Biogas upgrading and use as transport fuel

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Summary

Biogas is used as transportation fuel in a number of countries but in Europe it has only reached a major breakthrough in Sweden and in Switzerland . All of the biogas plants in Sweden that are in the planning or construction phase will be equipped with possibilities to deliver a biogas that is upgraded to natural gas quality, either for direct use as vehicle fuel or for injection into the natural gas grid. The development of biogas as vehicle fuel in Sweden is a result of a combination of a surplus of gas from biogas plants, primarily at the sewage treatment plants, and a low electricity price that forces the biogas into markets other than electricity production.

Introduction

Finnish biogas car refuelling
Eslöv, Sweden

The supply of petroleum fuels will gradually decrease and these will have to be replaced by sustainable fuels. This have been addressed by the European Commission in the directive 2003/30/EG where the following targets are set:

- 2% biofuels by the end of 2005
- 5,75% biofuels by the end of 2010.

In the short term this means that biofuels that already are present on the market and where suitable vehicle technology is available (biogas, ethanol, biodiesel) must be used and development activities in order to develop long term alternatives (e g hydrogen) must be intensified.
Biogas is a biofuel that in Europe in general mainly has been regarded as a fuel suitable for electricity generation in gas engines. Biogas can just as well be used in vehicle engines and there are today more than 4000 vehicles in Sweden running on biogas and natural gas.

Sources of biogas

Biogas comes from four main sources:

- **Sewage treatment plants**
- **Landfills**
- **Cleaning of organic industrial waste streams**
- **Mesophilic and thermophilic digestion of organic waste**

Many sewage treatment plants produce methane rich gases in the sludge fermentation stage. One third of the European biogas production comes from digestion of sewage sludge. Utilisation of methane from sewage plants is used on a large scale in many countries. Optimised process conditions can enhance the production and collection of these gases.
Landfills produce methane rich gases. Collection and utilisation of the gases is quite widely applied. Almost 40% of the European biogas is produced in landfills. Stricter legislation concerning methane

emissions from landfills can increase the incentives for landfill gas utilisation but the gradual decline of supply of organic material to landfills will have contrary effect in the long-term perspective.
Anaerobic digestion processes are often successfully applied to clean the liquid waste streams from food industries and other industries with large organic effluent streams. About one fourth of the European biogas production is produced in industrial wastewater plants.
Municipal organic waste is an important raw material for production of biogas but so far only 2% of the total production in Europe comes from municipal organic waste. The European directives, banning organic waste in landfills by the year 2005, will probably have a positive effect on the erection of new biogas plants for digestion of organic municipal waste.

Potential for biogas production in Europe

There are today more than 4500 biogas plants in Europe, including a large number of landfill sites. The average biogas production growth rate in the biogas sector was more than 6%/year in 2002. The two countries that account for the largest biogas production in Europe are Germany and England. The total European biogas production was in 2002 estimated to 92 PJ/year and the total European potential is estimated to 770 PJ/year in 2020. The countries with the highest biogas production per capita are the UK, Sweden, Denmark, Switzerland and the Netherlands. In the short term the main potential for biogas production is in the treatment of wet wastes like sewage water sludge, manure and waste from different kinds of food industries. In the long-term perspective the main source for biogas will be different kinds of agricultural products.

Upgrading of biogas to natural gas qualiity

Biogas has to be upgraded to natural gas quality in order to be used in normal vehicles, designed to use natural gas. There are today tree European countries with approved standards for biogas (Switzerland, Germany and Sweden).
The most common technologies for biogas upgrading are the water scrubber technology and the PSA-technology. Gas upgrading is normally performed in two steps where the main step is the process that removes the CO_2 from the gas. Minor contaminants (e.g. sulphurcompounds) are normally removed before the CO_2-removal and the water dew point can be adjusted before or after the upgrading (depending on process).

Water scrubber technology

Two types of water absorption processes are commonly used for upgrading of gas from anaerobic digestion, single pass absorption and regenerative absorption. The major difference between the two processes is that the water in the single pass process is used only once. A typical installation is at a sewage water treatment plant. Water can also be recycled and in this case a stripper collumn has to be integrated in the process (regenerative absorption).
Water scrubber units with capacities of 75 – 800 m^3/h capaciti have been installed at different locations in Sweden. The technology have proven to be very robuste but some plants have had operational distrubanices due to contamination by organic substansces of the packing in the collumns.

600 m^3/h upgrading plant with water scrubber technology
Henriksdal sewage water plant, Stockholm

PSA(Pressure Swing Adsorption) technology

350 m^3/h upgrading plant with PSA-technology
Helsingborg, Sweden

Pressure Swing Adsorption, or PSA, is a method for the separation of carbon dioxide from methane by adsorption/desorption of carbon dioxide on zeolites or activated carbon at different pressure levels. The adsorption material adsorbs hydrogen sulphide irreversibly and is thus poisoned by hydrogen sulphide. For this reason a hydrogen sulphide removing step is often included in the PSA process.
PSA units between 15 and 350 m^3/h have been built in Sweden and operation experiences are generally good. Some disturbances have been caused by dust from the adsorption material getting stuck in valves.

Other technologies

In some cases membrane technologies have been used for gas upgrading. The membrane technology has a potential to be energy efficient but there is for the moment very limited experience in Sweden with the technology. Chemical adsorption technologies seem to be an attractive solution due to low methane losses and high selectivity. The process requires rather high input of thermal energy in the regeneration of the chemical but can on the other hand be operated at low pressure that reduces the electrical energy demand of the process. A chemical absorption plant with a capacity of 300 m^3/h has been in operation in Borås, Sweden since 2002.

Chemical absorption plant, capacity 300 m^3/h
Borås, Sweden

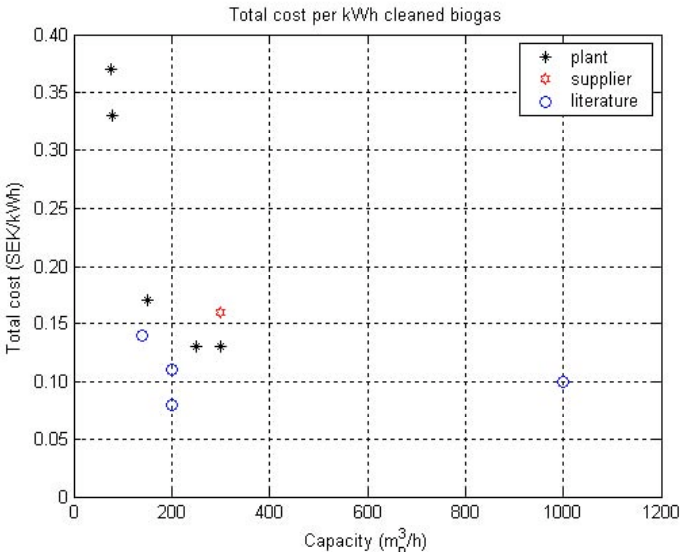
Economic and technical experience of gas upgrading

The economical and technical performance of the Swedish upgrading plants has been studied during 2003 and is presented in a report by the Swedish Gas Centre (www.sgc.se). 11 of the Swedish upgrading plants with longest operation experience have participated in the study. Some of the main conclusions from this study are:

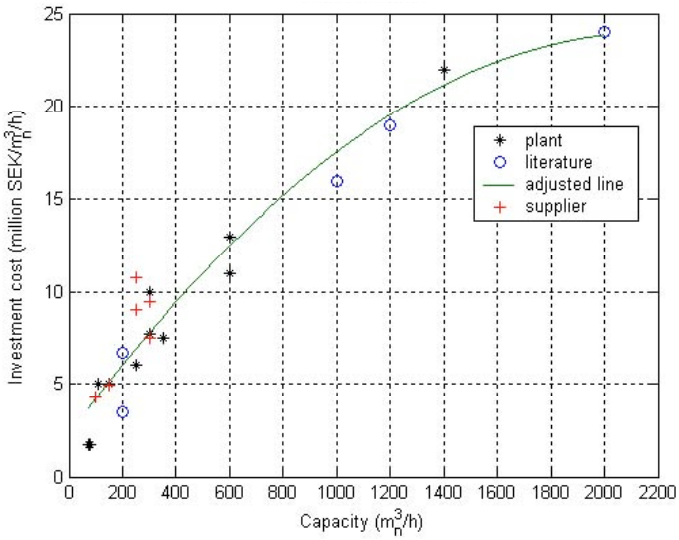
- The upgrading cost depends very much on the plant size. Small plants for <100 $m^3/h_{raw\ gas}$ have upgrading costs between 3 and 4 €c/$kWh_{upgraded\ gas}$ whereas upgrading plants in the range 200 - 300 $m^3/h_{raw\ gas}$ have upgrading costs around 1 - 1,5 €c/$kWh_{upgraded\ gas}$

- The electricity demand for upgrading corresponds to 3 - 6% of the energy content in the upgraded gas.
- The function of the upgrading plant is generally acceptable after the commissioning period. Common problems at the plants are malfunction in valves (PSA-plants) and deteriorating adsorption rates due to clogging (water adsorption systems).

Investment costs and total upgrading costs for a selected number of upgrading plants are shown in the diagrams below.



Upgrading costs for biogas to 97% methane



Investments cost for upgrading plants

Biogas vehicles

Biogas can be used in both heavy-duty and light duty vehicles. Light duty vehicles can normally run both on natural gas and biogas without any modifications whereas heavy-duty vehicles without closed loop control may have to be adjusted if they run alternately on biogas and natural gas. Sweden is today the only country in the world with a national standard for biogas as vehicle fuel. This standard essentially states that the methane content must be higher than 95% and also sets limits for dew point, sulphur content and some other minor constituents.
There are today more than 4000 vehicles in Sweden running on natural gas and biogas and several local fleets (e.g. Linköping, Uppsala, Kristianstad) where the major part of the urban public transports are operated on biogas.
Biogas vehicles have special benefits in many Swedish cities:

- Free parking
- Lower tax on biogas vehicles when used in commercial traffic
- No tax on biogas as vehicle fuel
- Exemption from city gate tolls for biogas vehicles
- Special lanes for biogas taxis
- Financial support for investment in biogas vehicles

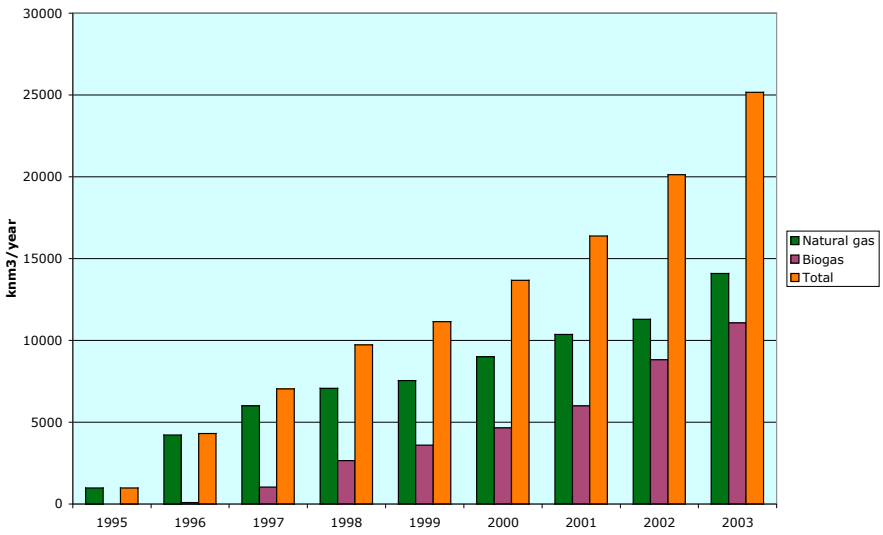
These benefits have created a very positive climate for a good development of the biogas vehicle sector.

Natural gas and biogas !

The development of the biogas vehicle sector has been undertaken in close co-operation between natural gas distributors and biogas distributors. Sweden does not have a very well developed distribution system for natural gas and a co-operation has been necessary in order to create a nationwide distribution system for methane gas. The tax on natural gas as vehicle fuel is small enough to make the market still interesting but big enough to make upgrading of biogas viable and competitive

with natural gas. This development can be seen on the next page where the sales of both natural gas and biogas as vehicle fuel are shown.

Conclusions



Development of biogas and natural gas sales as vehicle fuel in Sweden

Natural gas is a fossil fuel that has many advantages (high security of supply, low emissions, established distribution grid etc.) compared to liquid fuels like diesel and gasoline and has also been pointed out as a major alternative in the changeover to sustainable fuels. Upgraded biogas has the same advantages as natural gas but is in addition a sustainable fuel that can be manufactured from local waste streams thereby also solving local waste problems.
Production of biogas is a mature technology that is well established in many European countries and the biogas potential is considerable, especially when taking into account the possibilities to use set aside land for production of crops for biogas.
Upgrading of biogas is a relatively new technology but experience from Sweden and other countries shows that it now is possible to upgrade biogas with high reliability and to reasonable costs.
The Swedish experience shows that biogas can be an economical sustainable fuel with a potential to drastically reduce emissions in urban transport.

Literature

Holm J B, The future of biogas in Europe, a general overview.

Biogas Upgrading and Utilisation, IEA Bioenergy, Task 24, 2001

Hagen et al, Adding gas from biomass to the gas grid, SGC report 118, 2001

O. Jönsson, The Swedish Case for Methane Gas, ENGVA Annual Meeting 2001, Malmö, Sweden

Jönsson et al, Sustainable gas enters the European gas distribution system, World Gas Conference, Tokyo 2003

From Biogas to Energy, an European Overwiev, Solagro, 2001

M. Persson, Evaluation of Swedish plants for upgrading of biogas, SGC-report 142, 2003