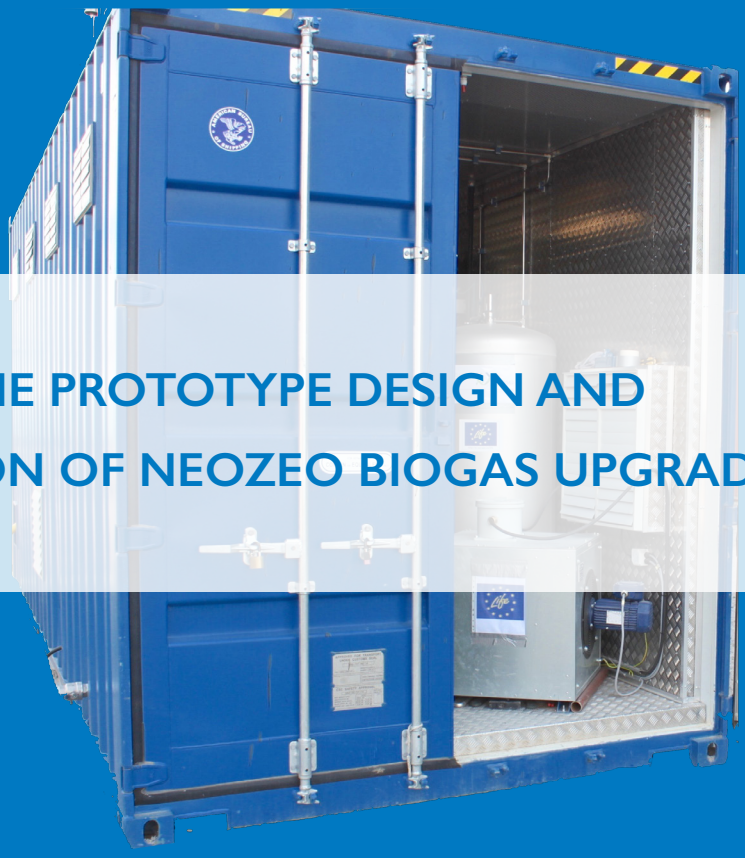
NeoZeo
Biogas upgrading

Life

BIOGAS Xpose
Maximized biogaspotential from resource innovation in the Biogas Öst region



REPORT ON THE PROTOTYPE DESIGN AND CONSTRUCTION OF NEOZEO BIOGAS UPGRADING MODULE

www.biogasxpose.eu

www.neo-zeo.com

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1. Background

Today raw biogas is mostly used for combined heat and power (CHP), while upgraded biogas, biomethane, carries double the energetic value, and is one of the world's cleanest fuels. Studies have shown that substituting fossil fuels with biomethane could drastically reduce emissions of toxic and carcinogenic substances, largely reduces CO_2 (by up to 97%), and the significantly decreases particle and NO_x emissions (up to 60%). Combustion of CH4 is not only much cleaner than combustion of petrol or diesel, but it is more energy effective as well.

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 Nm^3/h and many of the project are >1000 Nm^3/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 Nm^3/hour) of raw biogas.

1.1. Biogas Upgrading Technology.

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).

Pressure swing adsorption - PSA

The PSA technique separates the carbon dioxide from the biogas by adsorption on a surface under an elevated pressure (Masebinu, Aboyade, & Muzenda, 2014). Because the size of CO_2 molecules is smaller than those of CH_4, CO_2 can be captured in a proper adsorbent material and hence separated from CH_4 molecules (Niesner, Jecha & Stehlík, 2013). The adsorbing material is regenerated by a sequential decrease in pressure. In this way, the attractive forces, which held the adsorbate on the adsorbent are now weaker than those of the

chemical bonds, consequently, the adsorbate can be released before the column is reloaded again. PSA also enables to remove N_2 and O_2, however, the adsorption of hydrogen sulphide (H_2S) is normally irreversible in the adsorbents and thus a process to eliminate this gas should be placed before the PSA (Masebinu, Aboyade, & Muzenda, 2014).

The efficiency of the adsorption process depends mainly on temperature, pressure and adsorbent. In the case of PSA, the temperature is constant while the pressure "swings" between high and low pressure (the range of operating pressure is 4-10 bar). For commercial applications adsorbents like molecular sieves, zeolites and activated carbon are primarily employed (Niesner, Jecha & Stehlík, 2013).

The PSA method has many advantages compared to other methods for biogas enrichment. PSA has a flexible design and can use more than one absorbent. PSA is a dry process and therefore it does not require liquid chemicals, nor any water (excluding thus the problem of contaminated waste water). The technology requires less heat and has no bacteria contaminant of off-gas. Moreover, PSA is also economically and technologically suitable for small to medium scale plants (Masebinu, Aboyade, & Muzenda, 2014).

2. NeoZeo AB's Biogas Upgrading Technology.

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. After a while, the adsorbent becomes saturated with CO_2 and needs to be regenerated, which is done by reducing the pressure to a vacuum before the column is ready again for the next adsorption cycle. During the process, high-quality biomethane is supplied for a high-pressure compression to a high-pressure storage, and the CO_2 and other impurities are removed. Apart from CO_2 separation, NeoZeo's modules are designed to precondition the raw biogas, remove such impurities as hydrogen sulfide and moisture (H_2O).

As already mentioned, 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.

The development of NeoZeo's adsorbents, construction of the biogas upgrading module, and its implementation via a demonstration plant are described further.

3. Construction of the Prototype

The duration of the construction time of the biogas upgrading module was approx. 2 years: from 01.07.2013 to 31.07.2015. The specific steps undertaken as part of the construction process are specified below. By underlining these steps, NeoZeo provides with a provisional action plan and approximate time framework for other organizations that want to initiate a similar project, but need guidance to better structure and focus their efforts.

3.1. Tailoring and the evaluation of adsorbents. During this step, NeoZeo together with the "Exselent" center at Stockholm University have selected two adsorbents (adsorbent I and adsorbent II) for theoretical optimization of PSA unit. The adsorbent III was developed by NeoZeo and therefore was resulted in a new patent application, submitted on 5th of February 2014. The international patent application for the same adsorbent was submitted in February 2015. An additional candidate for the efficient biogas upgrading was identified - adsorbent IV, a patent application for this adsorbent was submitted in June 2015.

High thought output production tests of the adsorbent III were started in March 2015. The first granulation of the adsorbent III was registered in April 2015. Tests of the granulated adsorbent III showed that more R&D should be done on the granulation procedure of the adsorbent III. The R&D on the granulation of the adsorbent III was performed between Sep-Nov 2015 in cooperation with "Exselent" center.

3.2. Optimization of PSA unit. NeoZeo together with the "Exselent" center at Stockholm University worked, at the beginning of 2013, on theoretical optimization of PSA unit using Gproms software package. The modeling code for the PSA process was written. Tests of the code were performed using the parameters of the adsorbent I - the parameters being earlier identified in the activity 3.1.

3.3. Blueprints of PSA unit and full upgrading module. NeoZeo developed blueprints of the VPSA unit and the upgrading module in December 2014. The final blueprints of the full upgrading module and VPSA unit were finalized in August 2015.

3.4. Optimization of upgrading module. This activity started together with the tests and operation of the upgrading module and the PSA unit (3.2.) - in August of 2015. The optimization of the upgrading module is planned until the mid of 2018.

3.5. Certification of PSA unit and upgrading module. The certification of the PSA module was started in cooperation with Inspecta and will be finalized during spring 2016.

3.6. 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.

3.7. Production of adsorbent. The production of the adsorbents selected earlier (during 3.1.) has started in March 2015 and will continue till the end of the project.

3.8. Construction of the full upgrading module and its optimization. The full upgrading module was constructed and placed at Biogas Vecsiljani farm in Latvia for tests and optimization on the 7th of August 2015. Tests and optimization of the full operational upgrading module started in the same month - August 2015.

4. Upgrading Installation and the demonstration of the prototype in Sweden

The duration of the installation and demonstration of the prototype in Sweden is estimated to be till 01.07.2017. Main implementation steps that need to be undertaken and possible difficulties are specified below:

4.1. Implementation. It is important to find a visible place in the Mälaren area, which can provide a raw biogas with a price below market price of biomethane/vehicle gas (per kWh). Subsequent use of the biomethane as vehicle fuel is also in process of being identified. There is on-going discussion with SLU (Agricultural University at Uppsala) and other suppliers of raw biogas. Also there is a discussion with biomethane consumers e.g. Valtra and Scania for demonstration of the biomethane usage.

4.2. Difficulties. The difficulty faced is that the planned partner/supplier of raw biogas (SLU – agricultural university of Uppsala) has high production costs of the raw biogas (per kWh). Currently, their production costs are higher than the market price for biomethane/fordonsgas (per kWh). The suggested raw biogas production costs are based on sum of electricity, heat and local governmental subsidies. Furthermore, the planned partner has substantial rent and support costs to place the module for tests. Moreover, NeoZeo needs to relocate its current researchers and engineer to the test location, which will also increase the demonstration costs. Thus, the first conclusion was that the demonstration of the full biogas upgrading module at the Mälaren area requires a revision and possible increase of the budget for the related demonstration (chapter 3) and evaluation (chapter 5) activities.

NeoZeo has found a solution to the abovementioned difficulty: NeoZeo will have free of charge access and usage of the biogas produced by the SLU partner in Uppsala, with the condition that NeoZeo will return the produced biomethane. Such anarrangement solves the issue of high biogas procurement costs for NeoZeo, and thus is considered suitable for the purpose of installing a demonstration plant in Sweden.

5. Upgrading - Evaluation

The duration of the evaluation of the module is approx. 1 year: from 01.04.2016 to 01.07.2017. Main implementation steps that need to be undertaken and possible difficulties are specified below:

Implementation. The evaluation of the biogas upgrading module, which includes evaluation of biomethane competitiveness produced by the NeoZeo's module, should be performed with a possibility to produce the biomethane at a market price which should include the upgrading (OPEX) and investment costs (CAPEX). The action will start later, approx. during the summer 2016, after complete evaluation of other suppliers of raw biogas in the area and identifying an economical use of BM as vehicle fuel.

6. Conclusion

The present document introduced the reader with up-to-date, relevant information about the use of raw biogas, but most importantly about the applicability and advantages of biomethane usage, and described the main characteristics of the implemented VPSA biogas upgrading technology. This report shed light on the unexplored potential for producing raw biogas and biomethane - the farms and small waste enterprises. It further presented NeoZeo's unique offer to the aforementioned target group.

NeoZeo shared information regarding the steps taken to achieve the construction of its module, as well as the action plan and time framework for the next goals - the installation and demonstration prototype in Sweden and the further evaluation of the competitiveness of its technology within the Swedish biogas/biomethane market. Upon the successful completion of the goals set out, NeoZeo will write a final report, sharing its main takeaways and useful information with the public.

References

IEA Bioenergy (2015) Biogas Overview (Country Reports Summary) 2014 Task 37 Source: http://www.ieabioenergy.com/wp-content/uploads/2015/01/IEA-Bioenergy-Task-37 Country-Report-Summary-2014_Final.pdf accessed at 05.10.2015

Niesner J., Jecha D., & Stehlík P. (2013). Biogas upgrading technologies: State of art review in European region. Chem. Eng. Trans, 35, 517-522.

Masebinu S. O., Aboyade A., & Muzenda E. (2014). Enrichment of biogas for use as vehicular fuel: A review of the upgrading techniques.