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Land use changes, greenhouse gas emissions and fossil fuel substitution of biofuels compared to bioelectricity production for electric cars in Austria

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ABSTRACT

Bioenergy is one way of achieving the indicative target of 10% renewable energy in the transportation sector outlined in the EU Directive 2009/28/EC. This article assesses the consequences of increasing the use of bioenergy for road transportation on land use, greenhouse gas (GHG) emissions, and fossil fuel substitution. Different technologies, including first and second generation fuels and electric cars fuelled by bioelectricity are assessed in relation to existing bioenergy uses for heat and power production. The article applies a spatially explicit energy system model that is coupled with a land use optimization model to allow assessing impacts of increased biomass utilization for energy production on land use in agriculture and forest wood harvests. Uncertainty is explicitly assessed with Monte-Carlo simulations of model parameters. Results indicate that electric mobility could save GHG emissions without causing a significant increase in domestic land use for energy crop production. Costs of electric cars are still prohibitive. Second generation biofuels are more effective in producing fuels than first generation ethanol. However, competition with power and heat production from ligno-cellulosic feedstock causes an increase in GHG emissions when introducing second generation fuels in comparison to a baseline scenario.

1. Introduction

The directive 2009/28/EC requires all EU member states to guarantee a share of 10% of renewable fuels in the transportation sector by 2020. The target can be attained by various measures, including an increase in the share of biofuels and an increase in the utilization of renewably produced electricity in the transportation sector. In Austria, bioenergy is traditionally important providing around 8% of the primary energy demand in 2006, mainly for heating purposes [1]. Other uses of bioenergy developed in recent years include biofuel and power production. Austria has complied with the 5.75% indicative EU biofuel target since late 2008 and used around 4.00 TWh of biodiesel and 0.60 TWh of ethanol in 2008 [2]. A further increase of the supply of biofuels will be difficult to achieve, particularly if only domestic biomass supply is processed. However, new technologies are emerging that aim to increase biofuel productivity and diversify feedstock supply. Second generation biofuels that may use ligno-cellulosic feedstock for fuel production are regarded as a sustainable alternative to first generation biofuels which are mainly produced from food and feed crops [3],[4]. A technological alternative to the Internal Combustion Engine (ICE) is the Battery Electric Vehicle (BEV). Technical and economic barriers currently prevent the large scale introduction of electric cars. However, future potentials are considered to be significant [5],[6].

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Since the large scale introduction of biofuels in the US and the EU, an extensive discussion has evolved about direct and indirect land use changes and greenhouse gas (GHG) emissions [3],[7], as well as the increasing competition between food and fuels [8],[9]. Assessments of the effect of increasing bioenergy utilization in the transportation sector should therefore explicitly address the issue of land use change. Another important issue when assessing bioenergy policies is the effect of additional wood harvests on forest carbon stocks and the consequence on total GHG emissions in the carbon cycle [10].

Campbell et al. [11] conclude that bioelectricity production for electric mobility needs significantly less land than production of biofuels. However, they assess technical aspects such as crop production potentials and conversion efficiencies and do not take into account the costs of the various options. Steenhof et al. [12] present a detailed model but do not explicitly calculate land effects or costs of various options. Other studies [5],[13], compare costs and GHG emissions of various renewable transport options but do not explicitly address the issue of changes in land use and forest carbon stocks.

We link a land use optimization model with a spatially explicit energy system model to evaluate the use of first and second generation biofuels and bioelectricity in the transportation sector with respect to land use change, GHG emissions, and fossil fuel substitution in Austria. We track the effect of biofuel policies on the amount of food and feed crops replaced by energy crops and also track changes in forest wood harvests. The techno-economic characteristics of future biofuel production as well as of electric cars are not well known yet. Also, high uncertainty is attached to future energy price developments. We therefore apply a Monte-Carlo simulation of model parameters to explicitly address uncertainty in model outcomes.

The article is structured such that section 2 presents the applied methodology, section 3 reports results, and section 4 discusses and concludes.

2. Methodology

2.1. *Model components*

The data and the models used in the analysis are presented in Fig. 1. CropRota [14], EPIC [15] and PASMA [16] are used jointly to deliver spatially explicit supply curves for agricultural biomass. Soil, climate and management data as well as production costs and prices of agricultural commodities are necessary input for the model framework. A forest growth model that spatially explicitly estimates annual stock increases in forests is used to determine regional energy wood potentials from forestry. For each modeled region, a biomass supply curve is derived by combining energy wood potentials with historic prices and price elasticities estimated from historic data [17]. For different types of owners, i.e. small private owners, large private owners and state owned forests, different supply curves are derived because different price elasticities apply to the three distinct groups. A detailed description of the approach can be found in [18]. The heat demand is spatially explicitly estimated using data on buildings (type and age) [19], which are combined with average consumption values for such buildings. Performance data of bioenergy production technologies are taken from a literature

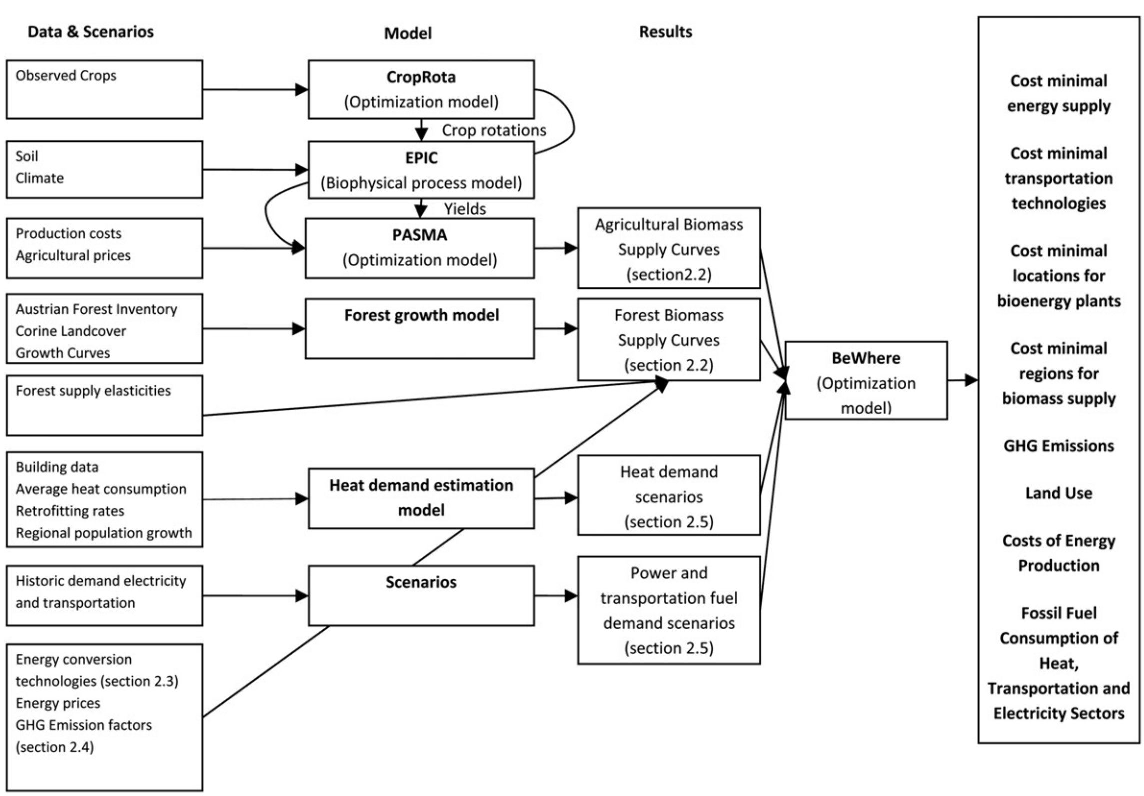

Fig. 1 – Model components.