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Integration of biofuel production into district heating – part I: an evaluation of biofuel production costs using four types of biofuel production plants as case studies

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ABSTRACT

This paper evaluates the effects on profitability of biofuel production if biofuel producers would sell the waste heat from the production to a local district heating system. All analyses have been performed considering four different technology cases for biofuel production. Two technology cases include ethanol production which is followed by by-production of raw biogas. This biogas can be upgraded and sold as biofuel (the first technology case) or directly used for combined heat and power production (the second technology case). The third and the fourth technology cases are Fischer-Tropsch diesel and dimethyl ether production plants based on biomass gasification. Two different district heating price levels and two different future energy market scenarios were considered. The sensitivity analyses of the discount rate were performed as well.

In the case of energy market conditions, the profitability depends above all on the price ratio between biomass (used as the feedstock for biofuel production) and crude oil (used as the feedstock for fossil diesel and gasoline production). The reason for this is that the gate biofuel prices (the prices on which the biofuel would be sold) were calculated assuming that the final prices at the filling stations are the same as the prices of the replaced fossil fuel. The price ratios between biomass and district heating, and between biomass and electricity, also have an influence on the profitability, since higher district heating and electricity prices lead to higher revenues from the heat/electricity by-produced.

Due to high biofuel (ethanol + biogas) efficiency, the ethanol production plant which produces upgraded biogas has the lowest biofuel production costs. Those costs would be lower than the biofuel gate prices even if the support for transportation fuel produced from renewable energy sources were not included. If the raw biogas that is by-produced would instead be used directly for combined heat and power production, the revenues from the electricity and heat would increase, but at the same time the biofuel efficiency would be lower, which would lead to higher production costs. On the other hand, due to the fact that it has the highest heat efficiency compared to the other technologies, the ethanol production in this plant shows a high sensitivity to the district heating price level, and the economic benefit from introducing such a plant into a district heating system is most obvious. Assuming a low discount rate (6%), the introduction of such a plant into a district heating system would lead to between 28% and 52% (depending on the district heating price level and energy market scenario) lower biofuel production costs. Due to the lower revenues from the heat and electricity co-produced, and higher capital investments compared to the ethanol production plants, Fischer-Tropsch diesel and dimethyl ether productions are shown to be profitable only if high support for transportation fuel produced from renewable energy sources is included.

Abbreviations: BHO, biomass-fuelled heat-only; BCHP, biomass-fuelled combined heat and power; CCP, coal condensing power; CHP, combined heat and power; CO_2, carbon dioxide; DH, district heating; DHS, district heating systems; DME, dimethyl ether; EM, energy market; EMS, energy market scenario; ENPAC, Energy Price and Carbon Balance tool; FTD, Fischer-Tropsch diesel; IEA, International Energy Agency; NGCC, natural gas combined cycle; RES–E, electricity produced from renewable energy sources; RES-T, transportation fuel produced from renewable energy sources; SNG, synthetic natural gas; SSF, simultaneous saccharification and fermentation; TS, transport sector; WEO-np, "New Policies Scenario"; WEO-450, "450 scenario".

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The results also show that an increase of the discount rate from 6% to 10% does not have a significant influence on the biofuel production costs. Depending on the biofuel production plant, and on the energy market and district heating conditions, when the discount rate increases from 6% to 10%, the biofuel production costs increase within a range from 2.2% to 6.8%.

1. Introduction

In 2007, the European Council established an integrated energy and climate change policy known as the 20–20–20 targets (European Commission, 2008). The policy aims to reach 20% of the total energy use from renewable sources, to reduce greenhouse gas emissions by 20% and to reduce primary energy use by 20%. These targets should be achieved by 2020. The reference year for those targets is 2005. An additional target is to increase the share of renewable energy in the transport sector (TS) up to 10%. In addition to this, the European Commission has also set a long-term goal to decrease the number of fossil-fuelled cars in the EU by 50% by 2030 (European Commission, 2011). Sweden's goal for renewable energy in TS for the year 2030 is to achieve complete fossil independence (SEA, 2010).

1.1. Technological transition

The transition to renewable energy in the TS is moving more slowly than in the other energy systems (IEA, 2011). A major concern of biofuel production is its economic feasibility. In a number of previous studies different kinds of strategies have been proposed in order to decrease biofuel production costs; e.g. developing industrial symbioses (Gonela and Zhang, 2013) or integrating with an existing combine heat and power (CHP) plant (Starfelt et al., 2010, 2009). Generally, a co-production of other products is shown to play a decisive role when the economic performance of biofuel production and efficient utilization of biomass are evaluated. Depending on the different combinations of co-products, overall energy efficiency and biofuel production costs may vary within a wide range (Barta et al., 2010b; Sassner and Zacchi, 2008). Furthermore, a number of studies have been published that evaluate the profitability of investing in biofuel production with a focus on other factors; e.g. with a focus on the whole process configuration (Piccolo and Bezzo, 2009; Porzio et al., 2012; Agostingo and Ortega, 2013) or only on one of the major process steps (Barta et al., 2010a), with the focus on production scale (Sotoft et al., 2010), type of the feedstock (Sassner et al., 2008), and operating hours (Leduc et al., 2009).

Parameters that also have large influences on the biofuel production costs are external factors such as: biomass availability and biomass transportation costs, the possibility to sell the residual heat to a local district heating (DH) system and the possibility to sell the biofuel locally (which decreases the biofuel transportation costs). These parameters should be considered when the capacity and the geographical positions of the biofuel production plants are determined. Leduc et al. (2008; Leduc et al., 2010, 2009) assessed advantageous locations for biomass based methanol production plants in the country of Austria, in Norrbotten in Sweden and in Baden-Württemberg in Germany. In the case studies of Austria (Leduc et al., 2008) and of Norrbotten (Leduc et al., 2010) the results showed that if a methanol production plant is located near a DH system (DHS), by selling the co-produced residual heat the methanol production costs may decrease by 12% and 10%, respectively. After conducting a transportation model, which minimizes the methanol production costs with respect to the biomass transportation costs and the methanol transportation costs, Leduc et al. (2009) concluded that the location of a methanol plant in Baden–Württemberg, Germany may influence those transportation costs by 60%. They also found that a typical optimal capacity of a methanol production plant, with an average transportation distance of biomass of 50 km, is large enough to supply more than 100 gas stations in the region. Large influences of those external factors on the biofuel production costs have been shown in some other studies also. Skarlis et al. (2012) investigated the profitability of investing in a small-scale biodiesel production plant in Crete, Greece, and they found that the investment in such a plant is profitable only if the oil feedstock is available at an acceptable price and if the local biodiesel sale is ensured. Wetterlund et al. (2012; Wetterlund, 2010) assessed proper locations for ethanol, methanol and Fischer-Tropsch diesel (FTD) production plants in the EU. The locations are assessed with a focus on investigating how different parameters (such as energy policy, energy prices, capital costs, biomass availability and heat delivery opportunities) affect: the biofuel production costs, the optimal plant location, the optimal plant capacity and the possible carbon dioxide (CO_2) emissions reduction. A general conclusion in those studies is that both the CO_2 reduction potential and the biofuel production costs are strongly connected to the co-production and utilization of electricity and heat. When the heat is co-produced, the DH price, which is usually determined by local DHS conditions, may have a significant influence on biofuel production costs.

There are also many studies that analyse how the introduction of biofuel production would affect DH production costs and global CO_2 emissions if the DH producers would invest in biofuel production instead of in CHP production (Djuric Ilic et al., 2012; Fahlén and Ahlgren, 2009; Difs et al., 2010; Wetterlund and Söderström, 2010). In those studies, when the DH production costs are analysed the biofuel produced is considered a by-product so the revenues from biofuel sales are included in the calculations as negative costs. The mentioned studies are described in more detail in the second part of this study (Djuric Ilic et al., 2014).

1.2. Objective of the study

In order to increase the share of biofuel used in the TSs in a cost-effective way, the introduction of biofuel production into DHSs can be of great interest. The investment in the biofuel production plants can be made by interdependent companies looking for opportunities to sell the residual heat from the process to a local DHS, or by DH companies interested in increasing the economic efficiency of the DH production by developing new business strategies. This paper is the first part of a two-part study which evaluates the possible economic effects of introducing biofuel production into DHSs from these two stand points. In this first part, it is assumed that the biofuel production plants would be built by interdependent companies.

In many of the previous studies the analyses of the biofuel production costs were performed based on the comparison of different process options, plant's capacities, types of feedstock and different external factors, such as biomass availability and the possibility to sell biofuel and residual heat locally. In some of those