Optimal biofuel futures: The role of functional units and fuel suitability

Markus Millinger and Daniela Thran, Email:markus.millinger@ufz.de

Helmholtz Centre for Environmental Research (UFZ), Germany

Abstract

Statement of the Problem: Biofuels are a renewable alternative for reducing the climate impact of transport. Policy uses different functional units for introducing biofuels, with resulting differing optimal biofuel pathways. Methodology & Theoretical Orientation: Several models are developed in order to assess the competitiveness of various crop based biofuel options, using different economic and environmental functional units, in Germany until 2050. Findings: Different functional units, as well as fuels and markets included result in different merit orders for the biofuel options. Currently most common conventional biofuels were found not to be competitive, and advanced liquid fuels were only competitive at extreme assumptions, contrary to common expectations. Instead, sugar beet based ethanol dominated for most of the time span when comparing energetic cost, whereas Synthetic Natural Gas (SNG) was competitive on a greenhouse gas abatement (GHG) cost basis, especially at a rapid decarbonisation of the power mix. Switching from current practise to higher yielding biofuel options can potentially increase GHG abatement per land unit by a factor of five. With such a functional unit, silage maize based biomethane was the best, with SNG converging only at very high renewables shares of the background systems; and the land passenger transport becomes the highest priority due to the suitability of higher yielding biofuel options, followed by land goods transport, shipping and finally aviation. If gaseous fuels are not possible to introduce on a large scale, goods transport and shipping become priority. Biofuel admixture quotas to sub-sectors of land transport renders a significantly lower climate benefit compared to an overall optimal usage. Conclusion & Significance: The direct importance of land use has thus far not received enough attention in terms of the economics of biofuels from dedicated crops, as well as for the greenhouse gas emissions policy.

The energy demand is growing worldwide. The total energy consumption has increased from 196 EJ (1018 Joule) in 1973 to more than 350 EJ in 2009 and the tendency is rising [1]. About 80% of this energy demand is delivered from fossil fuels with the consequence of an increase of greenhouse gas emissions in the atmosphere that provokes serious climate changes by global warming. Furthermore, the fossil fuels supplies are constantly diminishing. In consequence, the development of CO2-neutral fuels is one of the most urgent challenges facing our society and essential in order to meet the planned internationally specified targets, like the reduction of CO2 emissions in the range of 10–20% by 2020 (e.g., European Union). Therefore, there is an acute demand for sustainable, CO2-neutral resources to replace the demand of liquid fuels in the near future.

The potential of microalgae as renewable source for biofuel production is very promising due to higher growth rates and the capability to accumulate higher amounts of lipids (from 20% until 80% of dry weight) than conventional oil crops (not more than 5% of dry weight) and therefore the oil yield per hectare obtained from microalgae can greatly exceed the yield from oil plants like rapeseed, palm, or sunflower. Another advantage of microalgae over plants is their metabolic flexibility. That means that a variation in the biochemical composition of the biomass (towards higher lipid, carbohydrates or protein accumulation) can be regulated by varying the cultivation conditions. Photobioreactors can be located on nonarable land and microalgae can grow in seawater or brackish water. Therefore, there is no competition for resources with classical agriculture. Furthermore, in large-scale applications production during the whole year will be possible employing effective process engineering tools for inoculation, maintenance, harvesting, and so forth, much more than possible in agriculture.

In general the water demand for the cultivation of microalgae is low in comparison with crops, especially when closed systems (photobioreactors) are applied. The production of 1 liter of biofuel from oil crops requires around 3,000 liters of water. To obtain 1 liter of biofuel from microalgae with 50% lipid content, 10 to 20 liters are needed, taking into account the stoichiometric demand to fix 1 mol CO2 from 1 mol of water during the photosynthesis and that the cells themselves consist of up to 85% of water. Although the water demand is in practice much higher because reactor cooling is necessary in closed photobioreactors or for compensation of evaporation in open systems, the values are one to two orders of magnitude lower than for conventional agriculture. These low values reconfirm the high potential and motivation for using microalgae as sustainable feedstock for biofuels.

The drawbacks of the current state of microalgal biotechnology are the high investments costs and the high demand on auxiliary energy for biomass production and for lipid processing to biodiesel leading to high costs for biomass and biodiesel. The use of residual nutrient sources and nutrient recycling are one of the keys for a sustainable production of biodiesel from microalgae. Wastewater can be used to supply nitrogen and phosphorus, main nutrients needed for the cultivation of algal biomass. The use of residual algal biomass after lipid extraction for example as feed (because of the high vitamin content) is a key factor in biorefinery concepts in order to improve economic feasibility. The rest biomass can be also fermented to produce methane or ethanol. Therefore, the ongoing research and development efforts are focused on the improvement of both the economic feasibility and sustainability for the production of biofuels from microalgae. The biorefinery concept of fermentation of the rest biomass to biogas will be included on the energy and CO2 balances shown in this paper.

Biography :

Markus Millinger conducts research on bioenergy futures through systems modelling. He has developed several models for assessing biofuel future scenarios from different perspectives. Millinger has a background in mechanical engineering and industrial ecology from Chalmers University of Technology, Gothenburg, Sweden. Prof. Daniela Thrän works in system analysis of renewable resources for energy and materials. She holds the chair of bioenergy systems at Leipzig University

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