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Small and medium scale bioSNG production technology

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SMALL AND MEDIUM SCALE BIOSNG PRODUCTION TECHNOLOGY

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Preface

This project has been financed by the Swedish Energy Agency and the industrial gasification group at the Swedish Gas Technology Centre and carried out by Dr. Jörgen Held, Renewable Energy Technology International AB, during the period 15.02.2013 – 31.03.2013.

The findings from this project have also been published as an SGC Rapport.

Summary

The indirect gasification technology has seen a rapid development in the last decade and several commercial plants for CHP production have been built. The indirect gasification opens a possibility to produce syngas suitable for methanation in the small and medium scale. However, in order to produce bioSNG extensive gas cleaning is needed.

So far the focus have been on removing all harmful contaminants and tar separation using organic solvent scrubbers has been a logical choice. Even though the energy in the removed tar can be recovered by burning the tars together with the spent organic solvent in the combustor the investment and operating cost for the gas cleaning is discouraging especially if one moves to the smaller plant sizes.

agnion Technologies GmbH has circumvented this problem by catalytic tar reforming and accepting a slow and controlled deactivation of the catalyst. In fact the cost for the spent catalyst is in the same order as for spent organic solvent but the investment cost is about 50 % lower and no additional treatment of the waste water is needed. The deactivated nickel based catalyst material is returned to the vendor. This procedure is more or less cost neutral since the value of the nickel on the catalyst is in the same order as the cost for the recycling. Since small scale plants normally suffer from a high specific investment cost any cost reduction is essential to make small scale bioSNG production economic feasible.

There is potential for further cost reduction. The cost of the carbon dioxide removal constitutes a significant part of the investment and the operating cost in small scale bioSNG production. In these scales (600-4,000 Nm^3/h raw gas) the technology development is driven by the anaerobic digestion sector. In later years the development of carbon dioxide removal for biogas upgrading has seen a rapid progress and a significant decrease in specific cost. If the suppliers of biogas upgrading get interested in the market possibilities within small and medium scale bioSNG production through gasification and methanation then further cost reduction may be expected.

Fluidized bed methanation is one key technology to unlock cost-effective bio-SNG production in the medium scale. The fluidized bed reactor replaces both the water gas shift and the fixed bed methanation reactors. This reactor type is able to handle syngas with a wide range of CO/H_2-ratios, from 1:1 to 1:5 if water addition is optimised. The temperature and the carbon management inside the isothermal fluidized bed result in a conversion of ethylene into ethane and hydrogenation of deposited carbon. Normally ethylene in the syngas constitutes a problem since it’s a cause for coke formation and catalyst deactivation but here it’s actually beneficial since its hydrogenation increases the Wobbe index and the heating value of the bioSNG. Approx. 3 % ethane has been observed in the tests with the PSI/CTU fluidized bed methanation.

The next development step of the fluidized bed methanation is related to specific sorption of sulphur and elimination of the costly tar separation. In practice the syn-

gas and the tars will be fed first to a sulphur adsorber bed and then into the fluidized bed methanation reactor. Any remaining organic sulphur will give rise to catalyst deactivation but the huge reduction in investment cost will allow increased cost for the catalyst. In this way the fluidized bed methanation replaces tar reforming, water gas shift and fixed bed methanation reactors.

The findings in this study may be concluded as:

- New development opens up the possibilities for cost-effective bioSNG production in the small and medium scale based on indirect gasification.
- Small scale plants are associated with a higher specific investment cost and lower efficiency than large scale plants based on the same gasification, gas cleaning and gas conditioning technology. However, by changing technology a substantial cost reduction is possible. There are several other advantages with small and medium scale bioSNG production compared to large scale plants such as the lower economic risk and the good possibilities to secure the feedstock and integrate excess process heat with local heat demand. In addition small scale plants are more likely to reach the nth of a kind stage (NOAK), which is associated with a lower cost, much faster than large scale plants. In other words the speed with which the commercialization takes place is likely to be higher for small scale plants.
- The cost reduction is to a large extent associated with simplified gas cleaning.
- Further cost reduction is expected in relation to the carbon dioxide removal but here it’s essential that suppliers of biogas upgrading engage themselves in the bioSNG development.
- To meet the growing demand of biomethane in the transportation sector in Sweden there is a need for new production capacity. Since the major part of the current biogas production already is designated as transportation fuel gasification and methanation of lignocellulosic feedstock seems to be a promising route independent of plant size.

Markets like Sweden where biomethane is highly valued, the natural gas price is relatively high and the feedstock supply is good are likely to see the first installations of commercial small and medium scale bioSNG production.

However, since the biomethane market in Sweden is far from mature it’s still heavily dependent on political ambitions and associated instruments as well as local and regional initiatives.

Acronyms used in this report

Bara	Bar absolute
Barg	Bar gage (absolute pressure minus atmospheric pressure)
BioSNG	SNG produced from biomass/biofuel
CHP	Combined Heat and Power
CTU	CTU Clean Technology Universe
DFB	Dual Fluidized Bed
FOAK	First of a kind
HPR	HeatPipe Reformer
n.a.	Not available
Nm^3	Normal cubic metre (Temperature: 0 °C, Pressure: 1.01325 bara)
NOAK	N_{th} of a kind
PDU	Process Development Unit
PSI	Paul Scherrer Institute
RME	Rapeseed Methyl Ester
R&D	Research and Development
Sm^3	Standard cubic metre (Temperature: 15 °C, Pressure: 1.01325 bara)
SNG	A synthetic gas of natural gas quality

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1. Background

The production of bioSNG through gasification and methanation requires a synthesis gas free of nitrogen. This implies pressurized oxygen-blown gasification or indirect gasification[1]. Oxygen-blown gasification relies on an air separation unit and is not economically feasible for plants less than a few hundreds of MW_{th}. For small and medium scale plants (~5-30 MW_{th}) only the technology based on indirect gasification remains.

The development of indirect gasification has seen a rapid progress during the last decade[2]. In 2002 the indirect gasifier in Güssing was commissioned. Since then several plants for CHP production based on the same technology have been built in Austria and Germany.

In 2009 bioSNG production was demonstrated in Güssing based on the Paul Scherrer Institute (PSI) combined shift and methanation reactor. There are different types of indirect gasification, besides the Güssing concept, suitable for bioSNG production, e.g. MILENA developed by Energy Research Center of the Netherlands, the agnion Heatpipe Reformer, Blue Tower and SilvaGas. In addition several universities and research institutes conduct extensive R&D in the field of indirect gasification, e.g. Chalmers University of Technology in Sweden and VTT in Finland.

In the really small scale (< 10 MW_{th}) there are several ongoing development activities. However, so far it's only agnion who has communicated that they will offer commercial bio-SNG production in this scale.

Even though different types of indirect gasification technology may be used for medium scale bioSNG production the methanation technology needs to be adapted for this size. In this report the focus on the medium scale bioSNG production is associated with the PSI isothermal fluidized bed methanation technology targeted for plants in the 20-50 MW_{bioSNG} size.

On the downside, smaller plants are normally associated with higher specific investment and operating cost and lower efficiency. However, the advantages with technology adapted for small scale production of bioSNG are the low economic risk and the good possibilities to secure the feedstock and integrate the excess process heat with the local heat demand.

For Sweden bioSNG for the transportation sector is of great interest. The utilization of biomethane as vehicle fuel increases rapidly and reached 83 million Nm^3 in 2012[3], corresponding to 0.8 TWh. The southernmost part of Sweden, Scania, has set up a target of reaching 3 TWh/year biomethane in the province by 2020 and other regions in Sweden have similar targets, e.g. Västra Götaland region 2.4 TWh/year in 2020.

1.1 Small scale bioSNG production technology

As mentioned before, in the really small scale, the German company agnion offers bioSNG plants based on a heatpipe reformer concept with a capacity of approx. 5 MW_{th} corresponding to approx. 3 MW_{bioSNG}.

agnion Heatpipe Reformer

The agnion Heatpipe Reformer is based on two bubbling fluidized beds connected through heatpipes which transfer the heat from the combustion reactor to the reformer reactor. The research and development has been carried out by agnion Highterm Research GmbH and the technology has been commercialized by agnion Technologies GmbH in Pfaffenhofen a.d. Ilm, Germany.

In the heatpipe reformer heat is carried from the combustion reactor to the reformer reactor by means of a working media contained in the enclosed heatpipes. The transferred heat in combination with an oxidizing agent, in this case steam, results in a thermo-chemically decomposition of the biomass in the fluidized bed reformer into a tar rich syngas.

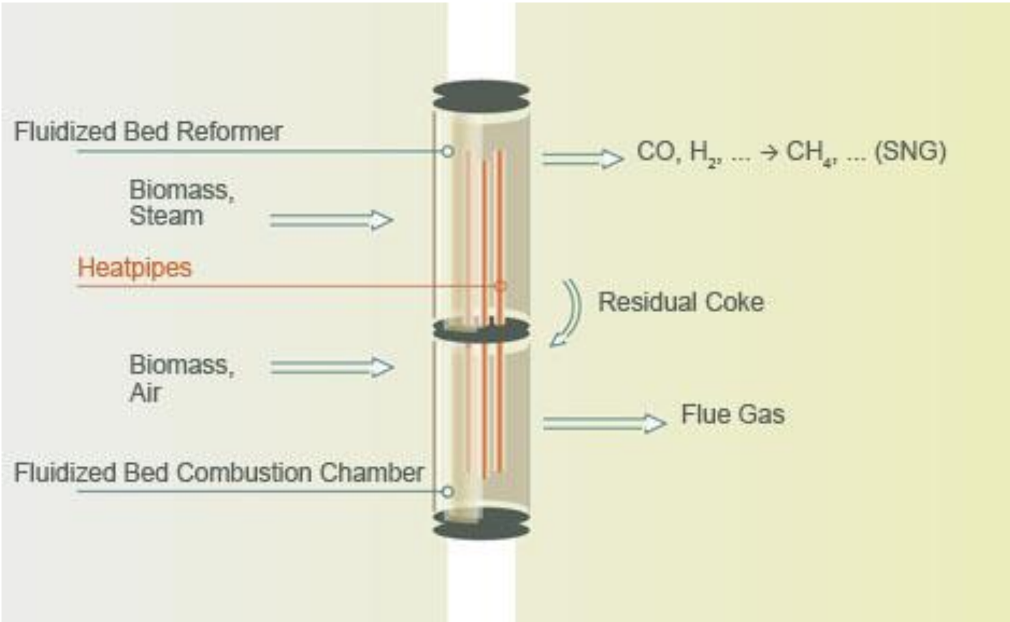

Figure 1. Heatpipe reformer by courtesy of agnion Technologies GmbH.

The major innovation provided by the agnion Heatpipe Reformer concept is that it allows a high thermal transfer at a low temperature gradient. In other words even though the temperature difference between the combustor and reformer is small sufficient amounts of heat is transferred through the heatpipes.

This is achieved through the working fluid that is contained in the enclosed pipes. The working fluid, such as sodium or potassium, evaporates in the part of the heatpipe that is in contact with the combustion reactor and condenses in the part of the heatpipe that is in contact with the fluidized bed reformer, see Figure 2.

The vertical heatpipes with the reformer on top of the combustor creates a self-induced circulation of the working fluid. The heat transfer is one order of magnitude higher compared to the heat transfer in a gas-to-gas heat exchanger.

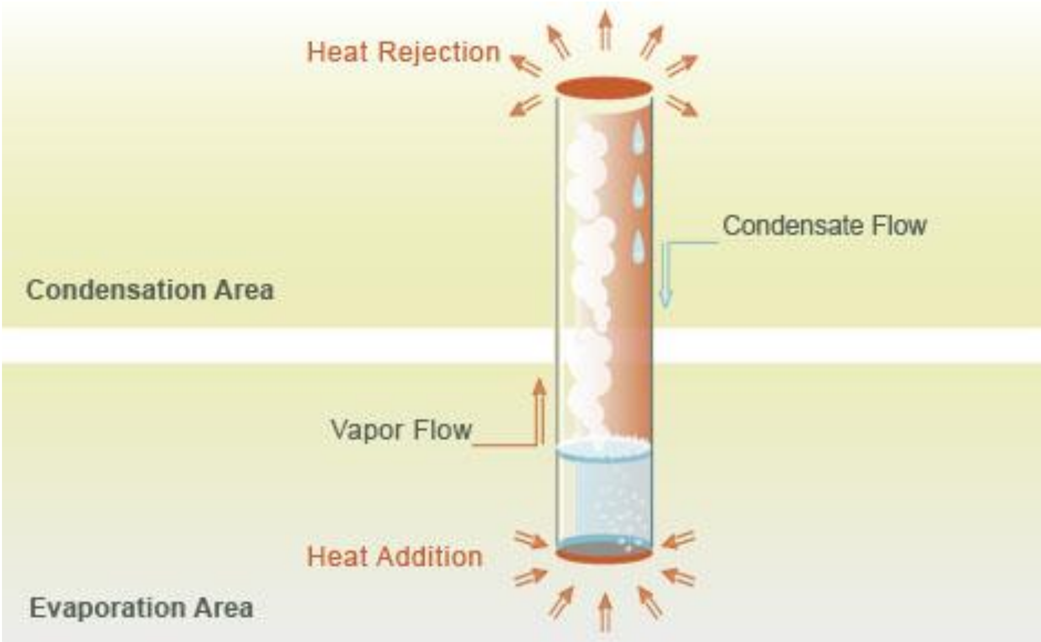

Figure 2. The vertical heatpipe by courtesy of agnion Technologies GmbH.

At present the agnion Heatpipe Reformer comes in modules of 1.4 MW_{th} (1.3 MW_{th} before). The commercial installations in Germany and Italy include tar separation based on an organic solvent scrubber (RME) and a gas engine for CHP production. Since the reformer operates at elevated pressure (4 barg) no additional compression is needed to feed the syngas into the gas engine.

Table 1. Commercial installations

Location	Fuel	Capacity	In operation	Mode
Grassau, Germany	Wood chips	1.3 MW_{th}	May 2012	CHP
Bozen, Italy	Wood chips	2 x 1.3 MW_{th}	Dec. 2012	CHP

The plant in Grassau was the first commercial installation. In the beginning the plant was fed with wood pellets and later on the fuel was switched to wood chips. The fuel switch was associated with some initial feeding problems but these problems have been solved and plants fuelled with wood chips are offered on commercial grounds.

The agnion Heatpipe reformer has a cold gas efficiency of 70 %. The electric efficiency for a 1.3 MW_{th} plant operating in CHP mode is 30 %, in addition 600 kW of heat suitable for district heating is produced giving an overall efficiency of 75 %[4]. The energy balance for the agnion Heatpipe Reformer is shown in Figure 3.

Figure 3. Energy balance of the agnion Heatpipe Reformer by courtesy of agnion Technologies GmbH.

<u>New development with focus on bioSNG production</u>

In the new development the tar separation has been replaced by catalytic tar reforming and the syngas is fed to a fixed bed methanation reactor. Finally the carbon dioxide is separated, see Figure 4. The result is a high heating value gas that can be used as vehicle fuel or injected into the gas grid.

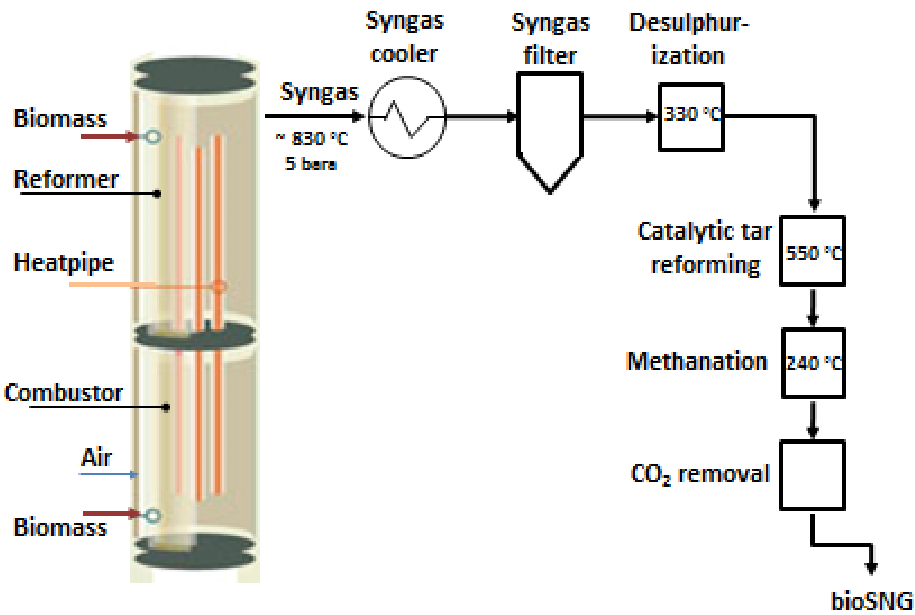

Figure 4. Simplified flow chart of a heatpipe reformer in bioSNG mode.

The desulphurization takes place in a simple fixed bed adsorber. Commercial ZnO and ZnO/Cu-desulphurization materials are used. Nickel is used as catalyst in the high-temperature tar reforming and methanation. Deactivation occurs due to carbon deposition and the remaining sulphur[5].

1.2 Medium scale bioSNG production technology

The isothermal fluidized bed methanation developed at PSI and commercialized by CTU has successfully been demonstrated in the 1 MW scale in Güssing. On the 24th of June 2009, the inauguration took place, and CNG cars were fuelled with bioSNG produced from wood, for the first time in history[6]. The whole process chain reaches high conversion efficiencies and has the potential for lower investment and lower operation costs than conventional SNG synthesis technology.

The advantages of a fluidized bed methanation reactor compared to fixed bed methanation reactors are the isothermal operation, the easy controlling, the possibility for the in-situ water gas shift reaction to adjust the H_2/CO ratio and the low risk of catalyst deactivation due to recirculation of the catalyst particles through the bed[7]. The main conversion occurs within the first few centimetres of the bed (CO-rich part), see Figure 5.

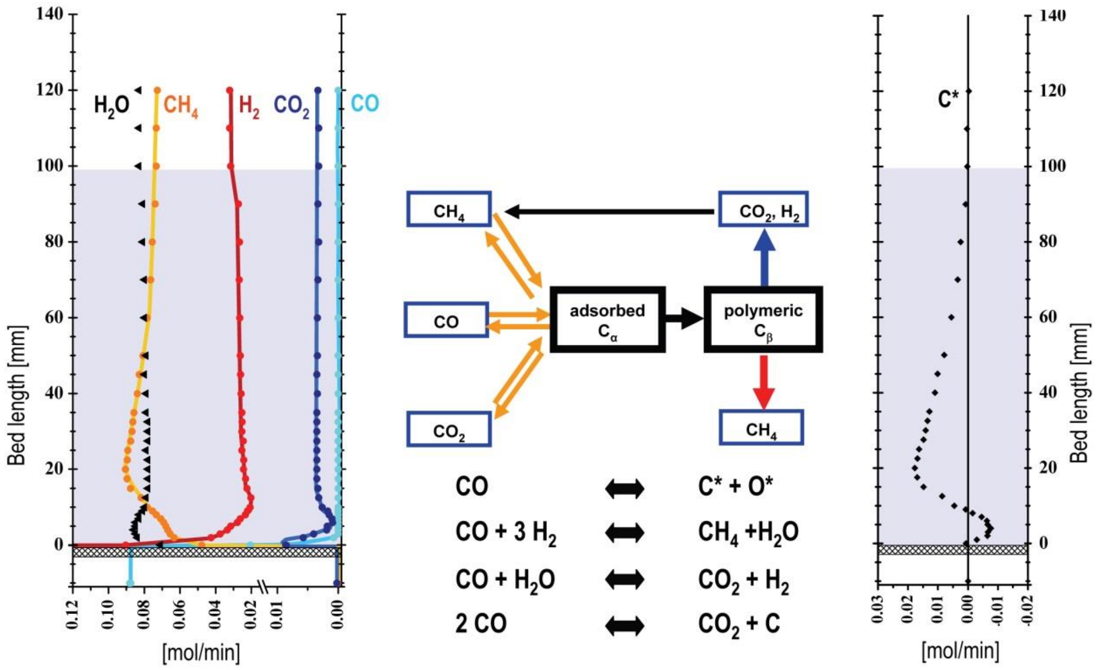

Figure 5. Methane formation as a function of the bed height (to the left) and the carbon management (to the right). By courtesy of Paul Scherrer Institute.

2. Methodology

This study is limited to technologies targeted for bioSNG production in the 5-30 MW_{th} scale, through thermo-chemical conversion of biomass. The information of the ongoing development has been gathered through literature studies and in-depth interviews with those research institutes that pursue technology development aimed at commercial small and medium scale bioSNG production. In this case, agnion Highterm Research GmbH who develops bioSNG production in the 5 MW_{th} scale based on their patented heat pipe reformer and Paul Scherrer Institute (PSI), who has developed and demonstrated a fluidized bed methanation reactor targeted for 20-50 MW_{th} bioSNG plants. Their commercial partners are agnion Technologies GmbH and CTU, respectively.

Other possible small and medium scale methanation routes, not within the scope of this report, are associated with biological processes such as anaerobic digestion and biological catalysis of syngas to biomethane.

The bioSNG production technologies are put in relation to the biomethane market within the Swedish transportation sector. The transportation sector is heavily dependent on fossil fuels and the replacement of petrol and diesel constitutes a tremendous challenge in all countries over the world. However, Sweden has had a good progress in the utilization of biomethane as vehicle fuel and there are strong regional ambitions to further improve the situation. The biomethane has a high value as a transportation fuel since it competes with petrol. In addition the taxation situation in Sweden is favourable for biomethane as vehicle fuel and the natural gas price is relatively high.

3. Results and discussion

There is a growing interest for biomethane for grid injection as a way to make the natural gas greener or to be used as vehicle fuel, especially in Sweden. In fact the steady growth of biomethane as vehicle fuel in Sweden surpassed the use of natural gas in the transportation sector in 2006 and the relation in the last years have been approx. 60% upgraded biogas and 40% natural gas.

3.1 The need for new bioSNG production capacity in Sweden

Based on the historical development of biogas as vehicle fuel, depicted in Table 2, one would expect the need of new production capacity in 2013 to amount to 10-15 million Nm^3, corresponding to 97-145 GWh. However, there are strong ambitions to further increase the utilization of biomethane in the transportation sector. Only the targets for Scania and the Västra Götaland region imply the need of new production capacity corresponding to of approx. 4,600 GWh/year in 2020.

Table 2. Development of biogas as vehicle fuel in Sweden

	2007	2008	2009	2010	2011	2012
Biogas as vehicle fuel [million Nm^3]	28,423	33,740	42,252	59,147	75,125	83,320
Yearly increase [million Nm^3]	-	5,317	8,512	16,895	15,978	8,195
Annual increase [%]	-	18.7	25.2	40.0	27.0	10.9

Since the major part of the biogas production through anaerobic digestion already is designated as vehicle fuel, see Table 3, new substrates and new production technologies, such as gasification and methanation of lignocellulosic feedstock are of major interest. Note that landfill gas is not used as vehicle fuel in Sweden.

Table 3. The share of biogas used as vehicle fuel[8,9,10,11]

	2008	2009	2010	2011	2012
Total biogas production [GWh]	1,359	1,363	1,387	1,473	n.a.
Total biogas production excluding landfill gas [GWh]	990	1,028	1,089	1,203	n.a.
Biogas sold as vehicle fuel [GWh]*	327	410	574	729 ᵻ	808 ᵻ
Share of biogas (excluding landfill gas) used as vehicle fuel [%]	33	40	53	61	n.a.

** Amount of sold biogas is taken from Swedish Statistics[3].*
ᵻ In these numbers small amounts of imported biogas used as vehicle fuel are included.

During the last years the focus in Sweden has been on relatively large scale bioSNG production, e.g. the GoBiGas project aiming at 100-120 MW_{bioSNG} and the E.ON Bio2G project which is planned to produce 200 MW_{bioSNG}. However, the realizations of these projects are heavily dependent on political ambitions and related instruments. The investment cost for these projects is several hundreds of million euro and the associated economic risk is discouraging.

On the other hand the development of small and medium scale bioSNG production technologies has seen a rapid progress in the last years and even though they suffer from a high specific investment cost there are several advantages as well. The low economic risk and the good possibility to secure the feedstock and integrate excess process heat with local heat demand are inherent features of small and medium scale bioSNG production technologies.

To fulfill the ambitions of the Scania province and the Västra Götaland region 80 MW of new production capacity is needed every year until 2020. This corresponds to approx. 200 new 3 MW_{bioSNG} plants or 30 new 20 MW_{bioSNG} plants until 2020. The plants are assumed to operate 7,500 hours/year.

3.2 Specific investment cost

The specific investment cost for small and medium scale bioSNG plants is shown in Table 4. However, the specific investment cost is only one part of the bioSNG production cost. Other factors are the feedstock cost, plant efficiency, operating costs, utilization of excess heat etcetera.

Table 4. Investment cost for a first of a kind plant. Note that the numbers are only indicative and difficult to compare since they don't include exactly the same costs.

	Fuel	**Capacity**	**Cost [M€]**	**Specific Invest. cost [€/kW_{bioSNG}]**	**Efficiency η_{bioSNG} [%]**
GoBiGas I, Gothenburg, Sweden*	Wood chips	32 MW_{th} 20 MW_{bioSNG}	168**	8,400	~62,5 %
agnion Heatpipe Reformer	Wood chips	1.4 MW_{th} 790 kW_{bioSNG}	3.6[ł]	4,557	~56 %
DFB, PSI/CTU methanantion[‡]	Wood chips	31 MW_{th} 20 MW_{bioSNG}	n.a.	n.a.	~64,5 %

** Demonstration plant. Güssing type of gasifier, tar separation with organic solvent scrubber and TREMP methanation In the next stage a 80-100 MW_{bioSNG} plant is planned to be built on commercial grounds.** The cost includes all pre-investment costs since the project started in 2005 and the foundation work.*

[ł] Based on a quotation for a 1.4 MW_{th} demonstration plant. Biomass dryer and storage, HPR, catalytic tar reforming, fixed bed methanation and membrane carbon dioxide removal. Foundation work is not included. Commercial plants are planned to consist of 4 HPR corresponding to 5.6 MW_{th} in order to reduce the specific cost for the carbon dioxide removal. For 5.6 MW_{th} plants amine wash or PSA are possible options for carbon dioxide removal.

[‡] Güssing type of gasifier, tar separation with organic solvent scrubber, PSI/CTU fluidized bed methanation and amine wash for carbon dioxide removal. It has not been possible to obtain a specific investment cost for a complete FOAK plant. CTU[1] indicates that for a 20 MW_{bioSNG} plant front end tar and sulphur removal, methanation unit and back end for SNG upgrade cost 20-30 M€. Repotec[2] has indicated that a 30 MW_{th} gasifier and gas cleaning will cost 26 M€. Costs related to foundation work, fuel storage and fuel preparation, compression prior to methanation and compression after SNG upgrading are not included.

[1] Mr. Giorgio Gadola, CEO CTU, email 28.03.2013
[2] Dr. Christian Aichernig, CEO Repotec, email 02.04.2013

Normally one expect that small scale plants have a higher specific investment cost than large scale plants. It's noteworthy that the 1.4 MW_{th} agnion Heatpipe Reformer plant has a lower specific investment cost than the 32 MW_{th} GoBiGas plant which is 25 times larger. Even if the GoBiGas investment cost includes pre-investment costs and foundation work the figure shows how hard technologies developed for larger scale plants are penalized when built in relatively small scale. The agnion Heatpipe Reformer on the other hand is based on technology suitable for small scale bioSNG production.

It might be noted that in the Finnish VETAANI project[12] a 100 MW_{th} nth of a kind ”GoBiGas”-plant with catalytic tar reforming and TREMP type of methanation is expected to have a specific investment cost below 2,000 euro/kW. Here, the up-scaling, the replacement of the tar separation with tar reforming and going from a FOAK to a NOAK plant are the main reasons for the dramatic decrease in the specific investment cost.

3.3 Gas quality

Both agnion's and PSI/CTU's methanation technology result in a high quality gas, see Table 5, suitable for grid injection or to be used as vehicle fuel.

Table 5. Gas quality

Plant	**Methane [vol-%]**	**Relative density [-]**	**Heating value, superior [kWh/Sm^3]**	**Wobbe Index superior [kWh/Sm^3]**
agnion HPR, lab scale unit	95	0.53*	10.1*	13.9*
PSI/CTU, PDU in Güssing[6]	95	0.56	10.7	14.2

** Calculated by Renewable Energy Technology International AB based on the gas composition provided by agnion Highterm Research GmbH.*

In Sweden grid injection will at present be supplemented with propane addition in order to adjust the heating value to that of the Danish natural gas, which presently is used in the Swedish natural gas grid. The methane level in the bioSNG comply with the Swedish standard[13] for biogas as vehicle fuel which requires a methane level of 97 % ± 2 % for cars equipped with a lambda sensor. All modern cars are equipped with a lambda sensor.

4. Conclusions and future outlook

The indirect gasification technology has seen a rapid development in the last decade and several commercial plants for CHP production have been built. The indirect gasification opens up a possibility to produce syngas suitable for methanation in the small and medium scale. However, in order to produce bioSNG extensive gas cleaning is needed.

So far the focus have been on removing all harmful contaminants and tar separation using organic solvent scrubbers has been the logical choice. Even though the energy in the removed tar can be recovered by burning the tars together with the organic solvent in the combustor the investment and operating cost for the gas cleaning is discouraging especially if one moves to the smaller plant sizes.

agnion Technologies GmbH has circumvented this problem by catalytic tar reforming and accepting a slow and controlled deactivation of the catalyst. In fact the cost for the spent catalyst is in the same order as for spent organic solvent but the investment is about 50 % lower and no additional treatment of the waste water is needed. The deactivated nickel based catalyst material is returned to the vendor. This procedure is more or less cost neutral since the value of the nickel on the catalyst is in the same order as the cost for the recycling. Since small scale plants normally suffer from a high specific investment cost reduction is essential to make small scale bioSNG production economic feasible.

There is potential for further cost reduction. The cost of the carbon dioxide removal constitutes a significant part of the investment and the operating cost. In these scales (600-4,000 Nm^3/h raw gas) the development is driven by the anaerobic digestion sector. In later years the development of carbon dioxide removal in biogas upgrading has seen a rapid progress[14,15] and a significant decrease in specific cost. The development of bioSNG production through gasification and methanation would strongly benefit through a closer connection to the suppliers of biogas upgrading and they in turn may benefit from new market possibilities. An initiative to bring the two sectors together was taken through a collaboration project[16] where different biogas upgrading technologies were investigated in the framework of gasification and methanation. If the suppliers of biogas upgrading engage themselves in the development of carbon dioxide removal in bioSNG production through gasification and methanation further cost reduction may be expected.

Fluidized bed methanation is one key technology to unlock cost-effective bio-SNG production in the medium scale. The fluidized bed reactor replaces both the water gas shift and the fixed bed methanation reactors. This reactor type is able to handle syngas with a wide range of CO/H_2-ratios, from 1:1 to 1:5 if water addition is optimised. The temperature and the carbon management inside the isothermal fluidized bed result in a conversion of ethylene into ethane. Normally ethylene in the syngas constitutes a problem since it’s a reason for coke formation and catalyst deactivation but here it’s actually beneficial since its hydrogenation increases the Wobbe index and the heating value of the bioSNG. As much as 3 % ethane has been observed in the tests with the PSI/CTU fluidized bed methanation.

The next development step of the fluidized bed methanation is related to specific sorption of sulphur and elimination of the costly tar separation. In practice the syngas and the tars will be fed first to a sulphur adsorber bed and then into the fluidized bed methanation reactor. Any remaining organic sulphur will give rise to catalyst deactivation but the huge reduction in investment cost will allow increased cost for the catalyst. In this way the fluidized bed methanation replaces tar reforming, water gas shift and fixed bed methanation.

The findings in this study may be concluded as:

- New development opens up the possibilities for cost-effective bioSNG production in the small and medium scale based on indirect gasification.
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- The cost reduction is to a large extent associated with simplified gas cleaning.
- Further cost reduction is expected regarding the carbon dioxide removal but here it’s essential that suppliers of biogas upgrading are engaged in the bioSNG development.
- To meet the growing demand of biomethane in the transportation sector in Sweden there is a need for new production capacity. Since the major part of the current biogas production already is designated as transportation fuel gasification and methanation of lignocellulosic feedstock seems to be a promising route independent of plant size.

<u>Future outlook</u>

The next step in the development of small and medium scale bioSNG production is related to pilot- or demonstration plants where long term duration tests can be conducted. The gasification technology is proven and commercial plants are built for CHP purposes but experiences of long term duration tests of catalytic tar reforming and methanation in” close- to-commercial” plant sizes still lack.

If the rapid progress in biogas upgrading can be interconnected with the bioSNG development there is a good prospect for further reduction in both the specific investment cost and the operating cost.

Markets like Sweden, where biomethane is highly valued, are likely to be the first places to see small and medium scale bioSNG production.

However, since the biomethane market in Sweden is far from mature it’s still heavily dependent on political ambitions and associated instruments, regional and local initiatives and the relatively high natural gas price.

5. Acknowledgement

The financial support by the Swedish Energy Agency and the industrial gasification group at SGC is acknowledged. The input from Dr. Thomas Kienberger, agnion Highterm Research and Dr. Serge Biollaz and Dr. Tilman Schildhauer, Paul Scherrer Institute is highly appreciated.

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