Applied Energy 102 (2013) 440–448

Contents lists available at SciVerse ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

# GHG emission performance of various liquid transportation biofuels in Finland in accordance with the EU sustainability criteria

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## HIGHLIGHTS

- GHG impacts of biofuels were studied according to the EU sustainability criteria.
- Uncertainty of the GHG assessment results is important but ignored by the criteria.
- The criteria might fail to promote the most climate-friendly biofuels.
- Propositions are made to make the EU sustainability criteria more accurate.

## ARTICLE INFO

*Article history:*
Received 24 January 2012
Received in revised form 24 May 2012
Accepted 21 July 2012
Available online 30 August 2012

*Keywords:*
Transportation biofuels
Greenhouse gas emissions
EU sustainability criteria
Uncertainty

## ABSTRACT

The European Union (EU) has set a binding greenhouse gas (GHG) emission reduction target for transportation biofuels and other bioliquids. In this study, the GHG emissions of various biofuel chains considered as relevant in large-scale production in Finland were calculated in accordance with the EU sustainability criteria. Special attention was paid to uncertainties and the sensitivities of certain parameters. According to the results, it is impossible in many cases to unambiguously conclude whether or not a biofuel chain passes the emission-saving limit provided by the EU. This may reduce the willingness to invest in biofuel production. Major sources of uncertainties and sensitivities are nitrous oxide emissions from soil and nitrogen fertilisation, emissions of process heat production and soil carbon stock changes in biomass production. Several propositions are made in order to reduce the uncertainty of the results and to make the EU sustainability criteria for biofuels more harmonised and accurate.



## 1. Introduction

The fuels derived from biomass are considered to be an important option to reduce greenhouse gas (GHG) emissions as well as the use of fossil fuels in the transportation sector. In the Renewable Energy Directive 28/2009/EC (RED), the European Union (EU) has set a binding target to increase the use of renewable energy in the transportation sector to 10% in all Member States by 2020 [1]. This target is intended to be filled mostly by producing transportation biofuels (later biofuels) [2]. Consequently, the production, use and imports of biofuels are likely to increase significantly during this decade in the EU [3]. Other countries as well – including the United States, Brazil, China and India – have set ambitious targets to increase the use of biofuels. In the International Energy Agency's scenarios, biofuels will meet 8% of global road-transport fuel consumption by 2035, up from 3% in 2009 [4]. The targets to increase the use of biofuels are also rationalised by the improvement of national energy supply security, reduction of oil dependency and improvement of regional economy, in addition to the anticipated GHG emission reductions gained compared to the use of fossil fuels [1,5–7].

The targets for rapid and significant increase of biofuel production have, however, raised concern for and discussion on the sustainability of biofuels [8]. Many recent studies [9–11], for example, have concluded that biofuels may cause significant environmental and social problems. Also, the assumed GHG emission reductions of biofuels compared to fossil fuels may not take place if the production of biomass or biofuels is emission-intensive and if, in particular, emissions due to direct or indirect land-use changes take place [12–15]. To avoid the potential negative environmental impacts related to the production of biofuels, the EU

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http://dx.doi.org/10.1016/j.apenergy.2012.07.023

**Nomenclature**

| | |
|---|---|
| $A$ | technology matrix |
| $a_{ij}$ | inflows or outflows of a commodity $i$ of a process $j$ |
| $B$ | unit emission matrix |
| $b_{ij}$ | amount of pollutants or natural resources $i$ emitted or consumed by a process $j$ |
| CHP | combined heat and power |
| $CO_2$-eq. | carbon dioxide equivalent |
| $E_B$ | total emission from the biofuel or other bioliguid (g $CO_2$-eq./MJ) |
| EC | European Commission |
| $E_F$ | total emission from the fossil fuel comparator (g $CO_2$-eq./MJ) |
| EU | European Union |
| $f$ | required net output |
| FT | Fischer–Tropsch |
| $g$ | emission inventory vector |
| GHG | greenhouse gas |
| GWP | global warming potential |
| HVO | hydrotreated vegetable oil |
| ILUC | indirect land use change |
| IPCC | intergovernmental panel on climate change |
| LCA | life cycle assessment |
| LHV | lower heating value (MJ/kg) |
| $N_2O$ | nitrous oxide |
| $N_2O$-N | nitrous oxide as nitrogen |
| RCG | reed-canary grass |
| RED | Renewable Energy Directive 28/2009/EC |
| $s$ | scaling vector |

has established sustainability criteria for transportation biofuels and other bioliquids in the RED. Only biofuels and bioliquids in compliance with these criteria can be counted in the biofuel targets of the Member States, and may benefit from the national support systems for biofuels.

There are two types of sustainability criteria in the RED: limitations concerning the areas of origin of biofuel raw materials, and limitations concerning the greenhouse gas (GHG) emissions produced during the life cycle of the biofuels. The RED does not introduce any criteria for other pollutants than GHGs or any quantitative criteria for other environmental impact categories than climate change. The RED criteria also exclude some important GHG emissions such as the indirect effects for example on land use. The EC is analysing the indirect land-use change (ILUC) issue further and it may be included in the sustainability criteria in the future [16]. Due to the narrow and incomplete consideration of the GHG emissions, Soimakallio and Koponen [15] concluded that the RED sustainability criteria cannot alone ensure that the GHG emissions are reduced by increased biofuel utilisation. Despite the discussion on the suitability of the RED criteria, they are being implemented to national legislation of the Member States, and the national sustainability schemes are being established. The sustainability of the biofuels may also be verified by Voluntary Schemes approved by the EC and the Member States [1]. In the future, the RED sustainability criteria may be expanded to cover also the use of solid or gaseous biomass sources in electricity production, heating, and cooling [17].

According to the RED criteria, the GHG emission reduction from the use of biofuels compared to the use of fossil fuel shall be at least 35% for current biofuels and at least 50% from 1 January 2017 onwards. From 1 January 2018, the emission reduction shall be at least 60% for biofuels produced in installations in which the production started on or after 1 January 2017. For certain biofuels, the RED provides a list of default emissions saving values, which can be used under certain conditions. However it is unclear if the default values can be used for certain biofuel chains – for example, if the default value of wheat ethanol can be used also for barley ethanol – or if the default value for waste or farmed wood can be used for forest residues. If a default value does not exist, cannot be used or lies below the required GHG emission reduction requirement, the actual GHG emission reduction must be calculated in accordance with a specific methodology presented in the RED.

The RED methodology is an application of the life cycle assessment (LCA) framework [18,19], as the whole life cycle of a biofuel is taken into account. The results of any LCA study are, however, susceptible to various uncertainties and sensitivities, due to the choice of system boundary and the allocation method used for dividing the emissions between main and co-products added to data uncertainty and modelling choices; e.g. the global warming potential (GWP) factors utilised [20–22]. Even though some of the choices required in LCA are fixed in the RED methodology, it leaves room for questions and various interpretations when assessing the GHG emissions of a biofuel production chain [15]. Guidance to some of these issues is given in the European Commission (EC) guidelines [23,24]. However, many questions are still left open. Such issues include the determination of various parameters required in the GHG calculation, the consideration of various emission components, the system boundary setting for biofuel processing, and the definition of waste and residue materials [15]. In addition, the RED does not include any guidance on how to handle with the uncertain calculation parameters. Earlier, Koponen et al. discussed the problem of the system boundary setting related to the RED methodology, and carried out some deterministic parameter uncertainty analyses for a case study of waste derived ethanol [25]. Soimakallio et al. [20] studied the uncertainties related to the GHG emissions of various biofuel chains by stochastic simulation.

The aim of this paper is to determine whether it is possible to conclude that a biofuel chain passes (or does not pass) the RED GHG emission-saving limit when the uncertainties and sensitivities related to the calculation parameters are taken into account. The RED methodology is applied for several biofuel chains and the parameter uncertainties are studied by stochastic simulation. Life cycle data has been collected related to the biofuel chains, which were considered to be relevant for large scale biofuel production from a Finnish perspective, as based on the published plans of the state and the biofuel companies [26–29]. Biofuel chains examined are: the production of ethanol from straw, reed-canary grass (RCG), and barley; the production of Fischer–Tropsch (FT) diesel from logging residues and stumps; and the production of hydrotreated vegetable oil (HVO) from rapeseed oil and imported palm oil. Production of diesel derived from crude tall oil is scheduled to be started in 2014 in Finland [30], but was not considered here due to the lack of published data about the process. The factors causing the most important uncertainty are analysed and discussed. Also, the major interpretation problems of the RED methodology when conducting the calculations are discussed. Finally, possible ways to reduce the uncertainty of the GHG emission-saving results are proposed in order to make the RED sustainability criteria more accurate and less open to various interpretations.