BIOGAS XPOSE

Compilation Report

Maximized biogaspotential from resource innovation in the Biogas Öst region

BACKGROUND

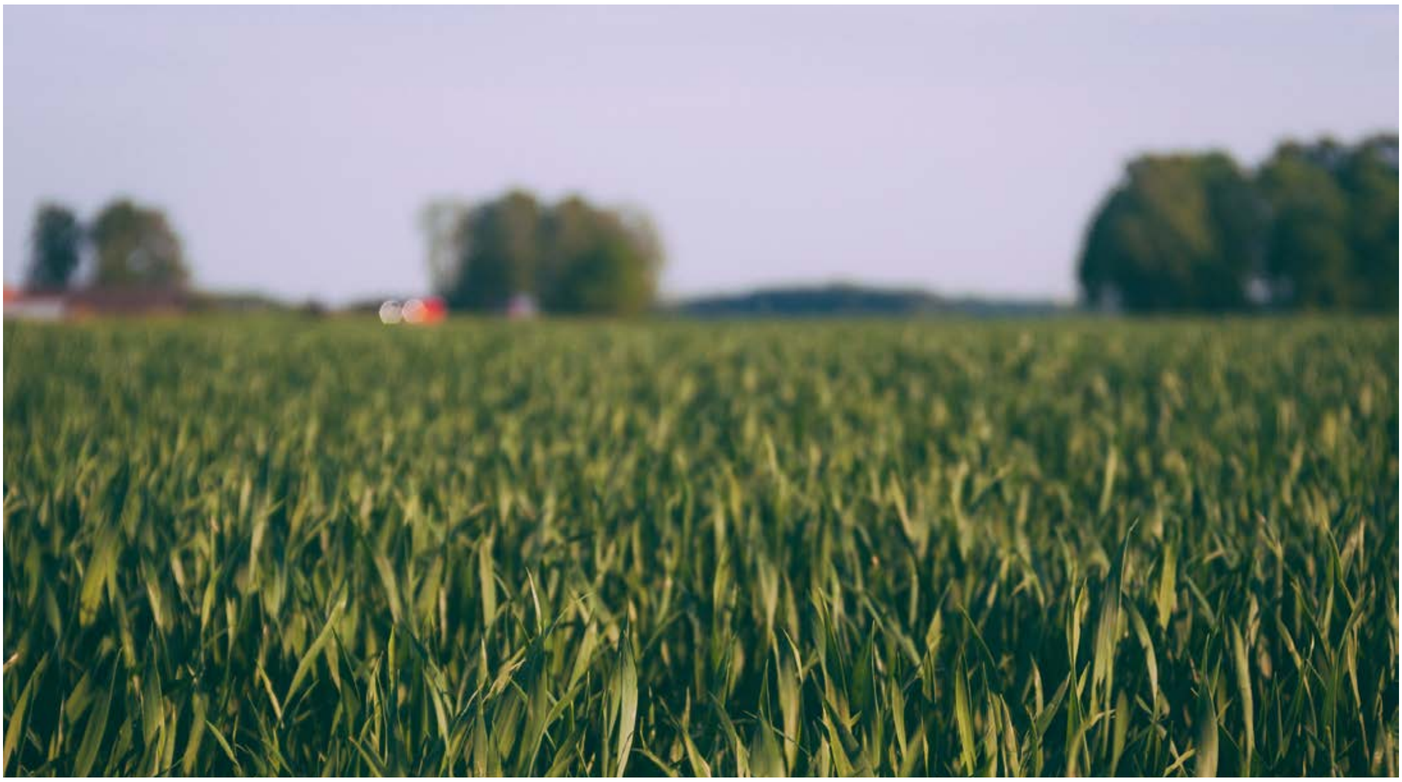
This report summarize and compile results from four different reports. The reports are:

- B8_1 Theoretical study on gasification ash
- B8_3 report on gasification of new substrates (part 2)
- B9_2 Summary report on installation of gas cleaning and distrinution system for CNG
- B12_1_Report on prototype design and construction
- B14_1 Evaluation small scale upgrading

INTRODUCTION

In the project proposal were possible synergies between the technologies included in the project mentioned. The technologist covered different parts of the biogas and biomethane (BM) value chain. The **small scale upgrading module** could, if successful, allow for BM production from agricultural waste products and small-to- medium sized waste water treatment plants. The **dry fermentation facility** could, if successful, allow for biogas and BM production from mixed house-hold waste that can't be used in wet fermentation (for example plastic containers that still contains a substantial amount of organic waste). The **gasification facility** could, if successful, allow for BM production from substrates such as mixed house hold waste of low quality (that is, hose hold waste of such low organic content that it neither can used for wet fermentation to dry fermentation) and waste products from the forest industry.
If all three technologies proved successful three could be all sorts of synergies. For example:

- House-hold waste could, after dry fermentation, be used for gasification thus maximize BM production.
- Organic waste could, after being wet fermented and upgraded with the small scale upgrading, be used for gasification.

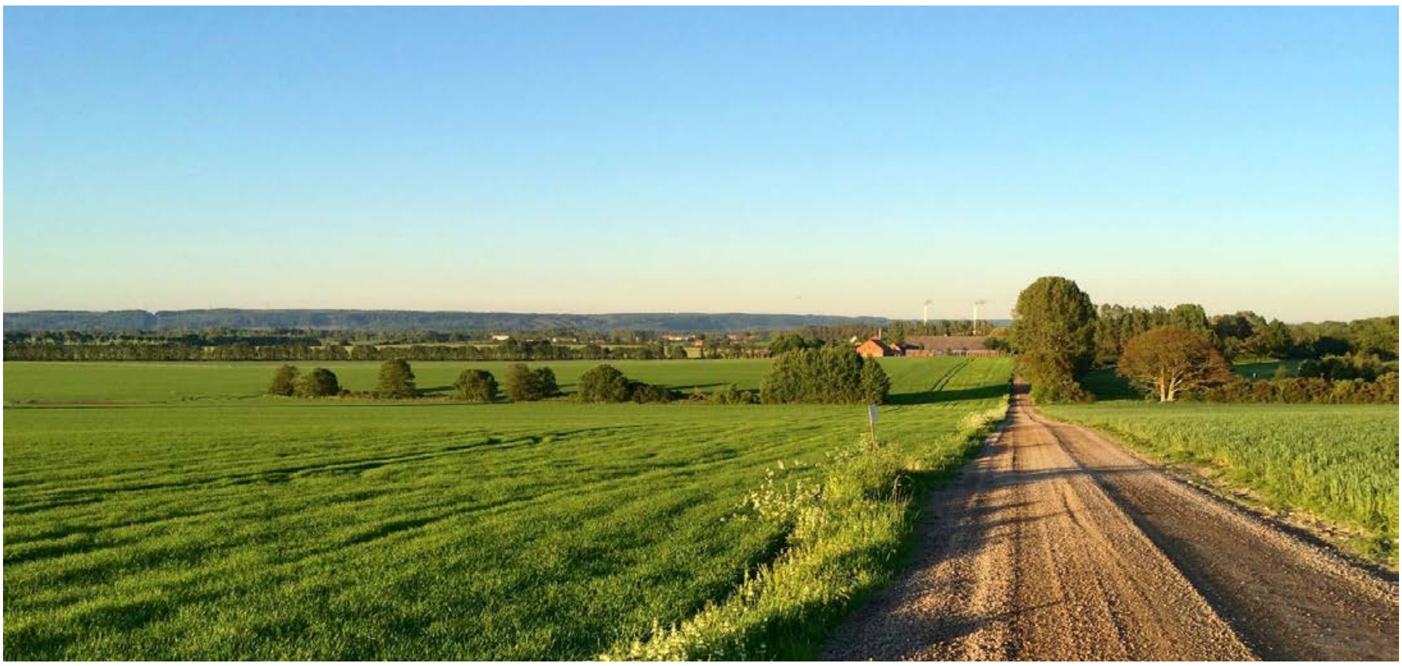


RESULTS

SMALL SCALE UPGRADING

The largest unexplored potential for producing raw biogas in Europe and around the globe lies within farms and small waste enterprises. The current market situation is such that most of the biogas upgrading equipment suppliers focus on large raw biogas producers with flows of >300 Nm3/h and many of the project are >1000 Nm3/h. Small flows are expensive to upgrade with the equipment on the market, and it has also been judged difficult to downscale such equipment economically.
As a response to this market situation, NeoZeo has developed **a state-of-the art technology**, and created a mobile, easily transportable biogas upgrading module, fitted into a standard- size sea container, which ensures its quick start-up and economical use even for small volumes (50-300 Nm3/hour) of raw biogas.

At present, there are more than 330 biogas upgrading plants in the European region; where, the most significant technologies for production of biomethane are: (1) water scrubbing (WATS) – approx. 35 % of all biomethane plants; (2) chemical scrubbing (CHEMS) -26% share; (3) pressure swing adsorption (PSA) -23% share; 4) membrane separation (MEMS) - 11 % share; and (5) physical scrubbing (PHYS) -4 % share (IEA, 2015).
NeoZeo's biogas upgrading modules are based on the Vacuum Pressure Swing Adsorption (VPSA) technology - a technology that combines features of Pressure Swing Adsorption (PSA) and Vacuum Swing Adsorption (VSA). VPSA is well suited for the upgrading of small-to medium flows of biogas. VPSA technology relies on the fact that under pressure, gases tend to be attracted to solid surfaces, or "adsorbed"; and the VPSA process is used to separate gases since some gases are attracted to surfaces more strongly than others. When biogas, compressed at a near-ambient pressure, is fed into the upgrading column, it is put in contact with an adsorbent material that selectively traps the target gas – carbon dioxide.
Among the most commonly used adsorbent materials are carbon molecular sieves, activated carbon, zeolites, and some others. In close cooperation with the Stockholm University, **NeoZeo developed a unique adsorbent material – a zeolite with a longer lifetime, lower cost, and higher operational efficiency, compared to other materials.** VPSA technology, which is considered to be among the most efficient systems, combined with the unique adsorbent materials allow for high gas recovery results. This, besides the high quality of the end product, **leads to lower power consumption and therefore lower operational costs.** Finally, NeoZeo's technology is water-free and chemicals- free and requires no other utility than electricity.



CONSTRUCTION

The construction time of the upgrading module was approximate 2 years in total (from 01.07.2013 to 31.07.2015). The specific steps undertaken were:

1. Tailoring and the evaluation of adsorbents
   During this step were a number of possible adsorbents (a key item in the small scale upgrading) selected for theoretical optimization of PSA unit.
2. Optimization of PSA unit
   Theoretical optimization of pressure swing adsorption (PSA) unit. Tests were performed using parameters of the adsorbents identified instep 1.
3. Blueprints of PSA unit and full upgrading module
   The final blueprints of the full upgrading module were finalized in August 2015.
4. Optimization of upgrading module
   Optimization continued throughout the whole project.
5. Certification of PSA unit and upgrading module
   Certification of the PSA module was finalized during 2016.
6. Construction, tests and modification of the PSA unit
   The construction of the PSA unit was finalized in June 2015, further tests and modifications were finalized in July 2015
7. Production of adsorbent
   Production of selected adsorbents earlier begun in March 2015 and will continued until the end of the project.
8. Construction of the full upgrading module and its optimization
   Construction of the full upgrading module was completed on the 7th of August 2015. Tests and optimization of the full operational upgrading module started in the same month and countrified until the end of the project.

RESULTS

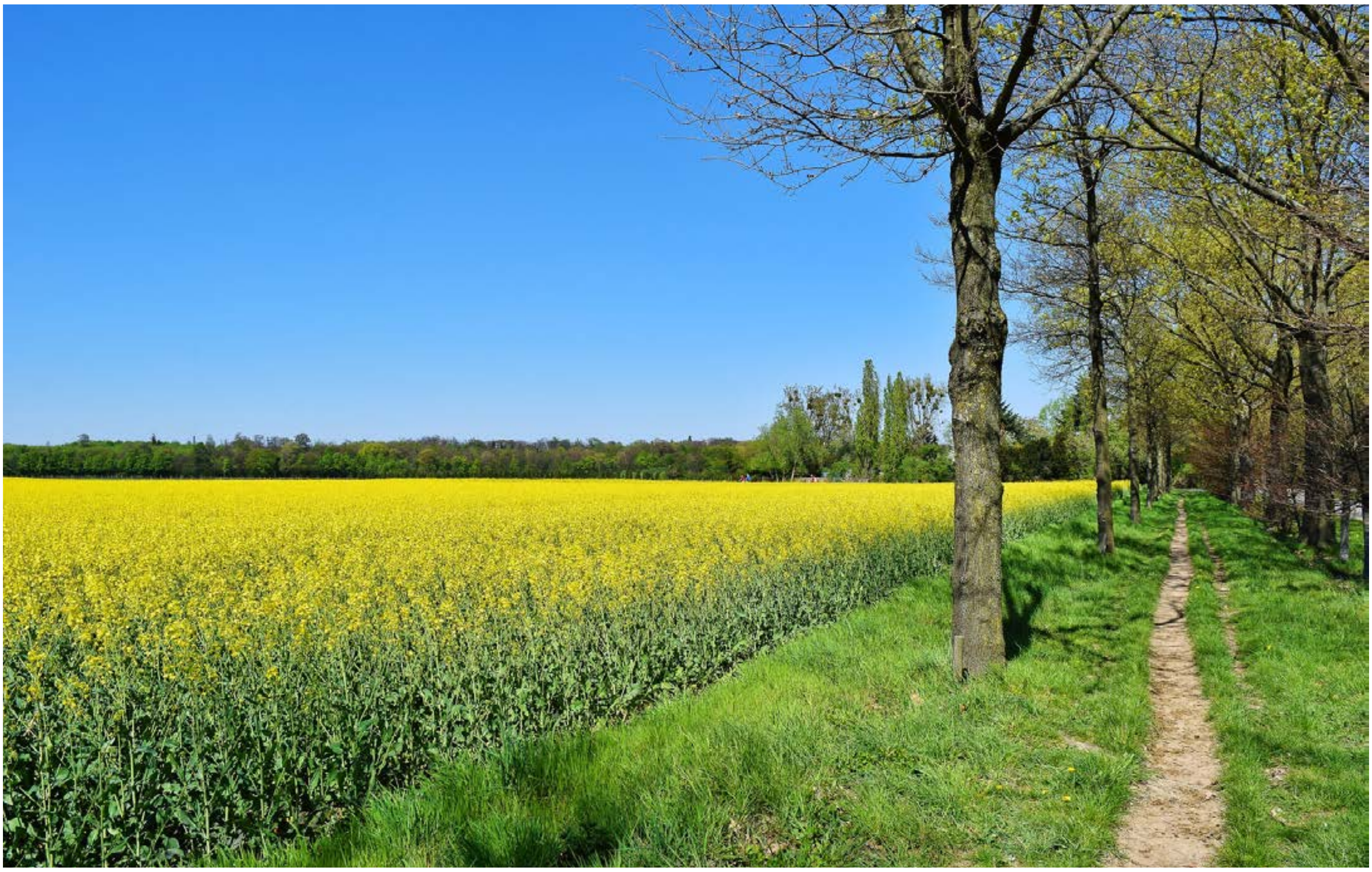
The construction time of the upgrading module was approximate 2 years in total (from 01.07.2013 to 31.07.2015). The specific steps undertaken were:

1. Flow of raw biogas and upgraded biogas (Nm3 per hour)
   30-70Nm3/hour of raw biogas flow.
2. Cost for electricity and cost per Nm3 methane produced
   Energy consumption of 0.24-0.28 kWh per cubic meter of raw biogas. Production costs (assuming 0.5SEK/kWh and 60% of methane in raw biogas) was approximatly 0.2-0.23 SEK/Nm3 of biomethane
3. Technical functionality of systems
   The module performance was stable and in accordance with the functional parts supplied to assemble the module.
4. Investment costs and critical points in the investment and construction
   Investment costs for 100Nm3/hour biogas upgrading module is 3.9MSEK. Construction time is estimated to be 6 months.
5. Total production cost of biogas and biomethane SEK/kWh and SEK/Nm3
   Production costs were 1.09 SEK per 1 Nm3 of raw biogas or 0.189 SEK per kWh.
6. Calculation of reduction of greenhouse gases due to produced biomethane
   A 100 Nm3/hour module during 10 years biomethane production can save over 90 thousands tonne of CO_2eq.

GASIFICATION FACILITY

WoodRoll®, is a beyond state-of-art gasification technology created and further developed by Cortus within the XPOSE project. The process is physically separated into drying, pyrolysis and gasification steps. The volatiles formed during pyrolysis is supplying the whole system with the heat from combustion, while the remaining char (fixed carbon) is gasified with only-steam in an entrained flow reactor which, in turn, at a sufficient high temperature, reduces steam to hydrogen in an endothermic process increasing enthalpy of the formed syngas. The gas of ca 11MJ/Nm^3 can be utilized for heat & power or upgraded catalytically to fuels. **In this case, the biomethane is converted from syngas through a 2-step chemical process being separated via PSA, eventually**.

A new system comprising the WoodRoll® gasification technology, an innovating Ni-based catalytic methanation process developed at Karlsruhe Institute of Technology was construced and technically and economically evaluated. Addition of a mixture of fibre sludge rich in lignin together with bark improves the processability of the feedstock through the facility. Furthermore, the yield of a volatile fraction after pyrolysis increases, which is beneficial for conversion of a very humid fuels. The empirical results generated from the test campaign was used for simulation of a commercial plant of capacity of 4,8, 9,6 and 16 MW SNG running on woodchips as a refence case. The results were subsequently confronted with a model using the data from the tests with lower quality fuels. Using of lower quality fuels is technically possible for all analysed cases. **Producing biomethane from woodchips will promise the best biomass-to-gas efficiency (around 64%) even though the cost of feedstock was as high as 150SEK/MWh. The model indicates a Return on capital (RoC) of 5,2 % for a 6 MW plant in that case.This case can compete with the same return on investment for the 50/50 mix of bark and fibre sludge of a price 55 SEK/MWh.** Mixing bark with fibre sludge not only improves its economic feasibility, the technical suitability increases compared as well compared to operation with “pure” bark. Lower cost feedstock increases the RoC to a maximum of 9,7 % if waste fuels for zero cost can be obtained**.**



CONSTRUCTION

1. In the beginning of 2015, the installation work for the gas cleaning system was started. The first pilot test of the new gas cleaning was carried out during April of 2015.
2. Numerous potential substrates were tested between 2015 to 2018.
3. All parts of the gasification system was fully functional and integrated in 2018.
4. On 07/06/2018 was a reference fuel (wood) gasified, the syngas was cleaned, biomethane was produced and compressed and finally a CNG car was filled and drove away.

RESULTS

1. In 2015 were three possible gasification substrates tested mixed household waste from Vafab, horse manure and house hold waste sludge. Key parameters tested were carbon content, moisture content, sulfur content and ash percentage. None of the tested substrates qualified for further gasification tests.
2. In 2016-2017 were new possible substrates (based on waste products from the paper industry) tested, bark, sedentary sludge, wood chips, fiber sludge and a mixture of sludge and wood chips. Results from the tests were satisfactory and the paper sludge based substrates were approved for further gasification tests.
3. In 2018 were the paper sludge based substrates tested in the gasification facility. The ash/char produced proved to be unsatisfactory and the test were halted before the methanation step.
4. In 2018 were a reference fuel (bark/wood chips) used to test whole gasification process. The test were successful and a car CNG car could be fueled. The methane content were slightly below Swedish CNG standards (92% compared to 96%).
5. Further work (after the end of the XPOSE-project) will be done in order to allow for more kind of substrates and to reach the CNG standard.
6. ROI estimates indicates a payback time (of a gasification facility) of 7-9 years if a suitable priced waste substrate can be found.

DRY FERMENTATION

The Dry Fermentation plant was not built.

SYNERGIES

Most of the possible synergies mentioned in the application required a dry fermentation plant. Since the DF plant was not build fewer synergies was achieved. Two possible synergies were found:

A successful synergy was that the technology behind the small scale upgrading can be used as part of the methanation step in the gasification facility which further increase the cost effectiveness.

The small scale upgrading unit is mostly aimed towards the agricultural sector. The substrates used for biogas production in that sector will most likely be suitable for gasification in the near future. It the small scale upgrading technology result in more agricultural based biogas and BM production it is likely that more cost efficient substrates suitable for gasification will be available

FUTURE SYNERGIES IN THE REGION

A dry fermentation plant was built in the project region (inaugurated late 2018). The owner of the plant (E.ON) is a member of the AB Biogas Öst. The synergies mentioned in the application (that required a dry fermentation plant) can hopefully be tested an evaluated during the next few years.