th</sup> century. Nowadays, technology of anaerobic digestion is used for sewage sludge treatment; also biogas systems for organic wastes or biomass treatment are built.

### Biogas as a renewable source of energy

Currently, the main part of energy consumption is covered by energy from fossil fuels. The EU sets a target of 12% gross consumption of energy from renewable sources, or 21% of electricity, by 2010. However, a share of renewable energies in primary energy consumption was 6.38% and in electrical consumption 13.97% in the EU in 2005 [1].

Biogas is a source of energy with significant environmental benefits. It has one important advantage – it is a renewable energy source. However, currently a share of biogas in renewable sources of energy is very low, as is illustrated in fig. 1. Thus, it is necessary to look for ways of its share increase. One possibility of its increase is the new substrates digestion. Biomass and processed biodegradable wastes are promising materials for fermentation. However, biogas plants were usually built as a part of farmstead, where



**Figure 1. Shares of individual resources in the renewable electricity generation in Czech Republic (2004) [2]**

livestock and poultry wastes were treated. Biogas at farmstead is predominantly used in gas engines for heat production. Electric power from biogas is produced mainly at waste water treatment plants, where anaerobic digestion is used for stabilizing raw sludge.

### Anaerobic digestion

Recently, new biogas stations utilizing anaerobic processes (methanization) have been built. These biogas stations treat mostly biodegradable wastes and biomass. Organic matter is decomposed by micro-organisms with absence of free oxygen and is converted to methane, carbon dioxide, water, and other simple compounds. So it can be concluded that during the process of methanization the micro-organisms transform biodegradable matter into “clean” energy of biogas. This method allows treating matter with high water content. It is a plus of this method because, for example, combustion is not economical in this case. Biogas is a renewable resource of energy and its benefits are:

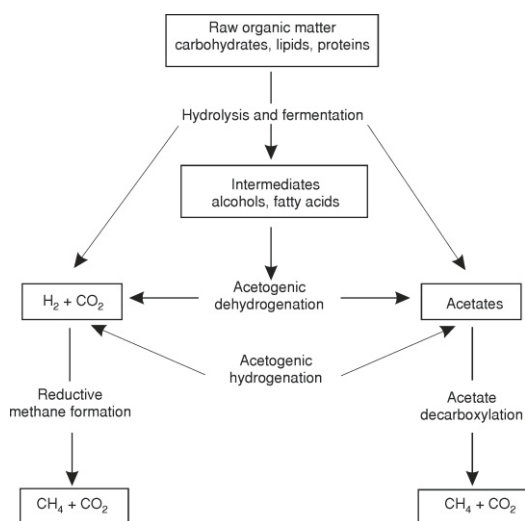
- good stability in storage, and
- wide range of utilization (generation of heat and power in co-generation units, fuel for cars, etc.).

### Process description

Anaerobic digestion of organic matter is a complex of processes [3]. Microbes decompose an organic matter in several steps (see fig. 2). The products of anaerobic digestion are biogas and digestate.

First stage of decomposition is called hydrolysis. Macromolecular substances (both solved and dissolved) are broken down into low-molecular substances (simple sugars, fatty acids, and amino acids). Products of hydrolysis are decomposed in second stage – acidogenesis. Fatty acids, alcohols, carbon dioxide and hydrogen are formed in this stage. Acetogenesis is the third stage of anaerobic digestion. Simple molecules of acidogenesis are digested to produce carbon dioxide, hydrogen, and acetic acid in this stage. The last stage is called methanogenesis and it produces methane. Carbon dioxide and water are among other products of methanogenesis. The above mentioned stages are consecutive but they are in motion simultaneously in continual processes (a biogas station operates usually under continual conditions).

Theoretical yield of biogas depends mainly on oxidation degree of the substrate which is usually expressed as chemical oxygen demand (COD). However, real yield of biogas is lower than theoretical because a part of the substrate is indecomposable. Real yield of biogas depends on a kind of substrate, its biological decomposability and on operating conditions. Thus, it is impossible to calculate the value and it must be measured in experimental equipment.



**Figure 2. Decomposition stages of one-step anaerobic digestion [3]**

### Products of anaerobic digestion

**Biogas.** It is a gaseous product of anaerobic digestion. Biogas is a mixture of gases where the content of methane ranges from 50 to 80%. Content of methane in biogas depends on the kind of substrate and on operating conditions. Content of methane in biogas is increased by following treatment (drying, desulphurization, *etc.*). Carbon dioxide is the second majority component. Its content ranges from 20 to 40% in biogas. Among other minority components in biogas there are hydrogen, nitrogen, oxygen, and hydrogen sulphide.

**Digestate.** Digestate is a mixture of solid and liquid residues of digestion. This slurry has approx. 4% of dry matter [4]. It is a stable material without health hazards. It is used as a fertilizer (in liquid form for better applicability) or it is dewatered. Dewatered material has about 20% of dry matter and is usually used for composting. Liquor from a centrifuge is used as diluting water for inlet substrate preparing.

### Biogas utilization

Recently, biogas has been produced mainly at waste water treatment plants and at agricultural biogas plants. Biogas is used for direct combustion (heat is obtained) or burnt in co-generation unit (heat and electricity is obtained) [5]. However, possibilities of biogas utilization are relatively wide (see fig. 4).

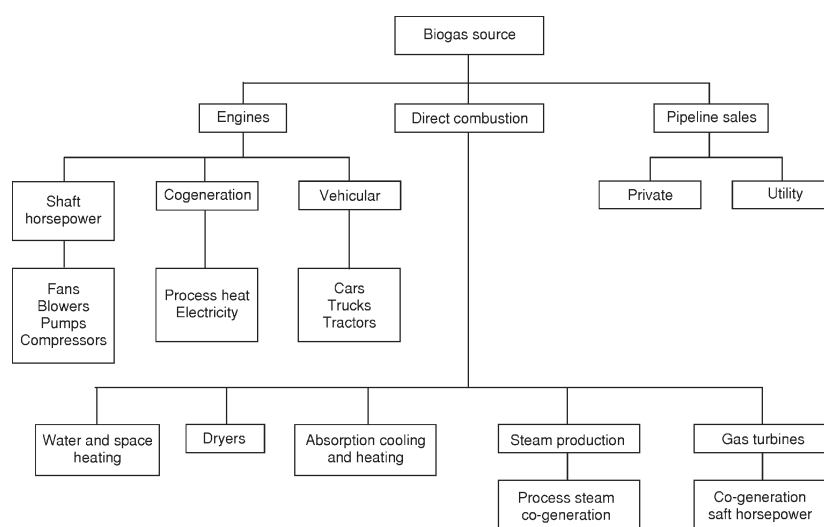
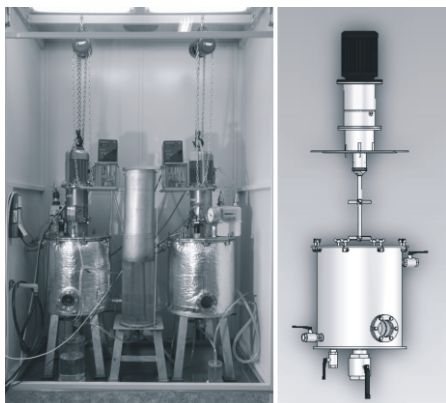


Figure 3. Biogas utilization [5]

### Laboratory fermentation unit

As was mentioned above, it is difficult to calculate biological decomposability and yield of methane for different kinds of wastes and biomass. A laboratory fermentation unit for experimental determination of biogas production was built at the Institute of Process and Environmental Engineering, Brno University of Technology (UPEI VUT). This unit displayed in fig. 4 consists of two fermenters with usable volume 25 l each, a wet gas holder and accessories for half-automatic operation. The laboratory fermentation unit serves to determine the amount and



**Figure 4. Laboratory fermentation unit**

quality of biogas which is produced by digestion of the tested substrates. It is possible to choose various digestion conditions and study their influence on biogas production.

### ***Fermenter***

The fermenter is a double-jacketed stainless vessel with flat bottom and un-mountable cover. Outlet and small opening for sampling is located at the bottom. The cover is equipped with a motor controlled by a frequency converter, driving a shaft with a twin impeller. An internal cylinder is equipped with buffers for better mixing of the feed. The cover is also equipped with openings for pH probe, feeding of chemicals and biogas collection. The fermenter

works in batch mode and it can operate both in mesophilic and thermophilic temperature. Heating of water in the shell is controlled by a thermostat.

### ***Gas holder***

The gas holder is an important part of the laboratory fermentation unit. It ensures that there is a sufficient gas pressure in the system. Biogas goes to the gas holder through a gas meter. Samples of biogas are taken from the gas holder and laboratory analyses are made. The rest of biogas is burned.

### **Biogas as fuel for cars – a case study**

As displayed in fig. 4, biogas can be used as a fuel for vehicular engines. A concrete example will be described in following paragraphs. A biogas plant and gas upgrading plant were built under the Väckkraft project [6] in which one of the co-authors participated. The biogas plant is situated near a Swedish town Västerås and it was finished in 2005. A separated biowaste from inhabitants of the town and ley crop from farmers is used as an inlet material. Produced biogas is treated and used mainly as fuel for public transport buses.

*Biogas plant.* The biogas plant produces 250-350 Nm<sup>3</sup> per hour of biogas. There is one more producer of biogas – a wastewater treatment plant. The wastewater treatment plant produces 150-250 Nm<sup>3</sup> per hour of biogas. Biogas from both producers is treated in a collective gas upgrading plant with capacity of 150-550 Nm<sup>3</sup> per hour of biogas. Processed biogas is piped into a bus depot where it is compressed. Compressed biogas is stored in the pressure vessels in a total amount of 6,000 Nm<sup>3</sup>. Schema of the gas network is displayed in fig. 5.

In fig. 6, the biogas flow sheet is shown. A dried ley crop is stored in plastic bags and is fed directly into the digester. Biowaste is pre-treated at first. The coarse mechanical pollutants must be removed. Then the waste is transported by screw conveyor into the turbo mixers where it is mixed with process water and liquid waste. Homogeneous slurry is pasteurised at 70 °C for one hour and then is pumped into the digester. The digester volume is 4,000 m<sup>3</sup> and it works continuously. The temperature is 37 °C (mesophilic mode) and the retention time is approximately 20 days. Stirring of charge is secured by produced biogas.

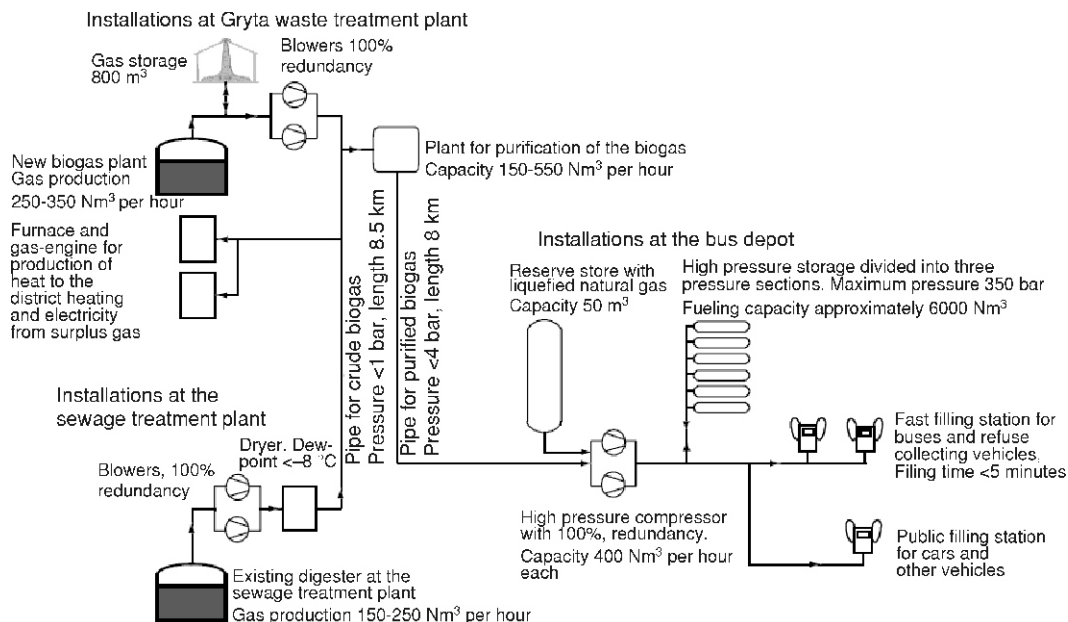


Figure 5. Gas network in Västerås [6]

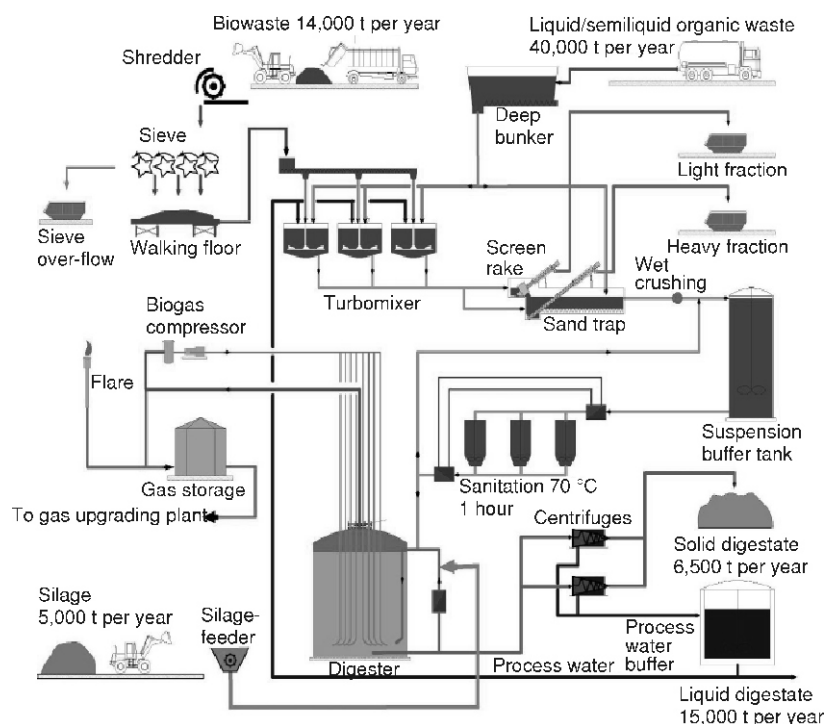


Figure 6. Flow chart of biogas plant [6]

Biogas is then collected and taken to a gas holder. The gas holder is a flexible rubber bag in a steel tank. The gas holder is not under pressure, it is designed for a two hour biogas pro-





greenhouse gases caused by 1,800 m<sup>3</sup> of diesel represents 4,800 tonnes of CO<sub>2</sub>-equivalents and the emission from biogas operated busses represents 200 tonnes of CO<sub>2</sub>-equivalents. Thus, the net annual reduction of greenhouse gases obtained by replacing fossil fuel is 4,600 tonnes of CO<sub>2</sub>-equivalents. The use of organic fertiliser (liquid and solid) involves both benefits and costs. The main benefit is the replacement of mineral fertilisers.

## Conclusions

The EU sets a target of 12% gross consumption of energy from renewable sources, or 21% of electricity by 2010. Biogas is an important source of renewable energy. Currently, renewable sources take approx. 14% of electricity consumption and a share of biogas in these sources is only 2%. One possibility of its increase is the new substrates digestion. Biomass and treated biodegradable wastes are promising materials for fermentation. The laboratory fermentation unit at the UPEI VUT was built for study of new materials fermentation and co-fermentation. Another way of increasing a share of energy from biogas in the total energy consumption is a better efficiency of its use. Biogas is used only for heat production at small biogas plants and small waste water treatment plants.

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