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Improved syngas processing for enhanced Bio-SNG production: A techno-economic assessment

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ABSTRACT

This study analyzes the modification of an existing process configuration train for Bio-SNG production using an indirectly-heated circulating fluidized bed gasifier. Taking the process design of the Gothenburg Biomass Gasification (GoBiGas) project, we investigate four modifications to the process design in order to analyze what the potential effect from implementation of the results from state-of-the-art research activities on bio-syngas conversion is. Firstly, aromatic compounds are converted into Bio-SNG. Secondly, olefin hydration and hydrodesulfurization units are combined in a high-temperature hydrodesulfurization unit. Thirdly, the methanation section is modified and the pre-reformer unit in the syngas conditioning section is eliminated. Finally, H_2S and CO_2 removal are combined in the same unit. In order to provide a comprehensive comparison of current GoBiGas process and the configuration investigated in this work, process flowcharts and energy and material balances are provided. The study reveals that the investigated configuration has the potential to reduce capital investment and operating costs. Considering Phase II of GoBiGas project, a potential reduction of 29% of the capital investment and 7 €/MWh of produced Bio-SNG could be achieved comparing planned and investigated configurations. The results prove that investigated modifications can have a large impact in the future commercialization of Bio-SNG.

1. Introduction

To substitute natural gas with gas from lignocellulosic biomass (Bio-SNG) is an important contribution to the reduction of GHG (greenhouse gas) emissions, providing that the biomass can be regarded as a renewable carbon source. Bio-SNG can be used as a substitute of diesel provided car-engines are adopted for natural gas as a fuel. The main strengths of Bio-SNG compared to other biofuels (diesel-FT and ethanol) are its versatility (domestic, heating and transportation fuel) and it can be directly injected to the European natural gas grid. Considering the high prices of natural gas in Europe (30–40 €/MWh) [1], the substitution of natural gas by Bio-SNG seems to be the most favored option.

The development of plants for Bio-SNG production is in progress mainly in Europe and there are currently three active demonstration projects: the Milena-SNG plant in The Netherlands, and the GoBiGas (Gothenburg Biomass Gasification) project and the Biomass-to-Gas (Bio2G) project in Sweden. Fig. 1 shows the main difference between the projects with respect to Bio-SNG generation, prior to the gas upgrading steps. The Milena-SNG project has been proposed by the Energy Research Center of The Netherlands (ECN) for the production of 10–12 $MW_{Bio\text{-}SNG}$. The plant will use the Milena technology for biomass gasification and the OLGA technology for gas cleaning [2]. The GoBiGas project is a two-step project initiated by the local utility *Göteborg Energi AB* for the production of Bio-SNG. The first phase (Phase I), which is in operation, is a 20 $MW_{Bio\text{-}SNG}$ plant and a second phase (Phase II) of 100 $MW_{Bio\text{-}SNG}$ is under planning. The Phase I plant is located in Gothenburg (Sweden) and it uses a dual bed indirectly-heated circulating fluidized bed (i-CFB) gasifier developed by REPOTEC [3]. The Bio2G project is under planning by E.ON and it targets the production of 200 $MW_{Bio\text{-}SNG}$. The plant will be located in Malmö (Sweden) and will use a pressurized oxygen blown direct fluidized bed (d-FB) gasifier developed by the Gas Technology Institute (GTI) connected to a tar-reformer. Both projects use wood pellets (for start-up) and forest residues as biomass

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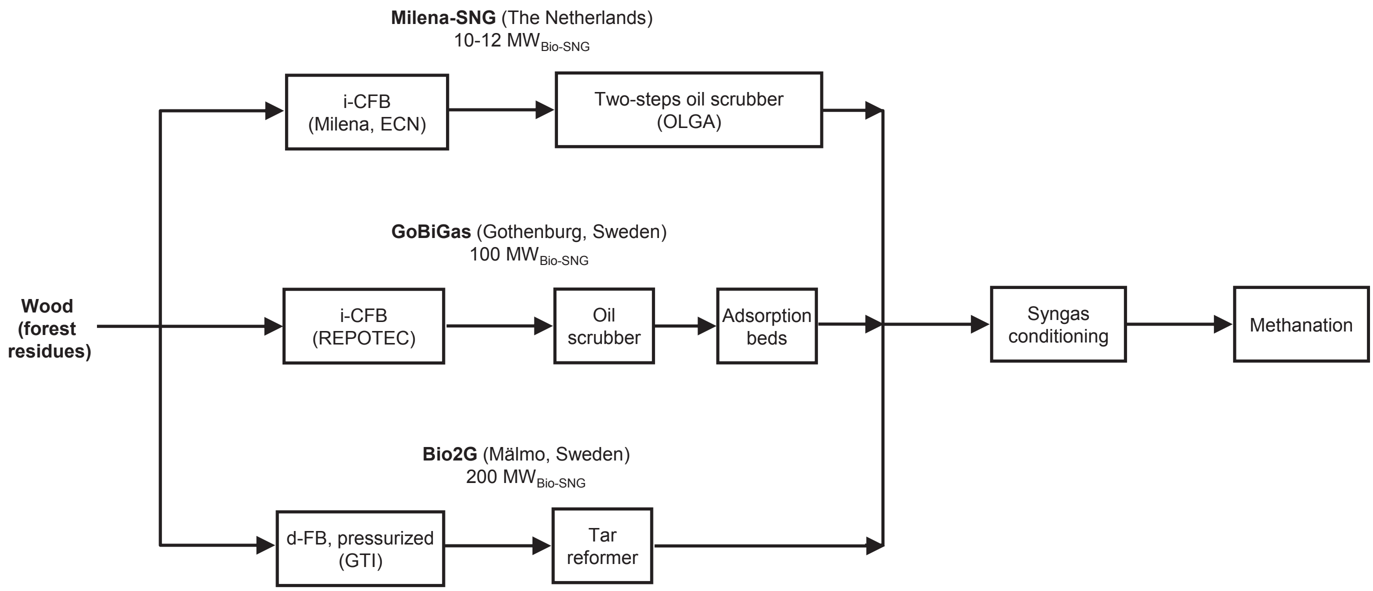

Fig. 1. General overview of active demonstration projects for Bio-SNG production (Europe) [2,3,6,7].

feedstock. A previous project was coordinated by the German Biomass Research Centre (DBFZ): a demonstration plant of 1 $MW_{Bio-SNG}$ in Güssing (Austria) using REPOTEC gasifier [4,5].

Regarding literature on Bio-SNG, Kopyscinski has reviewed SNG production from coal and biomass gasification [8]. Van der Maijden et al. provide a comparison of three different biomass gasification technologies (entrained flow, d-FB and i-CFB) on Bio-SNG production [9]. Gassner and Maréchal, Heyne and Harvey, and ECN have recently published different techno-economic assessments for Bio-SNG production [10–13]. However, these works cannot be compared with any of the demonstration Bio-SNG projects from Fig. 1. Hence, some technical aspects of these projects on bio-syngas cleaning and conditioning were not included.

The main bottlenecks for the commercialization of Bio-SNG are the operating cost and capital investment since these are higher than today's fossil fuel alternatives for which there is basically no capital cost. For the operating cost, the biomass price contributes most and, thus, any increment of Bio-SNG production (i.e. energy efficiency) is important in order to reduce the impact of biomass price. The energy efficiency can be increased either by enhancing the conversion of char in the gasifier or reducing the energy losses during syngas conditioning. The capital investment can be reduced if some process units can be eliminated or if their size and complexity can be reduced.

In this study, we compare the production of Bio-SNG from lignocellulosic biomass taking the Phase II of the GoBiGas project and a modified configuration investigated in this study as a basis for the design. The comparison is carried out in terms of a techno-economic assessment. The investigated modifications have the potential to enhance Bio-SNG production and reduce capital and operating costs. The biomass pretreatment and gasification process are excluded from the study, being the focus on the syngas treatment steps (cleaning and conditioning). We describe the fundamentals of each modification and the implications in the process design and economics.

2. Methodology

2.1. Description of GoBiGas process

Phase II of GoBiGas project considers the construction of a 100 $MW_{Bio-SNG}$ plant. Fig. 2 shows an overview of the process, where both wood pellets and forest residues can be used as feedstock. The gasification technology is by means of an i-CFB gasifier operating at atmospheric pressure and at a temperature of 800–900 °C. The produced gas is de-dusted and cooled and heavy tars removed in an oil scrubber using RME (rapeseed-oil methyl ester). Light tar (aromatic compounds) along with chlorine and nitrogen compounds are removed downstream using an adsorption bed with activated carbon. The tar-free bio-syngas is compressed up to approximately 35 bar. The bio-syngas enters the olefin hydrogenator, where olefins are converted into alkenes, and the hydrodesulfurization (HDS) reactor, where organic sulfur is converted into H_2S. Downstream, H_2S is removed and the H_2/CO molar ratio adjusted in a WGS (water–gas-shift) reactor to meet the requirements of the methanation section. The pre-reformer (pre-methanator) unit converts all alkenes into methane, but also produces a CO_2-rich gas. The CO_2 content of the cleaned bio-syngas is reduced before methanation. The methanation is carried out using in-series adiabatic reactors. Finally, the raw Bio-SNG meets natural gas standards after water removal.

2.2. Process modeling

Material and energy balances for planned GoBiGas and investigated configurations are obtained using Aspen Plus® process simulator (version 8.4). Biomass pretreatment, gasification, de-dusting and oil scrubber sections are not included in the study since they are not affected by the process modifications in the investigated configuration. Both the investigated and the planned GoBiGas configurations are designed to have the same Bio-SNG production (100 $MW_{Bio-SNG}$). The Soave–Redlich–Kwong (SRK) thermodynamic model is applied for the simulation of both configurations. Details of the modeling of process units for both configurations are given in Annex A.

2.3. Description of process modifications

The modifications to the GoBiGas syngas cleaning and conditioning investigated in this work have the aim to:

- Enhance the energy efficiency of the plant, reducing the amount of biomass feedstock (reducing operating cost).