International Gas Union

News, views and knowledge on gas – worldwide

Biogas - from refuse to energy

REPORT
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Foreword

Finished just in time for the World Gas Conference (WGC) in Paris 2015, we are very pleased to present IGU's first report on Biogas. The report comes in a time when we have high attention on climate and emissions but also on how to find sustainable energy solution to reduce poverty in the world. Biogas can contribute positively to the solution for both these challenges.

The report has been developed under the leadership and co-ordination by our Swedish Charter member, The Swedish Gas Association, and I would on behalf of IGU like to thank them for their efforts.

The report gives a good description of the production process from waste to biogas and how this helps to reduce the refuse mountain and securing energy supplies without impact on the environment, and how Sweden as a world leader, distilling biogas for use in vehicles. The report also gives a brief overview of how biogas is developing around the world, including the potential for global production and how the use of biogas can differ around the globe. It also gives a few examples on successful biogas initiatives in Sweden.

The potential for biogas production on a global basis is substantial and with biogas being regarded as a renewable fuel, it will have a very important role in the future energy mix not only as a transportation fuel but also as a clean replacement for biomass for indoor cooking and lightning, to improve the air quality.

Finally, I hope that you will find the report informative and most interesting to read.

Pål Rasmussen
Secretary General of IGU

Introduction

The extraction of fossil fuels has to be reduced if we are to meet new environmental and climate targets and prevent the growing greenhouse effect. In contrast to fossil fuels, biogas is CO2-neutral and renewable. Biogas is also the cleanest form of fuel on the market, and has the potential to replace a large part of fossil fuel use in Sweden. The bio-manure formed after decomposition is a high-value and soil-improving fertiliser. The biogas process lets us reuse society's organic waste, and makes it a resource. A sustainable circle of nutrients and energy is thus created between city and countryside, between consumers and production.

Sweden has already come far with regard to the use of biogas, and is a world leader within distilling biogas for use in vehicles. Investment in biogas plants has been made over a number of years, including with government subsidies. New plants and technology are continuously being developed. Nevertheless, demand for biogas continues to outstrip supply.

And demand is now growing in Europe, with no less than 12 European countries beginning to use biogas as a fuel for vehicles. Biogas is undoubtedly the fuel of the future.

Anders Mathiasson
President of the
Swedish Gas Association

Biogas – from refuse to energy

Biogas plays an important role in creating a sustainable society and reducing dependence on oil. By producing biogas, waste is converted to energy reducing the refuse mountain and securing energy supplies without impact on the environment.

Sewage slurry, waste food, manure, abattoir refuse and by-products from forestry can be converted to biogas by various techniques, such as decomposition or gasification. After processing, this climate-friendly gas can be used in vehicles and for the production of electricity or heat within industry. It also creates an eco-friendly and usable by-product - biomanure - used in farming.

Biogas is a renewable energy gas which primarily consists of methane. That means that it can replace and be mixed with other fuels such as natural gas, which is a fossil form of methane, and mixed in the same gas pipeline.

When biogas is burned, CO_2 and water are formed. Given that the CO_2 comes from the air absorbed by plants in the process of photosynthesis, biogas gives no increase in CO_2 emissions. The CO_2 is already in circulation above ground as opposed to fossil energy, where it is below ground. That gives biogas a climatic advantage compared to natural gas.

The way to greener transport
Several studies have shown that it is possible to produce 1 TWh biogas per 1 million people[1]. The calculation is based on the production of sewage slurry, organic refuse from homes and industry (food waste) plus abattoir waste, manure and crops from farming.

Around 500 million people live in the EU, giving a potential of 500 TWh. That means that biogas could theoretically account for over 10% of non-fossil fuelled transport in Europe. That corresponds to the EU's target in the Renewable Energy Directive - that 10% of the final energy consumption of the transport sector must come from renewable sources by 2020.

A sustainable opportunity for industry
Biogas is also in demand by industry as a fuel and raw material for a range of industrial processes, such as plastic, paint and lubricants. Industry and agriculture can be self-sufficient within heating and electricity by using their own biogas produced from the decomposition of various kinds of refuse.

[1] *Aebiom – A biogas roadmap for Europe*

One of the world's cleanest fuels

Biogas is a high-energy methane gas, and therefore highly usable. It is one of the fuels with the absolute lowest impact on climate and the environment. One of its major advantages is that it can be used as a fuel for vehicles. The transport sector currently accounts for one third of total global emissions of greenhouse gases. Biogas is a high-class alternative to petrol and diesel. It does not contribute to higher CO_2 emissions and is therefore one of the most climate-friendly vehicle fuels. Gas-powered vehicles also give reduced emissions of nitrogen oxide and particles, thus contributing to lower environmental impact.

Several of the world's leading auto manufacturers are already selling models powered by gas. At the moment, such vehicles usually run on natural gas, but have the advantage that they can run on biogas or a mixture. Biogas and natural gas come under the common heading of 'vehicle gas' in Sweden, but the international abbreviation is CNG.

Cars running on CNG usually have Dual fuel systems - i.e. separate tanks for petrol and gas. Buses and light goods vehicles usually run on gas only.

Liquid biomethane for heavy traffic
Heavy traffic, one of the major environmental sinners at the moment, can also reduce emissions using biogas. For heavy goods vehicles (HGVs) to be able to run long distances, cooling the gas to its liquid form is a major advantage. Cooling the gas reduces its volume, allowing the tank to hold more.

An infrastructure of filling stations for liquid CNG is currently being built all over the world. The USA and China are well in the lead when it comes to building filling stations for HGVs. The EU is investing a lot of money in replacing oil-dependency with liquid natural gas (LNG) and in the longer term, with liquid biogas (LBG). One of the EU's initiatives is the building of four chains of gas filling stations for HGVs at suitable intervals throughout Europe.

Microorganisms do the work

Biogas can be produced in several ways. The most common is to decompose various types of nutrients in an airtight tank. The ingredients can be food waste, manure, abattoir waste, crops or sewage slurry. Successful research is being carried out to develop various techniques of decomposition.

Biogas is formed when microorganisms break down organic material in a non-oxygen environment. This is a natural process that takes place in many oxygen-deficient environments, such as swamps, rice paddies and in the stomachs of ruminants. The power of nature is harnessed in biogas plants to produce an energy gas without environmental impact.

Food waste from homes, restaurants and industry
By collecting organic waste products, the amount of waste that has to be dealt with in other ways such as incineration can be reduced. It can be decomposed instead in a biogas plant in a process involving production and consumption of nutrients and energy in a cycle - an essential element of a sustainable society. When food waste is decomposed, the pure, nutrient-rich product can be used as biomanure.

Fertiliser, abattoir waste and crops from farms
Biogas has massive potential within agriculture. When animal manure is used to produce biogas on a farm, it reduces CO_2 emissions by 180%[1], as the methane emission from the manure is eliminated. Abattoir waste and crops can also be decomposed. The biogas produced can be used as fuel for tractors and other vehicles used on the farm. It can also be converted to electricity used on the farm or sold to the grid. Finally, biomanure can be returned to the fields to complete the cycle.

[1] *Swedish Gas Association report: : Biogas – a big step towards the sustainable society.*

Sewage slurry from sewage plants
Sewage slurry is a goldmine for biogas production. Large volumes of biogas can be produced by collecting slurry from water purification. Decomposed slurry can also be used as a valuable fertiliser, as it often contains high levels of phosphor. The slurry used on fields is specially certified. It can also be mixed with coarse materials such as wood chips and sand for use as a filler for roadbuilding for example, or for sealing old landfill sites to avoid methane leakage.

Methane leakage from landfill sites
Dumping organic waste in landfill sites has been banned in Sweden since 2005. But decomposition from existing landfill sites continues and makes it possible to extract biogas from such sites for another 30–50 years[2]. The environmental benefits are much greater if the leaked gas can be extracted because methane has an effect on the environment 23 times larger than the greenhouse effect of CO_2.

Forestry waste
Waste from the forestry industry such as branches and stumps can also be used to produce biogas. The process used is called gasification. Heating the material creates a synthetic gas which can then be methanised into biogas.

[2] *Biogasportal (www.biogasportalen.se)*

How biogas becomes an efficient fuel

Biogas has to be upgraded (processed) before it can be used as fuel for vehicles by separating the CO_2 and increasing the energy content. Water and pollutants have to be removed before the gas can be pressurised to 200 bar before use. There are a number of techniques used to purify biogas. The most common method used in Sweden is using a water scrubber, which is based on CO_2 being easier to dissolve in water than methane is.

Upgraded biogas has a methane content of at least 95%. It can then be used in the same way as natural gas, which consists of at least 90% methane. Non-upgraded biogas consists of 45–85% methane, depending on how it is produced.

Energy content in biogas compared with other fuels:	
1 Nm3 biogas (97% methane)	9.67 kWh
1 Nm3 natural gas	11.0 kWh
1 litre petrol	9.06 kWh
1 litre diesel	9.80 kWh
1 litre E85l	6.60 kWh

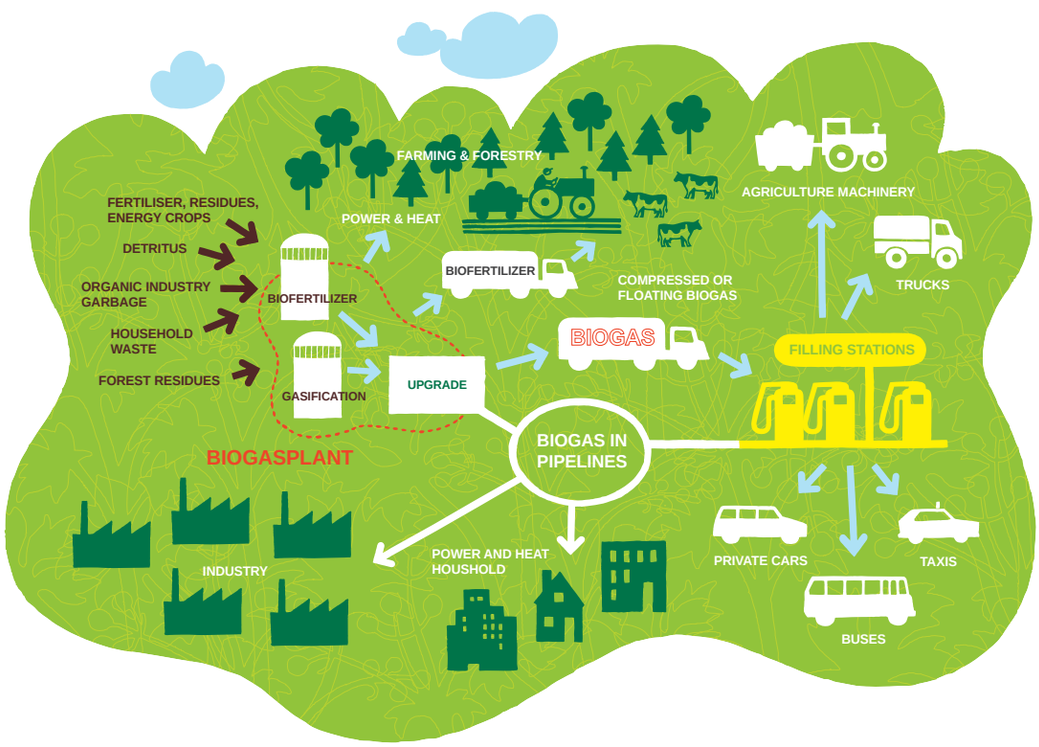
(www.biogasportalen.se)

Best distributed in a pipeline

The most efficient way of distributing biogas is via pipelines. A major advantage is that upgraded biogas can be distributed in the same pipes as natural gas, as they both consist of methane. The proportion of renewable energy also increases when biogas is supplied via a natural gas pipeline.

Biogas can also be distributed by road to the site where it is to be used, such as filling stations. In such instances, the gas is compressed and transported in bottles in a mobile container.

If it is cooled down to minus 163 degrees C, biogas becomes liquid, which also reduces its volume by 600 times. Liquid CNG contains more energy per volume unit than biogas in its gaseous form. That also makes it possible to use liquid biogas as a fuel for HGVs. Liquid CNG can also be transported more efficiently and is easier to store.



Sweden leads the world in biogas as a fuel

Sweden has been world leader in reducing the use of fossil fuels within the transport sector. The objective is a non-fossil dependent fleet by 2030 and a Sweden with no net greenhouse gas emissions by 2050. Over the last 15–20 years, successful initiatives have lead Sweden to become the world leader in the use of biogas as a vehicle fuel. Over 50% of the 1.7 TWh biogas produced annually is used in vehicles.

In the last five years, the number of gas-driven vehicles has doubled in Sweden to over 50,000. Everything from private cars through buses, trucks and HGVs have gas in their tanks. The expansion of filling stations stocking gas has also been rapid. There are now over 200, most of which also stock liquid gas for HGVs[1].

Such rapid development is largely due to progressive environment policies at state and local authority level. To boost the market, a range of subsidies and tax breaks have been introduced. Official car drivers have benefited from a big reduction in preferential tax and other examples include environmental awards, free parking and the waiving of road tolls.

Many local authorities set high environmental standards for the procurement of goods and services. Public buses have been an important driving factor for the increased use of biogas around the country. Using CNG has become a competitive parameter for many transport companies, such as taxis and hauliers, whose customers are become environmentally aware.

Partnership a vital element for success

Awareness of the benefits of biogas is growing, and in parts of Sweden demand is outstripping supply. Most of the biogas produced comes from the country's sewage works. Many local authorities also collect food waste from homes and restaurants. But the biggest potential lies in agriculture.

Sweden currently has just over 260 biogas plants, and around 50 plants for upgrading biogas to CNG. Many of these have been built with state investment subsidies over a ten-year period[2].

Successful investment in biogas depends primarily on partnership between a number of bodies ranging from the supply of raw materials to final distribution of biogas and biomanure. Local authorities, homes, farmers, owners of biogas plants, engineers, distributors, local bus companies - the list is long.

Biogas experience has made Sweden a world leader within environmental technology. Many new companies have been set up, and Swedish biogas expertise is an export product in demand.

For local initiatives and projects in Sweden, see Appendix 1.

[1] *Statistics Sweden/ Swedish Gas Association*
[2] *Swedish Energy Agency*

Biogas around the world

The biogas sector differs considerably in different parts of the world. The size of plants varies from small scale household units to major plants using such raw materials as household waste, industrial waste and manure. Biogas is used in other ways in large parts of the world, often for the production of electricity and heat or directly for cooking and lighting in small communities. Sweden stands out as the country that mainly upgrades biogas for use as a vehicle fuel.

Different countries have invested in different types of biogas systems depending on widely different environment and energy programmes. The UK and South Korea for example gain most of their biogas from landfill sites, whilst Switzerland and Sweden have built up systems for decomposition at sewage plants. Denmark uses manure to a large extent as this has been a means of dealing with the overproduction of manure there. Germany, the UK and Sweden are examples of countries where biogas production comes from collecting food waste.

Development is primarily influenced by the authorities - Germany for example has developed a largely agriculturally-based biogas production system through subsidising production.

China and Germany are world leaders within farm-based biogas production. There are no less than 24,000 small farm plants in China, and almost 8,000 agricultural plants in Germany of various sizes. The German plants contribute ca. 10,500 GWh of heat and 25,000 GWh of electricity per annum, corresponding to 3% of the country's electricity consumption. France, Holland, Austria and Italy also produce large amounts of farm-based biogas.

Gasification – a growing technology
Thermal gasification of cellulose biomass is a technology still in the development phase, but has major potential. There are currently commercial plants for electricity and heat production, and intensive research is taking place to develop the technology for vehicle gas production, e.g. GoBiGas in Sweden, see page 18.

When it comes to electricity and heat production from gasification, the plant in the Austrian town of Güssing is a good example. The plant was built in partnership with the Vienna University of Technology to develop the technology and to replace the use of expensive imported energy. The investment has been successful in that the plant is a leader within research and creates employment in the town, keeping it alive.

Small scale biogas production
Biogas in countries such as India and China has been produced at household level for some time. These small scale solutions use animal and human excrement as substrate, and the gas is used for cooking, lighting and in some instances small combustion engines. The decomposition process reduces the risk of the spread of infection from the substrate, and the biomanure is a valuable asset. The biogas system in this context helps to reduce global energy poverty and means women and children have to spend less time and energy collecting firewood. When the biogas system replaces biomass fuels indoors, air quality is considerably improved.

The government began to encourage small scale biogas production in villages in China in 1950. Continued development meant that between 2003 and 2013 an impressive 42 million small (8-12 m3) household units were built in China.

Figure 1. Biogas plants with upgrading unit.

Figure 2. Examples of small scale biogas production in Laos.

There are around 4 million household units in India, and there are projects in progress in many other countries - mainly in Asia and Africa to develop and spread the technology.

Example of successful investment
Dutch development organisation SNV works with local organisations in many different small scale energy projects in developing countries. A milestone was passed in 2014 when 600,000 household units for biogas production had been installed in less than 25 years. The project has helped supply 3 million people.

Potential and production
A fact sheet from the World Bioenergy Association estimates the global substrate potential for biogas production to 10,000 TWh. There are no exact figures for total biogas production in the world, but the same report estimates production at between 300 and 400 TWh, or just a fraction of the potential. Potential in China alone is estimated to be 3,500 TWh.
The diagram below shows biogas production in certain countries.

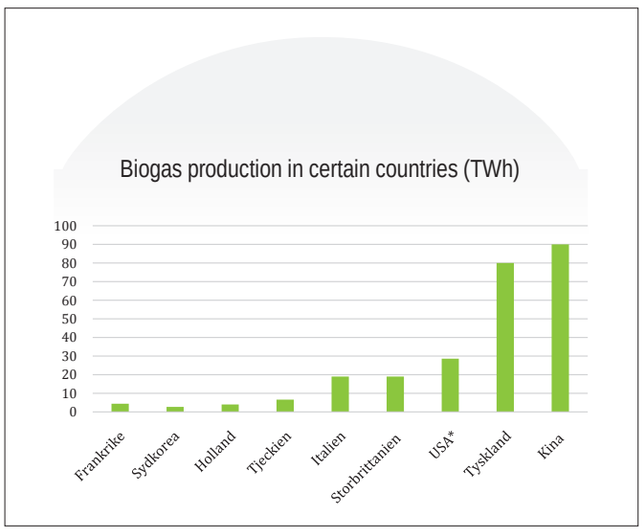


*Figure 3. Biogas production in certain countries. *Calculated on installed biogas-based electricity production in the country given a degree of efficiency of 35%.*

The installed biogas-based global electricity output in 2012 comprised 14,000 MW. 37 TWh is produced in Europe (with Germany accounting for 60%) and 10 TWh in the USA. Biogas-based electricity production in the EU increased to 52 TWh by 2013. Biogas is upgraded to natural gas quality at 258 plants in the EU, but this is still an unusual phenomenon in global terms. China and India had installed capacity of 800 and 91 MW electricity respectively in 2012.

Expected increases in production
India and China are rapidly increasing their biogas-based electricity production, including by composting waste from towns and industries. In Europe, the UK, Italy, Poland, France and the Czech Republic in particular are expected to expand biogas production. The USA also has ambitious plans for biogas production expansion. President Obama's "Climate Action Plan" from 2013 called for biogas production to become a means of reducing methane emissions and increasing energy security.
Gas as a fuel is also becoming more and more common in liquid form for heavy traffic and shippping. This change in infrastructure will most likely come to benefit the biogas sector.

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Did you know that…

- One bag of food waste composted to biogas is enough to power a gas-driven car for almost two kilometres.
- A bus with 55 passengers can run for 1000 km on the food waste produced by its passengers each year. *(Key figures for waste, biofertiliser and biogas (Waste Sweden))*
- A car running on biogas saves 2,600 kilos of greenhouse emissions per annum compared to a petrol-driven car. *(Key figures for waste, biofertiliser and biogas (Waste Sweden)*
- Every TWh of biogas produced corresponds to min. 1000 jobs.
- Biogas can be produced and used locally, and the ingredients do not need to be transported long distances or imported.
- Biomanure from the composting of biogas is excellent for use on fields and for replenishing nutrients - particularly nitrogen and phosphor. It also reduces the use of artificial fertilisers.
- Biogas production is growing rapidly in Europe. The fastest growth is occurring in the UK, France and Denmark. Most biogas is used for producing electricity.
- Sweden is one of the countries using biogas as a vehicle fuel. But there is growing interest in countries such as Denmark, Germany and South Korea.
- Germany has by far the most biogas plants in Europe. 10,000 plants produce around 80 TWh biogas per annum. *(IEA Bioenergy Task 37, Country report summary 2014)*
- Many crops are suitable for biogas production, e.g. forage crops, cereals, maize, sugar beet etc. Varied cultivation can mean a more balanced cultivation system with reduced need for pesticides.
- Current production of 1.7 TWh biogas at Swedish plants corresponds to 190 million litres of petrol. *(Key figures for waste, biofertiliser and biogas (Waste Sweden)*

Quotes…

The fact that the majority of the biogas produced in Sweden, is used in cars, buses and goods vehicles makes us a world leader. There is considerable international interest in the way Sweden have replaced some of the fossil fuels with organic waste fuel and reduced emissions. That means considerable export opportunities for eco-technology

Anders Mathiasson
CEO, Swedish Gas Association

The European biogas union has estimated that biogas should be able to replace 30% of current natural gas consumption in Europe over time. But to do so, a better infrastructure is required, that cannot be financially viable without natural gas flowing in the pipeline

Lennart Pihlskog
Chairman, NGVA Europe

Our vision is to contribute to a greener Stockholm by opening the gas network to anyone and, by doing so, make it possible to develop the biogas and gas market for transportation fuel, and to increase the access to biogas and gas. By distribution of gas through the gas network, we avoid having to transport the gas by road to the filling stations

Cecilia Hedqvist
CEO, Stockholm Gas
and Chair of Swedish Gas Association

Appendix 1

Stockholm gets greener transport

Stockholm's politicians have pursued the goal of increasing the use of biogas as a vehicle fuel to create a better environment for many years. The supply of biogas from the sewage treatment plant has made investments in a greener city possible.

Most of the biogas produced from sewage plants is now used in Stockholm's buses. Some of the biogas is pumped into a new network of vehicle gas to which more filling stations and bus depots are connecting. The demand for biogas in Stockholm is much higher than supply. To cope, biogas is mixed with natural gas.

The inhabitants of Stockholm will now start to sort their food waste. A new plant to produce biogas from household waste will therefore help boost biogas supplies in the region.

Eco-friendly transport company
The private transport companies have been quick to take advantage of the city's investment in the environment. A large taxi company started replacing its petrol and diesel-driven cars with gas relatively early. Its investment has paid off - financially and to the benefit of the environment.

The city of Stockholm has run a successful project to get more HGVs on the road with eco-friendly technology. One of the results is that there are now over 20 HGVs running on methane diesel powered by vehicle gas run by about ten transport companies in the region.

Stockholm also has the world's first vehicle gas-driven ambulances, the result of the environmental requirements laid down by the invitation to tender. Another example is how biogas has played an important role at the city's airport Arlanda, which has now invested heavily in fossil fuel free vehicles on the site. For example: there is a biogas filling station; taxis running on the gas take preference at taxi stands and even snow clearance is performed by biogas-driven snowploughs. All-in-all, the moves help the airport reduce its emissions.

There are now over 20 gas filling stations in the Stockholm area, and HGVs can even fill up with liquid gas.

Partnering created biogas city - Linköping

The Swedish university city of Linköping has around 100,000 inhabitants. All city buses run on biogas, the result of many years of partnership between local authority, gas producers and bus companies.

Discussions on a more climate-friendly fuel started as far back as the early 1990s in Linköping, when emissions from diesel buses caused severe air pollution. Because manure from farming and local abattoir waste were easily available, the choice fell on biogas.

The biogas plant built was one of the first in Sweden to upgrade biogas to vehicle fuel. Food waste from homes and restaurants is now an important raw material for production.

Commitment and risk-taking
Demand for biogas is much higher than the plant which is progressively expanded, supplies buses and HGVs and a number of filling stations in the region with gas. Even a train was run for a while on biogas, something which provoked international interest.

The focus on biogas in Linköping is to the benefit of the environment, and has given the city considerably cleaner air. Behind the success is considerable commitment and the willingness to take risks by the partners. But in the long term, the biogas project will be a profitable business. A number of cleantech companies have set up in the area, and the city has become a centre for biogas research in Sweden.

The plants of the future are already working

Two large scale Swedish biogas plants that can show the way for the green energy technology of the future were started in 2014.

Gobigas makes biogas from forestry waste
The Gobigas demonstration plant has been built in Gothenburg, western Sweden. Biogas from gasification of by-products from forestry operations, such as branches and tree tops is produced here. The biofuel is converted to combustible gas (synthetic gas) in the gasification plant and processed into biogas. The biogas is then fed into the West Sweden Transmission Grid for gas, where it is mixed with natural gas.

Gobigas is the first plant in the world to combine large scale gasification of forestry waste with methanisation. The plant is expected to be able to produce 160 GWh of biogas per annum, enough fuel for around 15,000 cars.

Gobigas is run by Gothenburg's energy company, which has been guaranteed nearly euro 58 million in EU subsidies if the project moves to full scale production. Such a plant will be able to produce fuel for up to 80,000 gas-driven cars. There is considerable international interest in Gobigas, and fact-finding missions come in a steady stream.

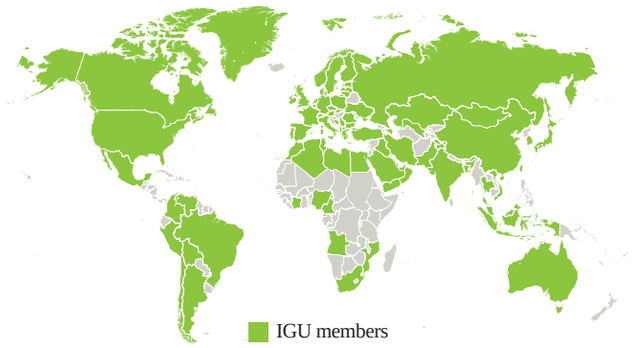
Jordberga produces biogas from crops
The town of Jordberga lies in southern Sweden and is home to the biggest biogas plant for crops. Rye, wheat, maize and sugar beet are transformed here to non-fossil fuels for the region's buses. The crops are supplied by local farms that also own the plant in partnership with a biogas and an energy company.

Jordberga produces 110 GWh of biogas per annum, corresponding to 6% of Sweden's total biogas production. The gas is upgraded to vehicle gas and pumped via a pipeline to the local distribution grid. A small amount is fed into the transmission grid and mixed with natural gas. A target for 2020 is that 20% of all gas in the transmission grid should be renewable biogas.

Almost all the biogas produced in Jordberga is sold in advance to local bus companies. The large addition of vehicle fuel means significantly reduced emissions of CO_2 in the area. Biogas production also produces nearly 100,000 tons of biomanure, driven out onto local fields by tanker. The Jordberga project has given its owners a taste for more and there are now plans for larger plants in northern Europe.

IGU

The International Gas Union (IGU), founded in 1931, is a worldwide non-profit organisation promoting the political, technical and economic progress of the gas industry with the mission to advocate gas as an integral part of a sustainable global energy system. The members are national associations and corporations of the gas industry. The working organisation of IGU covers the complete value chain of the gas industry upstream to downstream. For more information please visit www.igu.org.



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