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Energetical analysis of different configurations for Bio-SNG production from biomass gasification with integration of power and district heating

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Abstract: Natural gas is one of prime source of clean energy. The limited resources of natural gas provoke the research to produce it synthetically from renewable sources. This study has aim to produce the SNG from biomass gasification with process integration opportunities to find the potential of district heating and power production. The four configurations have studied for SNG production from 25MWLHV gasification of biomass with combine heat and power (CHP). The evaluating parameters are cold gas efficiency, District heating efficiency and Power efficiency are used for process evaluation. The use of humidifier has good impact on power production and district heating that is integrated with gasifier. The cold gas efficiency is higher in the case of dried biomass due to better yield of methane production. Humidification is enhanced the power production that enounces the economic viability of whole process.

Key words: Component; Formatting; Style; Styling; Insert

1. Introduction

Natural gas considers a clean fuel as compared to oil and coal. The importance of natural gas is increasing due to its utilization for electricity generation, domestic heating and cooling, industrial and transport fuel (CNG) and raw material for many chemical production (Meijden et al., 2010). Natural gas has also carried some advantages of transportation in the form of gas through pipelines and closed vessels and in liquid form in the form of liquid natural gas. The known reserves of natural gas are limited and not enough more than next 50 -60 years (Li et al., 2014). During the late 70,s and early 80,s the research was mature enough to produce synthetic natural gas (SNG) from commercially by coal gasification. However, owing to abundant reserves and low price of crude oil the natural gas did not gain so much popularity. In recent past due to abrupt hike in oil prices and environment concerns for using coal has compelled the scientists to deem for synthetic fuel. The advantages associated with SNG it could be used with existing natural gas distribution network, transport, industry and domestic sector without any modification (Molino and Braccio, 2015).

The cost of SNG production is high and have economic deficit on commercial scale. Biomass gasification to produce SNG and its integration with power production could economize the process. The production of bio-SNG from thermochemical gasification of biomass one of the efficient use of biomass (Rudra et al., 2015). Biomass is one of the largest energy source and it shares about 9 % in 2010 in world energy mix and it is excepted to be 18 % in 2050 (Lauri et al., 2014). Additionally, the broad types of biomass are available all over the globe to meet the local demands of countries. The use of biomass for SNG production decreases threat of depletion of due to its sustainable production every year. Significant work on combine heat and power (CHP) plant both on research and commercial scale is being carried out especially in Europe (Rudra et al., 2015). The cogeneration and process integrations has been used in many system (Normann et al., 2009). Hyene (2010) developed a process for SNG production from biomass and find the process integration opportunities to utilized the waste heat. Later on co generation concept used by phil et al. He produced electricity from biomass through integrated and hybridization with combine cycle gas turbine for natural gas production (Pihl et al., 2010). Martiz et al. (2014)derived smart CHP plants for using biomass residue for gas and electricity purpose . He made performance analysis of CHP plant by using different biomass residues and Integrated with SNG production through CHP is successfully tested commercially on pilot plant. Austria has built the 1MW plant in Gussing having capacity 120 SNG production from 360 kg of wood (Rehling et al., 2009). It is considered environmental friendly and already utilized in for DH system (Rudra et al., 2015).

Biomass is a local solution for CHP. This process is helpful in GHG mitigation and energy saving but not economical for small units (Dong et al., 2009). The use of it not only decreases the dependency of CHP plants on oil and natural gas as well as it

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reduces the carbon foot print as evidenced from its life cycle assessment. The SNG production from biomass and utilized the high temperature stream for power production and low temperature waste heat for district heating made it economical process. Many works has been going on to developed different process for CHP from biomass to economies the process. The objective of this work not only developed the new process configuration as well as it made comparison of them for different

In current work four process configurations for SNG production from biomass gasification are developed with combine power and district heating net. Main feature if introduction of humidifier in configuration. According to author knowledge, the use of humidifier in SNG production was not reported yet.The SNG production and potential of power production and district heating are evaluated in terms of MW for input and products. The SNG production was evaluated by using Cold gas efficiency. In addition electric and DH efficiency are also evaluated on the heating load of DH and power Organic Rankin Cycle (ORC).

2. Methodology

This study is done for Bio SNG production, utilization of process heat into power generation and district heating and firms heat integration concept to make SNG production economical; after carefully analyzing biomass gsification process, available commercial technologies for biomass drying, syngas cleaning, cooling, methnation and gas upgrading four process configurations was made. The following four configurations are developed as shown in Fig. 1.

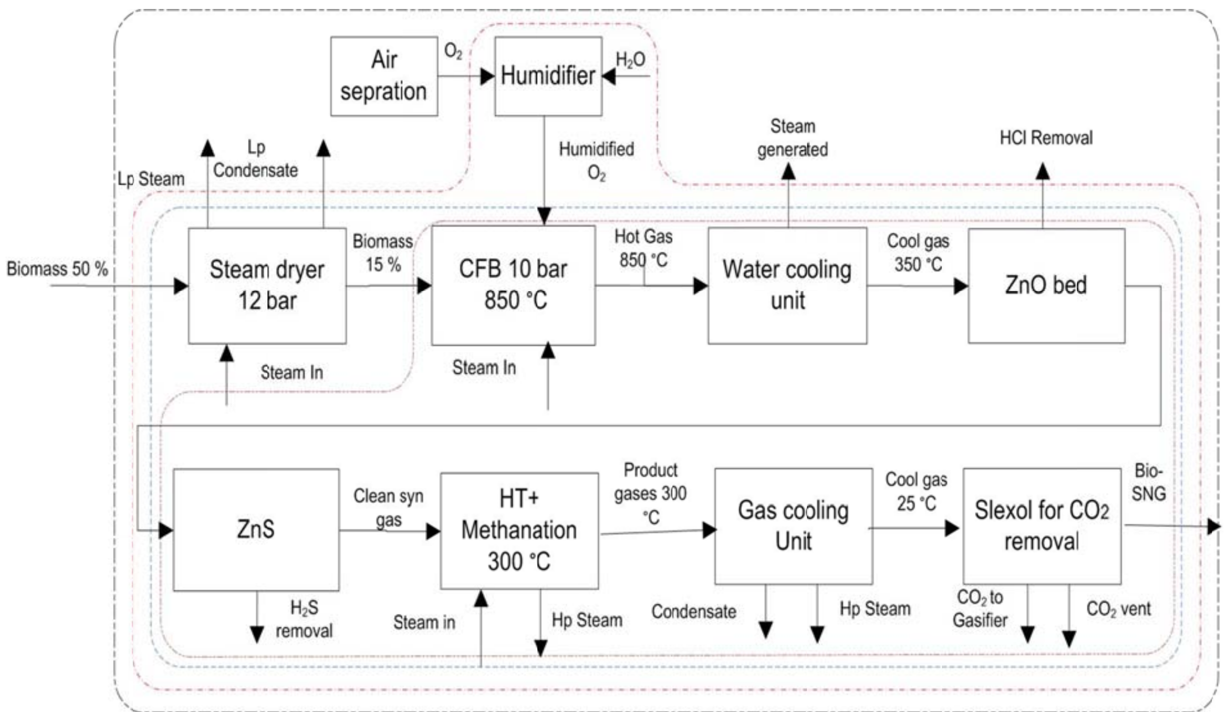

Fig. 1: Process flow diagram for configurations. GDB (gasification with dried biomass), GD (gasification with integrated dryer), GH (Gasifier with integrated humidifier) and GDH (gasification with integrated dryer and humidifier)

The reference capacity 25MW on LHV basis selected and heat and power production would be analyzed. Wood chips of 1-5 mm were used as raw material. The biomass composition and heating value are given in Table 1. The gasifier, gas cleaning, gas upgrading, and methanation steps were kept similar for making a valid comparison.

Table 1: Biomass composition and heating value

Biomass Composition (wood chips 1~5 mm)	Wt (%)
Carbon	50.63
Hydrogen	5.94
Oxygen	42.74
Nitrogen	0.62
Sulfur	0.06
Chlorine	0.01
LHV (MJ/kg)	18.82

2.1. Process scheme

In this process fluidized bed dryer used to remove the moisture content from 50% to 15 %. The biomass entered into dryer at 25 °C and dried with high pressure steam. Dryer was operated at 350 °C and 12 bar pressure. A low pressure steam of 3 bar at 150 °C was produced. This low pressure steam was utilized for DH or power production after process integration. The dried biomass was entered in circulating fluidized bed gasifier (CFB). Gasification of biomass was done at 850 °C and 10 bar pressure in the presence of Ni- olivine catalyst. The purpose of catalyst enhance the desired reaction for increase the gaseous products that enrich the

SNG production. Oxygen and steam both were used as gasifying agent. Pure oxygen was supplied from air separation unit. Recycled CO_2 was injected in order to transport the biomass at higher pressure. This CO_2 stream was obtained from gas upgrading unit and utilized here by using process integration. The producers gas that conation many gases namely, CO, CO_2, H_2, H_2S, HCL and H_2O were cool down till 371 °C in cooling section by using water. High pressure steam was produced that used in gasifier and methanator to full fill energy demand. The HCl, H_2S were impurities and removed in cleaning section by using bauxite and ZnO. The removal of tar is very costly process which affects the overall economy. So in this setup a new developed catalyst was used to avoid the formation of tar. So that its production was negligible due to use of Ni – olivine based catalyst (Rehling et al., 2009). The cleaned syngas was fed into methanator where it was converted into methane at 300 °C in the presence of steam and Ni as catalyst.

High pressure and temperature steam produced and some of it utilized in dryer (in case of GD and GDH) for integration process. The rest of steam used for power production or district heating depends on configuration. The gases obtained from methanator cooled and CO_2 removed by using solexol process and a part of CO_2 was recycled in gasifier. The SNG is ready for pumping in distribution network. The heat produced at different steps was available for district heating and power cycle by using process integration on the basis of following configuration. The process schemes is almost same only the addition of any equipment for any process configuration.

a): GDB: In this case dried biomass was used so all the waste heat could be utilized for power cycle and DH.

b): GD: In this case a part of available heat or steam used for integrated dryer. So less heat is available for power and DH.

c): GH: Humidifier was used to study the humidification effect on SNG. Dried biomass was used. A little part of energy available after integration was used in humidifier and rest for power and DH.

d): GDH: In this case the most part of available energy after process was utilized for integrated dryer and humidifier. The reaming energy used for power and district heating.

3. Results and discussion

The energetical analysis for all configurations was made by using numerical application that based on the stoichiometric calculation. The results of 25MW biomass gasification were summarized in terms of SNG production and heat load available for power production and District heating as shown in Table 2. The purpose of this study is also the process integration to determine the potential of power production and DH along SNG production. The available heat load for power and DH was found after process integration. The heat load and SNG production was analyzed on the basis of energy analysis (Fig. 2).

Table 2: SNG production from different configurations

Configuration	SNG(MW)	Heat Load(MW)	Power (MW)	DH(MW)
GDB	19.37	5.63	0.43	5.2
GD	19.5	5.50	0.40	5.1
GH	18.84	6.16	0.55	5.61
GDH	18.82	6.18	0.55	5.63

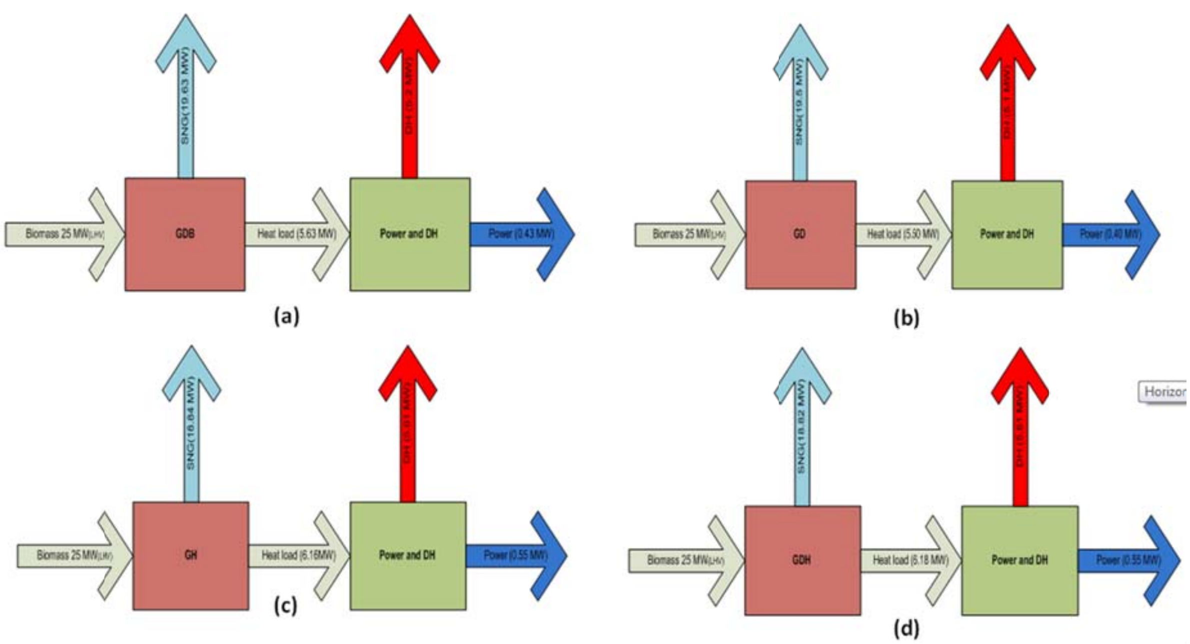

Fig. 2: Energy balance of system configuration (a) GDB, (b) GD, (C) GH and (d) GDH

3.1. SNG production

Main product of this process is SNG. The SNG production was calculated on the basis LHV in terms of MW from 25MW biomass. Steam was used as gasifying medium with oxygen. Steam not only enhanced the CH_4 production also suppressed the coke formation. It can be observed from Table 1 the SNG production is higher 19.37 MW and 19.37 MW in case of dried biomass and integrated drying respectively. Whereas, SNG production is lower in case of integrated humidifier and dryer and humidifier). The higher yield of SNG in (GDB and GD) configuration is due to the dry biomass. The Drop in SNG production is due to humidification. On the other hand higher heat load is available for power and DH system for integrated Dryer and humidifier configuration. The cold gas efficiency was calculated on the LHV basis of SNG and biomass input as shown in Fig 2. The cold gas efficiency is higher In case of dried biomass and integrated dryer is about 78 and 78.4 %. Whereas, in case of (GDH and GH) it is lower. It is clear that cold gas efficiency for GDB and GD configuration is about 2 -3 % higher than the humidifier based configurations. Carbon conversion is decreased due to moisture content. The moisture content not only decreased the carbon conversion efficiency but also increases the heating load in gasifier (Fig. 3).

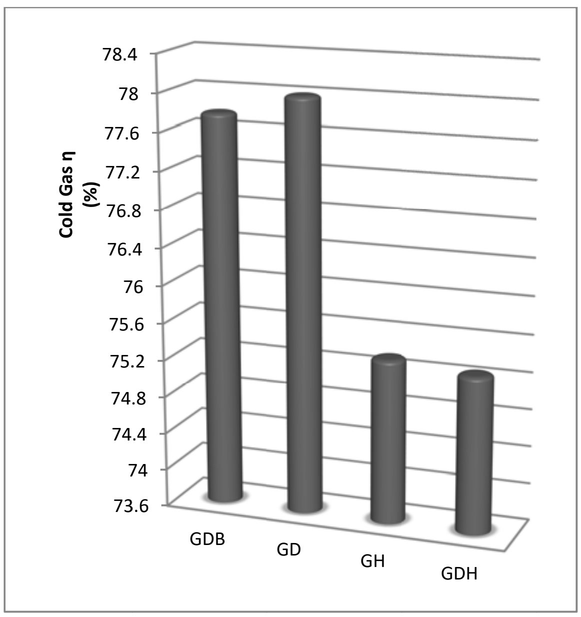

Fig. 3: Cold gas efficiency for SNG production process configurations

3.2. Power production and district heating

The heat load available after process integration is used for power and district heating depend on the high and lower pressure and temperature stream. The process integration of energy streams helped to find the heat load for power and district heating. Higher temperature streams was used for power production and DH carried out by utilizing lower temperature and pressure stream. The heat load available is higher for power production in case of integrated humidifier and humidifier + dryer were 6.16 and 6.18 MW as shown in Table 1. The power output 0.55 MW was same for both GH and GDH case. The energy utilized for DH is 5.63 and 5.61 for GH and GDH. On the other hand, less amount of heat 5.63 and 5.50 was available for power production and DH for GD and GDB configurations. The power and district heat output was also lower as compared to GH and GHD configuration. This higher value for GH and GDH case is due to humidification, because humidification reduced the steam required in gasifier. That excess steam was available for district heating. But this is on the cost of SNG production. Heyne et al. (2012) reported that power production is higher in case of wet biomass and steam gasification. The scope of this study related to combine heat and power production with SNG. The attachment of humidifier and dryer is economical viable because power unit price is higher than SNG unit (Figs. 4 and 5).

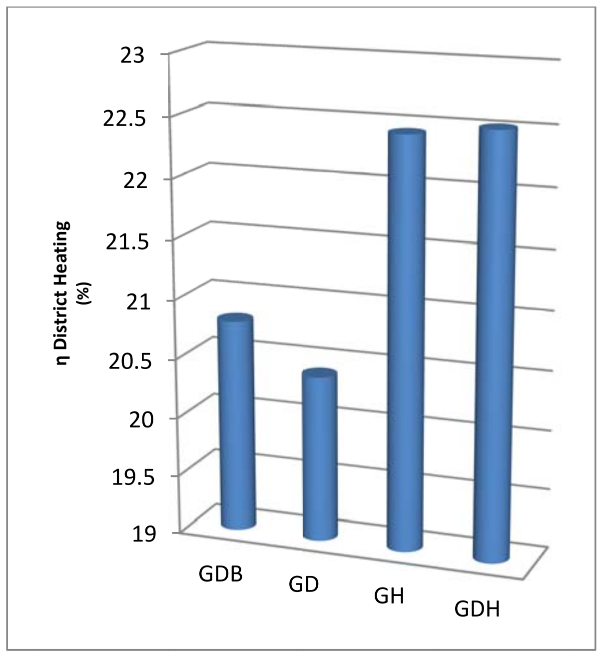

Fig. 4: District heating efficiency for configurations: a) GDB, b) GD, c) GH, d) GHD

The District heat and power output was divided by LHV of biomass input 25 MW for District heating and power electric efficiency. The DH and power electric efficiency is higher in all for GDH and GH configurations. Whereas, the Electric and district heat efficiency is lower in both case of GD and GDB. The configuration GDH shows highest district heating and electric efficiency whereas; the dried biomass GD configuration is the least one. Humidification has good effect on steam production that marginally increased the electric and power efficiency.

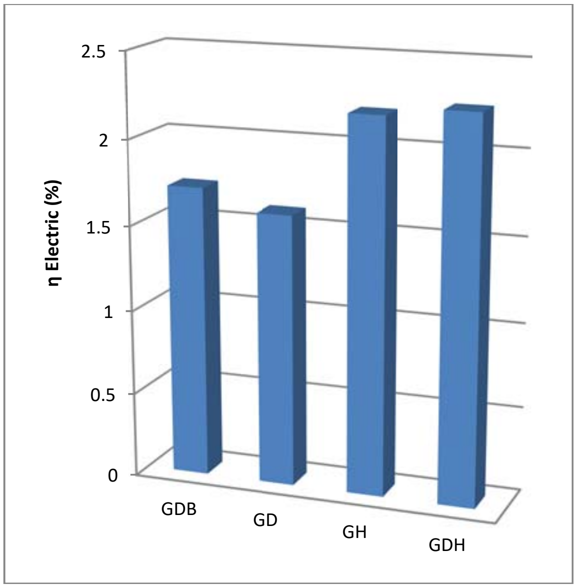

Fig. 5: Electric efficiency for SNG production process configurations

4. Conclusion

This study was done to determine the potential of power and district heating by integration of SNG production from biomass gasification. Four different process configurations analyzed and process integration was done. It concluded that the SNG production is higher in the case of dried biomass and integrated dryer system. But the energy is available for district heating and power production is lower as compared to GH and GDH. The humidification effect increases the heat load for DH and power production from 5.55 to maximum 6.6 MW. The evaluating parameters like Cold gas efficiency is 78.4 % are in case of GDB. But it is lower in case of integrated humidification about 75.2 % in GH configuration. The power efficiency and DH efficiency are 22.5 and 2.5 respectively for GDH system is higher as compared to dried biomass system. Humidification increases the power yield at the expanse of SNG production. Power unit price is high than SNG unit which make the process is economical.

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