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Biomass gasification for district heating

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Abstract

Latvia is required to increase the share of energy produced from renewable sources. This study is focused on the potential of biomass gasification in the production of energy for the purposes of district heating. This study describes an innovative technology for syngas production from wood chips. The sensible heat of the produced syngas was used to dry wood chips. Gasification plant was tested at various capacities with and without air flow separation at the primary and secondary flows. Syngas composition, temperature in the gasifier, syngas temperatures, char heating value and several other parameters are measured and analyzed. The energy balance of the gasification process is calculated and presented. Results show that air separation causes growth in the efficiency of the gasification process.

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Keywords: biomass gasification; district heating; wood chips; primary and secondary air

1. Introduction

Based on Directive 2009/28/EC of the European Parliament and Council the share of the energy produced from renewable sources in the gross final consumption of energy must be increased from 9.0 % in 2005 to 20 % in 2020. The target of Latvia is to increase this share from 32.6 % in 2005 to 40 % in 2020 [1]. According to the data of the Ministry of Economics of Latvia, 64.0 % of energy is still produced from fossil resources. The share of biomass in

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the total energy production was 28.3 % in 2015. At the same time, costs of producing heat energy from natural gas are 40–45 EUR per MW, but from wood chips – around 15 EUR per MW [2].

In Latvia wood resources are widely used for different industry sectors, including energy production. Nevertheless, the forest-covered area of Latvia is constantly increasing from 2.9 million hectares in 2000 to 3.3 million hectares in 2014. Currently, forests cover more than 50 % of the total area of the country. The total volume of the forest has also increased from 546 million cubic meters in 2000 to 668 million cubic meters in 2014 [3]. Due to this reason in Latvia there is a high potential for producing energy from local resources. There are different methods to convert biofuel to energy. Currently there is an expansion into the use of biomass gasification technologies. Biomass gasification is a thermochemical process in which solid biomass is converted into gaseous fuel or syngas. The process takes place in the absence of oxygen and at high temperatures. The gasification process consists of four stages – drying, pyrolysis, partial combustion and gasification or reduction. The produced gas typically consists of three combustible gases: carbon monoxide (CO), hydrogen (H_2) and methane (CH_4), and three non-combustible gases – carbon dioxide (CO_2), nitrogen (N_2) and water vapour (H_2O). However, tar and char are also formed during the gasification process. Tar is a complex mixture of light aromatics, polyaromatics, heterocycles, etc. Char is a not fully converted part of biomass which mainly consists of hydrogen and carbon, therefore it has high calorific value. Gasification has many advantages in biomass conversion into energy. The gasification produces lower amounts of emissions as compared to direct biofuel combustion. Also gasification has advantages over combustion of better controlled heating and electricity production [4].

The gasification process can be used in different ways and can be integrated into many systems. The analysis of the economic, social and environmental aspects analyze can be useful to determinate more effective possibilities for gasification process integration [5]. The biomass gasification process is widely used for producing energy and electricity in cogeneration stations. The potential of using the biomass gasification technology in the district heating system in Sweden was presented in the study done by Borjesson & Ahlgren et al. [6], and its use in decentralized power generation in India is described in [7]. Results show, that investments into biomass integrated gasification combined cycle plants is economically justifiable and can reduce global CO_2 emissions [8]. The possibility of biomass gasification integration into district heating strongly depends on policy tools and the price relation between biomass and fossil fuels. Location of gasification plants near to the existing natural gas combined cycle heat and power plants can be used to decrease investment costs [9].

Arena et al. [10] present a techno-economic comparison between two design solutions for energy and electricity production at the biomass gasifier. Micro gas turbine and solid oxide fuel cell possibilities to convert into electricity the syngas produced at the gasifier is described in the study done by Bang-Moller and Rokni [11]. Results show that efficiency of converting biomass into electricity by using the solid oxide fuel cell technology is 36.4 %, but by using micro gas turbine it is 28.1 %. Efficiency of converting biomass into electricity by using solid oxide fuel cell technology essentially depends on the gasification agent and can vary in a range from 18.5 % with air to 41.8 % with steam [12]. The electrical efficiency of power plants also depends on the type of gasifier and the scale of plants. Efficiency of big scale plants is much higher, however the investment cost for installation, if compared to the produced energy, also increases [13].

Biomass gasification can be used for producing hydrogen in the system integrated with energy and electricity production [14]. Results of Abuadala and Dincer [15] studies show that 70–75 g of hydrogen per 1 kg of biomass can be produced by using the biomass gasification process. Biomass gasification plant can be modified to generate syngas for production of liquid fuel or for the purposes of the chemical industry [4].

2. Description of the plant

The gasification plant can be divided into separate systems: biomass preparation and feeding system, gasifier reactor, syngas cooling, cleaning systems and other elements. The total gasification plant efficiency depends on all systems and their mutual internal operation. Typically, the choice of fuel feeding system, syngas cooling and cleaning systems depends on the type of the gasifier used. The design of the gasifier plays a dominant role in the process of converting solid fuel into gas. Downdraft, updraft and fluidized bed gasifiers are more popular for the needs of biomass gasification. It is important to choose an optimal type of gasifier depending on the required technical conditions of the plant.

A low capacity gasification plant was designed with the gasifier with nominal thermal output of 500 kW. Fluidized bed reactor typically is used for big plants with the capacity exceeding 5 MW, but capacity of downdraft gasifiers