EVALUATION OF CO-GASIFICATION OF BLACK LIQUOR AND PYROLYSIS LIQUIDS FROM A NATIONAL SYSTEMS PERSPECTIVE

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Overview

The transport sector accounts for one quarter of the total global CO_2 emissions. One pathway to reduce CO_2 emissions from the transport sector is to increase the usage of biofuels[1]. So called first generation biofuels, derived mainly from food or feed crops, are associated with imitated potential for CO_2 mitigation and production increase. Second generation, or advanced, biofuels based on e.g. ligno-cellulosic feedstocks, can address many problems associated with first generation fuels, but are still immature from a technology perspective.

For Sweden, with large availability of by-products from forestry and forest industry, biofuels based on forest biomass will likely be a key in order for the current target for a fossil fuel independent vehicle fleet by 2030 [1] to be met. Integrated production of biofuels or other biorefinery products in the forest industry can also offer opportunities for benefits in terms of e.g. economies of scale, increased overall energy efficiency and lower costs due to existing infrastructure and heat integration opportunities. One attractive biorefinery product could be methanol, which in addition to use as biofuel can also be used as a feedstock for production of other chemicals [2].

Utilisation of industrial by-products can entail high resource efficiency, as well as reduced transport distances and transport steps [3,4]. Production of biofuels via black liquor (BL) gasification has been identified as an industry-based supply chain configuration with high resource efficiency [3]. BL is a by-product from the kraft pulp process. Today it is incinerated in a recovery boiler for chemical recovery and steam production. BL-gasification is currently being developed as an alternative to the recovery boiler. Due to high alkali content in the BL, a catalytic effect is obtained during gasification which makes BL a suitable feedstock for gasification [5].

The availability of BL is related to the production capacity of the pulp mill, which limits the biofuel production potential for an individual mill. Current research on laboratory and pilot plant scale show that the catalytic effect from the alkali content in the BL can be utilised for co-gasification with other feedstocks, such as pyrolysis liquids (PL) [6], although higher blend ratios requires some addition of extra alkali in order to prevent precipitation [7]. By co-gasification of PL with the available BL, the biofuel production capacity from a given amount of BL can be more than tripled, compared to gasification of BL only [6]. By employing this concept, fewer pulp mills would have to be converted into biofuel production facilities in order to satisfy a given future national biofuel demand.

Including PL in the biofuel supply chain configuration requires both new conversion facilities and additional transport of biomass for production of PL. Several studies have examined the production of PL from fast pyrolysis (FP), both integrated at CHP plants, and as stand-alone units [8]. The transport cost could be reduced with decentralised upgrading of biomass to increase energy density. However, fixed costs are a large contributor for cost for transportation, and a decentralised upgrading increases transport steps which could increase transport cost [4].

In this work we evaluate different supply chain configurations with focus on the trade-offs between high resource efficiency of biofuel production from BL only on the one hand, and economy of scale of PL/BL co-gasification on the other hand. We also investigate transport related trade-offs related to centralised versus decentralised upgrading of biomass to PL. The general aim is to evaluate the economic viability of co-gasification of BL/PL when the entire value chain is considered, with cost for additional transport and production facilities and availability of biomass for production of PL.

The three supply chain configurations, illustrated in Figure 1, are:

- BL-gasification: Biofuel production with low specific usage of biomass and minimised transport distance for each individual production facility
- BL/PL-gasification, integrated PL: Biofuel production with increased economy of scale, integrated intermediate upgrading to reduce transportation steps

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[1] Biofuels refer in this text to renewable motor fuels

- BL/PL-gasification, decentralised PL: Biofuel production with increased economy of scale, decentralised intermediate upgrading to reduce transport cost for biomass
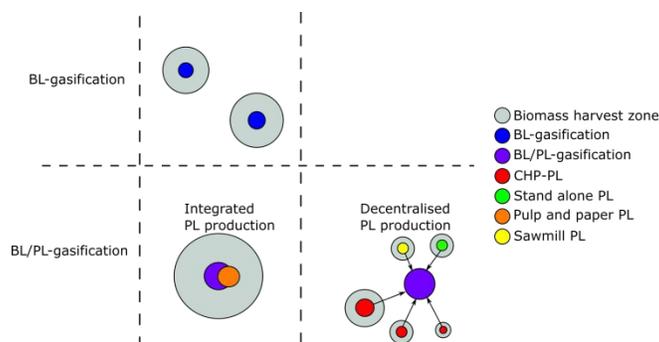

Figure 1. Supply chain configurations and technology options

Methods

This work utilises BeWhere Sweden, which is a geographically explicit Mixed Integer Linear Programming (MILP) model written in GAMS and using CPLEX as a solver. The model minimises the total system cost to satisfy a specific biofuel demand where the costs included are; biomass cost, transportation and distribution cost, operation and maintenance cost, investment cost, and revenues from co-produced energy carriers. Included in the model are the site specific data and localisation of different potential host industries as well as geographical data for biomass availability and competing demand for the available biomass resources.

Results and conclusions

This work identifies the characteristics of the supply chain configurations for BL/PL-gasification in comparison to BL-gasification. It will identify if there are some specific geographical conditions with respect to biomass availability and integration opportunities which favours certain supply chain configurations. Additionally it will identify industries of interest for integration of PL production from the Swedish national systems perspective.

Acknowledgements

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