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Test reports biogas production

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Innehåll

Test Reports Biogas Production - Euroslam 1
Background 2
Methods of and Solutions for Biogas Production and Their Impact on Efficiency 3
Energy Content of Biomass 3
Pre-treatment of Sludge 3
Method of Digestion 4
Drying and Up-grading of Biogas 4
Power and Heat Production 4
Form of Transportation 5
Biogas Production and Utilization in the Euroslam Project 5
Use of Gas for Heating of Industrial Process 6
Joint Digestion of Sludge 6
The Use of Biogas as Vehicle Gas 7
The Use of Biogas for Heating 7
Biogas Production in Lithuania 7
References 9

Background

Biogas can be used for three different purposes: electricity production, heat generation, and as vehicle gas. The chemical component of biogas is methane, which is the same as in natural gas, which is widely used for heat and power production, either in separate heat and power plants, or in facilities that produce heat and power in combination. In 2012 gas accounted for almost 24 per cent of global energy consumption (International Energy Agency). The vast majority of this volume consisted of natural gas and only a very small fraction was represented by biogas. Natural gas is produced through extraction from deposits in the ground or under the sea, in a way similar to that of producing oil. This is a comparatively inexpensive process where very large volumes of gas are extracted from giant gas fields, refined, and transported to markets.

Biogas is produced in biogas production plants through the digestion of different forms of biological waste. Biological waste is produced as a by-product of different types of human activities, such as food production and consumption. The volume of biological waste available is roughly proportional to the population of a country or a region. A municipality with 15,000 inhabitants thus produces on average ten per cent of the volume of biological waste of a municipality with 150,000 inhabitants. This rough estimate will differ depending on the existence of large food processing plants or large scale agriculture. These activities produce large volumes of biological waste as by-products of food production. Thus Denmark and Holland with disproportionately large agricultural sectors, focused on export, compared to their populations, are likely to produce more biological waste per capita than, for example, Singapore that mainly consists of a large urban area.

To put the biogas potential into perspective we can compare it to the world's use of oil. Each day one well-fed cow produces dung with an energy potential equivalent to 1 litre of diesel. If all of this dung could be collected and turned into biogas for all of the 1.3 billion cows in the world it would amount to almost ten per cent of the oil used. Sweden's 350 000 cows represent a fuel potential of almost one per cent of all oil imported by this country on an annual basis. The dung supplied by the 200 million cows of India is already to a large extent used for energy production, since people collect dung and use it to burn for cooking and heating purposes. The biogas potential of waste water sludge in Sweden, according to Energigas Sverige, amounts to 0,7 Terrawatt hours per year, which is equivalent to almost 0.4 per cent of the energy content of the oil imported every year. The total energy potential of Swedish biological waste and crops grown for the purpose of energy use is estimated to be17.5 Twh per year. 7.2Twh out of this amount emanate from energy crops. In 2012 a total of a little more than 1.5 TWh of biogas was produced in Sweden. Out of this some 0.8 TWh was upgraded to vehicle gas (Energigas Sverige).

Different countries have different levels of infrastructure for the distribution of gas. In most countries in Europe where gas has been used extensively for a long time, there exist national gas grids that reach all municipalities and a large share of households and industries. These national grids are connected into a European grid. Germany, for example, has a gas distribution network of 37,500 km, in which up-graded biogas can also be distributed. Sweden, on the contrary, only has a small back-bone network along the west coast of the country (spanning from Trelleborg to Stenungsund) and distribution networks in approximately 100 cities and towns along this major pipeline.

These factors all influence the cost of biogas production and distribution. The bulk of the German gas used consists of natural gas. Biogas is now produced in this country in more than 6,000 production units of different sizes . It can either be used locally in order to produce heat and/or power, or be up-graded and fed into the national gas grid in order to be used for any of these purposes, or as vehicle gas. Small-scale biogas production requires a larger investment per unit of capacity compared to the production in large plants.

For the above reasons the cost effectiveness of biogas production depends on the scale of production, the cost of distribution, and the availability of nearby customers that demand the volumes of gas produced.

The future of biogas production and use depends on the volumes of gas that will be produced and the future of biogas as a vehicle gas is also dependent on the adoption of gas as a vehicle fuel in many countries, and the relative success of other renewable fuel vehicles, such as electric vehicles and hybrids. Similar to the different width of railway tracks that used to exist, the fuels that are adopted by the large European economies are likely to prevail in the future.

Methods of and Solutions for Biogas Production and Their Impact on Efficiency

The cost and efficiency of biogas and energy production is influenced by a number of factors, including the choice of technologies used at different stages of the process. Different types of biomass have different energy content, pre-treatment of sludge can enhance methane production, different pre-treatment and digestion methods generate different volumes of methane, and the choice of transportation method for the gas results in different cost levels. There is also the cost of up-grading biogas in order to use it as vehicle gas.

Energy Content of Biomass

All types of biomass can be digested and sewage sludge can be mixed with other types of biological waste in order to increase the volumes to be digested and thus also make the investment more viable. Different types of sludge and waste from food industry and agriculture generate between 0.15 and 0.7 m3 of biogas per tonne of dry substance (Hanjie 2010).

Pre-treatment of Sludge

There are a number of different ways of pre-treating sludge in order to increase methane production. Methods for pre-treatment include thermal, chemical, thermo-chemical, and mechanical. The goal of pre-treatment is to make the cell walls within the sludge disintegrate, and thus facilitate the digestion process.

The various methods generate improvement rates of between 10 and 230 per cent. However, each type of pre-treatment also comes at a cost and there is no consensus as to which type of pre-treatment generates the most favourable return on investment. The cost of pre-treatment varies between 40 and 8300 euro per tonne, depending on method.

Pre-treatment also has a cost in terms of energy, which is also variable. Thermal and thermo-chemical methods require the use of a substantial share of the gas produced for the heating of sludge throughout the thermal process. Mechanical methods for pre-treatment require electricity to power grinders, belts, ultrasonic equipment, or equipment for high-pressure homogenization (Hanjie 2010).

Method of Digestion

There are mainly two different methods of digestion:

- Wet digestion, for sludge that can be pumped with less than 20 per cent of total solids.
- Dry digestion, for stackable sludge with between 20 and 35 per cent of total solids.

Up until now wet digestion has been the predominant method in Sweden. Wet digestion requires less time compared to dry digestion and the process is continuous and automatic. Dry digestion requires less complex facilities and less initial investment. It is a more stable production process, but the process involves manual activities, such as loading and unloading the digester, since the dry material cannot be pumped.

Drying and Up-grading of Biogas

In order to produce vehicle gas the water content of the raw biogas needs to be reduced and impurities have to be removed. This is done in a plant for up-grading of the biogas, which requires an investment in addition to that of the production plant. This process demands high volumes of gas in order to be financially viable.

Power and Heat Production

Biogas can be used in order to produce heat and electricity using a standard gas engine. However, the cost of small-scale production of power in combined heat and power (CHP) engines is relatively high and not competitive compared to the purchase of electricity from the grid. Instead it is more viable from a financial point of view to only produce heat.

Units for the sole production of heat are less complex and also less expensive. This makes the production cost of heat lower per unit of energy and this becomes a more viable option.

All sewage treatment plants use electricity for a number of purposes. If only they can produce biogas and use this to produce electricity at a cost that is financially sustainable, external purchases of electricity can be reduced. A plant uses large volumes of electricity for a number of different purposes, such as powering pumps and motors. The cost of energy amounts to between 25 and 40 per cent of the operational budget of a plant and approximately 80 per cent of the cost of producing and distributing drinking water is made up by the cost of energy (US Environmental Protection Agency).

Regardless of size of plant, the biogas that can be produced from sludge can cover approximately twenty per cent of the electricity needs of the waste water treatment plant. The cost of producing this biogas and electricity will be substantially higher per kWh of power in a small plant compared to a large one (Coelho et al 2006).

The use of biogas for the production of electricity or for the combined generation of heat and power (CHP) there is a need for larger facilities and the burning of large volumes of gas. It turned out that none of the municipalities had large enough volumes of sludge in order to supply a facility of an financially viable size. Now that five municipalities join together to invest in a digestion plant there is the opportunity that the gas produced might be sold to a company that produces both heat and power, but the test cases that were originally devised showed that none of the municipalities in isolation could produce enough to feed biogas to a local CHP unit in a financially viable manner.

In the case of the largest municipal sewage treatment plant in Latin America, located in a part of Sao Paolo called Barueri, the plant alone treats sewage from households of a total of 1.5 million people. Even for this size of plant it turned out that it was not financially viable, compared to purchasing electricity from the grid, to produce electricity internally. The benefits of the electricity production at the plant are mainly environmental (Coelho et al 2006).

Form of Transportation

In most European countries there is a national gas grid and most production sites where up-graded gas is produced can relatively inexpensively connect to this. Only Sweden, Finland, the Baltic States, and the states of the former Republic of Yugoslavia lack this type of infrastructure. In countries with an existing gas infrastructure there is always the opportunity to connect a production facility to the gas network and get paid the current rate for supplying gas to the grid.

In countries, such as Sweden and Lithuania, where no gas grid exists, supplying gas to customers can be done in either of two ways. A pipe can be built between the supplier and the customer, which requires a substantial initial investment, but over time reduces the cost of transportation. The second alternative is to transport compressed gas in flasks that are transported on a lorry. The third alternative of cooling gas and transporting it as a liquid is not economically viable for this type of small volume transportation.

Biogas Production and Utilization in the Euroslam Project

Each of the project partners has analyzed the potential and tested the idea for different applications. Most of the purposes have shown a limited potential to achieve a return on investment by investing in production facilities and start production. There are also two cases, however, where the efforts have borne fruit in the form of a well conceived cooperation between two or more partners, with substantial gains for all parties in terms of energy and financial savings. In one of these cases there is a nearby industrial customer with large-scale use of biogas in order to heat industrial processes. In the other case there is an opportunity to improve advantages of scale through the cooperation of a number of small municipalities around the joint production of biogas.

The result means that all three Swedish municipal partners of the Euroslam project have found opportunities to produce biogas from their waste. We deem this to be a highly successful outcome of the project.

Due to the fact that there are four municipalities and each of these has analyzed three different alternative uses, twelve test cases have been analyzed.

Use of Gas for Heating of Industrial Process

The first of the successful cases for biogas production involves cooperation between the municipality of Höganäs and the metal powder company Höganäs AB. The municipal wastewater treatment plant now delivers all the biogas produced from sludge directly via a 600 metre pipe-line to the hydrogen production facility of the company. The supply of biogas through this pipe-line covers part of the company's gas needs.

As part of this cooperation another pipe-line has been constructed, through which the company sends heated cooling water from the cooling of the hydrogen production process. This water is now used in order to heat both the biogas digester and the buildings belonging to the wastewater treatment plant. This entirely eliminates the need to use electricity for heating purposes at the plant and makes it possible to keep a positive net energy balance for the biogas production, which is very unusual in the case of this type of production. The production unit produces more energy than it consumes in order to keep the process going.

In addition to this, a drain belt for the dehydration of sludge has been installed at the wastewater treatment plant. This has been partly financed through the budget of Euroslam. The draining process increases gas production in the digester by 20 per cent.

This solution where a waste-water treatment plant combines efforts to reduce energy consumption with a company that uses large amounts of energy and that also, through its processes, heats large volumes of water that can be used in order to heat buildings and processes at the waste-water plant is far more efficient than efforts to improve energy consumption within each of these plants in isolation. If possible, it seems to be a good idea to locate waste-water treatment plants close to heavy industries in order to be able to utilize opportunities for similar types of combined efforts at saving energy.

Joint Digestion of Sludge

Through calculations it turned out at an early point in the process that small municipalities produce too small volumes of sludge from wastewater treatment in order to be able to build financially viable biogas production on their own. These small-scale production units turned out to be far too expensive to build and operate compared to the present ways of taking care of the sludge from the municipalities.

The financially viable alternative turned out to be joint digestion of sludge where five municipalities jointly invest in a new digestion facility where they can all send their sludge. The planning of the resulting project will start in 2015. The biogas that is produced in this plant will be used for heating.

The joint digestion solution provides enough advantages of size so that production costs reach a level that is competitive against the present way of taking care of sludge. Due to the fact that the five cooperating municipalities (Osby, Bromölla, Olofström, Hörby, and Östra Göinge) are located close to each other the cost of transporting the sludge becomes low as well.

The Use of Biogas as Vehicle Gas

Three of the Swedish test cases (one each for Hörby, Östra Göinge, and Höganäs) concerned using biogas as vehicle fuel. In the case of Hörby there is a bus terminal nearby, run by the region's transport administration, Region Skåne, and it was thought that it may turn out to be an advantage to be able to produce biogas for the buses. The municipality also has a number of vehicles that can be fuelled by gas.

The aspect of the production of biogas that is most demanding in terms of advantages of scale, however, is the purification and up-grading of gas to vehicle fuel. The volumes of sludge produced in Hörby are too small for the production of biogas and they are far too small for an investment in a facility for the up-grading of gas. The aspect of having a bus terminal in the area makes no significant difference. The same situation is true for the production of vehicle gas in Östra Göinge and Höganäs. The volumes produced by each municipality are prohibitively small and cannot carry the investment in an up-grading facility.

The Use of Biogas for Heating

Heat production is the least demanding application for biogas use, and the only one that is viable when gas volumes are small. As described above, Höganäs has initiated a cooperation agreement with Höganäs AB and supplies its gas via a pipe-line that has been recently constructed.

As discussed above, Östra Göinge and Hörby are going to cooperate with three other municipalities around the construction of a joint digestion plant. The gas produced in this plant will be utilized for the production of heat in a district heating system.

Biogas Production in Lithuania

In Lithuania large volumes of natural gas are used for heating and electricity production. The price of gas is perceived to be high and gas is used both for heating and electricity production. At the beginning of the project the circumstances for starting biogas production seemed promising.

Calculations revealed, however, that the production of biogas would be substantially more expensive. The investment in a production facility would be too high for a small municipality like Silale and the cost of the biogas would be very high compared to the price of natural gas. The volumes of sludge are small and the volumes of biogas would be small as well. Small municipalities in Lithuania have a weak financial position and Silale would find it difficult to borrow the money needed in order to build a facility for biogas production, even if calculations had been positive.

No gas is used as vehicle gas in Lithuania and it would not be realistic to start up production of vehicle gas based on the small volumes that could be produced from sludge in a small municipality.

The overall conclusion was that there is no opportunity at present to produce biogas in Silale.

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