BIO2G - A FULL-SCALE REFERENCE PLANT FOR PRODUCTION OF BIO-SNG (BIOMETHANE) BASED ON THERMAL GASIFICATION OF BIOMASS IN SWEDEN

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ABSTRACT: E.ON Sverige is planning for a 200 MW_{gas} bio-SNG (1,6 TWh/year) plant in southern Sweden based on thermal gasification of forest residues and other biomasses. The project is called Bio2G and has been developed during the past five years. Bio-SNG (biomethane) is a unique product which has a great potential on all fuel markets. It can be used as a transport fuel, for combined heat & power production, for domestic heating purposes as well as for industrial feedstock. It is fully compatible with natural gas and can be distributed by the same existing infrastructure. A project like Bio2G may even create the security of supply needed for the current natural gas supply which in Sweden is based on a single connection from Denmark. Bio-SNG may also be produced in liquefied state, LBG, and transported and sold in the same way as Liquefied Natural Gas (LNG).

The location of the plant is not finally decided but an Environmental Impact Assessment has been performed for two alternative sites in the harbours of Landskrona and Malmö. The project has developed through pre-studies, conceptual studies and finally a pre-FEED (Front End Engineering and Design) for the plant and is now ready to submit the Environmental Permit application and start the final FEED and procurement phase. Start of operation is targeted to 2018. The time schedule is highly dependent on the market development for renewable transportation fuels that in turn is strongly dependant on political initiatives. In July 2012, the Swedish Government launched a public investigation which will propose the way forward and measures in order to achieve 10% renewable fuels in the Swedish transportation sector by 2020, an independence of fossil transportation fuels by 2030 and the more visionary target to have climate neutral transports by 2050. This work will be reported by the end of this year.

The plant is designed for a production of 200 MW_{gas} (1,6 TWh/year) gaseous and liquid bio-SNG, 16-24 MW_e and up to 60 MW_{heat} of district heating. The fuel supply is estimated to 345 MW_{th} biomass, mainly forest residues, which corresponds to about one million tonnes wood chips per year. About 250 000 m^2 land will be required for the process plant and the fuel yard and the fuel will be transported by trucks, trains and ships. The fuel will be dried before it is fed in to the pressurized fluidized bed gasifier (10bar/850°C) and converted into a product gas, which is cleaned from particulates and gaseous contaminants. Oxygen/steam will be used as gasification agent in order to minimise the content of nitrogen in the final product and an air separation unit will be included in the plant. The tar content in the gas is reduced in a catalytic reformer and the gas is further conditioned to clean synthesis gas before compression and methanation. Acid gases as H_2S and CO_2 are removed upstream the methanation and remaining CO_2 and water are removed downstream the methanation. Finally, the bio-SNG is compressed to the required pressure of the existing natural gas transportation grid. The Bio2G plant will be the first of its kind, a reference plant, and in the future, thermal gasification of ligno-cellulosic fuels and methanation will offer bio-SNG yields in excess of 65%.

The pre-FEED constituting a complete design as well as supporting test activities has been performed in close collaboration between E.ON Gasification Development AB, Carbona OY, Finland, a subsidiary to the Andritz Group and Haldor Topsoe A/S, Denmark.

Keywords: Alternative fuel vehicle, biogas, catalytic conversion, circulating fluidised bed, clean synthesis gas, gaseous biofuel, gasification, second generation, synthetic natural gas (SNG).

1 BACKGROUND & MOTIVES

The European climate targets for 2020 and the even more stringent national targets in Sweden aiming for independence of fossil fuels in the transportation sector by 2030 and climate neutral by 2050 as well as the regional target in the Scania region (Southern Sweden) to increase the biogas production to 3 TWh biogas (bio-SNG) in 2020 urge E.ON Nordic to increase the biogas production via fermentation and also to introduce biogas production based on thermal gasification. The latter technology has a great potential to produce large amounts of biogas from ligno-cellulosic biomass. An estimation of the technical potential of biogas production from domestic, hitherto, unused, forest residues sums up to about 60 TWh in Sweden. A similar estimation of biogas produced via the fermentation route is about 15 TWh in Sweden.

Even if bio-SNG can replace any use of fossil natural gas, the vehicle fuel market is seen as an obvious entry market where biogas fits with political aims and savings on greenhouse gases will be substantial. Already today, more than 40000 vehicles are operating on vehicle gas in Sweden with a minimum of 50% biogas blend (current value is 60%) with natural gas in and the market demand for renewable gas is increasing. The fossil transportation fuels have a high tax rate and the ability to pay a higher price for a renewable biofuel alternative is more favourable compared to power production sector or industrial use where tax reduction is common. However, a stable and long term regulatory environment is a necessary prerequisite for the substantial investments needed to establish biofuel production in large amounts.

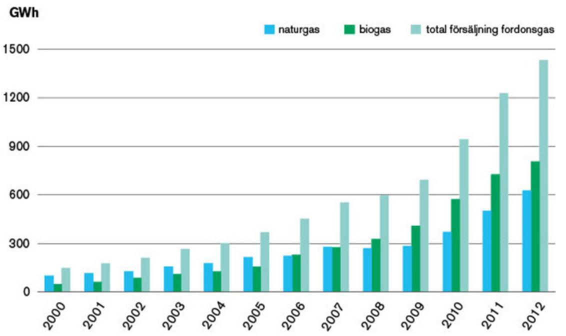

Figure 1: Vehicle gas sales in Sweden – a growing market (Reference: http://www.gasbilen.se/Att-tanka-pa-miljon/Fordonsgas-i-siffror/FordonsgasutvecklingSverige).

Gas grid operators in Belgium, Denmark, France, the Netherlands and Sweden have recently and jointly committed themselves to the target 100% carbon neutral gas in 2050 in their gas grids. (Reference: http://www.swedegas.se/aktuellt/100%20procent%20fornybar%20gas%20i%20svenska%20gasnatet%202050).

The Swedish Government has initiated a public investigation “Fossil Independent Vehicle Fleet” in order to propose new incentives, intermediate targets and a roadmap to achieve the environmental targets by 2030 and 2050, respectively.

In order to meet these political targets and the increasing demand for renewable gas, E.ON Nordic has invested considerable efforts and costs to verify the feasibility for a 200 MW_{SNG} (1,6 TWh/a) plant in southern Sweden based on thermal gasification of forest residues and other woody biomasses. During this work, technical and logistic as well as business model aspects has been considered. Production of 1,6 TWh bio-SNG corresponds to about 145 million m^3 methane which is sufficient to provide renewable CBG (Compressed Bio Gas) to more than 150 000 cars and in addition supply district heating for about 20 000 households in Sweden. The project, named Bio2G, is in line with E.ONs commitment to cleaner and better energy and decisions to launch a FEED (Front End Engineering and Design) and apply for permits are pending. The Environmental Permit is expected to be granted within about a year from submission of the application. Scheduling of permitting, FEED and EPC-phases are aligned to a firm target to have the plant ready for commissioning in early 2018.

The ambitious targets set out, both by the Swedish Government/politicians and E.ON are really challenging, but history shows that similar developments and changes are possible to obtain within a relatively short time frame. In 1980, almost all district heat in Sweden was produced by oil and 25 years later, in 2005, the production has changed into being based almost entirely on renewable sources, **Figure 2.**

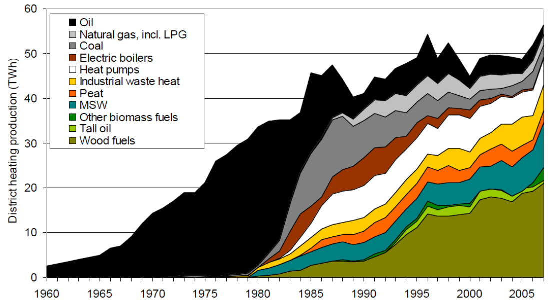

Figure 2: Historic use of fuels in district heating in Sweden (Reference: Ericsson, K., Svenningsson P. (2009) Introduction and development of the Swedish district heating systems - Critical factors and lessons learned, RES-H/C Policy project report, Environmental and Energy Systems Studies, Lund University, Lund, Sweden).

This example supports the vision that similar development could be achieved in the transportation sector by applying a mix of electrification, drop-in fuels and dedicated biofuels where bio-SNG has a significant role to play both as a drop-in fuel to CNG/LNG as well as a dedicated biofuel.

2 THE BIO2G PROJECT

The Bio2G project has been developed during the past 5 years and aims primarily for production of bio-SNG, a second generation vehicle biofuel. The product being equivalent to natural gas will be distributed via existing infrastructure for gas and might in a longer term be of interest also for many other markets e.g. heat & power, domestic use, industrial feedstock etc. Also supply in liquid form (liquid bio-SNG, LBG) is considered and can be utilized very effectively in an integrated plant as Bio2G.

The Bio2G project development has included a very thorough assessment of a wide range of technology alternatives and potential suppliers/developers. The assessment was brought further into parallel conceptual process designs for a number of alternatives and later also a pre-FEED for a few selected cases. The last step being a basic design for a complete plant including not only core processes (gasification, gas cleaning & methane synthesis) but also all necessary auxiliaries as heat and power integration, fuel handling, storage and preparation, ASU integration etc.

2.1 Localisation and fuel supply

Two sites have been prioritized out of a selection of around 60 potential locations; the harbour area at Landskrona and at the Northern Harbour of Malmö. Both alternatives have a suitable infrastructure for fuel transports and gas distribution as well as access to a district heating grid where surplus heat from the process can be utilized. A complete environmental impact assessment has been made for both sites including a number of sub-investigations to provide sufficient information to file an environmental permit application. A photomontage of one of the sites is shown in **Figure 3**.

A crucial factor when establishing a production plant in this size is the fuel supply and fuel handling on the site. Annually, roughly 1 million tons of wood fuels have to be transported into the site and a preliminary estimate is that one third will be transported by truck, by rail and by ship, respectively. The fuel processing part of the plant will be equipped to handle almost all fuel fractions from saw dust to logs. The area requirement for the total plant including the fuel processing and storage is approximately 250 000 m^2.

Figure 3: Photomontage of one of the alternative sites

The fuel supply is mainly foreseen to come from domestic sources but import is of course also a possibility to some extent. In general, Sweden has large forest areas all over the country but the largest potential of unused residues exist in the southern and mid part of Sweden, where the growth rate is higher compared to the north. Transportation by truck will be the most efficient way for transports with short distance while ships are more efficient for long-distance e.g. overseas, from northern Sweden or the Baltic region. Railroad is always an interesting alternative in medium to long distance transports.

2.2 Process description

The process starts with chipping the wood, if necessary, and mixing a suitable fuel blend before the fuel enters the drying section. It is necessary to dry the fuel to a moisture content of 15-20% to produce a suitable gas for the methane synthesis. It is foreseen to use low temperature belt dryers in order to avoid foul smell, VOC emissions and at the same time improve the economy by using low grade process heat.

Since the gasification is planned to be made by a pressurized fluidized bed gasifier the fuel is fed through lock hoppers pressurized by excess CO_2 from the process and fed into the two parallel gasifiers. Gas cleaning is made in several steps including hot gas filtering at highest possible temperature and a catalytic reforming, where the remaining tars and higher hydrocarbons are transformed into hydrogen, carbon monoxide and methane. Oxygen/steam mix is used as gasification agent to minimize the nitrogen content in the gas and an ASU (air separation unit) will for this reason be an integrated unit at the site.

Between the gas cleaning systems and the final gas conditioning, the gas is cooled and pressurized to the pressure required by the stepwise methane synthesis where also removal of acid gases are integrated. The sulphur will be recovered as sulphuric acid and exported from the plant. Content of sulphur in the biofuel is low but venting sulphuric off-gases to the environment is not considered appropriate and thus a recovery process was integrated.

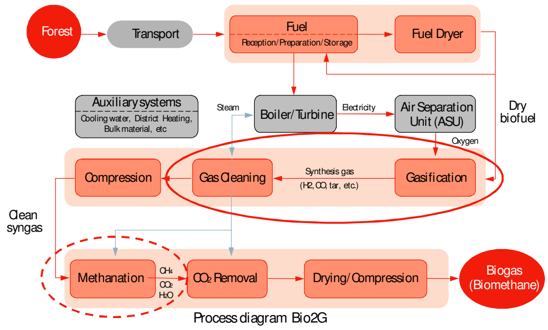

Figure 4: Simplified process diagram of the Bio2G plant

Finally, the gas will be dried and pressurized to the required pressure (typically 40-60 bars) in the main natural gas transportation grid. Optionally, liquefied bio-SNG can by a few additional means be produced by utilizing liquid nitrogen production in the air separation unit. The main reasons would be biofuel supply to e.g. heavy trucks and ships, which need a larger on-board fuel capacity or distribution to areas far away from any available gas grid.

The various processes in the plant are consuming or producing heat as steam or hot water and electric power is needed, especially in the air separation unit. A power island (CHP) will be integrated in the plant in order to produce the required power and heat, optimize and add flexibility to the operation, and minimize the streams of emissions, effluents and residuals from the production. As an example, the somewhat troublesome fly ash from the gasifiers will be combusted and the exported ash should rather be seen as a useful by-product than a waste product.

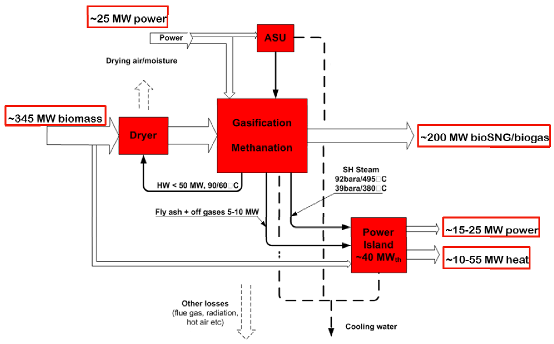

Figure 5: Simplified energy balance of the Bio2G plant

All waste water, except sanitary water, will be treated by conventional technology at the plant and together with the surface water from the fuel storage be discharged to the recipient, the sea, after passing a system of basins for sedimentation, biological treatment and an artificial wetland. In fact, the fresh water consumption is surprisingly low, since water is produced in the process.

2.3 Time schedule

A time line for the different phases in the Bio2G project is shown in **Figure 6**, below. The pre-FEED phase is more or less finalised and the FEED phase is pending further decisions. The aim is to have the plant ready for commissioning at the beginning of 2018.

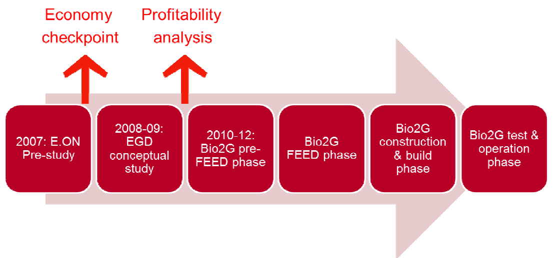

Figure 6: Bio2G project phases

Presently, further verification tests are planned in order to further increase confidence in the process design and advanced design studies of crucial systems are on-going. An application to the second call of the EC NER 300 instrument has been submitted and will, if granted, limit the financial risk.

3 PERFORMANCE AND ECONOMICS

The performance in terms of efficiencies has to be handled with care. What is included? What is not? It is always hard to compare different studies without knowing all details used in the calculations and depending on how system boundaries are defined. However, we calculate the bio-SNG yield to 60-65% and overall efficiency of 75-80%, incl. biogas, power, heat production and all auxiliaries in the Bio2G plant.

It can be concluded that comparing production of biomass based fuels SNG has excellent performance and yield. In **Figure 7**, an example comparing some other biofuels on similar boundary conditions as for Bio2G but a fuel input of 300 MW (LHV) is shown.

Product	Methanol	DME	FTD	Biogas (SNG)
Net Power export	0 MW	-9,5 MW	-2 MW	-12 MW
District heat export	63 MW	60 MW	101 MW	72 MW
Main product export	148 MW	172 MW	140 MW	191 MW
Overall efficiency	70 %	70 %	79 %	77 %
Main product yield	**49 %**	**57 %**	**47 %**	**64 %**

Figure 7: Comparison of efficiencies

The environmental performance of bio-SNG production based on ligno-cellulosic biomass is in general terms very good and, according to our calculations, much better compared to many other renewable biofuels. Of course, it is anticipated that the forestry itself is managed in a sustainable way following legislations, present or future directives, etc.

The presently most relevant sustainability criterion for bio-SNG production based on the feedstock supply for the planned Bio2G plant is the CO_2 footprint. Based on our project data including feedstock production, fuel transport according to our expected fuel supply portfolio, technical performance of the Bio2G plant and site conditions, we calculate the total amount of GHG to about 13 gCO_2 eqv/ $MJ_{bio\text{-}SNG}$ or around 85% reduction compared to gasoline. The European threshold for a sustainable biofuel will be increased to 60% in 2017. About one third of the Bio2G CO_2 footprint originates from the forestry and two thirds originate from transports. The bio-SNG production facility itself only contributes with a few percentages.

With regard to economics the estimated total investment cost in “the first of its kind” Bio2G plant is about 500 million Euros which corresponds to a production cost of 80-90 $Euro/MWh_{bio\text{-}SNG}$. The feedstock cost represents the major and is included.