Method for establishing lifecycle greenhouse gas emission factors for sustainable aviation fuels

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Introduction

Annex 16, Volume IV defines a "CORSIA eligible fuel" as a "CORSIA sustainable aviation fuel" (SAF) or a "CORSIA lower carbon aviation fuel" (LCAF), which an operator may use to reduce its carbon offsetting requirements. This article introduces the approved lifecycle emissions accounting approach that has been developed for SAF, as one core component of the overarching process by which operators can claim emissions reduction from the use of SAF.

The use of SAF can reduce greenhouse gas (GHG) emissions attributable to aviation. However, the potential to reduce GHG emissions can vary between different SAF pathways due to different factors, such as, for example, the specific feedstock used and its production location, the agricultural practices, the specific fuel conversion process, and the choice of utilities used in its conversion process.

There are two main reasons why the heterogeneity of emission factors between different SAF pathways within CORSIA has to be appropriately accounted for:

- First, sustainability criterion 1.1. of the ICAO document CORSIA "Sustainability Criteria for CORSIA Eligible Fuels" mandates that CORSIA eligible fuels such as SAFs need to achieve lifecycle greenhouse gas emissions reductions of at least 10% compared to the baseline life-cycle emissions value for aviation fuel (e.g. conventional, petroleum-derived jet fuel). Therefore, for every type of SAF, it has to be established if it fulfils this criterion.

- Second, Section 3.3. of Annex 16, Volume IV establishes a crediting system for operators from the use of CORSIA-Eligible Fuels, such as SAF, in which the CO_2 offsetting requirements are reduced as a function of the mass of SAF used and the SAF-specific emission reduction compared to the use of conventional jet fuel. Therefore, for every type of SAF, its lifecycle greenhouse gas emission factor has to be defined.

CAEP tasked the Alternative Fuels Task Force and later the Fuels Task Group with developing an life cycle assessment (LCA)-based methodology for accounting for lifecycle greenhouse gas emission factors of different types of SAF, and for establishing appropriate emission factors. A wide system boundary was drawn for the lifecycle analysis in which both direct and indirect land use changes (summarized together by the term of "induced" land use change- ILUC) are included in the lifecycle. Emission types considered in the method are CO_2 for the SAF combustion step, and CO_2, CH_4, and N_2O for the other lifecycle steps, and they are added up using their 100-year Global Warming Potentials. Direct emissions occurring

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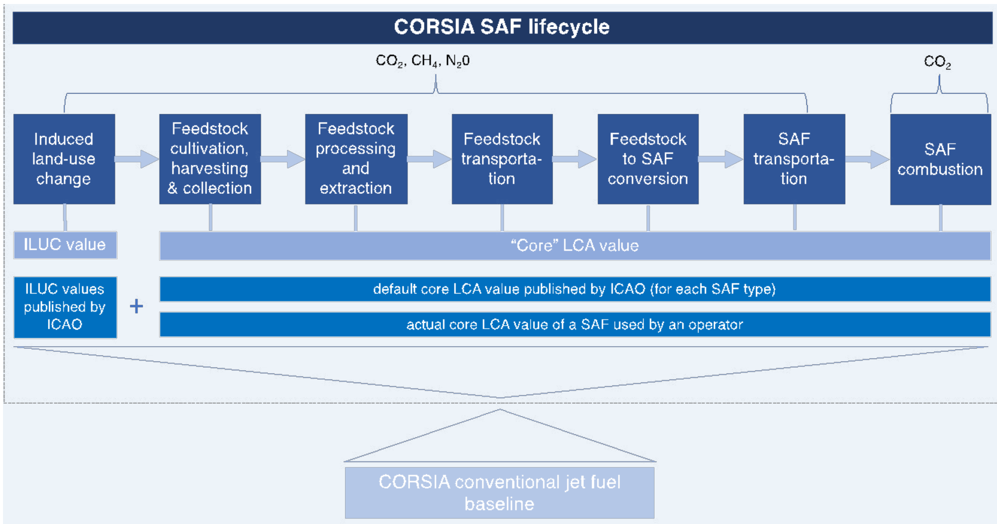

FIGURE 1: Lifecycle approach for SAF within CORSIA, including emissions scope by lifecycle step

from the full SAF production chain (e.g. CO_2 combustion emissions from the use of process fuels) are included, as well as indirect emissions associated with the production of feedstocks, utilities, chemicals and other inputs. One-time infrastructure-related emissions are not included, as their contribution to the lifecycle emission value of SAF is usually relatively small.

For ease of analysis, lifecycle emissions of SAF are first calculated separately for the ILUC emissions component of the lifecycle ("ILUC value"), and for the rest of the lifecycle ("core LCA"), and then summed up to yield the lifecycle emissions factor of a certain type of SAF, expressed in CO_{2e} per MJ (calculated on the lower heating value) of SAF used. Finally, results are compared to the lifecycle emissions of conventional, petroleum-derived jet fuel. Figure 1 summarizes the lifecycle approach for SAF under CORSIA.

Currently, two subgroups within the Fuels Task Group are responsible for conducting the work on SAF lifecycle values. The "Core LCA" subgroup developed the LCA methodologies for SAFs and continues to propose core LCA emission values for selected SAF pathways. The "ILUC" subgroup developed results in relevant modeling tools and continues to propose ILUC values for selected SAF pathways. Both subgroups closely interact so that parameters or assumptions are harmonized, where needed.

Method for establishing core LCA values

In the core LCA analysis, emissions from feedstock cultivation to SAF combustion are accounted for (see Figure 1), and are added up according to equation 1, where:

- e_{fe_c} denotes emissions from feedstock cultivation;
- e_{fe_hc} from feedstock harvesting and collection;
- e_{fe_p} from feedstock processing;
- e_{fe_t} from transportation of the feedstock to the processing and fuel production facilities;
- e_{fefu_p} from feedstock-to-fuel conversion processes;
- e_{fu_t} from fuel transportation and distribution;
- and e_{fu_c} denotes emissions from fuel combustion in an aircraft engine.

For purposes of reporting or accounting SAF emissions, the latter term (e_{fu_c}) is considered zero for SAF fractions produced from biogenic carbon. We also note that for waste, residue and by-product feedstocks, the system boundary only starts at the point of feedstock collection.

$$\text{Core LCA value } [gCO_2e/MJ] = e_{fe\_c} + e_{fe\_hc} + e_{fe\_p} + e_{fe\_t} + e_{fefu\_p} + e_{fu\_t} + e_{fu\_c}$$

Equation (1)

In many SAF pathways, there are multiple co-products produced along the supply chain, and a decision has to be taken as to how to allocate emissions to the different co-products, including to SAF. For example, turning vegetable oils into SAF by means of the HEFA process also creates other liquid fuel products such as diesel or gasoline, as well as further upstream vegetable meal that can be used as animal feed. The CORSIA approach allocates emissions to the different co-products at the point of separation of production streams, based on the relative energy content of the different co-products.

An airplane operator has two options on how to apply the core LCA method (see Figure 1). It can either rely on a so called "default" core LCA value or it can use a so called "actual value".

Default core values are pathway-specific emission factors agreed upon by ICAO and published in the ICAO document "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels". For the default core LCA values, several institutions (Argonne National Laboratory, European Commission - Joint Research Centre, Massachusetts Institute of Technology, University of Hasselt, University of Toronto, and Universidade Estadual de Campinas) contributed to the establishment of a life-cycle inventory for the different SAF pathways. Between the different modelling groups, core LCA results for a specific SAF pathway differ because of, inter alia, different type of data (e.g. industry versus simulation data; agricultural yield and practices assumptions, transportation distance and mode mix assumptions). Differences were assessed in detail and input assumptions reconciled, where judicious. In order to set a single default core LCA value for a SAF pathway, the CORSIA methodologies consider that a distinct SAF pathway is defined by a maximum variability in results of 8.9 gCO_2e/MJ (10% of the jet fuel baseline GHG intensity), and that the mid-point value of the highest and lowest core LCA value estimated by the different modeling institutions was taken as core LCA default value for this pathway. If differences remained outside of the 8.9g envelope even after reconciliation, then the data was split into two or more pathways and the mid-point value was used as default value for these separate pathways based on the remaining variability in the dataset. For each SAF pathway, results were validated by a modeling institution not previously involved in the calculations for this specific pathway.

Alternatively, to the use of the proposed default core values, an operator can bring forward 'actual core LCA' values that replace the default core LCA value. In order to do so, it needs to select an ICAO-approved Sustainability Certification Scheme that certifies that the actual LCA analysis is in accordance with the CORSIA LCA methodology. In order to define the calculation and reporting requirements for the actual LCA value, a separate ICAO document was developed by the Fuels Task Group ("CORSIA Methodology for Calculating Actual Life Cycle Emissions Values"[2]).

Method to establish ILUC values

For the ILUC value, only values established by ICAO and published in the ICAO document "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels" may be used. That is, irrespective of whether an operator brings forward an actual core LCA value for a specific amount of a certain type of SAF, the ILUC value established for this type of SAF has to be added to the core value in order to establish the lifecycle emissions factor for this specific amount of SAF.

In order to appropriately account for the inherent uncertainty with regard to ILUC emissions, two different economic models are employed, both of which are very well established in the domain. GTAP-BIO is a computable general equilibrium model developed at Purdue University. GLOBIOM is a partial equilibrium model developed at the International Institute for Applied Systems Analysis (IIASA).

The two original models have different structures, and use datasets and parameters from different sources, and are a priori expected to provide different results. Therefore, significant effort was devoted to understanding differences in initial modeling results, and to reconcile and harmonize data inputs wherever it was judicious to do so.

2 Available at https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

Differences between the results of the two economic models were assessed in detail and input assumptions reconciled, where judicious. In order to set a single default ILUC value for a SAF pathway, it was decided to follow the same recompilation approach applied to the Core LCA values.

Default life-cycle emission factors

The default lifecycle emissions values for SAF pathways are published in the ICAO document "CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels". The Fuels Task Group is continuously establishing lifecycle emission factors for additional SAF pathways and brings them forward for CAEP and ICAO Council approval, after which the document is updated. As the time of writing, 81 distinct default values have been established, representing 22 different feedstocks, and 6 different conversion technologies. Figure 2 presents a graphical representation of the approved default values, specific for each feedstock-conversion technology combination, assessed, so far. Some feedstock-conversion technology combinations have different ILUC values associated with them, and the resulting default lifecycle emission factors are represented by separate dots in the figure.

The Next Three Years

The ICAO document "CORSIA Default Life Cycle Emissions Values For CORSIA Eligible Fuels"[3] will be updated when default LCA values have been established by the Fuels Task Group and agreed by CAEP. ICAO Member States, Observer Organizations, and ICAO-Approved SCSs can file a request for CAEP to consider a conversion process, feedstock, and/or region in this ICAO document. The process and required information is detailed in the CORSIA Supporting Document "LCA methodologies", Part I[2]. The Fuels Task Group will continue its work on establishing values for additional Sustainable Aviation Fuels, focusing on fuels that have reached high maturity in the ASTM-approval process, and therefore are likely to be used by the aviation sector in the future.

3 Available at https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-Eligible-Fuels.aspx

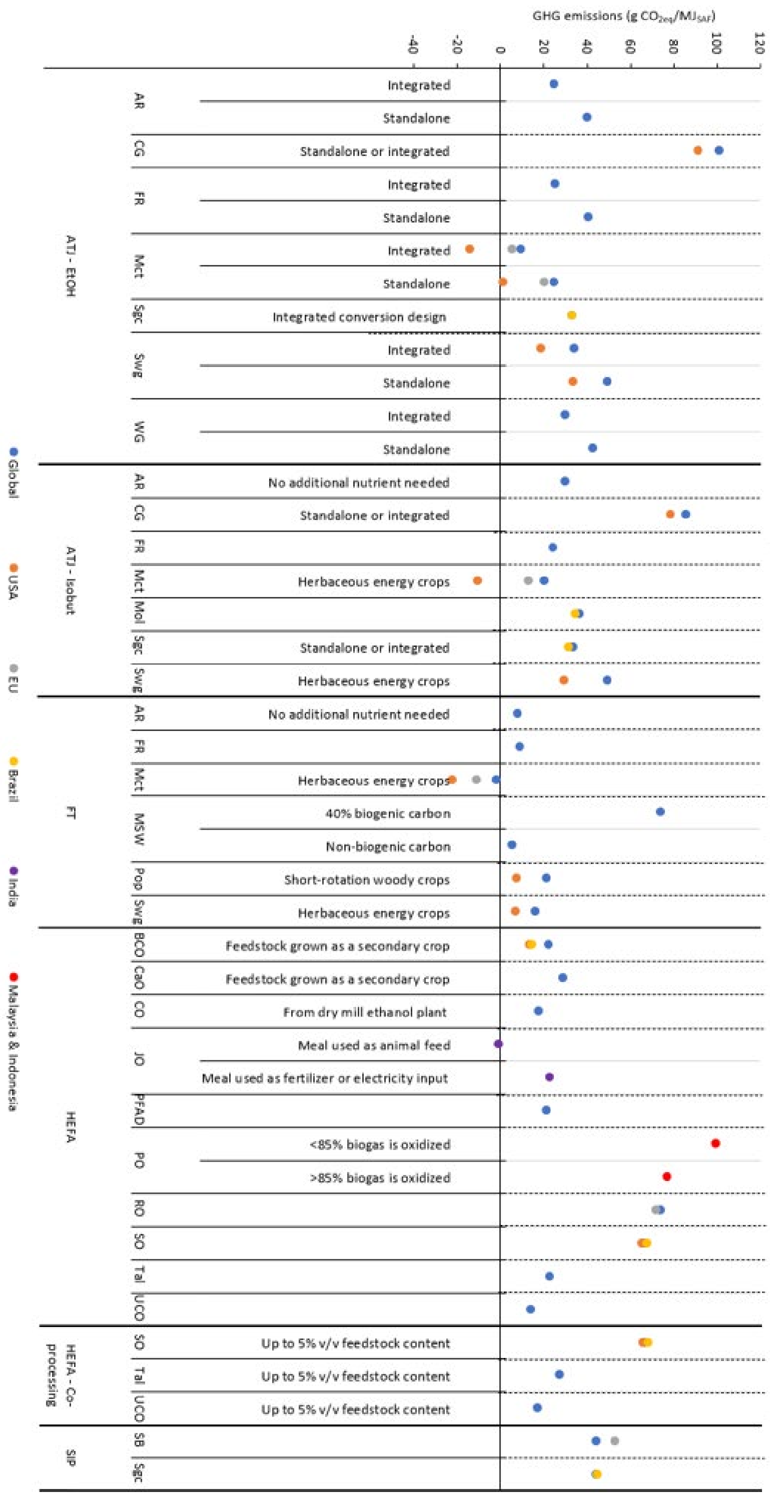

FIGURE 2: Default lifecycle greenhouse gas emission factors under CORSIA, shown by feedstock-conversion technology combination. Each dot in the figure denotes one distinct default value for a specific SAF pathway. For MSW , two values are shown, one for 40% biogenic carbon, and one for 100%. In the CORSIA method, an equation has been defined that links biogenic content for MSW to the default value. AR, Agricultural residues. CG, Corn grain. FR, Forestry residues. Mct, Miscanthus. Sgc, Sugarcane. Swg, Switchgrass. WG, Waste gases. Mol, Molasses. MSW, Municipal solid waste. Pop, Poplar. BCO, Brassica carinata oil. CaO, Camelina oil. CO, Corn Oil. JO, Jatropha oil. PFAD, Palm fatty acid distillate. PO, Palm oil. RO, Rapeseed oil. SO, Soybean oil. Tal, Tallow. UCO, Used cooking oil. SB, Sugar beet