Optimizing the Supply Chain of Biofuels Including the Use of Waste Process Heat: an Austrian Case Study

Johannes Schmidt, Sylvain Leduc, Erik Dotzauer, Georg Kindermann and Erwin Schmid

***Abstract* – Biofuel generation through second generation technology is expected to lower emissions in comparison to first generation biofuels as it allows the use of a broad variety of organic resources as feedstock. A spatially explicit mixed-integer programming model has been built to assess the costs and the emission balance of such fuels. It is used to find the cost optimal locations of both ethanol and methanol plants in Austria. Costs of the full supply chain are regarded. The model includes forest woods as possible feedstock for methanol or ethanol production through gasification or fermentation respectively. Revenues from selling heat, power and biogas as by-products of biofuel production are considered. The results of the model indicate that biofuel production through second generation technologies is competitive to fossil fuels and that their use allows a decrease in fuel emissions in Austria. For ethanol-technology, selling heat to district heating networks can considerably decrease costs of production.**[1]

INTRODUCTION

First generation biofuels produced from energy crops do not necessarily reach the environmental goal of reducing greenhouse gas (GHG) emissions in comparison to fossil fuel use. A promising alternative are second generation biofuels produced either through gasification (methanol) or fermentation (ethanol). These technologies allow the use of a broad variety of organic resources like wood and waste products. The use of such feedstock is expected to decrease total emissions in comparison to first generation biofuels (Rolf et al. 2007). This paper investigates the cost optimal location of both ethanol and methanol plants in Austria to assess the competitiveness of these new technologies. We also estimate whether these technologies are able to offset GHG emissions.

DATA AND METHODS

A mixed-integer programming model has been built to find the optimal location of biofuel plants by minimizing the costs of the full supply chain. The basic model is presented in Leduc et al. (2008a), though the version used in this paper contains an add-on which explicitly models the use of the waste heat for district heating purposes. The supply chain consists of biomass production, biomass transport to biofuel plants, production of biofuels and by-products, distribution of biofuels and distribution of heat to consumers.

Forest woods are used as feedstock. Estimations of forestry yields and production costs are considered (Kindermann et al. 2006). The model considers surplus wood that is not currently used by other wood industries. Transportation costs to the plant as well as the costs for converting biomass into biofuels and by-products for different technologies are included. The costs of delivering the fuel to the final consumers are also part of the model. The spatial distribution of gasoline consumption is estimated by combining a population map with average yearly consumption values.

Biofuel plants produce a considerable amount of different by-products. Table 1 lists the efficiencies of converting biomass to various products for the two technologies of gasification and fermentation. While power and biogas are not modelled in detail – it is assumed that they can be sold to the market at a fixed price – the use of waste heat for district heating purposes is handled spatially explicit. Spatial distribution of heat consumption is estimated by combining data on Austrian dwelling areas and on employees based on the census of 2001 with average consumption per square meter of living area and per employee. The methodology was adapted from Dorfinger (2007).

Heat has to be transported to district heating consumers using an extensive pipeline network. Costs of the pipeline network mainly depend on the distance between plant and final demand as well as on the demand density. Areas of high heat demand are assumed to be supplied at lower unit costs than low demand areas. As different sources state very

Table 1. Efficiencies of converting biomass into fuel and by-products (Leduc et al. 2008a; Leduc et al. 2008b)

Product	Gasification	Fermentation
Fuel	0.5	0.292
Heat	0.05	0.234
Power	0	0.127
Biogas	0	0.183

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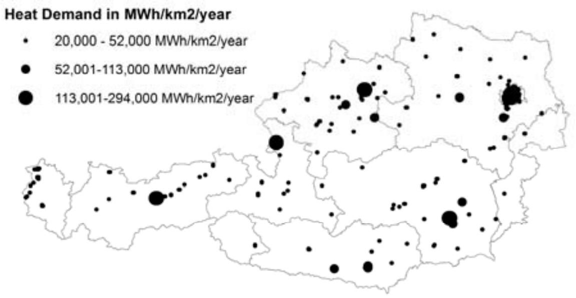

Figure 1. Heat Demand Distribution in Austria. Only heat density above 20,000 MWh/km^2/a is considered.

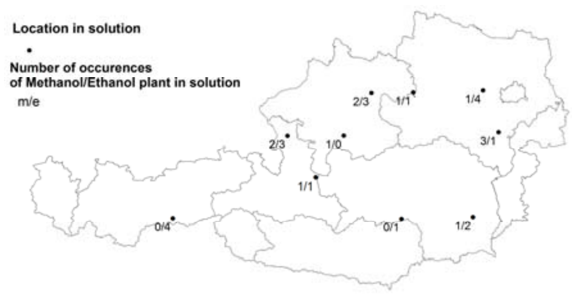

Figure 2. Locations selected in solution of four scenarios.

different infrastructure costs for heat distribution networks in relation to heat density (Schiffer 1977; Konstantin 2007), a sensitivity analysis is used to determine the influence of network infrastructure costs on the costs of the final product.

GHG emissions of the model are compared with those created in a non biofuel scenario. On the biofuel side all transport emissions from the biomass production sites to the end consumers are considered. Emissions from burning biofuels are assumed to be totally recycled in biomass production. Emissions from well to wheel are regarded for fossil fuels (Rolf 2007). To estimate emission reduction through substitution of fossil fired heating systems by district heat, average emission factors which represent the mix of heating fuels in use are calculated.

RESULTS

Figure 1 shows the results of the heat demand estimation. Only demand locations which heat densities above 20,000 MWh/km^2/a are included. Biofuel production was modelled in four scenarios for both technologies. A baseline scenario (Sc1) was compared to three scenarios to test sensitivity of the results by doubling district heating infrastructure costs (Sc2), doubling biomass costs (Sc3) and by not using waste heat (Sc4). In each scenario, 3 plants were built for the Methanol case and 5 plants for the Ethanol case. Ethanol production needs more plants due to a higher use of biomass. Fig. 2 shows how often plant locations were selected in the four scenarios.

Methanol (ethanol) could cover 7% (4%) of the gasoline demand in Austria if 50% of the surplus forest yields would be used in production. Ethanol is cheaper than Methanol because the by-products, particularly heat, allow additional revenues. Still, these results are sensitive to the costs of district heating distribution. Table 2 gives a summary of costs and emission savings per year for each scenario. Costs are given in Euro / litres of oil equivalent (€/l_{oe}). These results indicate that second generation ethanol is competitive to fossil gasoline and that about 2% of Austrian total GHG emissions can be saved using this technology.

Table 2. Costs of biofuel production and emission savings in comparison to fossil fuels.

	Methanol		Ethanol	
	Costs (*Euro/l_{oe}*)	Emission Savings (*Gg CO_2*/y)	Costs (*Euro/l_{oe}*)	Emission Savings (*Gg CO_2*/y)
Sc1	0.80	1,130	0.38	1,990
Sc2	0.82	1,130	0.56	1,950
Sc3	1.12	1,130	1.01	1,990
Sc4	0.86	1,090	0.84	1,670

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