BIOMASS AND BIOENERGY 38 (2012) 95–101

Available at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

BIOMASS & BIOENERGY

Greenhouse gas and energy analysis of substitute natural gas from biomass for space heat

Johanna Pucker[a,*], *Robin Zwart*[b], *Gerfried Jungmeier*[a]

[a] *JOANNEUM RESEARCH Forschungsgesellschaft mbH, RESOURCES – Institute for Water, Energy and Sustainability, Steyrergasse 17, 8010 Graz, Austria*

[b] *Energy Research Centre of The Netherlands (ECN), Westerduinweg 3, 1755 LE Petten, The Netherlands*

ARTICLE INFO

Article history:
Received 26 August 2010
Received in revised form
17 February 2011
Accepted 18 February 2011
Available online 30 March 2011

Keywords:
Substitute natural gas
Bioenergy
Life cycle assessment
Greenhouse gas emissions
Primary energy consumption
Gasification

ABSTRACT

In this paper, the greenhouse gas and energy balances of the production and use for space heating of substitute natural gas from biomass (bio-SNG) for space heat are analysed. These balances are compared to the use of natural gas and solid biomass as wood chips to provide the same service. The reduction of the greenhouse gas emissions (CO_2-eq.) – carbon dioxide, methane and nitrous oxide – and of the fossil primary energy use is investigated in a life cycle assessment (LCA). This assessment was performed for nine systems for bio-SNG; three types of gasification technologies (O_2-blown entrained flow, O_2-blown circulating fluidised bed and air–steam indirect gasification) with three different types of feedstock (forest residues, miscanthus and short rotation forestry). The greenhouse gas analysis shows that forest residues using the air–steam indirect gasification technology result in the lowest greenhouse gas emissions (in CO_2-eq. 32 kg MWh^{-1} of heat output). This combination results in 80% reduction of greenhouse gas emissions when compared to natural gas and a 29% reduction of greenhouse gases if the forest residues were converted to wood chips and combusted. The gasification technologies O_2-blown entrained flow and O_2-blown circulating fluidised bed gasification have higher greenhouse gas emissions that range between in CO_2-eq. 41 to 75 kg MWh^{-1} of heat output depending on the feedstock. When comparing feedstocks in the bio-SNG systems, miscanthus had the highest greenhouse gas emissions bio-SNG systems producing in CO_2-eq. 57–75 kg MWh^{-1} of heat output. Energy analysis shows that the total primary energy use is higher for bio-SNG systems (1.59–2.13 MWh MWh^{-1} of heat output) than for the reference systems (in 1.37–1.51 MWh MWh^{-1} of heat output). However, with bio-SNG the fossil primary energy consumption is reduced compared to natural gas. For example, fossil primary energy use is reduced by 92% when air–steam indirect gasification technology and forest residues is compared to natural gas. There is no significant difference of the fossil primary energy consumption between the use of solid biomass (0.13–0.15 MWh MWh^{-1} of heat output) and the bio-SNG systems (0.12–0.18 MWh MWh^{-1} of heat output).

* *Corresponding author*. Tel.: +43 316 876 1433; fax: +43 316 876 1320.
E-mail address: johanna.pucker@joanneum.at (J. Pucker).

0961-9534/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.biombioe.2011.02.040

1. Introduction

In the EU, energy consumption for heat accounts for 46% of the final energy use. Heat use is larger than final energy use for transportation (32% of the EU final energy use) and much larger than the use of electricity (18.5% of the EU final energy use) [1].

Currently biomass for heating is used directly in its solid form as logs, chips or pellets in boilers for heating households and industry and to supply heat for district heating systems. The present use of biomass for heating could be increased by introducing additional supply chains.

Based on data on energy consumption by Eurostat, it can be estimated that about 50% of heat consumed in the EU is produced from natural gas [1,2]. Production of substitute natural gas from biomass (bio-SNG) is an interesting option to increase the share of heat generation from biomass by exploiting the synergies with natural gas. Conversion of biomass into bio-SNG and subsequent distribution and use can be considered as an additional supply chain for heat from biomass. By distributing energy from biomass in the form of bio-SNG the end user can have a fuel that offers all the advantages of natural gas, such as low emissions, social acceptance, existing infrastructure, wide-spread end use appliance, and the inherent storage and distribution capacity of the natural gas grid to cope with the variable demand. The production of bio-SNG could serve as an alternative gas source, securing the current supply of natural gas and making the EU gas market less dependent from imports.

From the perspective of the biomass chain, there are also advantages: local transportation of solid biomass can be avoided and after the conversion to bio-SNG the distribution losses are minimised. The alternative of heat distribution from solid fuelled combined heat and power installations is restricted to relatively short distances before heat distribution losses become very large.

Bio-SNG can be produced from biomass by anaerobic digestion and upgrading of the produced biogas. In this context it is also called bio methane. Anaerobic digestion is, however, only suitable for a limited number of feedstock that can be digested by the bacteria used in the process. Large-scale thermo chemical production of bio-SNG is suitable for a wider range of biomass feedstock. Thermo chemical production of bio-SNG comprises gasification to convert biomass in a raw product gas, gas cleanup and methanation to convert the product gas in bio-SNG.

This paper presents the results of a life cycle assessment (LCA) which was performed to determine the potential of bio-SNG to reduce greenhouse gas (GHG) emissions and fossil primary energy use, when used for space heating applications. In this analysis bio-SNG is compared to the use of natural gas and the use of solid biomass as wood chips for space heating applications. The main focus of the analysis is put on the evaluation of large-scale bio-SNG systems and GHG emissions.

Table 1 – Global warming potentials.

Gas	CO_2-equivalent
CO_2	1
CH_4	25
N_2O	298

2. Materials and methods

2.1. *Life cycle assessment*

The calculation of GHG emissions and primary energy use is based on an LCA. The LCA includes all processes, which influence emissions and energy consumption from cradle to grave. It starts with the raw material production (e.g. collection of forest residues, cultivation of energy crops) and ends with the supply of useful energy at the consumer site (e.g. space heat) including all transportation and conversion processes. The life cycle assessment was performed following EN ISO 14040:2006 “Environmental management - life cycle assessment - principles and framework”.

Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are considered in the LCA. These latter two gases are converted into the equivalent amounts of CO_2 (CO_2-eq.) using global warming potential (GWP) listed in Table 1 [3]. CO_2-emissions from biomass are balanced zero, according to IPCC guidelines.

Primary energy use includes all energy inputs which are needed to deliver useful energy, in this case space heat, to the consumer using bio-SNG from biomass, natural gas or directly biomass. The amount of primary energy use is subject to feedstock and technologies used. In this analysis the primary energy use is divided into:

Table 2 – Basic data of the biomass feedstock used for bio-SNG production.

Feedstock	Yield	H_2O-content	Fuel consumption	Fertilizer use				Herbicides	Seeds
				Calcium	Potassium	Nitrogen	Phosphate		
	[t ha^{-1} y^{-1}]	[%]	[l ha^{-1} y^{-1}]	[kg ha^{-1} y^{-1}]	[kg ha^{-1} y^{-1}]	[kg ha^{-1} y^{-1}]	[kg ha^{-1} y^{-1}]	[kg ha^{-1} y^{-1}]	[kg ha^{-1} y^{-1}]
Poplar	20	50	136	350	–	–	–	–	500
Miscanthus	30	50	60	–	80	60	10	0.8	150
Forest residues	–[a]	50	9	–	–	–	–	–	–

a Collection of forest residues.