BIOGAS IN SOCIETY
A Case Story from
IEA BIOENERGY TASK 37
"Energy from Biogas"

FREDERICIA BIOGAS UPGRADING

THE FIRST FULL SCALE UPGRADING PLANT IN DENMARK OPENS THE WAY FOR USE OF BIOGAS FOR BIOMETHANE FUEL PRODUCTION

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INTRODUCTION

Biogas recovered from anaerobic digestion is widely used to generate energy in the form of heat and electricity. Electricity is readily exported to national grids. However, heat is very often not used outside the biogas plant and consequently a significant proportion of the energy in the biogas is wasted. An attractive alternative is to upgrade the biogas to pipeline or vehicle fuel quality biomethane. Biomethane can be readily injected in the natural gas grid and used in exactly the same way as natural gas or used directly as a vehicle fuel.

The first full scale biogas up-grading plant in Denmark, was built by Dong Energy, one of the leading energy groups in Northern Europe, in the autumn of 2011. The plant upgrades the biogas produced by Fredericia municipality's wastewater treatment plant, and delivers the upgraded biogas to the national gas grid.

The idea of establishing a biogas up-grading plant in Fredericia arose in 2008, as a stepping stone in the "climate partnership" signed between Fredericia Municipality and Dong Energy. The agreement is based inter alia on the objective of the municipality to have the municipal buses running on environmentally friendly gas, on one hand, and on the other hand on the overall strategy of gradually switching to green energy production. In the same "green" context, Fredericia Municipality has launched the project, "Fredericia Forms Future – From North Sea Gas to Fredericia Gas", where biogas has a central role. The project is a public-private innovation partnership between Fredericia and Dong Energy's technology company, REnescience, aiming to make Fredericia a municipality that uses waste and wastewater as resources to create value and jobs, through production of renewable energy.

MISSION AND VISION

Policy makers in Denmark agree that the biogas sector has been a success to-date, and that there is great potential for expansion in the future. Both the energy and the agricultural sectors are aware of the great potential and benefits of biogas. Upgrading and grid injection is considered a must in a situation where the Danish CHP-plants cannot use all biogas produced and where residual heat is not utilised.

A NEW APPROACH

The wastewater treatment plant in Fredericia is Denmark's second largest, treating around 10 million m^3 of wastewater annually from very large companies including a Shell Refinery, Dong's plant at the port, Carlsberg and Arla. The wastewater treatment plant (Fig.1) is also one of the biggest energy consumers in Fredericia Municipality, with a great potential to be a net source of energy.

Biogas is a by-product of the wastewater treatment process. The sludge generated by the wastewater treatment is fed to the biogas reactors to be co-digested with bio-pulp, which is added to boost the digestion process. The biogas produced at the wastewater plant was earlier used to produce a small amount of power, for process heat and for heating various warehouse buildings in the area while the surplus was simply flared, and therefore wasted.
The very fact that the municipality’s approach to biogas changed from being considered a by-product to being seen as a valuable resource paved the way for many opportunities and for new challenges. One of them was to double the amount of biogas produced by feeding more methane-rich feedstock material to the biogas reactors. The source of more methane proved to be the digestible household waste from the municipality. Before being fed to the biogas reactors, the household waste is pre-treated at ambient temperature using the REnescience technology for separation and enzymatic treatment of solid waste.

BIOGAS UPGRADING

To upgrade the biogas to natural gas quality biomethane, a water scrubbing technology was chosen with a well-established and energy efficient upgrading unit. The modular unit installed is designed for raw gas capacities of 300 Nm^3/h[1)], which represents roughly the equivalent of powering 1250 cars per year with petrol or heat demand of 500 households (Figs. 2 & 3).
Using a well-established upgrading system was important for ensuring efficient use and minimum maintenance. The modular unit enabled rapid installation. The technology adopted is environmentally friendly, as the main process uses water as the cleaning fluid (Tables 1 & 2).

PROCESS DESCRIPTION

The raw biogas, which is moist, but not containing condense water, is fed into the upgrading facility where it is compressed to a pressure of around 6 bar. The compressed gas is then scrubbed with process water. As the ability of water to absorb CO_2 under pressure is significantly better than its ability to absorb methane under the same conditions, CO_2, H_2S and siloxanes bind to water in this part of the process.
This process is sufficient to purify biogas to a quality which complies with the requirements of Danish Gas Regulations, and is then ready to be injected into the natural gas grid. The process water is fed to the stripper where the pressure is removed and the CO_2, H_2S and siloxanes are released from the process water, which is subsequently recycled and reused.

Figure 1: General view of Fredericia WWT-plant.
Source: Fredericia Rensningsanlæg.

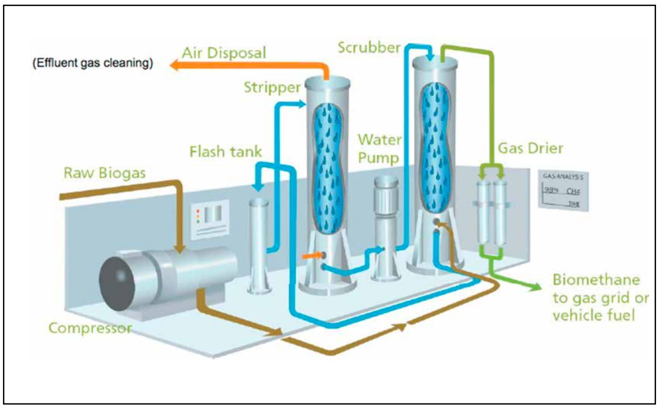

Figure 2: Schematic representation of the water scrubber.
Source: Greenlane Biogas and DONG Energy.

Figure 3: The upgrading plant. Source: DONG Energy.

[1)] Corresponding fuel need per year based on an average mileage for new cars of 15 000 km per hear an average fuel consumption of 0,8 liter/10 km. Source. Biogas Portal, Sweden.

In order to avoid unwanted deposits in the downstream equipment, the removed siloxanes are captured by an activated carbon filter. The exhaust air is cleaned by a thermal process, where the small amount of methane, which has been transferred to the water, is converted to CO_2 and water. H_2S is also readily removed.
All operational steps and sub-processes at the plant are monitored and controlled by a PLC system, which ensures optimal technical operational safety. The PLC system can be remotely monitored via the Internet by the supplier and by operating staff of the plant.

RESULTS AND FUTURE PLANS

The project in Fredericia has demonstrated an effective strategy for changing from low grade heat and power generation to high efficiency biogas upgrading to biomethane using a well-established technology and grid injection. This has led to accelerating the development of biogas up-grading and eased the way for future biogas upgrading projects in Denmark. The project has highlighted the specific needs related to gas grid connection in the country, the challenges related to gas quality and certification standards, specific needs for procurement of equipment, construction and commissioning as well as operation and maintenance routines. Overall, the plant is now considered a "hands on" experience of establishing and operating a biogas upgrading plant, complete with lessons learned ranging from the choice of materials to keeping the process water clean. The future plans of the Fredericia plant are to continue the process optimisation. The lessons learned will be used not only for operational optimisation and troubleshooting, but also to guide future equipment procurement and installation and to optimise the framework for future biogas upgrading plants in terms of overall financial performance throughout the operating life. Operating and maintenance procedures will be continuously improved.

Table 1: PROCESS DESIGN DATA

Nominal Capacity	100 – 300 Nm^3/hr (raw gas)
Raw Gas Requirements (Typical)	CH_4 = 50 – 65% volume CO_2 = 35 – 50% volume H_2S = <2500ppm (extra cost may apply if exceeded) O_2 + N_2 + Other = < 0.5% (higher inerts may degrade outlet gas quality) H_2O = Saturated Inlet Pressure ≥ 50 mbar(g), ≤ 200 mbar(g)
Product Gas Delivery (Typical)	Inlet temperature, nominal 30°C CH_4 = 98% ± 1% volume CO_2 = 1 – 2% volume Total Inerts (O_2, N_2) = <1 – 2% volume H_2S < 5 ppm (0.1 – 1ppm very typical) Dew point @ 1 bar(a) = -80°C or less Pressure = 8 – 9 bar(g) at maximum raw gas flow
Product Gas Flow	Dependent on raw gas flow and composition

CONCLUSIONS

Upgrading biogas to biomethane is an effective and environmentally sound approach to minimising energy losses in biogas utilisation. Although a large share of the biogas produced at the wastewater treatment plant is still used for CHP, the share of biogas which was previously flared is now upgraded. One additional benefit is that biomethane can also be readily stored which gives the possibility to meet fluctuating demand for fuel as well as energy. The upgrading plant in Fredericia opens the way for changing the traditional use of biogas in Denmark from CHP to biomethane and biofuel production.

Table 2: KEY COMPONENTS

Gas Compressor	Single Stage Screw Compressor, SRM K419
Compressor Motor	45 kW, 2 Pole, IP55, ATEX, High Speed Electric Motor (For EU)
Process Water Pump	Lowara Vertical Multistage Pump, Model SV3307/1N185T
Water Pump Motor	18.5 kW, 2 Pole, IP55, ATEX, Electric Motor (For EU)
Variable Speed Drives	Main Drive Compressor VSD: 45kW 88 Amps IP21 CFW110105T4OSZ (For EU) Water Pump Motor VSD: 18.5kW 38 Amps IP21 CFW110038T4OFAZ (For EU)
Process Vessels	Scrubbing Vessel, GRP with polypropylene packing media and distribution trays Stripping/Flashing Vessel, GRP with polypropylene packing media and distribution trays
Biomethane Drying and Polishing	Patented PSA/TSA adsorber is included. Dual column type with auto changeover valving. Installed Regeneration Heater, 3 kW, EX rated.
PLC & HMI	PLC = Siemens 6ES7-200 Safety PLC; HMI = 5.7” Colour Touchscreen Model KTP600
Communication Protocols	Ethernet and/or Profibus
Switch Gear/ MCC & Isolation	Included, typically Schneider NS/NSX switchgear, GV2 motor protection, C60 MCB, DPN Vigi RCD, LC1 contactors

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