DIMENSIONING OF VALUE CHAINS FOR PRODUCTION OF LIQUIFIED BIO-SNG

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Overview

There is an increasing interest in substituting fossil fuels with renewable fuels produced from biomass in biorefineries. Within the transport sector goals have been stated, for example in Sweden where there is a goal of a fossil-independent transport sector by 2030 [1]. Demand for second generation biofuels produced from lignocellulosic feedstock is projected to increase significantly in the future, as part of reaching these targets, especially in forest-rich countries like Sweden [1].

Biofuels based on lignocellulosic feedstock are under development. The two main production routes are gasification, followed by synthesis into, for example, methanol, dimethyl ether (DME), synthetic natural gas (SNG) or Fischer-Tropsch (FT) fuels, and ethanol produced via fermentation. Several comparisons of lignocellulosic-based value chains with different end-products indicate high energy and cost efficiency, as well as large potential to reduce fossil greenhouse gas emissions (GHG), for SNG (see e.g. [2, 3]). This is due to the high yield (biomass-to-SNG) and total energy system efficiency that can be achieved for integrated gasification-based SNG production. There is, though, a disadvantage with SNG as an energy carrier – in comparison with liquid energy carriers, it has low energy density, a fact that makes distribution of the product relatively inefficient and expensive for all cases where it cannot be transported in pipelines. An alternative to solve the problem with the expensive product transportation is to liquefy the gas, changing the end-product to liquefied SNG (further on called LBG - liquefied biogas). Furthermore, this alternative is an interesting opportunity from another perspective, as the demand for liquefied natural gas (LNG) from the transport sector has increased. There are several ship manufacturers that have developed LNG propelled ships in order to live up to coming emission limitations and also for transport with heavy duty vehicles the demand for LNG as a fuel is increasing, see e.g. [4].

In order for long-term use of biomass resources to be sustainable, the harvesting potentials are limited by ecological restrictions related to e.g. growth rate and soil quality preservation. This means that biomass use should be efficient in order to maximize the benefits from replaced fossil fuels. Integration of biofuel production with existing industry or district heating systems is a way to increase the overall efficiency. Results from [2] indicate that integration of a facility for production of LBG through biomass gasification with sawmills could be of interest. Streams of sawdust, bark and wood chips are natural excess by-products at any sawmill, and could constitute feedstock to a gasifier. There are also heat demands within sawmills, mainly for drying of the sawn wood. The gasification and SNG synthesis processes release heat at high temperatures that can be used to cover the sawmill's heating needs, thus providing for integration possibilities in two ways; through feedstock integration and through heat integration.

This study focuses on value chains for sawmill integrated production of LBG. The aim is to investigate how different dimension criteria for the integrated LBG plant influence the economic performance and the GHG emissions of the value chains. The dimension criteria include dimensioning the integrated process according to the available by-products from the sawmill as well as according to the available excess heat from the LBG process. The influence of important parameters will be investigated by varying e.g. the availability of biomass, product delivery distance or available room for heat integration.

Methods

In the study all parts of the value chain are considered, including transportation of the feedstock to the sawmill, conversion processes at the sawmill, and finally the distribution of the finished product (LBG). A well-to-tank perspective is applied and thus any emissions or energy balances related to the end use of the fuel is omitted.

The data used for estimating the energy balances of the SNG production unit in this study was generated in the simulations presented by [5], whereas the data for cost estimations are taken from [3]. The process uses an indirect gasifier, a chemical looping reformer together with a cyclone to remove tar from the syngas, an adiabatic methanation unit and the feedstock is dried with an air dryer. Three different sawmill sizes are considered; 50,000 m³, 250,000 m³ and 500,000 m³ of annual sawn wood production, representing, by Swedish standards, a small, an average, and a large mill. To estimate the possibilities for heat integration within the LBG plant and between the LBG plant and the sawmill, pinch analysis is used [6]. Since there is a large temperature difference between the produced syngas and the temperature required in the sawmill, direct heat exchanging is inefficient from a thermodynamic perspective and therefore the heat is cascaded through an integrated heat recovering steam cycle (HRSC). The steam is used for electricity production in a back-pressure steam turbine with draw-offs at the pressure levels required to cover the process steam demands. To optimize the steam network for each specific case a linear optimization model developed by [7] is applied, which is also used to perform the pinch analysis calculations.

Data for the sawmill is taken from [8]. Each sawmill size is subject to heat and feedstock integration with gasification-based LBG production, with three considered dimensioning cases:

1. Dimensioning by the available sawmill by-products. In this case the heat demand of the sawmill is larger than the heat that can be provided from the steam cycle. Therefore, parts of the by-products is combusted in a biomass boiler producing high pressure steam to the steam cycle.
2. Dimensioning according to the sawmill's heat demand. This means that biomass, additional to the sawmill by-products, needs to be purchased.
3. Dimensioning according to fixed production of 500 MW LBG.
4. A final case, where a linear relation between the size of the sawmill and the harvesting area of timber is estimated, using data from [9]. It is then assumed that a certain fraction of the available roots, branches and tops is used as feedstock for the LBG plant.

In order to account for the entire value chain, a relation between production size and feedstock as well as product distribution distance is estimated, using input from [9]. Using the energy balances for each case, together with the transportation distances and assumptions regarding methane slip, well-to-tank calculations for each case are performed.

Results and conclusions

The results are presented in terms of two key performance indicators; GHG emissions per MWh of used biomass and cost per produced MWh of LBG, calculated for the entire value chain from forest biomass to distributed LBG. The results will provide indications of how the size of LBG production integrated with sawmills affect the cost efficiency and the ability to reduce GHG emissions and how this is influenced by a number of parameters, including heat and feedstock integrating possibilities, and the availability of biomass feedstock around the sawmill.

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