**Academic year 2017-2018**

# Title: Life Cycle Assessment of Biofuels in EU/CH

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**Submission Date:** 3rd December 2018

## Abstract

In Europe, 80% of the total GHG emissions is related to the energy system, with transport sector being the second main source of pollution, comparable to industries. The use of biofuels represents one of the three main sources of GHG reduction that could help the energy transition of the transport sector. This Thesis evaluates what are currently the biofuels supply chains in EU/CH with the lowest environmental impact. Moreover, by looking at technology developments, it is given an indication over possible production pathways in the mid- to long-term future.

First the biomass species prevalently used for the production of 1st generation bioethanol and biodiesel are identified. Sugar beet, wheat and maize are largely used for bioethanol production, while rapeseed and imported palm oil are mostly used for the production of biodiesel. Afterwards, it is investigated what are possible feedstocks for the production of 2nd generation biofuels. Wheat straw, being the most abundant agricultural residue in Europe is an interesting feedstock for 2nd generation bioethanol, while Used Cooking Oil is interesting for 2nd generation biodiesel. As for Switzerland, cereals, root crops or oilseeds have no sustainable potential for biofuel production. The only feedstocks with relevant sustainable potential are wood/forestry residues and animal manure. Therefore, it is also analyzed 2nd generation bioethanol production from wood/forestry residues, as possible solution for the homemade production of biofuels in CH. Finally, it is also assessed the environmental impact of algae-biodiesel (3rd generation).

Life Cycle Assessment is the Methodology used to assess the environmental impact of the supply chains of interest, and SimaPro is the software used to compute GHG emissions as well as other impact categories according to the calculation method used (ILCD 2011 Midpoint). Together with the impact categories, GHG savings and Energy Return on Investment are also calculated. According to the LCA conducted, 1st generation bioethanol from sugar beet and 1st generation biodiesel from rapeseed are currently the biofuel supply chains with the lower environmental impact in Europe. 43.5 $gCO_{2,eq}$/MJ are emitted from sugar beet-ethanol production, and 62.5 $gCO_{2,eq}$/MJ from rapeseed-diesel. Thanks to the low emissions, GHG savings are estimated to be 54% and 34% respectively, taking into account for emissions due to Indirect Land Use Change. Biofuel supply chains that use wheat, maize and palm oil as feedstock for their processes do not show substantial GHG savings. As for 2nd generation, 16 $gCO_{2,eq}$ are emitted to produce 1 MJ of ethanol from wheat straw, and 27 $gCO_{2,eq}$/MJ of ethanol from forestry residues, with GHG savings of 83% and 71% respectively. Production of biodiesel from UCO emits 11 $gCO_{2,eq}$ /MJ biodiesel, with GHG savings up to 89%. For the pathways analyzed, emissions related to 2nd generation biofuel production are lower than those related to 1st generation biofuel production and offer higher GHG savings.

With regards to the efficiency of the processes, sugar beet-ethanol production has a higher E-ROI compared to 2nd generation bioethanol. The same is true for rapeseed-biodiesel compared to UCO-biodiesel. However, considering the high GHG savings potential, the current investments and technology improvements, it is likely that ethanol production from straw/ forestry residues, and biodiesel production from UCO will cover an important role in the mid- to long-term future. 3rd generation biodiesel, mainly due to the high emissions associated with algae cultivation, provide way less GHG savings (25%) compared to 2nd generation biodiesel. Moreover, the EROI is the lowest among all the pathways analyzed, reflecting the immature technology that characterizes this generation. Considering the low GHG savings and low energy efficiency, it is not likely that this generation will cover an important role in the near future.