REPORT for

European Waste-based & Advanced Biofuels Association (EWABA)

SUBJECT

Comparison of UCO-based fuel emission values for the road and aviation sectors and quantify displacement effects

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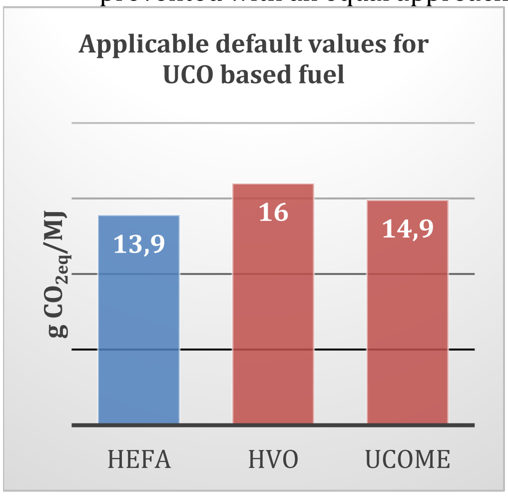
EXECUTIVE SUMMARY

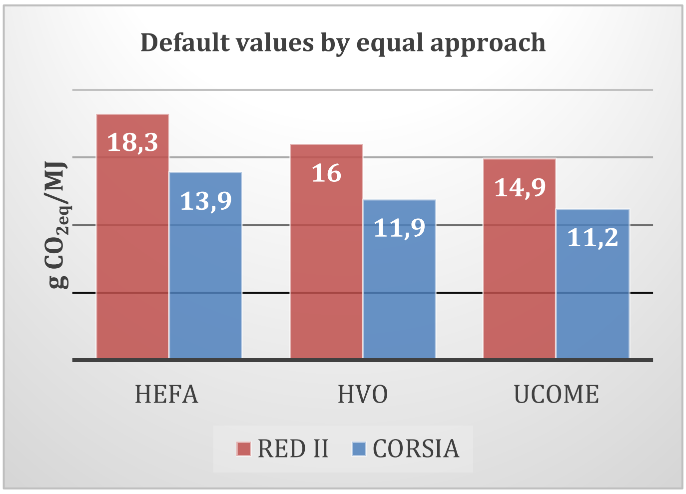
BACKGROUND

- European biofuel producers can report greenhouse gas (GHG) emissions via two regulations. The "Directive EU 2018/2001" (RED II) for the road sector and the "Carbon Offsetting and Reduction Scheme for International Aviation" (CORSIA) for the aviation sector.
- CORSIA is expected to play a comparable role for the aviation sector as RED II based voluntary schemes do for the road sector today.
- Used cooking oil (UCO) is an important feedstock for biofuels in both sectors for the production of HEFA, HVO and UCOME. But the use of UCO will most likely lead to displacement effects from one sector to the other:
    - As UCO is a waste and therefore not selectively producible and thus severely limited.
    - And UCO as a feedstock of established production technologies is highly sought after with little untapped potential.
- Based on the specifications of two recognized certification systems operated by ISCC, (ISCC-EU for RED II) and (ISCC-CORSIA for CORSIA), this report compares the assessment of emissions from UCO-based biofuels by default values in RED II and CORSIA to quantify possible feedstock displacement impacts from competition for UCO between fuel production pathways.

UCOME better than HEFA in CORSIA if equal rules are followed

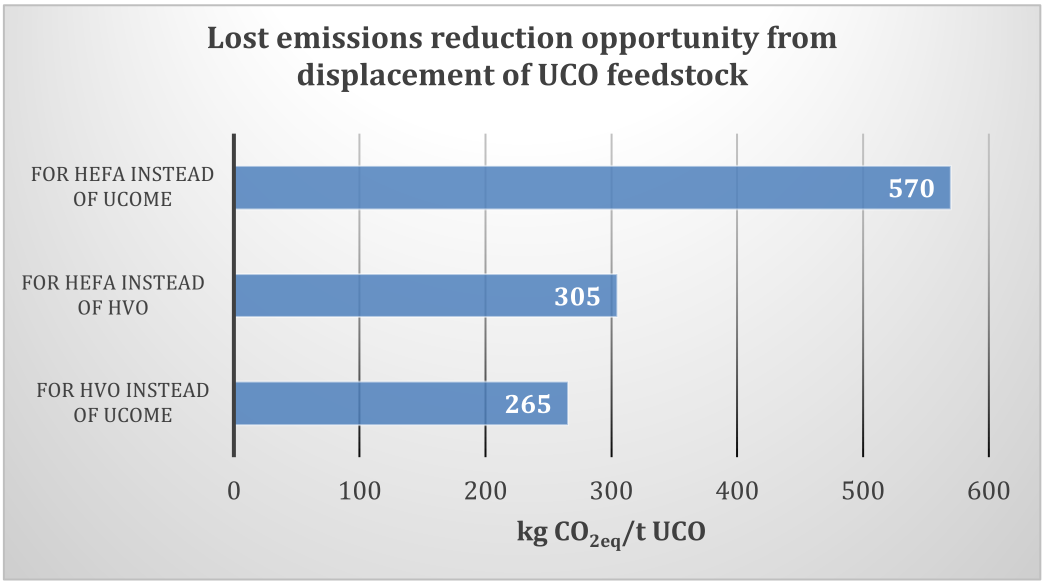
- Different approaches for default values lead to unequal emission reports from the two schemes.
- UCO based HEFA, despite having higher emission values, can be reported with lower emission values in the aviation sector than UCO based HVO or UCOME in the road sector. This could be prevented with an equal approach for default values.



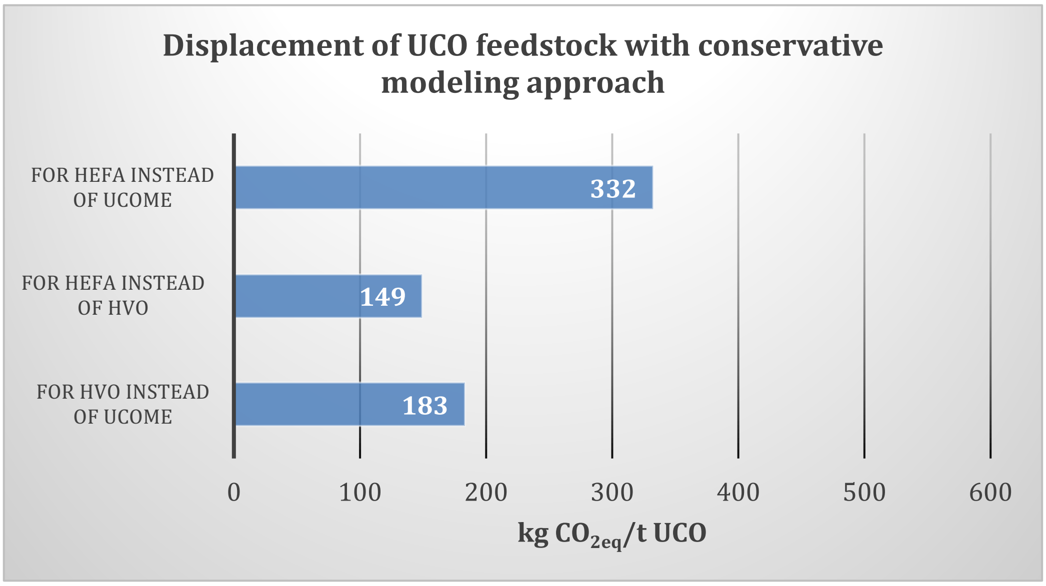


The production of HEFA causes a substantial loss of CO_2 savings

- A reduction in potential emission savings due to displacement of UCO between fuel production pathways could be quantified when using UCO for HEFA or HVO rather than for UCOME. The largest loss of potential emission savings was quantified when UCO was used for HEFA production.



- Even with a conservative modeling approach in favor of HEFA (by considering potential emission savings from by-products), UCOME remained the most effective method for emission savings in the comparison.



1. INTRODUCTION

In order to be able to apply the use of sustainable fuels for greenhouse gas savings within the European Union, an economic operator provides evidence or data obtained in accordance with a scheme according to which the operator is certified. The requirements for the road sector are regulated by "Directive EU 2018/2001" (RED II)[1]. However, the aviation sector has a different scheme available to it that isn't currently available to terrestrial sectors. The "Carbon Offsetting and Reduction Scheme for International Aviation" (CORSIA)[2] performs a comparable function to RED II as presented under the Fit for 55 package: "It is essential that aircraft operators can claim the use of sustainable aviation fuels under greenhouse gas schemes such as the EU Emissions Trading System or CORSIA, depending on the route of their flights"[3].

Although GHG savings may be recognized under both RED II and CORSIA, the two schemes differ in how they assess GHG emissions. So-called "default values" can be used in both RED II and CORSIA to report emission values for fuels. However, the methods by which some of these are determined differ significantly between the two schemes.

GHG emissions savings are reported according to RED II and CORSIA via a comparison with fossil fuels. Primarily counted is the avoidance of emissions by replacing the regular fossil fuel with low-emission alternatives. These alternatives are often waste and residue-based fuels.

Waste lipids are a commonly used feedstock for the alternative fuels for GHG emission reduction. Used Cooking Oil (UCO) is currently the economically best available feedstock for this process, but despite its relatively good availability compared to other wastes, like all wastes UCO is limited in quantity[3] as it cannot be produced in a targeted manner. UCO has been used for many years in the road sector as feedstock to produce biodiesel (UCOME) or hydrotreated vegetable oil (HVO). Recently, there has been a surge of interest in also using UCO to produce "hydroprocessed esters and fatty acids" (HEFA) for the aviation sector.

UCOME and HVO fuels have been on the market for some time, and HEFA is also already considered a commercially mature pathway[3] by the commission because it is produced using the same hydrotreating processes as HVO. Converting HVO production to HEFA production is less expensive than the development of technologies using less established feedstock for low-emission fuels, most of which cannot yet be produced on an industrial scale today. Accordingly the current demand for UCO based fuels of all types is high with a potential strong increase in the future[4]. While there are still potentials to be tapped as through household collection, collection from individual households is only in its early developmental stage in most EU member states with only around 200.000 t at max per year until 2030 to be collected in a self-described optimistic scenario by Greenea[5].

Because of its limited quantity, it is very likely that the use of UCO for fuels in one sector (such as for HEFA production for aviation) would lead to less available UCO for fuels in another transport sector (such as UCOME production for road transport).

The different fuels for the sectors are produced with different efficiencies and produce different overall GHG emissions reductions. These differences can lead to a situation where the production of one fuel at the

[1] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, Official Journal of the European Union, L 328/82, December 11, 2018, https://eur-lex.europa.eu/legal-content/DE/TXT/?uri=CELEX%3A32018L2001

[2] The ICAO CORSIA Implementation Element "CORSIA eligible fuels" is reflected in five ICAO documents. https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

[3] Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport, European Commission, COM(2021) 561 final, July 14, 2021, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

[4] A. van Grinsven et al. (2020). Used Cooking Oil (UCO) as biofuel feedstock in the EU

[5] Greenea (2016). Analysis of the current development of household UCO collection systems in the EU

expense of another fuel results in lower overall GHG emission savings than if only the more efficient fuel for emissions savings is produced.

This "displacement effect" for UCO-based fuels is not included in RED II and CORSIA. Including such an effect when assessing the emissions savings potential of a fuel could both favor the production of the fuels with the most effective savings potential and serve as an incentive for investment in alternative and not yet industrially developed feedstock for fuel production.

The aim of this report is to compare the different GHG emission quantification methods of RED II and CORSIA using their respective default values and to quantify the displacement effect for UCO-based fuels in potential CO_{2eq} quantities. For the comparison of methods, the specification of two recognized certification schemes operated by “International Sustainability & Carbon Certification” (ISCC), (ISCC-EU for RED II) and (ISCC-CORSIA for CORSIA) are compared. For the quantification of the "displacement effect", the potential emission savings of biofuels UCOME, HVO and HEFA produced from UCO are compared taking into account emission factors and yields.

2. EQUAL APPROACH FOR DEFAULT VALUES

Default values in ISCC EU (for RED II) and ISCC CORSIA (for CORSIA) are values that can be reported for a finished fuel instead of calculating actual emission values[6] [7]. The actual default values are adopted by RED II and the “International Civil Aviation Organization” (ICAO)[8]. The ISCC schemes adopt possible future changes directly. The default values usable in the schemes for UCO based HEFA, HVO and UCOME are as follows.

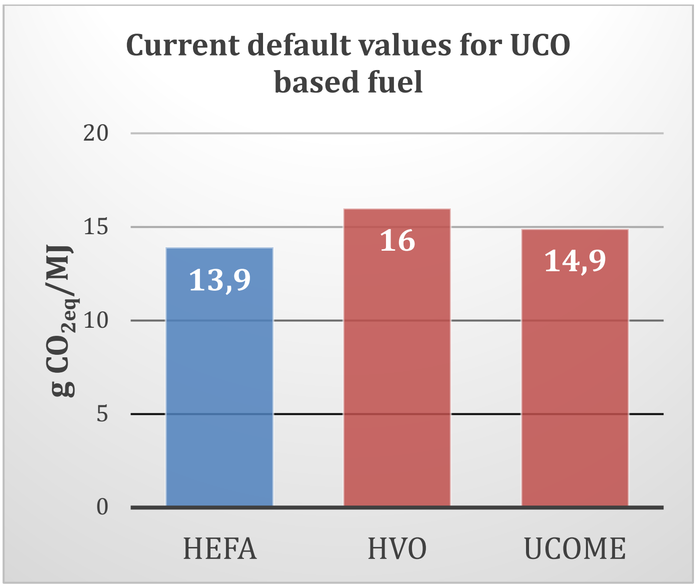


Figure 1: Current default values for RED II and CORSIA

Therefore, HEFA can be reported with a lower default value than HVO or UCOME because the default value for UCO-HEFA is estimated using a different methodology than the default values for UCO-HVO and UCOME. Although this is not a scientifically appropriate way to compare different fuel options, the current “two system approach” allows it to happen. We will next evaluate the differences between the two schemes used to arrive at these total values.

[6] ISCC (2021). ISCC CORSIA System Document 205: Life Cycle Emissions Version 1.1

[7] ISCC (2021). ISCC EU 205 Greenhouse Gas Emissions Version 4.0

[8] ICAO (2021). CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels

2.1 LIFE CYCLE EMISSION

In both RED II and ICAO, the life-cycle assessment (LCA) is divided into stages that are added up to the total value. We summarize the stages relevant for the LCA of the three considered fuels as follows (for this report we used the abbreviations of RED II).

Stage name for report	Stage name for CORSIA[9]	Stage name for RED II[1]
e_{ec}	Feedstock cultivation and collection	e_{ec} = emissions from the extraction or cultivation of raw materials
e_{td}	Feedstock and fuel transportation	e_{td} = emissions from transport and distribution
e_p	Feedstock to fuel conversion	e_p = emissions from processing

Table 1: Stage names LCA

The final use of the fuel is defined as zero in RED II and CORSIA. The pure LCA values are called "core LCA value" in CORSIA and "typical values" in RED II. In RED II, the LCA values are given as follows:

UCO based Fuel	e_{ec} (g CO_{2eq}/MJ)	e_{td} (g CO_{2eq}/MJ)	e_p (g CO_{2eq}/MJ)	LCA (g CO_{2eq}/MJ)
HVO	0	1,7	10,2	11,9
UCOME	0	1,9	9,3	11,2

Table 2: LCA RED II

The LCA in CORSIA[9] results from the mean of two data providers „Massachusetts Institute of Technology"(MIT) and "Joint Research Center European Commission" (JRC). (Values were copied without rounding)

Data provider	e_{ec} (g CO_{2eq}/MJ)	e_{td} (g CO_{2eq}/MJ)	e_p (g CO_{2eq}/MJ)	LCA (g CO_{2eq}/MJ)	Midpoint value (g CO_{2eq}/MJ)
MIT	3,6	0,8	10,5	14,8	13,9
JRC	0	2,0	11,0	13,0	

Table 3: LCA CORSIA

[9] ICAO (2019). CORSIA supporting document — Life cycle assessment methodology

2.2 DEFAULT VALUE

In CORSIA the default value (also named total life cycle emissions factor (LS_f)) is the sum of the LCA with the indirect land use change (ILUC) LCA value which is zero for UCO based HEFA. Therefore, the resulting default value for UCO based HEFA is 13,9 g CO_{2eq}/MJ as developed in Section 2.1. Comparing the default value for UCO-HEFA under CORSIA to the "typical values" for UCOME and UCO-HVO under RED-II, it is clear that UCO-HEFA produces more than 20% greater net GHG emissions than UCOME and UCO-HVO.

However, the RED II scheme does not ultimately use the "typical values" as its default values. A default value under RED II is derived from a typical value with the further application of a "conservative approach factor". The RED II states that: "In the case of an adaptation of, or addition to, the list of default values in Annexes V and VI: (a) where the contribution of a factor to overall emissions is small, where there is limited variation, or where the cost or difficulty of establishing actual values is high, the default values shall be typical of normal production processes; (b) in all other cases, the default values shall be conservative compared to normal production processes."[1]; here related to possible new entries in the default values list.

This approach by RED II was intended to encourage the calculation of actual values for established technologies, whereby optimized production routes can be considered, and the use of newer not yet established technologies. However, default values are used in many ways, including in discussions that lead to government policies and rules, and are therefore impact many important decisions. Although the default value for UCO-HVO from CORSIA (i.e., the "core LCA value") is the equivalent of a "typical value" under the RED II scheme, the default values in RED II require an additional "conservative approach factor" to be applied to the processing emission value e_p for UCOME and UCO-HVO because those technologies are established on the market. This factor is applied by multiplying the processing emission value e_p by a factor of 1,4. This increases the "default values" substantially over the "typical values" described in Section 2.1 and thereby prevents any meaningful comparisons with the "core LCA values" provided by the CORSIA scheme.

UCO based Fuel	e_p typical value (g CO_{2eq}/MJ)	e_p default value (g CO_{2eq}/MJ)	Typical value (g CO_{2eq}/MJ)	Default value (g CO_{2eq}/MJ)
HVO	10,2	14,3	11,9	16,0
UCOME	9,3	13,0	11,2	14,9

Table 4: RED II conservative approach

2.2 EQUAL APPROACH

The conservative approach factor of RED II is absent from CORSIA, creating an inequity in the reportability of completed fuels between RED II and CORSIA. In the case of an addition of UCO based HEFA to the list of default values in Annexes V of the RED II, for this report we assume, that the default value would be set conservatively because the HEFA processing emission:

- makes a substantial contribution to the total emissions;
- has large variability, as pathways of UCO based HEFA differ in literature at least between 13,9 g CO_{2eq}/MJ to 27 g CO_{2eq}/MJ [8 10];
- can be determined relatively easily by HEFA producers who wish to avoid the conservative approach because HEFA production is a commercially mature pathway[3]

With this conservative e_p values, the revised parts of Table 3 would look like the following.

e_p (g CO_{2eq}/MJ)	LCA (g CO_{2eq}/MJ)	Midpoint Value (g CO_{2eq}/MJ)
(10,5 * 1,4 =) 14,7	19,1	18,3
(11,0 * 1,4 =) 15,4	17,4	

Table 5: LCA CORSIA conservative

UCO based HEFA would therefore have a default value of 18,3 g CO_{2eq}/MJ using the same conservative approach required for HVO and UCOME in the RED II scheme. This correction allows an appropriate comparison of the default values and LCA impacts for all three fuel with equal approaches, once again showing that UCO-HEFA produces more than 20% greater net GHG emissions than UCOME and UCO-HVO.

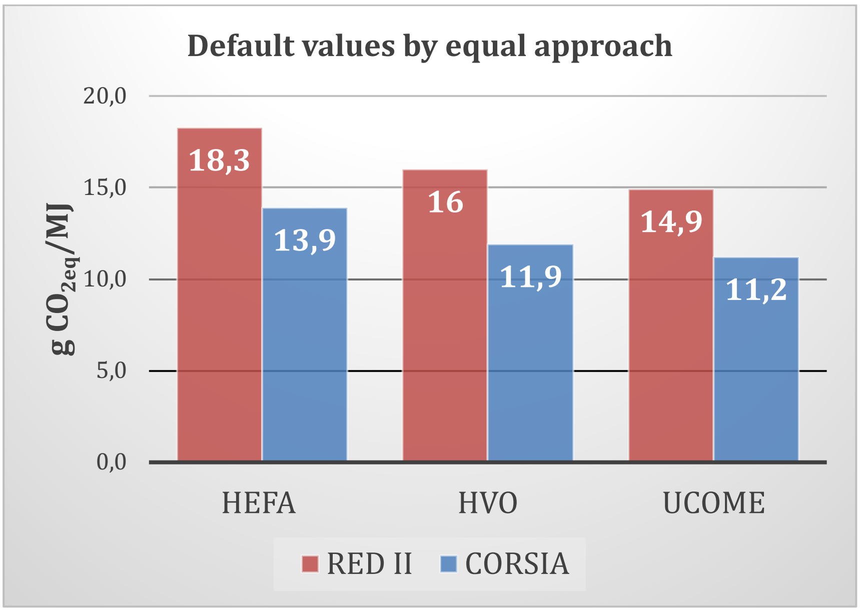


Figure 2: Default values by equal approach

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10 Antonissen (2016). Greenhouse gas performance of renewable jet fuel: a comparison of conversion pathways

3. DISPLACEMENT EFFECT

For the determination of the "displacement effect" the three UCO based fuels UCOME, HVO and HEFA are compared. For this, the potential emission savings are calculated by the amount of UCO used as feedstock for the fuels, taking into account emission factors and yield.

3.1 EMISSION FACTORS

Since this report refers to the reporting of emissions under the RED II and CORSIA regulations, only the emission factors specified in these regulations are used here. The LCAs are applied as shown in chapter 2.1. The conservative approach of RED II is not applied, and the ILUC factor in RED II and CORSIA is zero for UCO based fuels.

Further, comparators are used in the regulations to determine the savings over conventional fossil fuel, which are also used here.

Fossil fuel (RED II)	94 g CO_{2eq}/MJ
Jet fuel (CORSIA)	89 g CO_{2eq}/MJ

Table 6: conventional fuel comparators

3.2 YIELD

For the yield, we are using the results of a study by studio Gear Up[11] which also compared the three fuels and thus present yields that are comparable with each other. In addition to the main products (UCOME, HVO or HEFA), the yield also includes one or more by-products. These are glycerol for UCOME, propane, naphtha and fuel gas for HVO, and propane and naphtha for HEFA. In addition, HEFA production also generates quantities of HVO, which in turn can be used for road transport to reduce emissions.

Processing	**Yield factor**		**By-products factor**
UCO to HEFA	0,610 HEFA	0,1357 HVO	0,1779 by-product
UCO to HVO	0,778 HVO		0,1288 by-product
UCO to UCOME	1,004 UCOME		0,106 by-product

Table 7: Yield and by-product

[11] studio Gear Up. (2021). Conversion efficiencies of fuel pathways for Used Cooking Oil

The yield must be converted into an energetic quantity for further calculation, for which the energy content by weight specified in the RED II is used.

Fuel	Energy content by weight
HEFA	44 MJ/kg
HVO	44 MJ/kg
UCOME	37 MJ/kg

Table 8: energy content by weight

3.3 RESULTS

The results are divided into two considerations:

1. A comparison of the potential emission savings of the produced quantities of UCOME, HVO, and HEFA.
2. A comparison in which, in addition to the approach for the first comparison, the by-product quantities are included.

3.3.1 POTENTIAL EMISSION SAVINGS OF THE PRODUCED QUANTITIES OF UCOME, HVO AND HEFA

To calculate the displacement effect, the potential emission savings using UCO for fuel production are compared. For this purpose, the yield was converted into energetic quantity in each case and the emission quantity was determined in kg CO_{2eq} using the LCA values in chapter 2.1. These were subtracted from the emission quantities according to the fossil comparator values of the schemes at the same energetic quantity in order to determine the potential emission savings. HVO quantities, generated during HEFA production, were included for potential HEFA production emission savings.

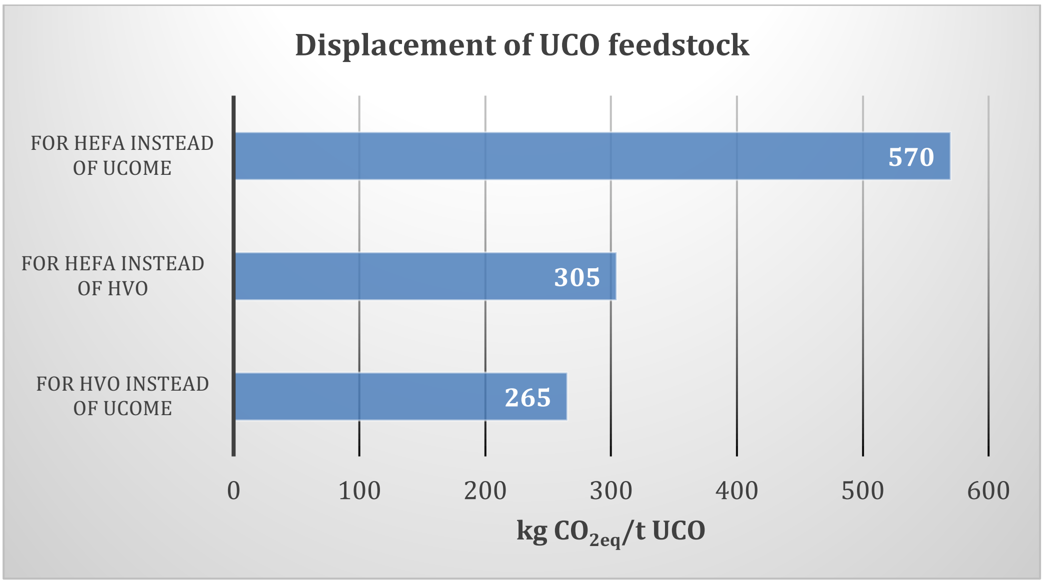

Figure 3: Displacement effect of UCO feedstock

The largest displacement effects occur when using UCO for HEFA, with the largest difference when using UCO for HEFA instead of UCOME with 570 kg CO_{2eq}/t UCO of potential lost emission savings. However, using UCO for HVO instead of UCOME also results in losses of potential emissions savings, although not quite as large.

3.3.2 POTENTIAL EMISSION SAVINGS TAKING INTO ACCOUNT BY-PRODUCTS

UCOME, HVO, and HEFA production also produce varying amounts of by-products (glycerol, propane, naphtha, and fuel gas). UCOME production generates the least amount of by-products, followed by HVO and HEFA (see table 7). Since the by-products could possibly also be used for emission savings, even outside the transport sector, a conservative approach is taken in the second comparison in which they are also taken into account.

In order to assess whether the different proportions of by-products in the total production have a noticeable effect on the potential emission savings, a conservative approach was chosen in favor of production pathways with a high proportion of by-products, i.e. especially HEFA but also HVO. For this purpose, the differences in by-product quantities to the lowest by-product quantities of the UCOME production pathway were fully credited to the main product quantities of the HEFA und HVO production, so the yield of main product is improved by the differences in by-product quantities.

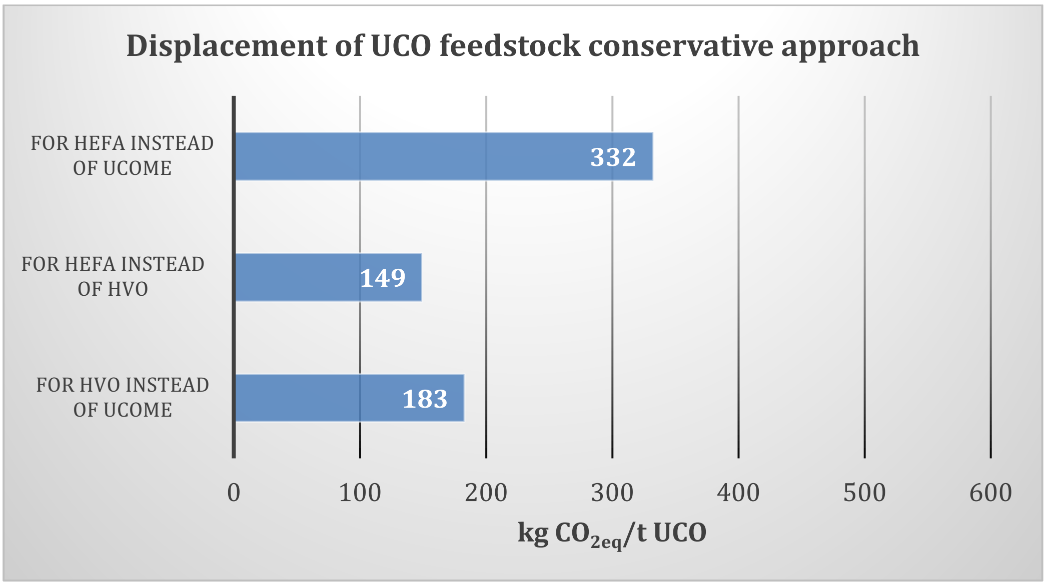

Figure 4: Displacement effect of UCO feedstock with conservative approach

The inclusion of the by-product quantities with a conservative approach in favor of by-product heavy production pathways like the HEFA and also HVO production could reduce the displacement effect somewhat compared to figure 3. Nevertheless, the results remain that the largest displacement effects occur when using UCO for HEFA with the largest difference when using UCO for HEFA instead of UCOME.

4. CONCLUSION AND DISCUSSION

For three fuel types produced from the feedstock UCO, the different GHG emission estimation methods of RED II and CORSIA were compared using default values provided by the two schemes. A feedstock "displacement effect" for UCO-based fuels was quantified for the potential lost GHG emission reductions compared to the largest possible emissions reduction.

It was found that the default value rules in the CORSIA scheme produce lower GHG emissions estimates for UCO-HEFA than the RED II default value rules produce for UCO-HVO and UCOME for the road sector, in spite of the fact that the LCA values for HEFA in CORSIA are higher than the LCA values for HVO and UCOME in RED II. The reason is a requirement for a "conservative approach factor" that is included in RED II but not in CORSIA. This analysis shows that with an equal approach for both RED II and CORSIA, the picture would be reversed and UCO-HEFA would consistently be reported to have with the highest GHG emission value of the three UCO-derived fuel options.

Such a difference in valuation between these two schemes is of great concern when RED II and CORSIA are used equivalently but separately to determine emission savings for a member country. A solution could be an adjusted weighting of the emission savings reported according to the respective schemes or an alignment of the content of the schemes in the default values. Failure to do so will create an incentive to produce a fuel that could negatively impact the overall emissions savings potential for biofuels and, with HEFA as a commercially mature production pathway, reduce incentives to develop less established feedstock sources.

This is particularly important in the case of UCO-based fuels, where feedstock demand is already high with little untapped potential for increasing utilization of UCO for fuel. Disproportionate valuation of aviation fuel because of discrepancies between GHG emission estimation schemes would inevitably lead to a displacement effects like in this analysis. If our current two scheme approach causes a low carbon intensity feedstock to be artificially favored for a fuel that is less effective in reducing GHG emissions, our potential overall GHG emission reductions compared to fossil fuels would be reduced because we would produce less of the more effective fuel than we would under a single scheme. The potential losses of emission savings due to displacement effects between the fuels considered in the report amounted to up to 570 kg CO_{2eq}/t UCO for the use of UCO for HEFA production instead of UCOME production. This fits with the lower emission factors for UCOME compared to HVO and HEFA in the literature and the schemes themselves.

However, since HEFA and HVO production generate proportionately larger amounts of by-products than UCOME production, and the by-products could potentially also be used to reduce emissions, a conservative approach was applied to also account for a high proportion of by-products. This approach reduced the displacement effect to a maximum value of still 332 kg CO_{2eq}/t UCO. Therefore, including by-products did not change the fact that the use of UCO for HEFA production instead of UCOME production causes the highest displacement effect.

These results for the feedstock "displacement effect" are based on emission factors for typical emissions for the production pathways and may differ depending on individual production processes. This analysis is not intended to represent all possible processes for producing fuel from UCO. It was developed to demonstrate the potential importance of feedstock displacement effects on our overall potential for actual GHG emissions reductions. We strongly recommend that this concept always be considered when estimating emissions reductions for fuels that could compete for the same feedstock. This recommendation is particularly urgent when the competing fuels are evaluated under different emissions estimation schemes, as is the case with HEFA under CORSIA and HVO and FAME under RED II.