Beslutsunderlag

Ansökan om medel för förstudie

Ansökan skickas till:

Mittuniversitetet och Sundsvalls Kommun

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Namn på förstudie **Biogas from biomethanation of syngas (BiGaSyn)**	Datum för start av förstudie 2017-04-01	Datum för avslut förstudie 2020-03-31
Sökt belopp 1 500 000,		

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Förstudietägare Kaarlo Niskanen, Mittuniversitet/FSCN	E-post kaarlo.niskanen@miun.se	Mobil 076 8078599
Avdelning/enhet Bioenergy Group/FSCN		
Datum 2016-10-01		
Diarienummer		

:

1. Sammanfattning förstudie

In Sweden, about 1 TWh biogas vehicle fuel is produced each year. Biogas as a vehicle fuel has been commercialized well in Sweden. However, further development of the biogas market is limited by the amount of available organic waste as well as the number of biogas filling station. On the other hand, biomass can be gasified into syngas and then synthesized into bio-SNG through catalytic methanation, or biomass gasification can be integrated into the biogas system to produce methane through biological methanation. In this way, biomethane vehicle fuel can give a significant contribution to the Swedish target: Free fossil fuel traffic by 2030. Biogas can be an important energy carrier in the future smart energy grids. By means of biogas system for electricity and vehicle fuel production, the increased proportion of variable renewable electricity (solar and wind) on the grid can be balanced. More importantly for Sweden, biogas production can be increased to a full scale to meet transport fuel demand by integrating biomass gasification into biogas system. For this purpose, a novel pathway is proposed to be studied in this project:

Biomass gasification – H2+CO – Biogas digester – Upgrading – Natural gas network

The project is 1) to further develop biomass dual-fluidized bed gasifier to produce a good quality syngas, and 2) to study the biogas production from biological methanation or bio-methanation of syngas. The technology feasibility, the bioreactor design, the process synergy and the integration of the gasification plant with the biogas plant will be studied in detail. A techno-economic analysis will be made for commercialization of vehicle fuel production from biomass gasification and digestion, together with MittSverige Vatten (MSV), Hemab, and other companies.

2. Syfte, mål, målgrupp, avgränsning samt leverabler

Syfte

In Sweden, about 1 TWh biogas vehicle fuel is produced each year. Biogas as a vehicle fuel has been commercialized well in Sweden. However, further development of the biogas market is limited by the amount of available organic waste as well as the number of biogas filling station. On the other hand, biomass can be gasified into syngas and then synthesized into bio-SNG through catalytic methanation, or biomass gasification can be integrated into the biogas system to produce methane through biological methanation. In this way, biomethane vehicle fuel can give a significant contribution to the Swedish target: Free fossil fuel traffic by 2030. Biogas can be an important energy carrier in the future smart energy grids. By means of biogas system for electricity and vehicle fuel production, the increased proportion of variable renewable electricity (solar and wind) on the grid can be balanced. More importantly for Sweden, biogas production can be increased to a full scale to meet transport fuel demand by integrating biomass gasification into biogas system.

This project is to further develop biomass dual-fluidized bed gasifier (DFBG) to produce a good quality syngas and to study the biological methanation as well as the process synergy and the integration of the gasification plant with the biogas plant, and to investigate the

possibility of commercialization of vehicle fuel production from biomass gasification and digestion together with MittSverige vatten AB and other partners.

Mål

- A novel internal tar reformer is developed for high quality syngas production with tar content below 1g/m3 from DFBGs.
- The methane content in the raw biogas from digesters can increase from 55% to 90%.
- Digestion bio-sludge can be utilized as a feedstock to biomass gasification together with wood pellet or chips, so that more methane can be produced in biogas plant.
- Successful bio-methanation of syngas can lead to patent application.
- Biomass gasification for vehicle fuel production can be commercialized easily when the barrier of the costly syngas cleaning and tar reduction is avoided by integration with biogas plant.
- Biomass-to-methane efficiency can increase from 65% of thermo-catalytic methanation to 80% of bio-methanation of syngas.
- A biomass-to-methane mathematic model is developed based on Aspen-plus and built up for techno-economic analysis, which can provide solid basis for company's decision of investment and projecting.

Målgrupp

The project targeted groups are waste water treatment plants, household, agricultural and industrial organic wastes treatment, boiler/gasifier manufacture, energy companies, gas infrastructure companies and all actors in transport sector and environmental, oil, bioenergy and forest industries. It is also useful for official, kommun, länsstyrelse and national myndigheten to make decision.

Avgränsning

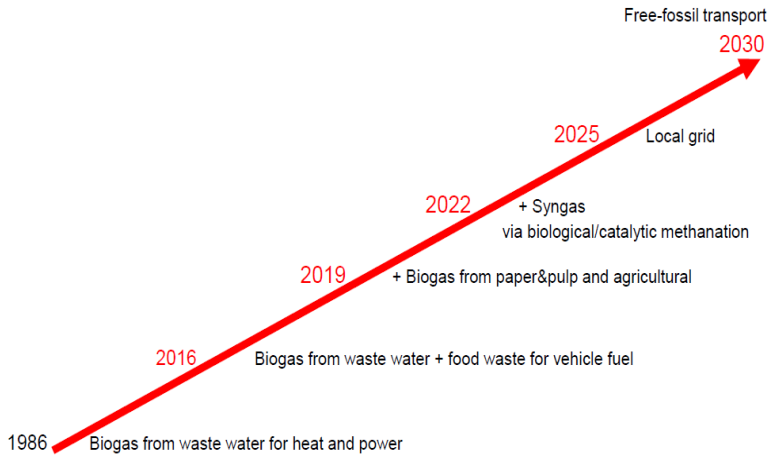
The work focuses on the gaseous vehicle fuel production. Liquid transport fuels are not involved directly, but indirectly as long as biomass gasification is involved.

Leverabler efter förstudiefasen genomförd

- A report about Sundsvall biogas development
- A patent application with internal tar reformer for high quality syngas production
- Successful bio-methanation of syngas can lead to patent application.
- A biomass-to-methane mathematic model is developed for techno-economic analysis.
- At least 5 journal publications and one PhD dissertation can be made from Bioenergy Group at Miun.

3. Behov/efterfrågan i regionens näringsliv och samhälle

In Sundsvall-Härnösand region, biogas has been produced for 30 years by MSV for heat and power, and by Hemab for transportation recently. There is now a great interest to upgrade the biogas for vehicle fuel production as shown in a vision suggested below:



A Vision of Sundsvall-Härnösand biogas development.

This project will focus on the biogas production from bio-methanation of syngas which is supposed to be commercialized between 2022 and 2025 shown in the above vision.

Biogas is produced from digestion of bio-sludge, food wastes, animal manure, agricultural wastes etc. while bio-SNG is produced from gasification of solid fuel such as coal and biomass. Both the raw fuel gases from digester and gasifier can be upgraded to bio-methane after gas cleaning, and used as vehicle fuels and chemicals. There is a strong synergy effect between the two processes regarding the feedstock resources, plant scale, gas cleaning, CO2 removal and utilization, energy integration and optimization as well as end-uses. The solid residue from biogas process can be utilized in the gasifier. The low grade waste heat from the gasification process can be utilized to maintain the mesophilic or thermophilic temperatures of the digester. The acid gas and CO2 in biogas and syngas can be removed by the same cleaning system. In particular, the dirty syngas from gasification can be treated by the biological methanation, while the CO2 from digester can be treated by the biological or catalytic methanation. There is a highly academic interest as well as application attraction to make a possibility study on the integration process of digestion and gasification.

Energy technology commercialization is highly associated to political instruments, so must be academic and industrial activities. It is especially true for transport biofuels. In EU, the first generation transport biofuels produced from agricultural crops is limited to maximum 7% in the transport fuel market, while the second generation transport biofuels (advanced biofuels) are encouraged to be produced at least 0.5% by 2020 according to EU Biofuel Sustainability directive 2012 and EU Indirect Land Use Change directive 2015. The EU Infrastructure directive 2014 claims that all member states must build up infrastructure as below:

- Charge station for electric car in cities and densely populated area by 2020
- CNG (compressed natural gas) filling station in cities and densely populated area by 2025
- LNG (liquefied natural gas) filling station in TEN-T (trans-European transport networks) by 2025

This implies that the electric car and biogas car will be important in the future transport system. The current fast development of biogas vehicle fuel market in the European continent is supported by the well-established gas pipeline network. In northern Sweden, biogas market development can be supported by the gasification of rich forest biomass residues and regional gas network.

4. Kartläggning kompetens och verksamhet Mittuniversitetet

The Bioenergy Research Group is one of groups included in FSCN. The project is highly relevant to FORIC. Transport fuel from biomass such as bio-sludge, household and industrial wastes as well as agricultural and forest residues etc. is the new and promising business area for forest industry. In many ways, the project can strengthen the Transformation Technologies's strategic action regarding renewable energy aspects at Miun. The Bioenergy group is part of the Swedish Gasification Centre, and owns a gasification pilot plant and its lab. facilities. In 2014, two PhD exams are finished from the group. From this project, co-production in bioenergy area with industry can be enhanced. A further progress towards research subject in energy engineering at Miun can be made, which can give a strong support to a sustainable education program of present Energy Engineering and also Chemical Engineering.

This project is based on the previous EU-structure fond projects: "FORE - Gasification-based biorefinery for mechnical pulp industry (2011.01 – 2013.12)", "EnergyWise – S&M scale biopower production from biomass with gasification (2011.08 – 2013.12)" and the current Energimyndigheten project: "Swedish Gasification Centre (2011 – 2020)". The works have led to two PhD exams (Göransson 2014, He 2014). The other main outputs are listed in the table below:

Previous project outputs

Type of output	Main person responsible	Description	Date
Pilot plant	Ulf Söderlind	150 kW Dual fluidized bed biomass gasifier (DFBG)	2007
Instrumentation and measurement	Ulf Söderlind	Measurements of temperature, pressure, gas, tar, fuels (Göransson 2011)	2011
Catalytic bed material	Kristina Göransson	Evaluation of Fe/olivine for tar reforming	2012
Internal reformer	Kristina Göransson	Patent to crack tar in syngas (Söderlind 2014)	2014
Aspen+ software package	Jie He	Modeling of gasifier (He 2012) Simulation of BTL (He 2011) Techno-economic analysis of biorefinery (He 2014)	2012 2012 2013
International cooperation	Wennan Zhang Ulf Söderlind	Gasifier + DME synthesizer from Guangzhou Energy Institute of Chinese Academy of Sciences	2012
Collaboration network	Wennan Zhang	Swedish National Gasification Centrum (SFC)	2011
Courses development	Wennan Zhang	Biofuels for heat & power Biofuels for transportation	2001 2002

5. Koppling övergripande strategier

The project can make the following contributions to Sundsvall Kommun strategy described in ”RIKARE”:

- To promote a sustainable energy system in Sundsvall by replacing fossil fuels with biofuels for better environment, air quality and cheap energy supply in the future.
- To produce advanced renewable transport biofuels for a secure and fossil-free transportation infrastructure.
- To increase regional competence of energy engineering subject at Miun and cooperation with other running activities such as “Green Highway” and “Biofuel Region”.
- To keep the competence for present Energy Engineer Education Program at Miun, and for the attraction of research funding from EU and national program e.g. Energimyndigheten.
- To take care of municipal, household, agricultural and industrial wastes and bio-sludge in a better way for a good environment and people healthy.

6. Koppling framtida profilområde

The bioenergy group is a research group in FSCN, and relevant to FORIC and KK-environment at Miun.

7. Relation forskning och R&D nationellt och internationellt

Anaerobic digestion is suitable for converting organic materials to methane, but is difficult to treat more recalcitrant substrates such as lignocellulosic biomass and wastes (plastic, rubber etc.). Gasification of all kind of biomass and wastes, followed by a biological process for the conversion of the resulting syngas to methane would be a promising alternative for the valorization of recalcitrant materials. Syngas bioconversion has several advantages over thermal catalytic process: it can operate at milder temperatures and pressures, a fix CO/H2 ratio is not required, there is less susceptibility to the impurities such as H2S, organic acids and NH4 etc. in the gas, and it does not require any costly pre-treatment of the feed gas or costly metal catalysts. The production of ethanol through syngas fermentation is well known and is in demonstration stage. Syngas conversion to methane by anaerobic cultures is practically unexplored, and few reports are available on this subject. Biological methanation integrating biomass gasification is a relatively new idea or technology. On the other hand, the following pathways have been receiving intensive attractions and R&D recent years or have been commercialized very well based on fossil fuels:

1) Power to gas (PtG)
   Electricity → H2 → Biogas digester → Upgrading → Natural gas network.

PtG allows conversion of surplus electricity to hydrogen or preferably to methane due to infrastructure reason. Recent strong development in solar and wind power industries in Europe and China leads to large scale variable electricity production (35% wind power in Denmark for example) which must be balanced from other energy sources or energy carriers. Biogas has been the best choice at present for some countries and receiving intensive research recent years.

2) Biomass to bio-SNG

Biomass gasification → syngas → cleaning + shift → synthesis → Natural gas network.

Biomass gasification for vehicle fuel production is in the demonstration stage worldwide and especially most progressive in EU for production of FT-diesel, DME, methanol and bio-SNG (substitute natural gas). For example, the GoBiGas project in Gothenburg is a demonstration project to produce 20 MW methane from forest residues and other wood fuels with gasification. The gas is fed into the natural gas grid and used mainly as vehicle fuels. The demonstration plant has been running since the beginning of 2015. Miun is involved in this activity via Swedish Gasification Centre as a member. E.ON plans to build up a full scale Bio-SNG production plant of 200MW in Småland in 2017, which has been granted 199M€ by EU for the investment.

3) Catalytic methanation

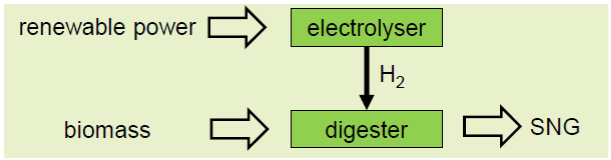
Biomass gasification → syngas → H2+CO + biogas CO2 → Natural gas network.

- SNG technology was well developed in the 1960-1980th for coal, current plants in China
- Fixed bed reactor concepts are well established technology
- Fluidized bed, honeycomb and 3 phase reactors are alternatives
- In the last 15 years, catalytic methanation was examined in context with biomass gasification, e.g. GoBiGas in Gothenberg.
- First demonstration plant (Audi E-Gas) of PtG started operation this year.

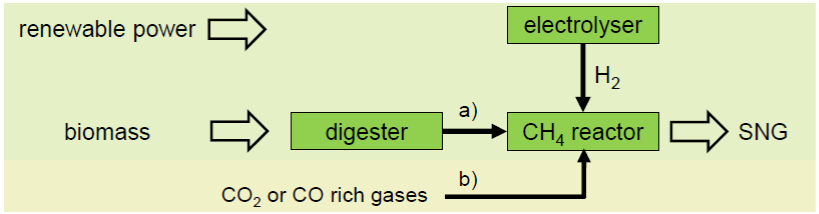
4) Biological methanation

Biomass gasification → H2+CO → Biogas digester → Upgrading → Natural gas network.

- Fundamentals are investigated for decades
- Wide range of input gases is feasible (CO rich gases, flue gas, biogas etc.)
- Challenging is the mass transfer of hydrogen to the microorganisms
- First pilot plants are in operation phase.



in situ digester



separate reactor

A comparison of catalytic and biological methanations is shown below:

	Catalytic Methanation	Biological Methanation	Advantage of Biological Methanation
Temperature	300 – 400°C	35 - 65°C	High energy efficiency and low engineering complexity
Contamination toletance (H2S, O2, KOH)	low	high	Ability to use raw syngas without intensive cleaning
H2/CO ratio	fixed	flexible	No extra shift reactor required
Product	CH4 + CO2 …	CH4 only	No by-product separation required
Plant complexity	high	low	Low capital investment
Plant size	large	small	Economic viability even at small scales

8. Relationer andra aktiviteter

The project is relevant to Swedish Gasification Centre supported by Energimyndigheten, and is also relevant to FORIC at Miun. Recently established Biogas MittSverige AB in Sundsvall will be an important partner in the project.

9. Partner och andra aktörer

MSV(MittSverige Vatten AB) is recently established by merging Sundsvall/Timrå/Nordanstig Vatten and Sundsvall Reko, owns waste water treatment plant with biogas digester. The biogas is currently used for heat and power production. The digestion bio-sludge is treated by incineration with a certain amount of cost.

Hemab(Härnösand Energi och Miljö AB) has built up a small scale biogas and upgrading plant for vehicle fuel production and a filling station in Härnösand recently. This project may help to increase the methane yield of its digester and to scale up biogas production to be more economic with respect to expensive gaseous infrastructure.

BiMAB(Biogas I Mellannorrland AB) is recently established for biogas development, and is owned by 3 counties: Sundsvall, Östersund and Hudiksvall, which shows a big ambition in biogas development in the middle of Sweden.

Jämtlandsgas?

Sundfrakt/TRB?

10. Samhällseffekter

- Biofuels replace fossil fuels to reduce CO2 emission.
- Contribution to Swedish target “Fossil-free transport by 2030”.
- Production of advanced transport biofuels and chemicals in addition to paper & pulp to save forest industry.
- Establishment of international level R&D competence in the area of energy engineering in Sundsvall
- A competitive infrastructure where energy and material use, as well as environmental and health impact emissions are minimized.

11. Kommunikation

The project results will be summarized as a report, and will also be published through journal papers and conference presentation. The participation companies have closely access to the project result and may consider for commercialization in the future. The project infomation will be publioshed on university website.

12. Organisation för genomförande av förstudie

The project will be undertaken by Bioenergy Research Group/FSCN at Miun:
Asso. Prof. Wennan Zhang,
Dr. Kristina Göransson,
Ulf Söderlind Research engineer
Possible Ph.D students,
together with 5 companies: MSV, Hemab, BiMAB, Jämtlandsgas and TRB. Prof. Henrik Thuman at Chalmers University of Technology will join the project as a co-supervisor for PhD students employed in the project, and also contribute to the project with good competence in system analysis as well as biomass gasification and catalytic methanation. A 150 kW indirect biomass gasifier pilot plant was built up at Mid Sweden Univeristy, Härnösand, in 2007. This available biomass gasifier will be further improved and used for this project.

13. Planerade aktiviteter, tidplan och kostnader

The project is organized by 6 working packages as listed below, including company participation and each task schedule:

WP1 , Biogas plant pre-projecting
(Participation partner: MSV + Hemab + Jäntlandsgas + BiMAB) 2017.04 – 2018.10
Hemab has been working fairly long with biogas production from bio-sludge, food wastes etc.. Hemab has built up a small scale biogas upgrading plant in Härnösand with support of Energimyndigheten last year. BiMAB is recently established. Biogas vehicle fuel production will be the company important target. A pre-study of biogas in Sundsvall was carried out by BiMAB under the administration of Sundsvall Energi AB three years ago, which can contribute to this WP. Pre-projecting can provide guideline and inputs to the modeling of biogas + bio-SNG plant for techno-economic analysis.

WP2, Improvement test on the internal reformer of Miun gasifier
(Miun) 2017.04 – 2018.04
In order to complete the "FreeRef" patent application, more study on the internal reformer is needed. The catalytic material particle size and the bed height should be optimized. The catalyst deactivation should be studied further. A good tar internal reformer is an important milestone for finally commercialization of biogas + bio-SNG production process.

WP3, High quality syngas production for bio-methanation
(Miun + Chalmers) 2018.04 – 2019.04
Experimental test will be carried out in Miun gasifier to study bed material and operation parameters in order to produce good quality syngas for biological methanation later in biogas digester. The ratio of H2 to CO will be adjusted so that the H2 content can reach 80%.

WP4, Biological methanation
(Miun + MSV + Hemab + Jämtlandsgas) 2018.04 – 2019.10
80% hydrogen in the syngas can be easily produced when an appropriate bed material is used in the Miun dual fluidized bed gasifier. The hydrogen is added to the anaerobic reactor and reacted with raw biogas, referred to as in-situ biological methanation. The hydrogen can also be reacted with raw biogas after the digester in a separate biological reactor, referred to as ex-situ biological methanation. Thus, a simple biogas upgrading plant without CO2 removal can be employed to finally produce biomethane vehicle fuels from both digestion and gasification plants. The novel processes, e.g. the syngas impurities inhibition to microorganisms, needs to be studied in detail, especially for the first one. The water-gas shift reaction can also be realized biologically so that all the major components, CO, H2 and CO2 in the syngas and the raw biogas can be converted to methane. Due to the low solubility of supply gases (CO and H2), an efficient supply of gases to the nicroorganisms is a decisive factor in a process using gaseous substrates. The mass transfer in the liquid phase and reactor design need to be studied.

WP5, Catalytic methanation (Miun + Chalmers) 2018.04 – 2018.12
Methanation of hydrogen from biomass gasifier and biogas from digester can be realized in a catalytic reactor at 300 – 500°C with help of nickel catalyst. Or the concentrated CO2 from biogas upgrading plant is used to react with the hydrogen from biomass gasifier under the catalytic condition to form methane. This process is studied theoretically in order to properly add the process in the biogas+bio-SNG mathematic model for comparison of different pathways in the techno-economic analysis.

WP6, Integration & Modeling of biogas + Bio-SNG processes
(Miun + Chalmers + MSV + Hemab + Jåmtlandsgas) 2017.04 – 2019.04
A mathematic model will be built up by means of Aspen-plus to simulate the integration of gasification into biogas process for methane production from biological/catalytic methanation with techno-economic analysis. The previous model of biomass to bio-SNG developed by

Miun will be modified when integrated into biogas plant. Appropriate integration will be an important milestone for the model development. The previous Ph.D work "Gasification-based biorefinery for mechanical pulp mills" provides a strong backup for success in this WP. Experience and inputs from partner companies are important.

WP7, Techno-economic analysis on biogas + Bio-SNG plant
(Miun + Chalmers + MSV + Hemab + BiMAB + Jämtlandsgas) 2019.04 – 2020.04
A techno-economic analysis will be given based on the mathematic model and practical knowledge from companies in order to commercialize biogas + bio-SNG production from biomass. The analysis can be made not only for Härnösand and Sundsvall special cases but also for cases in general. The results and conclusions will be used by the project partner companies to make decision for construction of biogas + bio-SNG vehicle fuel production plant.

Project Miun cost (Skr)

Manpower	Salary × 1.51	Working percent %	Month	Total
Wennan Zhang	72 144.	80	36	2 077 747.
Ulf Södwerlind	60 121.	70	36	1 515 049.
Kristina Göransson	48 899.	50	36	880 180.
PhD student	30 729.	80	36	847 441.
PhD student	30 729.	80	36	847 441.
Manpower sum				**6 167 858.**
External service				400 000.
Office rent				329 522.
Investment				500 000.
Material				100 000.
Travelling				150 000.
Overhead	20% of manpower			1 233 571.
Total cost				**8 481 351.**

Financial plan

Organization	Financial support (kr)		Item
	has been granted	to be applied	
Sundsvall Kommun		1 500 000	
Västernorrland Länsstyrelsen		500 000	
Miun	900 000		Co-finance to Swedish Gasification Centre
Energimyndigheten	900 000		Swedish Gasification Centre
E.on, Valmet and Göteborg Energi	900 000		Swedish Gasification Centre
EU Regional fond		4 000 000	Research/lab. Engineers and Project Leader
Hemab	300 000		In-kind
MittSverige Vatten	?		In-kind
Jämtlandsgas	?		In-kind
Sundfrakt/TRB	?		In-kind
BiMAB	?		In-kind
Total finance by cash	**2 700 000**	**6 000 000**	

14. Risker

Risk	**Åtgärd**
Difficult test in commercial digester	Construction of lab. scale digester
Not profitable for commercialization	Political support to transport biofuel in Sweden

15. Undertecknande

Undertecknad enligt §10 i Personuppgiftslagen (PUL, 1998:204), att de personuppgifter om undertecknad som har lämnats i ansökan, får behandlas på sådant sätt och i sådan omfattning som är nödvändig för hantering av ärendet (registrering i diarium o. likn.) och enligt §34 PUL att de publiceras på Internet i information om förstudien.

Sundsvall 2016-04-15		Wennan Zhang
Plats och datum	Förstudieledarens underskrift	Namnförtydligande