BIOGAS – a renewable fuel for the transport sector for the present and the future

Biogas has been used as vehicle fuel since the beginning of the 90´s in Sweden. So far there are 30 upgrading plants in operation or construction phase, which makes Sweden a world leader in this area. Today there are over 11 500 vehicles that use methane fuel in the country. Biogas is used in large scale systems and in several cities like Kristianstad and Linköping all of the city buses run on biogas. The market for biogas as vehicle fuel is growing in Sweden and the sales increased with almost 50 % 2006 compared with 2005. So far most of the biogas is distributed in local grids to filling stations, but the possibility to inject the gas into the national gas grid is now used more frequently. Biogas is a renewable fuel and there are several incentives in Sweden for using the fuel for vehicles. Incentives are for instance investment support for new plants and reduced valuation tax for company car users.

In Sweden biogas is produced mainly in sewage treatment plants. The total production of biogas in 2005 corresponded to 1,3 TWh. Of this 43 % was produced at the 139 sewage treatment plants that digest sewage sludge. Biogas is also withdrawn at landfills. By the end of 2005 there where also 13 co-digestion plants that digested manure, industrial waste and household waste. Energy crops are seen as an interesting feedstock for new plants.

Biogas production at the sewage treatment plant in Jönköping.

An increasing portion of the biogas in Sweden is used as fuel for vehicles, but the major utilization is still heating of the plant, heating of buildings in the vicinity of the plant or distribution of the heat to a local district heating system. In 2005 12 % of the biogas produced in Sweden was used as vehicle fuel.

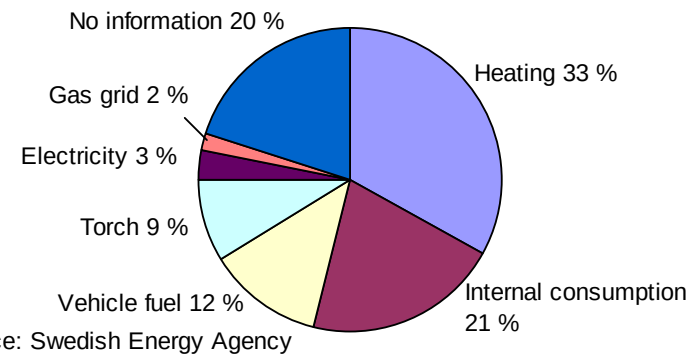
Statistics – Biogas production 2005 in Sweden

Total production 1,3 TWh at 233 plants

	Plants	% of production (GWh)
Sewage treatment plants	139	43
Co-digestion plants	13	13
Landfills	70	36
Industry sewage	4	7
Farm plants	7	4

Source: Swedish Energy Agency

Biogas utilization (GWh) in Sweden 2005



Source: Swedish Energy Agency

Biogas as vehicle fuel is expanding since the first pilot plants in the early 90´s in Sweden. By the end of 2006 there where more than 11 500 vehicles that used methane as fuel in the country. These vehicles can run both on biogas and on natural gas. The year 2006 was a big breakthrough for biogas in Sweden since it was the first year that the sales of biogas exceeded the sales of natural gas to

Statistics – end of 2006
Methane as vehicle fuel

Filling stations
68 public filling stations
27 filling stations for buses

Vehicles
10 400 cars
760 buses
340 trucks

Sold volumes – 2006
Biogas 23,7 million Nm^3
Natural gas 20,1 million Nm^3

Source: Swedish Gas Association

vehicles. Of the total sales of methane gas for vehicles biogas stood for 54 %. During 2006 about 24 million normal cubic meter of biogas was used for vehicles which replaced an equivalent of 25 million litre of petrol.

So far only biogas from sewage treatment plants and co-digestion has been used for vehicles in Sweden. Landfill gas has not yet been used since it contains higher levels of nitrogen and more pollutants.

In order to use biogas as vehicle fuel the gas needs to be treated, this process is called biogas upgrading and is more extensive than the treatment needed to use the fuel for heat or electricity production. The biogas is upgraded to obtain a standardized quality and meet the requirements of the gas applications. This implies and even fuel quality independent of production site. Upgrading biogas to vehicle fuel quality includes separation of hydrogen sulphide, particles, carbon dioxide and drying. In Sweden there is a standard, SS 15 54 38, which sets the maximum and minimum limits of different components in the gas.

Swedish Standard for biogas as vehicle fuel, extract from SS 15 54 28.

Parameter	Unit	Demand in standard
Lower Wobbe index	MJ/nm^3	43,9 – 47,3[1]
MON (motor octane number)	-	>130 calculated according to ISO 15403
Water dew point	°C	<t[2] -5
$CO_2+O_2+N_2$	vol-%	<5
O_2	vol-%	<1
Total sulphur	mg/ nm^3	<23
NH_3	mg/ nm^3	20

[1] Corresponds to 95-99 % methane
[2] t = ambient temperature

Water scrubber is the most common method to separate carbon dioxide. This plant is situated in the town of Kristianstad.

Carbon dioxide is the component in the gas that requires the most process equipment to separate. There are several techniques that can be used to separate carbon dioxide from biogas. The technique for separating carbon dioxide also affects how the other components like hydrogen sulphide and water is separated.

The most common method in Sweden for separating carbon dioxide is water scrubbing. There are about twenty of these plants in operation or in construction phase in Sweden. In this process biogas is compressed and fed into a column where it meets a counter flow of water. Since carbon dioxide has a higher solubility in water than methane the gas leaving the top of the column has a high methane content. The pressure in the column is around 7-10 bar. In the water other pollutants like hydrogen sulphide is also separated. The biogas leaving the top of the column is dried, odorised and compressed to about 200 bar before being used as vehicle fuel. The process can either use new water all the time or regenerate the water from the carbon dioxide through desorption with air.

The second most common upgrading technique in Sweden is Pressure Swing Adsorption. There are eight plants of this type in Sweden. In this method carbon dioxide is separated through adsorption on a material for instance activated carbon at elevated pressure 4-7 bar. Before biogas is feed into the vessel it needs to be dried, this is usually done by cooling the gas. Also hydrogen sulphide needs to be pre-separated and this is usually done in an extra vessel with activated carbon. When the material is saturated with hydrogen sulphide it needs to be changed. In the adsorption column carbon dioxide is adsorbed but methane passes through and the gas leaving the top of the column is enriched with methane. The columns are regenerated through reducing the pressure down to a slight vacuum.

Another method for upgrading biogas is called COOAB and is used in two plants in Sweden. It is also an absorption method like water scrubber but instead of water it uses an organic solvent. The solvent is selective for carbon dioxide and the absorption takes place at atmospheric pressure. The chemical is regenerated in a reversible chemical process driven by heat. Hydrogen sulphide is removed prior to the absorption process and the gas is dried afterwards. Since separation of carbon dioxide takes place at atmospheric pressure this method demands less electricity than water scrubber and PSA, but instead it demands more heat for the regeneration.

An organic solvent can also be used to separate carbon dioxide. This method allows the separation to take place at atmospheric pressure.

Swedish suppliers of upgrading plants

Flotech – water scrubber
www.flotech.com

Läckeby Water – COOAB
www.lackebywater.se

Malmberg Water – water scrubber
www.malmberg.se

YIT Vatten och Miljöteknik – water scrubber, PSA
www.yit.se

The cost to upgrade biogas is about 0.1 SEK per kWh cleaned gas for a plant with an annual production of about 20 GWh. This cost includes capital cost, as well as cost for operation and maintenance. In total there are about 30 upgrading plants in operation in Sweden. The majority of these upgrade biogas that is directly used as vehicle fuel. Today there are also four cities in Sweden where biogas is upgraded and injected into the national gas grid. The gas then needs the same upgrading treatment as for vehicle fuel. The difference is that it then can be somewhat lower restrictions concerning water content. Natural gas used in Sweden comes today from the North see through Denmark. This gas has a fairly high calorific value since it contains higher hydrocarbons. To reach the same caloric with the biogas as for natural gas propane is added to the biogas before it is being injected into the national gas grid. The correct calorific value is needed in the gas since customers are charged in terms of energy consumption but at each customer only flow is measured, meaning that the energy content needs to be known at all times.

Public filling station for biogas in Linköping.

The advantage of injecting biogas into the gas grid is that 100 % of the biogas can be used and the gas can reach new costumers. If the gas should be used for combined heat and power production this also means that this production can take place where there is a need for the heat. At several sites in Sweden injecting the biogas into the gas grid has resulted in no need for flaring biogas in the summer when the heat demand is low.

In Sweden there is also a third way of how biogas is distributed to the filling station, apart from distribution in local grids or distribution through the national gas grid. The third way is to compress the biogas and transport it in steel cylinders in a container that is driven with a truck to the filling station. By the end of 2006 there where about 70 public filling stations in Sweden. Of these about 20 where

supplied with biogas or natural gas on a truck. This method is used when there is no national gas grid and no possibility to have a local gas grid, like in Stockholm. With this so called daughter stations a market for biogas as vehicle fuel can be started awaiting local biogas production.

Introduction of biogas as vehicle fuel has had both governmental and local support in Sweden. For instance has many biogas plants being given a 30 % investment support from governmental investment programmes. The program that is going on at present is called the Climate investment programme, KLIMP. Above this a special investment support of 15 million Euro has also been declared for biogas filling stations during 2006 and 2007.

Use of biogas as vehicle fuel is exempted from tax and the tax on natural gas is rather low 0,13 SEK/kWh compared to a tax of 0,70 SEK/kWh for petrol. For company car users there is a 40 % reduction on the valuation tax, which can be as much as 16 000 SEK per year. Several cities like Gothenburg have free parking for biogas cars and other environmentally friendly cars. When it comes to the price on biogas the gas suppliers have declared that they will try to keep the biogas price about 20-30 % below the equivalent price for petrol, as long as the market for biogas as vehicle fuel is under development.

Introduction of biogas as vehicle fuel in the early 90´ was initiated by the municipalities. Today commercial companies has entered the arena, but the municipalities still play an important roll since they produce the majority of the gas at sewage treatment plants and often take the investment decision of an upgrading plant. The municipalities can also affect the public transport. When it comes to selling biogas and building filling stations private companies today play an important roll. The confident in using methane gas, like biogas is strong in Sweden and the Swedish Gas Association has declared a goal of 500 filling stations and 70 000 vehicles by 2010.

List of selected reference plants in Sweden with biogas upgrading

City	CO_2 removal technique	Supplier	Plant capacity (Nm^3/h of raw gas)	In operation since
Boden	Water scrubber	YIT	200	2007
Borås	Chemical absorption	Läckeby Water	300	2002
Eskilstuna	Water scrubber	YIT	330	2003
Göteborg	Chemical absorption	Läckeby Water	1 600	2007
Helsingborg	PSA Water scrubber	Carbo Tech Malmberg Water	350 650	2002 2007
Jönköping	Water scrubber	Malmberg Water	150	2000
Kristianstad	Water scrubber	Malmberg Water	300 600	1999 2006
Linköping	Water scrubber	Flotech YIT	660 1400	1997 2002
Norrköping	Water scrubber	Malmberg Water	275	2004
Norrköping	Water scrubber	YIT	240	2006
Skellefteå	Water scrubber	Malmberg Water	250	2007
Skövde	PSA	YIT	110	2003
Stockholm	PSA	Carbo Tech	600	2000
Stockholm	Water scrubber	Malmberg Water	600 800	2003 2006
Trollhättan	Water scrubber	Flotech Flotech	140 400	1996 2001
Uppsala	Water scrubber	Malmberg Water	400	2002
Västerås	Water scrubber	YIT	480	2004

This information was gathered by

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