

PhD position nr 2007/59 -- Project Description**Production of synthetic natural gas (SNG) from gasified biomass – Process integration aspects****Goal**

The goal of the project is to use process integration methods and tools to identify options for improving the energy efficiency of process plants for production of synthetic natural gas (also called bio-methane) from gasified biomass.

Motivation

Gas fuels are expected to play a central role in future energy systems. Gas can be used to replace oil and coal fuels in industry, as well as as a fuel for efficient cogeneration plants, and as an alternative fuel in the transportation sector. Natural gas is however a fossil fuel, hence the current strong interest to investigate options for producing synthetic natural gas (SNG) from gasified biomass that can be distributed in the existing natural gas grid infrastructure. Potential feedstocks include forest fuels, organic household waste streams, agricultural waste, energy crops, etc. The main advantages with distribution of SNG in the natural gas grid are (i) 100 % usage of the gas that is produced; (ii) natural gas constitutes a back-up at all times; (iii) renewable SNG can be phased into the grid as production capacity is brought on-line.

Natural gas currently accounts for around 2 % of Sweden's energy supply. A study of opportunities for SNG in southern Sweden was recently conducted by SGC (Svenskt Gastekniskt Center AB) who estimate the potential biomass feedstock at 34 TWh/yr in 2010. If this feedstock were to be used exclusively for SNG production, 23 TWh/yr of SNG could be produced. In the long run, the theoretical potential for SNG in Southern Sweden could exceed 1000 TWh/yr.

Göteborg Energi has recently initiated the GoBiGas (Gothenburg Biomass Gasification) project. The project aims at planning a commercial scale biomass-to-SNG plant sized to cover around 20 % of Göteborg's gas consumption. Göteborg Energi's vision is that natural gas should be completely replaced by SNG by 2050.

During the initial phase of the GoBiGas project, Göteborg Energi identified the need to investigate process integration issues for different process options for SNG production. This PhD project was thus initiated in order to respond to this need. In order for the PhD project to succeed it is important that it be conducted with a high level of scientific expertise. The Heat and Power Technology group at Chalmers has a long tradition of developing and using process integration methods and tools within a variety of application areas, e.g. pulp and paper industry, black liquor gasification, biomass gasification, hydrogen production, CO₂ separation, etc. *Process integration* refers to a holistic approach to process design which considers the interactions between different unit operations from the outset, rather than optimising them separately. This can also be called integrated process design or process synthesis.

Background

The main production stages in a biomass-to-SNG process are illustrated in Figure 1. Gasification of biomass yields a product gas containing mainly CO, H₂ and CH₄. In order to achieve a gas composition similar to that of natural gas, CO and H₂ must be converted to CH₄ in a methanation stage, after gas clean-up. In the final stage, CO₂ is removed to further increase the CH₄ content and heating value of the gas. Of particular importance when producing SNG from biomass is to crack tar compounds to CO, H₂ and CH₄. Different technologies can be used for gasification, tar cracking, gas clean-up and methanation. ECN in

the Netherlands has investigated general biomass-to-SNG process routes and identified the following concepts as being especially relevant¹:

- [1] Pressurized oxygen-blown gasification in a circulating fluidized bed (CFB) reactor, followed by methanation
- [2] Pressurized hydrogasification in a bubbling fluidized bed reactor, followed by methanation
- [3] Atmospheric indirect gasification, followed by methanation

One major problem with the hydrogasification option is limited availability of hydrogen from renewable sources. Pressurized gasification is mainly of interest for plant sizes above 100 MW_{th}, whereas indirect indirect gasification is better suited for smaller plants.

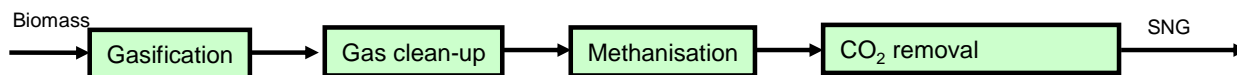


Figure 1 Main production stages in a biomass-to-SNG process

As discussed previously, Göteborg Energi has recently initiated the GoBiGas (Gothenburg Biomass Gasification) project. The project aims at planning a commercial scale plant (around 100 MW) for production of SNG from gasified biomass sized to cover around 20 % of Göteborg’s gas consumption. The plan is that such a plant should be operational by 2010. Göteborg Energi’s vision is that natural gas should be completely replaced by SNG by 2050. The initial pre-study identified indirect gasification as the most suitable technology for the plant (see Figure 2).

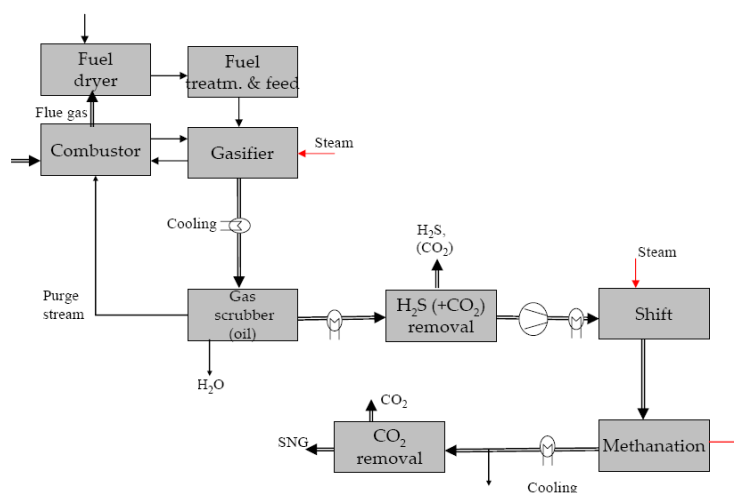


Figure 2: Production of SNG from gasified biomass (indirect gasification route)

Aim

The purpose of this PhD project is to increase knowledge about how process integration methods can be used to identify synergy effects between different sub-processes in biomass-to-SNG process plants, thereby increasing the competitiveness of this technology.

The aim of the project is to identify profitable opportunities for process integration within a process for production of SNG. The main focus will be on identifying opportunities for reducing electricity consumption and increased conversion of biomass to SNG. Opportunities for maximum conversion of process off-gases and waste heat to electricity and district heat will also be studied (i.e. *polygeneration* concepts). A final goal is to quantify the potential for reduction of CO₂ emissions associated with production and usage of SNG from gasified biomass.

¹ M.Mozaffarian & R.W.R. Zwart, "Feasibility of Biomass/Waste-related SNG technologies", ECN report nr ECN-C-03-066, July 2003.

Execution

Different process schemes will be identified using methods and computer tools for process integration and process simulation available at the department. Opportunities for energy efficiency measures will be studied using the pinch analysis method. Design of the process energy systems will be accomplished using appropriate computer software, e.g. the matrix method. Biomethane production costs will be assessed for different future conditions using *energy market scenarios* developed at the department.

The project will contain the following parts:

- Compilation of technical characteristics of important process steps, including drying of the biomass feedstock, gasifier, gas clean-up, methanation, CO₂ removal, and air separation for processes that require pure oxygen as oxidising agent in the gasifier.
- Optimisation of the steam system (number of steam levels and pressure levels)
- Optimisation of the pressure level in the sub-processes listed above
- Optimisation of the complete process (from biomass feedstock to SNG), accounting for the value of process by-products, such as off-gases, electricity and heat for different future energy market scenarios
- System aspects, including consequences for CO₂ emissions associated with production and use of SNG from gasified biomass.

Expected results:

- Proposal for the optimal layout for a biomass-to-SNG plant, including the steam system (number of steam levels and pressure levels) and pressure levels in important process steps, including drying of the biomass feedstock, gasifier, gas clean-up, methanation, CO₂ removal, and air separation for processes that require pure oxygen as oxidising agent in the gasifier
- Quantification of the potential for electric power and energy savings for an optimised biomass-to-SNG process, compared to the processes that have been proposed within the pre-study phase of Göteborg Energi's GoBiGas project
- Identification of economically attractive opportunities for process integration within a biomass-to-SNG plant for different future energy market scenarios
- Quantification of CO₂ emissions associated with production and use of SNG from gasified biomass.

The project will be undertaken by a PhD student at Chalmers, Division of Heat and Power Technology. The project will be conducted in collaboration with other ongoing projects related to production of SNG, e.g. at KTH, Dept of Chemical Engineering, and Chalmers, Division of Energy Technology. It is also important that good contact is established with the CHRISGAS project in Värnamo, and SGC's gasification and methanation group. The project will be conducted in close collaboration with Göteborg Energi's GoBiGas project.

Qualification requirements

Qualified applicants should hold a M.Sc. degree (civ.ing.) in an engineering discipline such as Mechanical, Energy or Chemical Engineering awarded by an internationally recognised university-level institution – or documented equivalent thereof.

Further information

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