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Module No: Biogas

by ARID

Definition of biogas

Biogas typically refers to a mixture of different gases produced out of organic materials in an oxygen-free (anaerobic) environment. Obtained biogas is mainly utilized for producing renewable electricity and heat.

Biogas consists mainly of a mixture of methane (CH_4) (50-75%) and carbon dioxide (CO_2) (25-45%) and may have small amounts of hydrogen sulphide (H_2S) (0,1-5,5%), moisture/ water (2-7%) and siloxanes. The gas is a result of an anaerobic digestion process: 'a process in which micro-organisms derive energy and grow by metabolizing organic material in an oxygen-free environment resulting in the production of methane'.

Source: own picture

Definition of biogas

For a good anaerobic digestion process, the biomass inputs should contain carbohydrates, proteins, fats, cellulose and hemicelluloses. The final gas yield is dependent on the carbohydrate, protein and fat content. (Economic and institutional aspects of biogas production, 2012).

Biogas is known as an environmentally-friendly energy source because it alleviates two major environmental problems simultaneously:

1. The global waste epidemic that releases dangerous levels of methane gas every day,
2. The reliance on fossil fuel energy to meet global energy demand.

Source: wikipedia

Sources of biogas

Biomass can be converted to other useful forms of energy, such as biogas. Organic substances both from agricultural and industrial production may be used for the production of agricultural biogas. Major substrates of agricultural origin used in the production of biogas include animal manure, energy crops and waste from plant breeding while industrial substrates include waste from the production of food, dairy, sugar and meat.

Biogas can be thus obtained from all agricultural products from both animal and plant production. Biogas can be produced from virtually any agricultural material and this material (substrate) has varied energy value, which is the potential to produce a given amount of methane.

Source: own picture

Anaerobic digestion, the process

The anaerobic digestion technique to make biogas out of organic material is applied all over the whole world. For example, in many developing countries people have their own small-scale biogas plant running on excreta, urine and kitchen waste. The obtained biogas is used to cook. In more technologically advanced countries, biogas production is used on a larger scale. In those countries, biogas production and use is seen as a way to become less dependent on fossil fuels. Another reason is that biogas production directly can lead to less greenhouse gas emissions by capturing methane (21 times more harmful greenhouse gas than carbon dioxide) for biogas utilization. An indirect effect is that other environmental unfriendly energy sources are avoided (linked with first reason).

Anaerobic digestion – a microbiological process occurring in the absence of oxygen in which organic compounds (carbohydrates, proteins, fats) are converted by anaerobic microorganisms into methane and carbon dioxide.

The name "methane fermentation" was given before the essence of this process was known and can be misleading. In fact, it is a set of biochemical changes that occur in the absence of oxygen hence the name “anaerobic digestion” is also used.

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Anaerobic digestion, the process

Three groups of microorganisms are involved in the transformation of organic compounds into the fermentation gas:

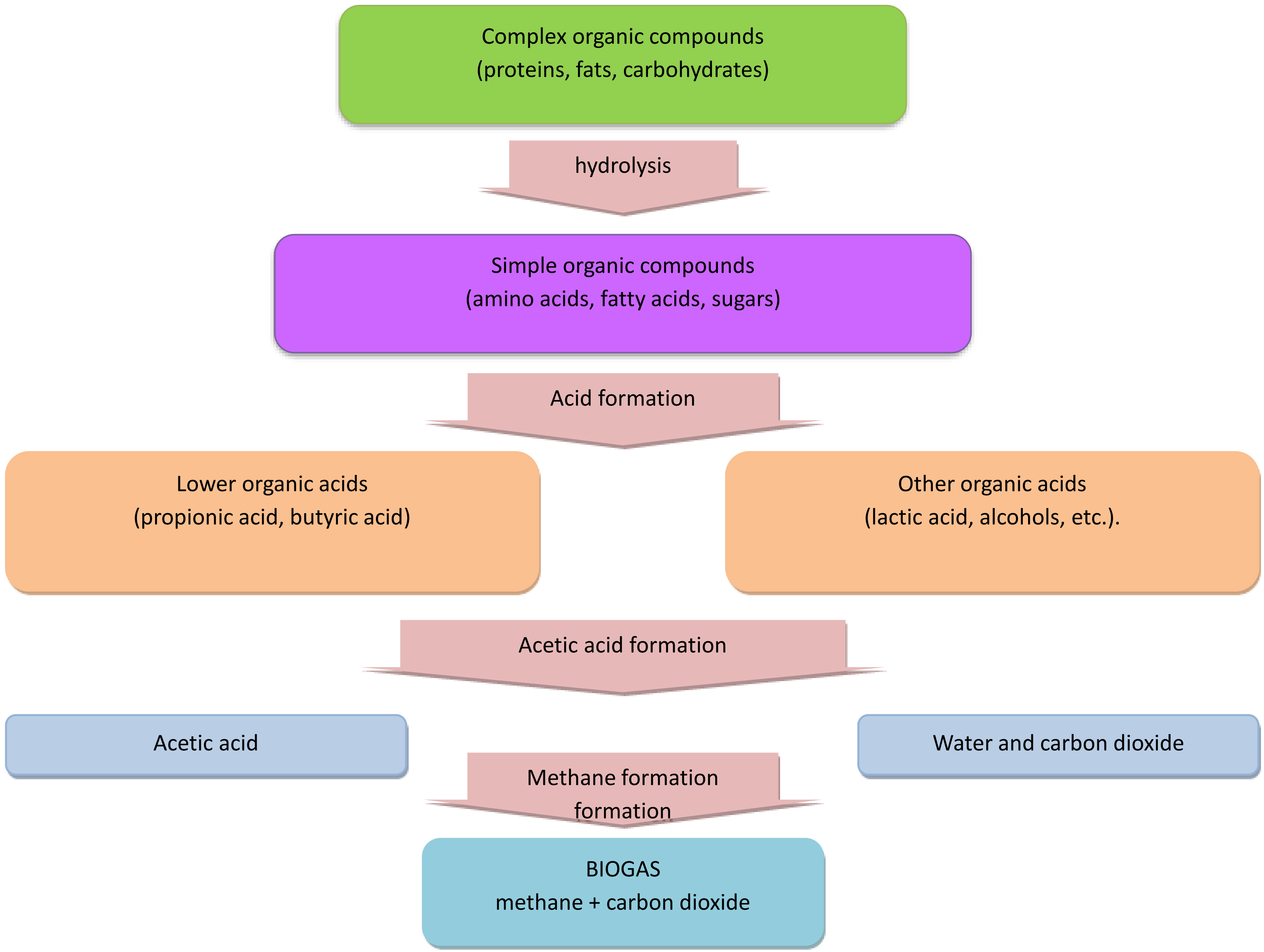
1. bacteria responsible for the first two stages of the process are bacteria that hydrolyze organic compounds. Optimal conditions for these microorganisms are pH of approx. 6 and approx. 30°C.
2. acetate bacteria - responsible for the production of acetates.
3. methanogenic bacteria - are among the group of absolute anaerobes.

If there is even 0.01 mg/dm3 of oxygen, they are inhibited, the concentration of organic acids increases and the pH of the environment lowers. They are very diverse and specialized to the use of specific substrates. Optimum methanogenesis temperature is 35-45°C and the pH of 7.

Source: powerpoint clipards

Anaerobic digestion, the process

The process of biogas generation can be divided into several steps. In the first step, hydrolysis, the compounds of input material (e.g. carbohydrates, proteins, fats) are decomposed to simple organic compounds (e.g. amino acids, sugar, fatty acids). Bacteria participating in this process release enzymes that break down the material by biochemical reactions. Then, the intermediate products formed are broken down by acidogenic bacteria in the so-called acidogenesis into fatty acids (acetic acid, propionic acid and butyric acid), carbon dioxide and hydrogen. Besides, the small amounts of lactic acid and alcohol are created as well. In the next stage, acetogenesis, these products are converted by bacteria into substances preceding the formation of biogas (acetic acid, hydrogen and carbon dioxide). Since too high hydrogen content is detrimental to acetic acid bacteria, they must cooperate with methanogenic bacteria. During the production of methane, they consume hydrogen and thus ensure adequate living conditions for acetic acid bacteria. In the next phase, methanogenesis, the last stage of the biogas production, methane is produced from the products of acetogenesis.


Complex organic compounds
(proteins, fats, carbohydrates)
hydrolysis
Simple organic compounds
(amino acids, fatty acids, sugars)
Acid formation
Lower organic acids
(propionic acid, butyric acid)
Other organic acids
(lactic acid, alcohols, etc.).
Acetic acid formation
Acetic acid
Water and carbon dioxide
Methane formation
formation
BIOGAS
methane + carbon dioxide

Bio-digesters

Biogas can be used to produce electricity, thermal energy, or both simultaneously. In practice, the most common systems use biogas produced to generate electricity and thermal energy. Such a system is called a CHP (Combined Heat and Power) system. In order to produce electricity and thermal energy it is necessary to install a device called a CHP unit. It is a combustion engine adapted for methane combustion with an integral generator depending on the size of the biogas plant. The heat generated in the combustion engine is used as a source of thermal energy. A less common way to use biogas is burning it for heating purposes. In such a biogas plant the device that processes the biogas into thermal energy is a gas furnace that is appropriately modified to burn methane.

Every agricultural biogas plant consists of several basic elements.

Additional elements installed in biogas plants depend on their use and power.

Source: own picture

Bio-digesters

The basic elements of every biogas plant are:

1. Substrates storage site - every biogas plant must be equipped with a storage site. The storage site is necessary to maintain a constant biogas production volume. The capacity of the storage site should amount to 0.5 - 2 times the volume of the substrate produced per day. A storage tank for liquid substrates can be made of different materials such as concrete, steel or plastic. The material used to make the tank depends on the stored material.

There are in-ground and above-surface tanks. Liquid and semi-liquid substrates storage tanks should be hermetic and be sufficiently large in relation to the production of the substrate. Plant substrate storage tank should be equipped with a suitable leachate discharge installation in order to prevent leachate from entering the soil. This tank should be tightly covered in order to prevent substrate from drying or rain water from getting inside the tank.

2. Device transporting substrate from the tank to the reactor - in order to ensure a constant, appropriate level of the biogas production, it is necessary to provide a continuous supply of substrate of an adequate quality to the digester. Depending on the type of substrate, it is possible to use pumps (liquid substrate, e.g. liquid manure), screw conveyors (semi-liquid substrate) and hoppers located by the digesters with the capacity allowing to be filled with the amount of substrate sufficient per one day.

Bio-digesters

3. Digester (fermentation chamber, bioreactor) - the most important element of the biogas plant in which the process of methane fermentation takes place. The effectiveness of the entire investment depends on the correctness of the design and proper construction of the digester. The walls of the digester must be sealed to prevent leakage of liquids and gases. Good insulation ensuring minimized heat loss is also necessary. The better the insulation, the smaller dependence on the outside temperature. Fermentation chamber should have a hatch allowing conducting the inspection of the interior and possible repair. Depending on the technology used, the biogas plant may be equipped with one or more chambers. Fermentation chambers may be horizontal or vertical, made of steel, concrete or plastic. The chamber need to be equipped with a device for mixing the content (mixer or other mixing system) and a heating system in order to achieve the required fermentation temperature and maintain it at a constant level. Fermented mass is discharged from the bioreactor usually in an overflow pipe.

Bio-digesters

4. Mixing systems – mixing the pulp fermenting in the tank is an important part of the process of biogas generation. There are 3 types of mixers: pneumatic, hydraulic and mechanical. Mechanical mixers are used in the majority of biogas plants. Mechanical mixers can be divided into 3 groups: diagonal, horizontal and vertical. The most common is the system of 2-3 diagonal or horizontal mixers. Vertical (central) mixers can be used only in the case of a tank with a fixed, reinforced roof. Incomplete mixing may lead to disturbances of fermentation and formation of scum.

5. Gas holder - a separate biogas storage tank operating at the required pressure in the gas network. Biogas accumulated in the tank is stored until the demand for energy appears. Biogas holder has a form of a flexible balloon which gets bigger as it is filled with the increasing amount of biogas produced. The tank may be placed directly over the reactor or, in the case of a horizontal reactor, it may be located next to the reactor. In this case the tank must be located in a proper building ensuring safe work of the tank. Every tank is fitted with a safety valve to prevent excessive pressure increase in the tank. If the allowable pressure is exceeded, the valve releases excess biogas to the outside.

Bio-digesters

6. Biogas purification device - biogas purification prior to its use is essential because it prevents the corrosion of installations and equipment and is required by the environmental protection regulations.
7. Fermentation residues storage tank - a separate, external tank allowing the storage of the fermented substrate, which is a valuable fertilizer, and can be used in a liquid form or to make compost to respond market needs.

Source: phys.org

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Biogas producing wastes

Most of the N and all other mineral elements contained in the input substrates remain in the biogas digestates. These include major plant nutrients such as phosphorus, potassium and calcium. While there are suitable inorganic substitutes for the nutrients nitrogen, potassium and phosphorous from organic fertilizer, there is no artificial substitute for other substances such as protein, cellulose, lignin, etc.. They all contribute to increasing a soil's permeability and hygroscopicity while preventing erosion and improving agricultural conditions in general. Organic substances also constitute the basis for the development of the microorganisms responsible for converting soil nutrients into a form that can be readily incorporated by plants.

Therefore, it is common practice to use biogas digestates as organic fertilizers, which at the same time saves costs for both mineral fertilizer and potential disposal of the digestates. The good fertilizing value of biogas digestates in comparison to mineral fertilizer has been confirmed in several studies. Also, the remaining carbon bound in the organic matter helps to maintain or even increase soil organic matter, which is particularly valuable in marginal soils.

Biogas producing wastes

Due to the decomposition and breakdown of parts of its organic content, digested sludge provides fast-acting nutrients that easily enter into the soil solution, thus becoming immediately available to the plants.

The humic matter and humic acids present in the sludge contribute to a more rapid humification, which in turn helps reduce the rate of erosion while increasing the nutrient supply, hygroscopicity, etc.

The elevated ammonium content of digested sludge helps reduce the rate of nitrogen washout as compared to fertilizers containing substantial amounts of more water-soluable nitrates and nitrites (dung, compost).

Source: wikimedia.org

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Biogas producing wastes

Crop yields are generally aknowledged to be higher following fertilization with digested sludge. Most vegetable crops such as potatos, radishes, carrots, cabbage, onions, garlic, etc., and many types of fruit (oranges, apples, guaves, mangos, etc.), sugar cane, rice and jute appear to react favorably to sludge fertilization. In contrast, crops such as wheat, oilseed, cotton and baccra react less favorably. Sludge is a good fertilizer for pastures and meadows. The available data vary widely, because the fertilizing effect is not only plant-specific, but also dependent on the climate and type of soil. Information is still extensively lacking on the degree of reciprocity between soil fertility, type of soil and the effect of fertilizers (particularly N-fertilizers) in arid and semi-arid climates. Thus, no definitive information can be offered to date. Nor, for the same reason, is it possible to offer an economic comparison of the cost of chemical fertilizers vs. biogas sludge. The only undisputed fact that can be stated is that biogas sludge is better from an ecological point of view.

The energy content of biogas

Biomass constituting the raw material for the production of biogas consists of three basic groups of organic compounds: carbohydrates, proteins and fats. In addition, the growth of microorganisms responsible for the fermentation occurs in the presence of soluble forms of potassium, sodium, iron, magnesium, calcium and trace elements. The most biogas can be obtained from the decomposition of fats.

Substrate	Biogas production dm^3/kg	Methane content [%]	CO_2 content [%]
Carbohydrates	790	50	50
Fats	1250	68	32
Proteins	700	71	29

The energy content of biogas

Relevant parameters in the production of biogas are:

- Dry mass content (d.m.) [%]
- Organic dry mass content (o.d.m.) [% d.m.]
- CH_4 efficiency [m^3/kg o.d.m.]

Substrate	Dry mass content (%)	Organic dry mass content (%)	Biogas yield (m^3/t s.m.o.)	Methane content CH_4 (% vol.)
Natural fertilizers				
Cow liquid manure	8-11	75-82	200-500	**50-60**
Calf liquid manure	10-13	80-84	220-560	**50-57**
Pig liquid manure	approx. 7	75-86	300-700	**60-70**
Sheep liquid manure	12-16	80-85	180-320	**50-56**
Cattle manure	approx. 25	68-76	210-300	**55-60**
Pig manure	20-25	75-80	270-450	**55-60**
Chicken manure	30-32	63-80	250-450	**57-70**
Horse manure	**20-40**	**65-95**	**280-350**	**55-65**

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The energy content of biogas

Substrate	Dry mass content (%)	Organic dry mass content (%)	Biogas yield (m^3/t s.m.o.)	Methane content CH_4 (% vol.)
Plants				
corn silage	20-35	85-95	450-700	**50-55**
rye	30-35	92-98	550-680	**ok. 55**
Grasses				
cut grass	approx.12	83-92	550-680	**55-65**
grass silage	25-50	70-95	550-620	**54-55**
Agricultural industry by-products				
brewers grains	20-25	70-80	580-750	**59-60**
distillers grains	6-8	83-88	430-700	**58-65**
potato pulp	6-7	85-95	400-700	**58-65**
fruit pomace	25-45	90-95	590-660	**65-70**
Other substrates for the biogas plant				
grocery store waste	5-20	80-90	400-600	**60-65**
gastric content	12-15	75-86	250-450	**60-70**

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The energy content of biogas

Apart from the temperature of the process and time in which substrates are kept in the reactor, the chemical composition of fermented organic compounds determines the quantity and composition of the biogas.

The useful part of the energy of biogas is the calorific value of its CH_4 content. The other components have strictly speaking an energy content also but they do not participate in a combustion process. Instead of contributing they rather absorb energy from the combustion of CH_4 as they usually leave a process at a higher temperature (exhaust) than the one they had before the process (mainly ambient temperature).

The actual calorific value of the biogas is a function of the CH_4 percentage, the temperature and the absolute pressure, all of which differ from case to case. The calorific value of the biogas is a vital parameter for the performance of an engine, a burner or any other application using biogas as a fuel.

The energy content of biogas

A typical normal cubic meter of methane has a calorific value of around 10kWh, while carbon dioxide has zero. The energy content of biogas istherefore directly related to the methane concentration. In other words,assuming a biogas composition with 60% methane, then, the energycontent would in this case be around 6.0 kWh per normal cubic meter.

Vehicle fuel	Vehicle fuel
1 nm^3 upgraded biogas(97 % methane)	9.67
1 nm^3 natural gas	11.0
1 litre petrol	9.06
1 litre diesel	9.8

This implies that the energy content in 1 nm^3 biogas corresponds toaround 1.1 litre petrol.

However, when we convert biogas to electricity, in a biogas powered electric generator, we get about 2 kWh of useable electricity, the rest turns into heat which can also be used for heating applications.

2 kWh is enough energy to power a 100 W light bulb for 20 hours or a 2000W hair dryer for 1 hour.

Basic designs of the digester

Digester is the heart of the biogas plant. Biogas digesters can vary greatly in capacity, ranging from small-scale units used by households to larger communal and industrial digesters. Feedstocks added to the digester can include many types of biomass such as animal, food and agricultural waste, but materials that are difficult for the bacteria to digest (e.g. wood) should be avoided. The amount of biogas produced depends on a range of factors including the type and amount of biomass used, the digester size and temperature.
There may be one or two chambers, depending on the technology used. They can be concrete or steel. They are equipped with a heating and insulation system, ensuring the maintenance of a suitable temperature for chemical reactions. The feedstock may be heated directly by diluting it with hot water or steam, or indirectly by heat exchangers embedded in the walls or bottom of the fermentation chamber. The content of the chamber is not uniform. Therefore, an important element of the chamber is a mixing system, whose task is to make the composition of the content uniform and degas fermenting feedstock. There are various ways of mixing: pump - external pump system forcing circulation in the chamber; mixing by pumping the gas inside the chamber; screw mixers - pumping agitator located in the central conveying pipe; mixing with low speed mixing propellers arranged vertically or diagonally.

End uses of biogas

Biogas is a fuel with an average energy value. It can be used in households, industry, agriculture – to produce heat/cold, electricity or as a biofuel.

Biogas can be used in many ways. Typical applications include:

Heat - the gas is combusted in a boiler. The heat generated warms upwater which can be used to heat the digester and nearbybuildings or be exchanged on a local district heating network. Agas boiler works like a boiler for solid and liquid fuels, but withthe difference that the boiler is specially modified to combustgas.

Heat/Power - biogas can be used as a fuel in stationary engines, typically Otto or diesel engines, or gas turbines. About 30-40% of the energy in the fuel is used to produce electricity while the remaining energy becomes heat.

End uses of biogas

Vehicle fuel - biogas can be used as a vehicle fuel for cars, buses and trucks, providing it is upgraded by removing carbon dioxide, water andhydrogen sulphide. In order to use biogas as a vehicle propellant, it must be processed in order to reach a quality acceptable by automotive engines. It usually means the quality level of natural gas. The installation of the vehicle must be properly adapted to the gas supply as well. At the same time automotive companies are working on solutions that would allow the engine to operate on two types of fuels, e.g. diesel + biogas. Water scrubbing, chemical scrubbing and PSA are the most widely used techniques for upgrading biogas to vehicle fuel quality. The gas must also be odourised and pressurised to around 200 bar before it can be used as vehicle fuel.

Upgraded biogas can also be introduced into the national gas grid, whichwill stimulate the development of new markets and applications.

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End uses of biogas

CHP (Combined Heat and Power) is a designation of cogeneration engines that produce both electricity and thermal energy in the process of biogas combustion. Biogas is burned in the place of its production. This solution is very beneficial both for economic and environmental reasons. The energy efficiency of traditional solutions that generate either thermal energy or electricity is approx. 40% compared with 90% efficiency of a cogenerator.

The efficiency of electricity gain in the newest big units ranges from 30 to 40% and thermal efficiency from 40 to 44%. In the case of smaller plants, the electrical efficiency ranges from 25 to 33%, while thermal efficiency is usually higher than 50%. Efficiency rates typically increase with the increase of electric power of the installation.

End uses of biogas

The most common solution for low-power CHP systems are reciprocating engines.

They are characterized by:

- availability in a wide range of electrical power (5 kW to 50 MW)
- possibility to optimally adjust the system to the needs of the individual customer,
- possibility of the modular design of larger power systems,
- possibility of using different fuels, including biogas,
- necessity of cooling even in the absence of heat reception,
- large dimensions and low power to weight indicator,
- loud noise requiring the use of acoustic shields,
- relatively high level of vibration requiring the use of vibration dampers.

Source: wikimedia.org

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End uses of biogas

The minimum required level of methane in gas intended to be used as fuel is usually set by manufacturers at over 30% of volume, which corresponds to the calorific value of gas at a level not lower than 13 MJ/Nm^3.

CHP systems with reciprocating gas engines (internal combustion engine) are used mostly for electricity production on the coupled generator and waste heat is used to produce hot water or, in an additional boiler, saturated steam. The heat is recovered from the compressed biogas exchanger, engine jacket exchanger, oil exchanger and exhaust gases exchanger. Biogas engines can be integrated with the building or be present in a mobile (container) version.

Another group of the most common devices used in the cogeneration systems is gas turbines used generally in systems with the electrical power higher than 1 MW.

The gas turbine compared to the reciprocating engine is characterized by a considerably smaller size and weight. Gas turbines have lower energy efficiency and lower electrical power to thermal power ratio.

End uses of biogas

The next stage of development of technical solutions based on gas turbines with heat regeneration is micro gas turbines. These are stationary gas turbine sets characterized by a small electrical power of approx. 25-500 kW. They consist of a radial turbine, a compressor and a regenerative air heater integrated in the entire system.

Microturbines are mainly used in CHP systems in which hot water is produced. Impurities in the biogas can damage microturbines, therefore biogas must be cleaned and dried beforehand. Microturbines burn biogas with a methane content of 35 to 100% and have considerably lower exhaust emission. This enables the development of new ways to use the exhaust gases e.g. in agricultural dryers or to use CO_2 in greenhouses. Recovered heat has a relatively high temperature and is transported only by exhaust gases. They achieve thermal efficiency in the range of 40 to 60%, and electrical efficiency in the range of 20 to 35%, the total efficiency of the cogeneration system is more than 80 %.

Environmental impacts of using biogas energy

Biogas can reduce the environmental impact of energy use in many ways. Switching to biogas can reduce CO_2 emissions from energy use, as well as methane emissions (if biogas is produced from waste). It can also have positive benefits for indoor air pollution and land degradation when it replaces the use of solid biofuels.

The actual gain in green house gas emissions when replacing fossil fuels with biogas depends on the substrate used. It is possible to reduce the greenhouse gas emission by more than 100% by including for example the decreased need of fertilizer. The large environmental benefit for biogas produced from manure depends on the decreased leakage of methane and nitrous oxides compared to the traditional manure storage systems.

Environmental impacts of using biogas energy

Substrate	Reduction of greenhouse gas emissionscompared to fossil fuels [%]
Grass	86
Sugar beet (incl. tops)	85
Maize	75
Manure	148
Waste from the food industry	119
Organic household waste	103

Through the production of biogas (CH_4 and CO_2) in the fermentation process, the amount of carbon is significantly (>50%) reduced. Depending on the operating system (including pH and temperature) of the biogas plant, N can also be lost (as NH_3) to a certain extent.

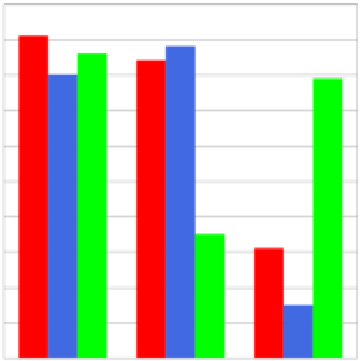
Economics of the small-scale biogas energy systems

When a potential operator is deciding whether to build a biogas plant, the crucial consideration is: can the future plant be operated at a profit? The economic profitability of biogas plants therefore needs to be assessed.

A biogas plant can generate revenues in the following ways:

- sale of electricity
- sale of heat
- sale of gas
- revenues from disposal of digestion substrates
- sale of digestate.

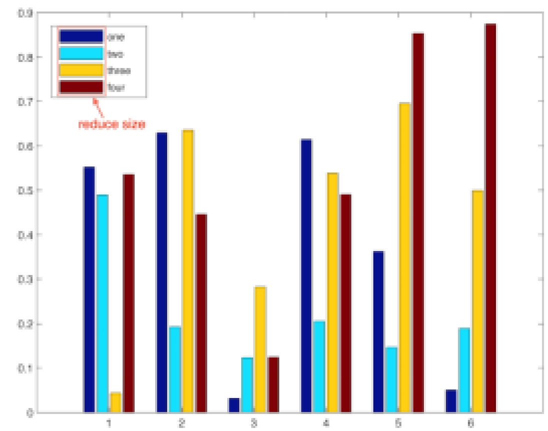
The principal source of revenue for biogas plants, apart from those which feed gas into a grid, is the saleof electricity.



Economics of the small-scale biogas energy systems

The situation relating to the sale of heat is significantly more problematic than for electricity. From the very outset, therefore, consideration should be given to potential heat offtakers when the site of the plant is being chosen. In practice it will not be possible to putall the arising heat energy to meaningful use, partly because a certain percentage will be required as process heat and partly because most heat offtakers willhave widely differing seasonal heat demands. In most cases, because of the biogas plant's own heat demand,the quantity of heat that can be supplied by the plant will run counter to the heat demand of potential offtakers.

It may be the plant operator's aim not to convert the biogas into electricity by a CHP process, but to upgrade the gas and feed it into the natural gas grid. Such plants obtain most of their revenues from the gas they sell.



Economics of the small-scale biogas energy systems

The cost items can essentially be broken down according to the following structure:

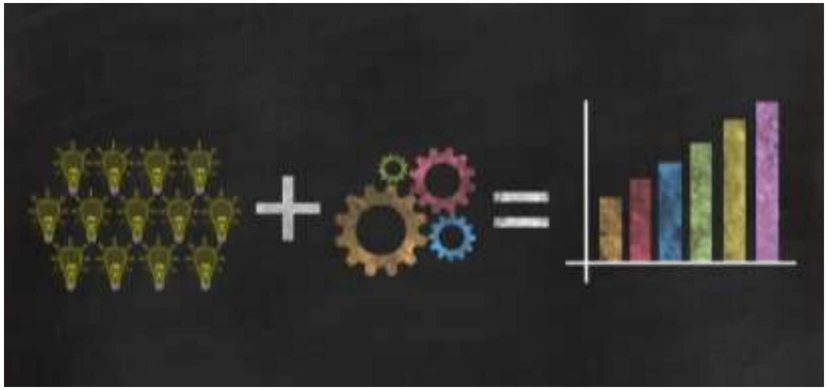
Variable costs

- substrates costs can account for up to 50% of total costs. This is particularly likely to be the case for plants that use exclusively energy crops and other related renewable resources.
- consumables - primarily comprise electricity, ignition oil, lubricating oil and diesel, as well as plastic sheets and sandbags for covering the silage. For gas feed-in to the grid, the consumables also include propane, which is added to the biogas for gas conditioning.
- maintenance and repairs are estimated at 1–2% ofcapital costs, depending on the component.
- laboratory analyses - professional process control requires laboratory analysis of the digester contents.

Economics of the small-scale biogas energy systems

Fixed costs

- capital-expenditure-dependent costs are made up of depreciation, interest and insurance. The depreciation allowance is component specific.
- labour costs - as the work at a biogas plant is generally performed by permanent employees and as there are no particular labour peaks, labour costs can be included in the fixed costs. The time required for control, monitoring and maintenance is assumed to be a function of the installed capacity,
- land costs - if the plant is operated as a community plant or commercial plant, additional cost items, such as lease or rent, must also be taken into account.



Source: pixabay.com

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Case Study

Description of the agricultural biogas plant with 500 kWe capacity in the experimental unit of The National Research Institute Of Animal Production Odrzechowa Sp. z o.o. Agricultural biogas plant with 500 kWe capacity located in Odrzechowa, gmina Zarszyn, Sanok county, Podkarpackie Voivodeship.

Technical data:
Electrical nominal power:
500 kWe
Nominal heat power:
518 kWt
Gross electricity production:
4 157 MWh/year
Gross heat production:
15 817 GJ/year
Connection to the grid:
line 15 kV

Source: own picture

Case Study

Description of the facilities of the biogas plant:

Fermentation chambers

They are circular, monolithic, reinforced concrete tanks with internal diameters of 23,0m and 26m and a height of 6m, covered with membrane roof constituting the gas holder. On the inside, the tanks are insulated in the gas area against aggressive environmental influence. From the outside, the tanks are thermally insulated and covered with trapezoidal sheets. The tanks are equipped with two submersible mixers with adjustable height and angle and with the heating and piping installation.

Fermentation residues storage tank

It is a circular, monolithic, reinforced concrete tank with internal diameter of 30,0m and a height of 6m. The function of the fermentation residues storage tank will be also fulfilled on the farm by the existing liquid manure tank. The tank is equipped with two submersible mixers with adjustable height and angle and with the piping installation.

Collecting tank

It is a circular, monolithic, reinforced concrete tank with internal diameter of 6,40m and a height of 3m. The tank is equipped with a submersible mixer with vertical and horizontal adjustment and with the piping installation.

Case Study

Silage silo

The silage silo is a 3-chamber, monolithic, reinforced concrete tank, 4,2m high, 30m wide and 50m long.

Technical building and technical room of the pumping station

The technical building was constructed based on a traditional technology. In the building there are: a cogenerator room, a transformer, a control room, a technical room and a social room. In the technical room of the pumping station there are thermal and technological network systems and control cabinets. Other technological elements (nonbuilding) of the biogas plant are the detached devices standing on reinforced concrete slabs on the ground.

Source: own picture

Case Study

Technology of the biogas plant:

The technology involves the processing of substrates of plant origin such as corn silage, grass silage and other plant waste as well as manure and liquid manure in various proportions. Manure will be delivered directly to the biogas plant from the farm. All solid substrates will be delivered to the dosing hopper from which they will be automatically transported to the fermentation chamber. Liquid substrates will be transported in the pipeline directly to the collecting tank. Dosage of substrates from the collecting tank to the production process will be carried out automatically. Solid substrates will be transported to the mixing and dosing device wherein the solid substrate will be mixed with the liquid substrate to the pumpable form. The homogeneous mixture of substrates will be pumped in appropriate amounts and proportions into two main fermentation chambers. The proposed system ensures conducting the technological process in two stages: initial fermentation and secondary fermentation.

Case Study

Fermentation occurs in two digesters. The process of intensive production of biogas occurs in both tanks. Both tanks are equipped with a heating system responsible for maintaining a stable process temperature in the range of 37-40°C. Biogas generated in the fermentation process is subject to the desulfurization: in the gas space of reactors it comes to the biological desulfurization process which consists in dispensing small amounts of air, which contributes to the expansion of bacteria reducing the concentration of hydrogen sulphide in the biogas. Desulfurized biogas flows through gas intakes from fermentation chambers to the biogas network in which it is transported to the compression and second degree treatment devices. Second degree treatment involves dehydration treatment consisting in condensation of moisture as a result of decrease of gas temperature. The condensate from the biogas flows down by gravity to the condensate sump, from which it is pumped into the fermentation residues storage tank.

Case Study

Thus prepared, biogas is directed to the cogeneration unit, where its chemical energy is converted into electricity and heat. Electricity is used to cover the needs of the facility and to power the grid. The heat from the cogeneration has the form of hot water and is used to cover the needs of the facility with the possibility to be used for other utility purpose. In the case of failure to use all the heat from cogeneration as utility water, its excess is directed to the fan cooler. Post-fermentation liquid is transported to the separator of the solid fraction of the post-fermentation fertilizer. The solid fraction will be received in the container to which the solid fertilizer falls by gravity. The liquid fraction of the fertilizer will be directed to the storage tank - fermentation residues storage tank.

Type of substrates:

- corn silage in the amount of max 2500 Mg/year,
- green left-overs in the amount of approx. 600 Mg/year (within the period between V-VII)
- grass in the amount of approx. 800 Mg/year (within the period between VIII-IX)
- beetroot pulp in the amount of approx. 5000 Mg/year (limiting the corn silage)
- waste from animal husbandry: cattle manure in the amount of 8300 Mg/year, unfermented liquid manure in the amount of 900 m^3/year, fermented liquid manure in the amount of 4500 m^3/year.

Resources & Links

http://www.cire.pl/pliki/2/Mikrogeneracja_Technika.pdf
biogasportal.info - Guide to Biogas From production to use (https://mediathek.fnr.de/media/downloadable/files/samples/g/u/guide_biogas_engl_2012.pdf)
International Renewable Energy Agency (IRENA) - Measuring small-scale biogas capacity and production (https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Statistics_Measuring_small-scale_biogas_2016.pdf)
Organic Fertilizer from Biogas Plants (https://energypedia.info/wiki/Organic_Fertilizer_from_Biogas_Plants)
Fertilizing Potential of Separated Biogas Digestates in Annual and Perennial Biomass Production Systems, Andrea Ehmann, Ulrich Thumm and Iris Lewandowski (https://www.frontiersin.org/articles/10.3389/fsufs.2018.00012/full)
Basic Data on Biogas (http://www.sgc.se/ckfinder/userfiles/files/BasicDataonBiogas2012.pdf)
Agrobiogazownia, a collective work edited by K. Węglarzy, W. Podkówka, Instytut Zootechniki PIB, Grodziec Śląski 2010
Biogazownie rolnicze. Opracowanie monograficzne, ed. J. Walczak, Instytut Zootechniki PIB, Kraków 2010
Biogazownie szansą dla rolnictwa i środowiska, dr Alina Kowalczyk-Juśko, FDPA Fundacja na rzecz Rozwoju Polskiego Rolnictwa, Warszawa
Mikrogeneracja ciepła i energii elektrycznej w lokalnych systemach zasilania, Radosław Szczerbowski, Politechnika Poznańska, in: „Energia Elektryczna" – January 2011
Budowa i eksploatacja biogazowni rolniczych. Poradnik dla inwestorów zainteresowanych budową biogazowni rolniczych, a collective work edited by A. Myczko, Wydawnictwo ITP, Warszawa-Poznań 2011
Wykorzystanie energii odnawialnych, ed. dr Małgorzata Bereza, Instytut Zootechniki PIB ZD Grodziec Śląski sp. z o.o., Kostkowice 2009