BIOMASS AND BIOENERGY 34 (2010) 302–311

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BIOMASS & BIOENERGY

The production of synthetic natural gas (SNG): A comparison of three wood gasification systems for energy balance and overall efficiency

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ARTICLE INFO

Article history:
Received 31 January 2008
Received in revised form
28 October 2009
Accepted 6 November 2009
Available online 20 November 2009

Keywords:
Biomass
Allothermal
Gasification
Twin-bed
Indirect gasification
CFB
Entrained flow
SNG
Bio-SNG
Bio-CNG
Natural gas
Biogas
Aspen plus®
CCS

ABSTRACT

The production of Synthetic Natural Gas from biomass (Bio-SNG) by gasification and upgrading of the gas is an attractive option to reduce CO_2 emissions and replace declining fossil natural gas reserves. Production of energy from biomass is approximately CO_2 neutral. Production of Bio-SNG can even be CO_2 negative, since in the final upgrading step, part of the biomass carbon is removed as CO_2, which can be stored. The use of biomass for CO_2 reduction will increase the biomass demand and therefore will increase the price of biomass. Consequently, a high overall efficiency is a prerequisite for any biomass conversion process. Various biomass gasification technologies are suitable to produce SNG. The present article contains an analysis of the Bio-SNG process efficiency that can be obtained using three different gasification technologies and associated gas cleaning and methanation equipment. These technologies are: 1) Entrained Flow, 2) Circulating Fluidized Bed and 3) Allothermal or Indirect gasification. The aim of this work is to identify the gasification route with the highest process efficiency from biomass to SNG and to quantify the differences in overall efficiency. Aspen Plus® was used as modeling tool. The heat and mass balances are based on experimental data from literature and our own experience.

Overall efficiency to SNG is highest for Allothermal gasification. The net overall efficiencies on LHV basis, including electricity consumption and pre-treatment but excluding transport of biomass are 54% for Entrained Flow, 58% for CFB and 67% for Allothermal gasification. Because of the significantly higher efficiency to SNG for the route via Allothermal gasification, ECN is working on the further development of Allothermal gasification. ECN has built and tested a 30 kW_{th} lab scale gasifier connected to a gas cleaning test rig and methanation unit and presently is building a 0.8 MWth pilot plant, called Milena, which will be connected to the existing pilot scale gas cleaning.

1. Introduction

Natural gas is increasingly important as a primary energy source. It is used for electricity production, industrial and domestic heating purposes, as chemical feedstock and gaining importance a transportation fuel (CNG). In the Netherlands about 50% of the primary energy consumed is covered by natural gas. A sustainable alternative is required anyhow, as the natural gas reserves are finite and their use contributes to greenhouse gas emissions. Clearly, ambitious plans to derive

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0961-9534/$ – see front matter
doi:10.1016/j.biombioe.2009.11.001

30% of the primary energy used from renewable sources cannot be realized, without a renewable alternative for natural gas.

Renewable Synthetic Natural Gas (SNG) production via digestion has been developed and implemented on a small scale. The limited amount of suitable digestible feed stocks [1], some 60 PJ per year in the Netherlands, demands for development of a production technology for SNG by gasification, because that route has a much larger potential as a wider range of fuels (e.g. wood) can be used. World-wide the net available biomass is estimated to be 200–700 EJ per year [2].

Fig. 1 shows a simplified scheme of a biomass to SNG configuration. Biomass is gasified at high temperature, producing a syngas which is cooled before it enters the gas cleaning section. The cleaned gas is sent to the methanation unit where CO and H_2 are converted into CH_4 and CO_2. After CO_2 removal and drying, the gas is ready for injection into the natural gas grid.

The methanation of gas produced by the gasification of coal was investigated intensely in the 1970s and 1980s. Most demonstrations were not successful because of the low natural gas price. The Dakota Gasification Company SNG installation survived and is now a commercial success. The installation built in the 1970s and 1980s uses lignite as a fuel. As the price of lignite is low, high efficiency was less of an issue. Biomass is a more expensive feedstock. The price may even increase further because of increasing demand, fueled by the CO_2 reduction objectives. Hence, the production of SNG from biomass requires a process with high overall efficiency. As the overall efficiency is mainly determined by the type of gasifier, the gas cleaning and the level of heat integration, the goal of the work described here is to calculate the difference in efficiency for the various options.

The three gasifier types under consideration all deliver gas suitable for upgrading to SNG, but the high temperature Entrained Flow gasifier (≈1300 °C) produces a syngas containing mostly CO, H_2, CO_2 and H_2O while the medium temperature Allothermal and CFB gasifiers (≈850 °C) give a producer gas which in addition to CO, H_2, CO_2 and H_2O contains CH_4, unsaturated and aromatic hydrocarbons like C_2H_4 and C_6H_6 and tar. Pollutants like dust, sulphur and chloride need to be removed from the gas in all cases. The medium temperature gasifiers also require tar removal. Fig. 2 shows the general process efficiencies for wood to SNG. A high amount of 'instant SNG' gives the highest efficiency to SNG, because the loss caused by the exothermic synthesis of CO and H_2 is minimized.

Syngas, as produced conventionally by oil or coal gasifiers, is seen as a more common feedstock gas than producer gas because gas-cleaning processes for syngas applications are already commercially available. The gas cleaning processes for producer gas are still under development.

Both types of cleaned gasses can be converted into a gas containing only CH_4, CO_2, H_2O and a small amount of Ar and N_2. CO_2 and H_2O are easily removed from the gas, leaving an SNG that can contain small amounts of N_2 and Ar. The maximum allowable concentration of non-combustible gasses is site-specific.

In this study a model is made to calculate the overall efficiencies to SNG for large scale systems of 1 GWth input on HHV basis, based on three different types of gasifiers. The relatively large scale was selected because it matches the commercial scale of Entrained Flow coal gasifiers and the production capacity of a small natural gas field. Oxygen blown Entrained Flow gasification is compared to both Indirect (or Allothermal) gasification and oxygen-blown Circulating Fluidized Bed gasification at the same scale. The comparison is solely based on energetic efficiency numbers. Economics and transport of biomass are not taken into account. The goal of this comparison is to quantify the differences in overall process efficiencies for the three different gasifiers. The results were used by ECN to select to most promising gasification technology for SNG production.

Dry wood (moisture content = 15 wt.%) was selected as the fuel for this study, as it can be readily used for all three different types of gasifiers. Wood mixed with coal was gasified in the Shell Entrained Flow gasifier in Buggenum in the Netherlands and wood is gasified in several fluidized bed gasifiers.

The next paragraph describes the system layout for each gasification technology. Sub systems are described in detail in separate paragraphs. The final paragraph presents results of the analysis.

2. Process configurations

In all cases the gas cleaning and gas upgrading steps are kept similar as much as possible to allow an honest comparison of the overall efficiencies due to various types of gasifiers. Operating pressures were selected on the basis of what is thought to be commercially available in the near future. Fig. 3 shows the process scheme for the Entrained Flow SNG system. Entrained flow gasification requires an energy intensive pretreatment to produce fine powder. Torrefaction [3] is selected, followed by milling, because of the relatively low energy requirement. Dried biomass is fed into the torrefaction reactor (T in Fig. 3). The torrefied biomass is milled, pressurized with CO_2 and pneumatically fed into the Entrained Flow gasifier (EF in Fig. 3) which operates at 3 MPa and 1300 °C. Syngas leaving the gasifier is first cooled by a gas quench down to 600 °C and subsequently cooled in a heat exchanger producing steam. Fly ashes are removed from the cooled gas by a filter. Part of the gas is recycled to act as quench gas. Sulphur and chloride are

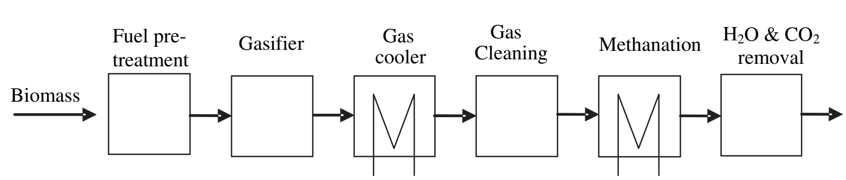

Fig. 1 – Simplified scheme of Biomass to SNG configuration.