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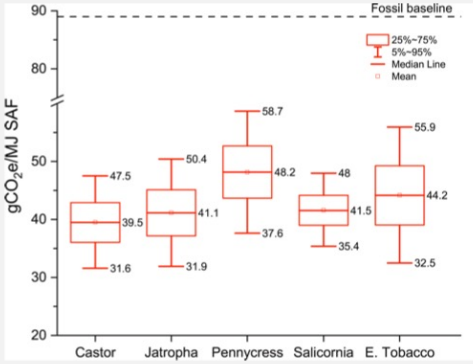
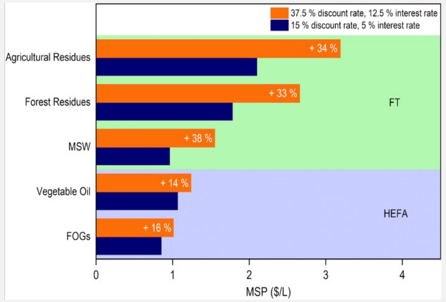
The integration of power to liquid fuels in international climate regulation for aviation

Robert Malina

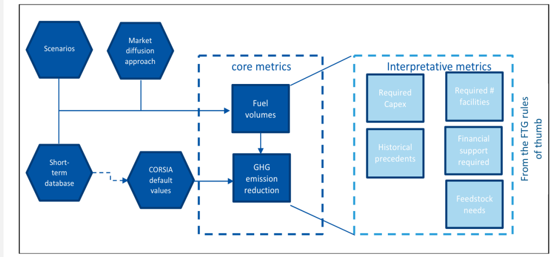
GARS Workshop "Decarbonizing Aviation: Where do We Stand Today?"
19 June 2024

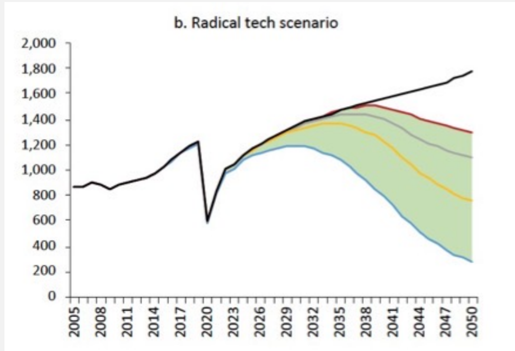
What we do in the space of SAF



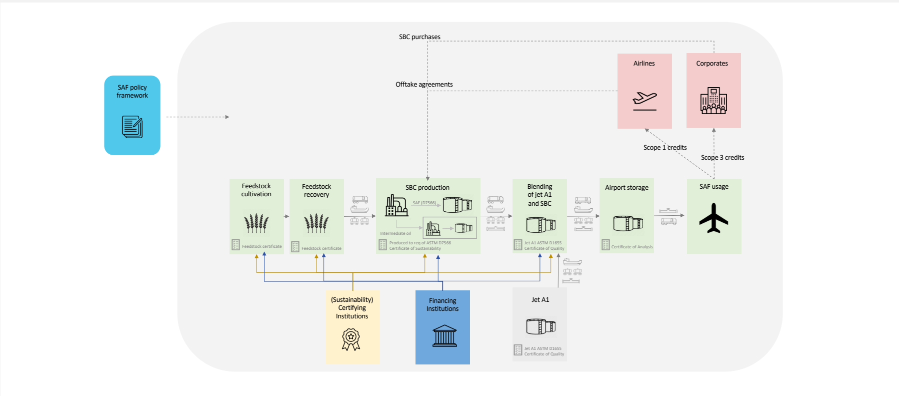


SAF-specific economics & environmental impact

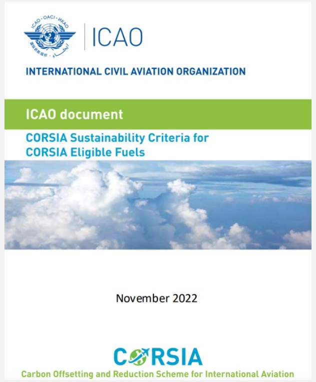


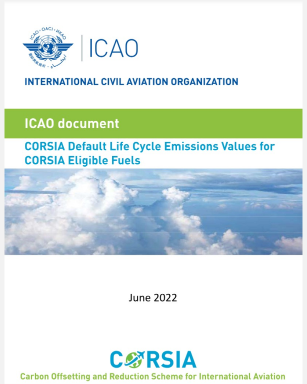


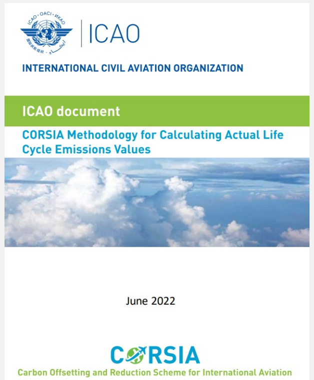
Availability projections & decarbonization contribution



Supply chain development







Climate regulation development & deployment

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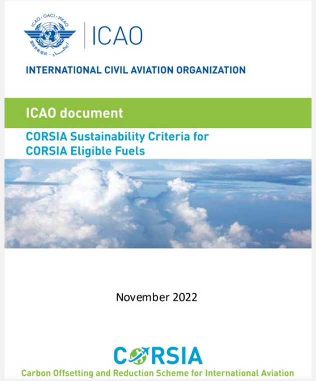
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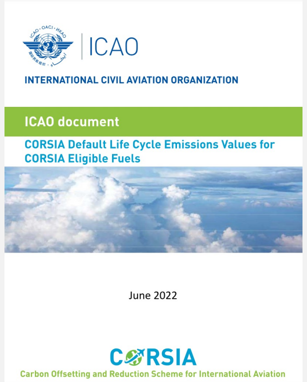
CORSIA Sustainability Criteria for CORSIA Eligible Fuels
November 2022
CORSIA
Carbon Offsetting and Reduction Scheme for International Aviation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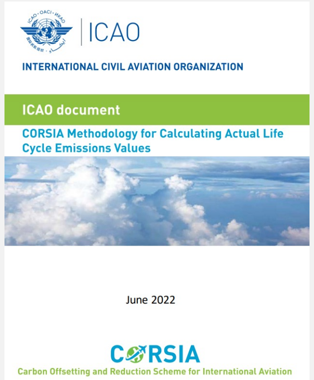
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Climate Regulation Development & Implementation

CORSIA

Carbon Offsetting and Reduction Scheme for International Aviation

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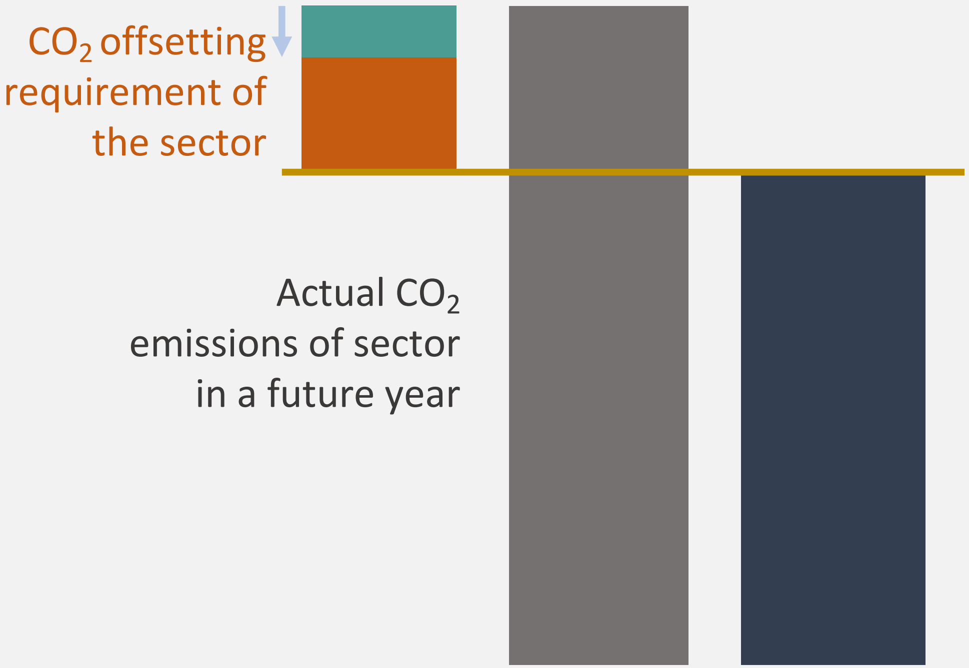
How does CORSIA work?

Sustainable Aviation Fuel integration in CORSIA in a nutshell

CEF:
CORSIA-Eligible Fuels reduce offsetting requirements as a **function of the lifecycle emission benefit of the specific fuel used.**

CORSIA-Eligible Fuels

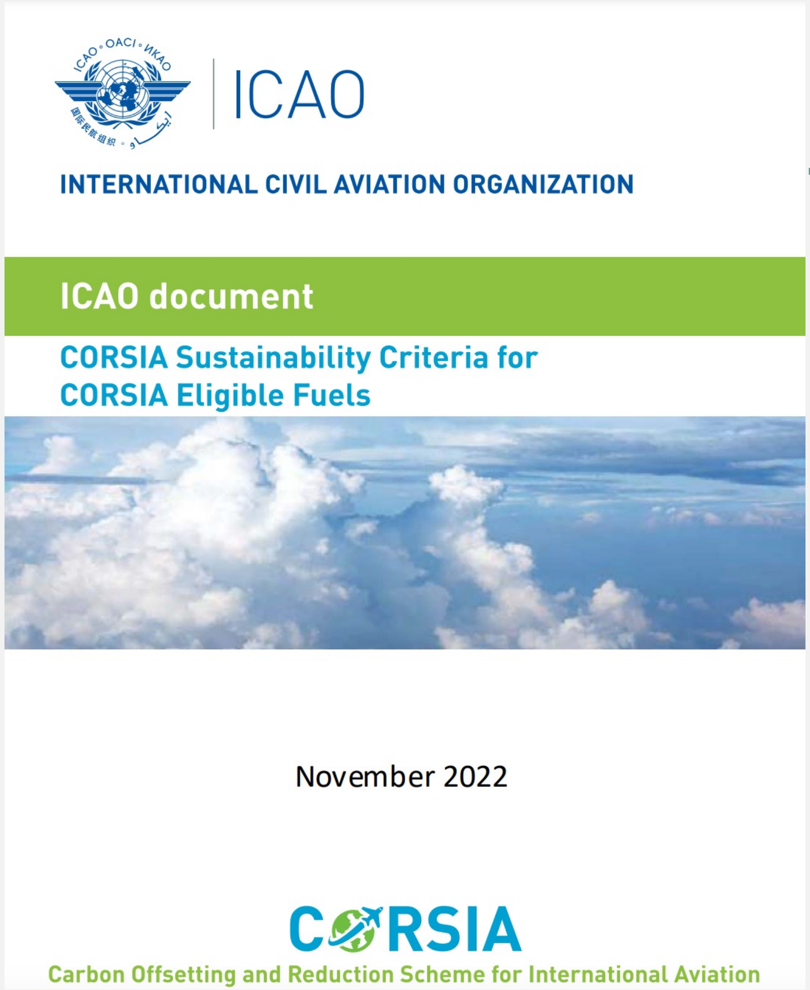
"A CORSIA sustainable aviation fuel or a CORSIA lower carbon aviation fuel, which an operator may use to reduce their offsetting requirements"



85 % of annual CO_2 emissions of sector in **2019** (**from 2024 to 2035**)

Simplified schematic at the sector level. Actual process more complicated.

How do fuels qualify under CORSIA?



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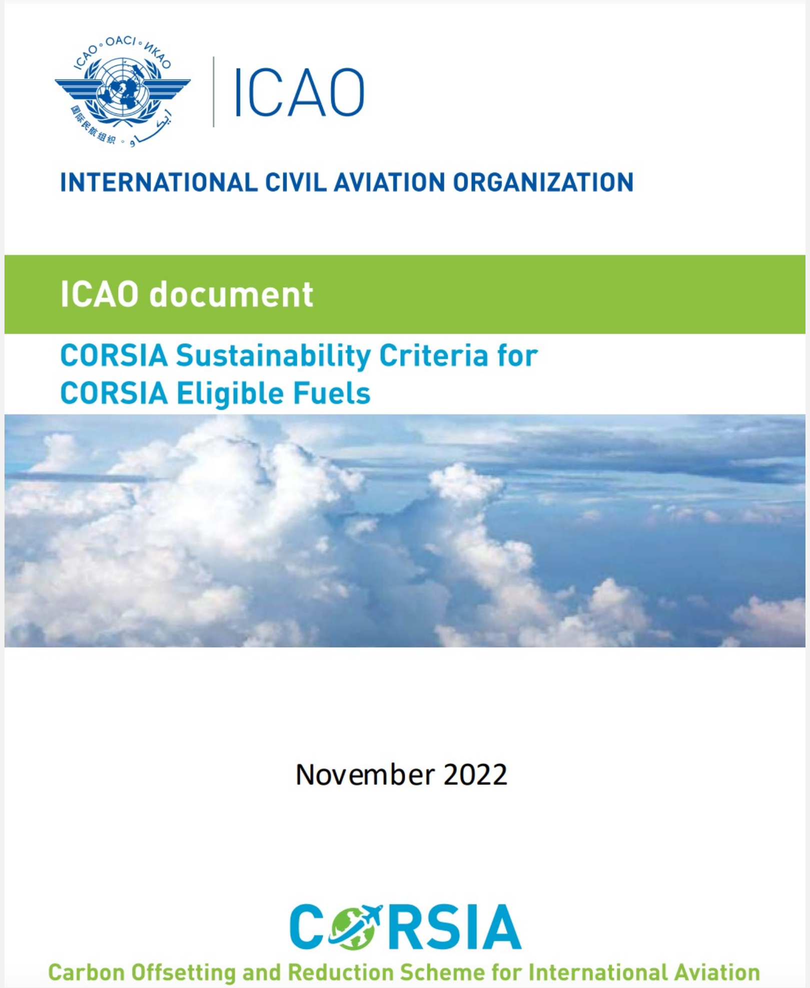
1. Greenhouse Gases
2. Carbon Stock

for CEF produced before Jan 1, 2024

3. Water
4. Soil
5. Air
6. Conservation
7. Waste and Chemicals
8. Human Rights and labour rights
9. Land use rights and and land use
10. Water use rights
11. Local and social development
12. Food security

additional themes for CEF produced from Jan 1, 2024

The GHG criterion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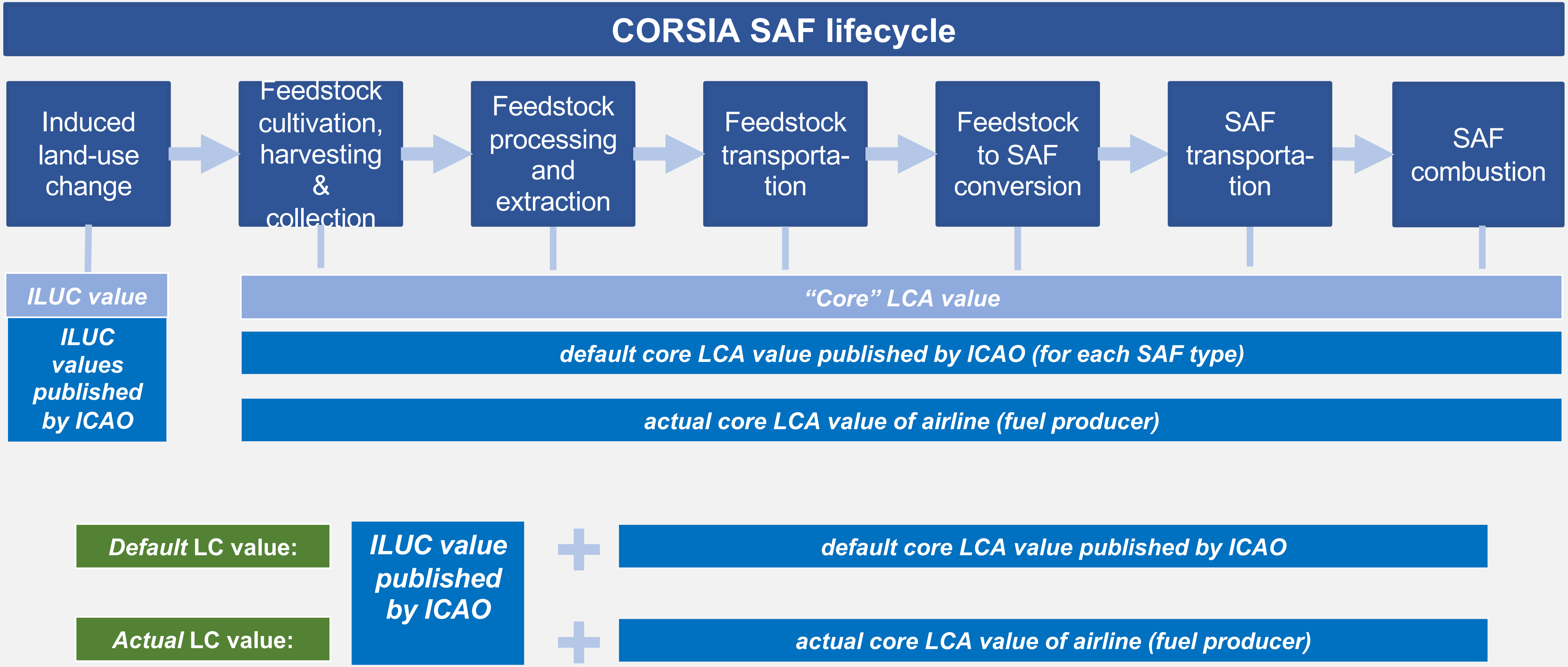
1. Greenhouse Gases

1.1: CORSIA-eligible fuel will achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.

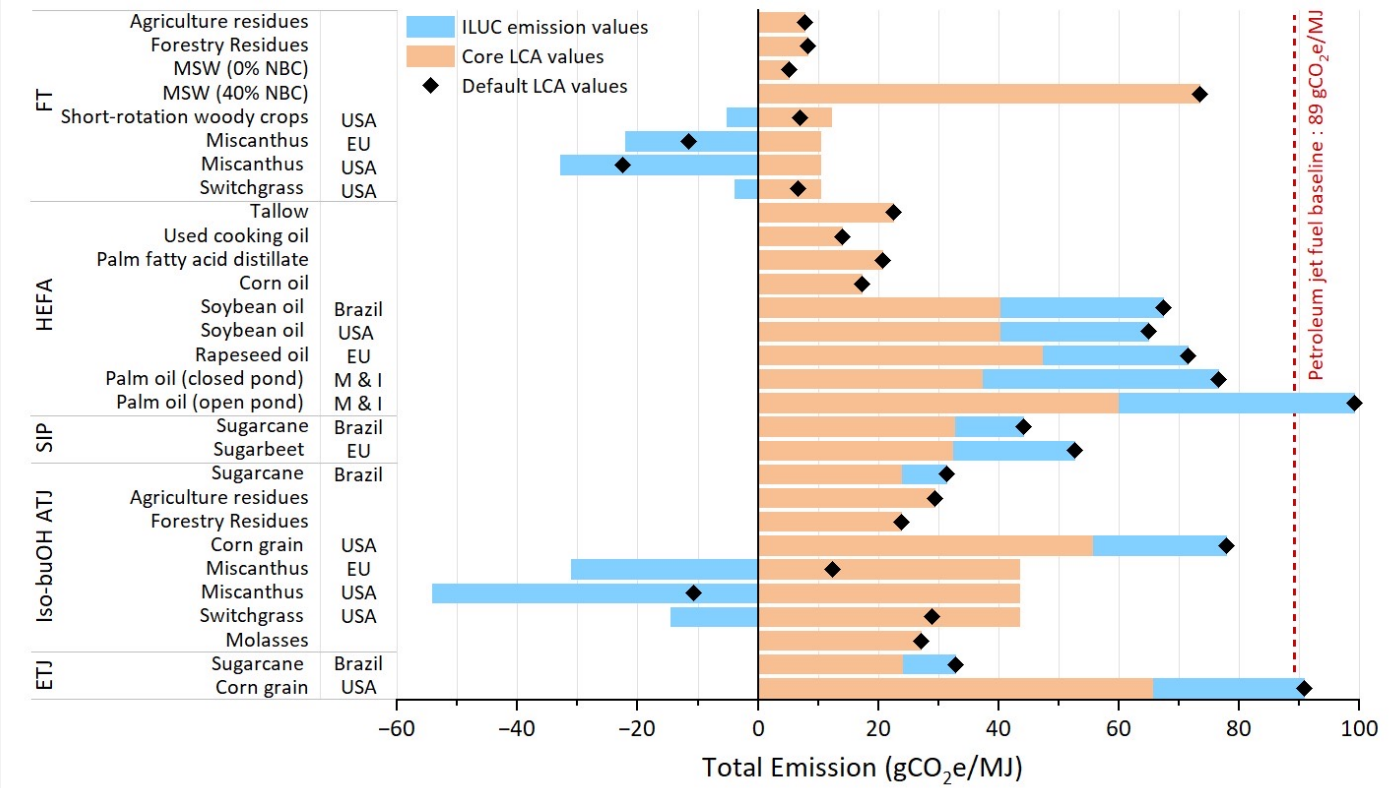
GHG emissions of CEF can be established by means of a *default LC* value or an *actual LC* value

Lifecycle GHG emission calculations under CORSIA



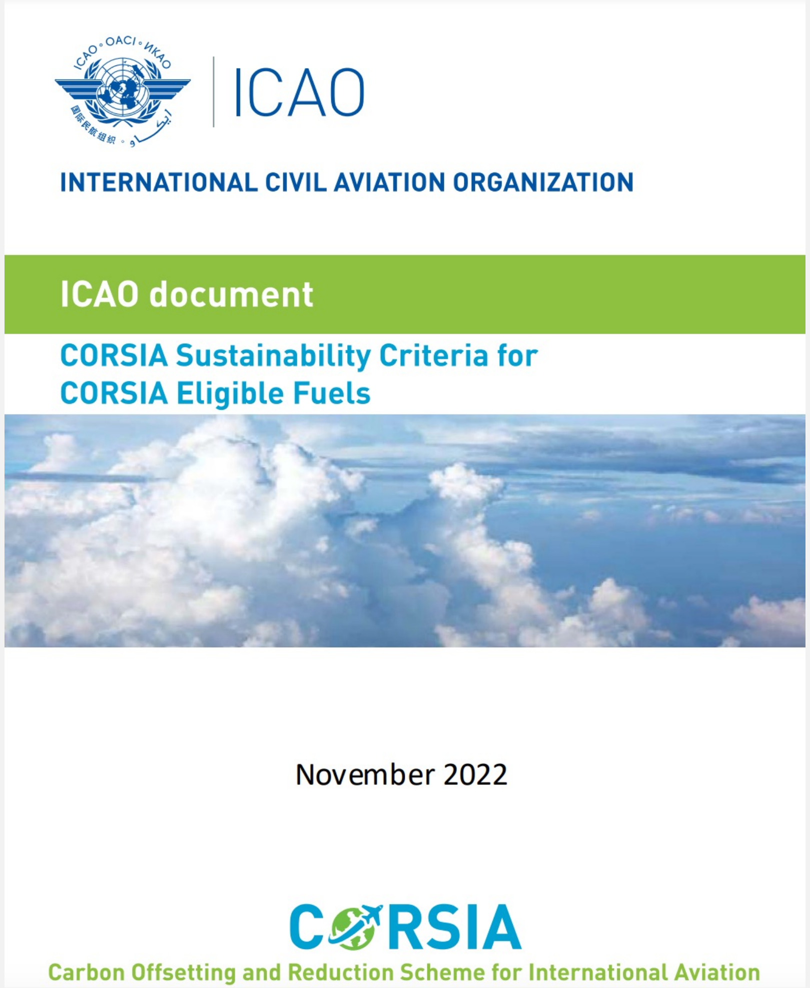
Default LC emission values in CORSIA

Goal is the establishment of default values for **all relevant ASTM-approved SAF pathways** (i.e. feedstock and conversion technology combinations): Each of those has/should have a dedicated default LC value.



Prussi et al. (2021). By now, additional default values have been established.

Scope of CORSIA CEFs

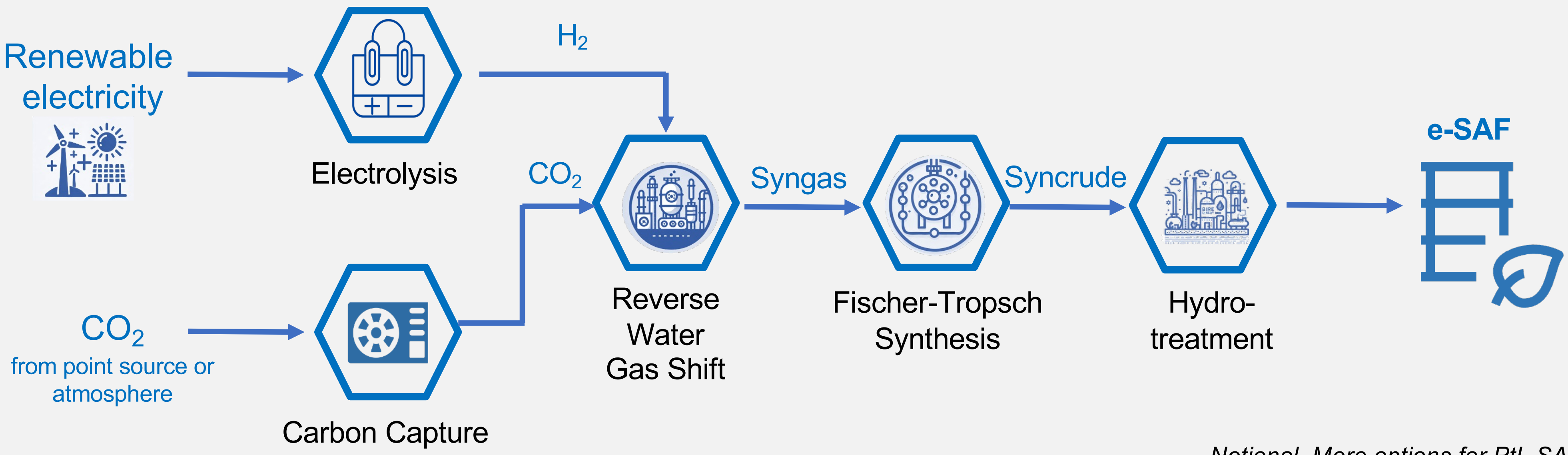


Criteria were originally developed for "**traditional**" **SAF**.

Got extended to cover **Lower Carbon Aviation Fuels** recently.

Are currently being extended to account for **PtL Fuels** ("**high-electricity-input fuel**"), as well.

PtL SAF Pathway flow chart and pathway Importance



Notional. More options for PtL SAF exist.

Importance of PtL SAF:

- **More scalable than other SAF**
- **Very low lifecycle GHG emissions possible**
- **No/less food versus feed issues**

Essential component of the net zero carbon strategy of the industry and regulators!

What are key considerations for augmenting CORSIA to account for idiosyncrasies of “Power to liquid fuels”?

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2. Carbon accounting and sourcing
3. Other adjustments to CORSIA sustainability criteria

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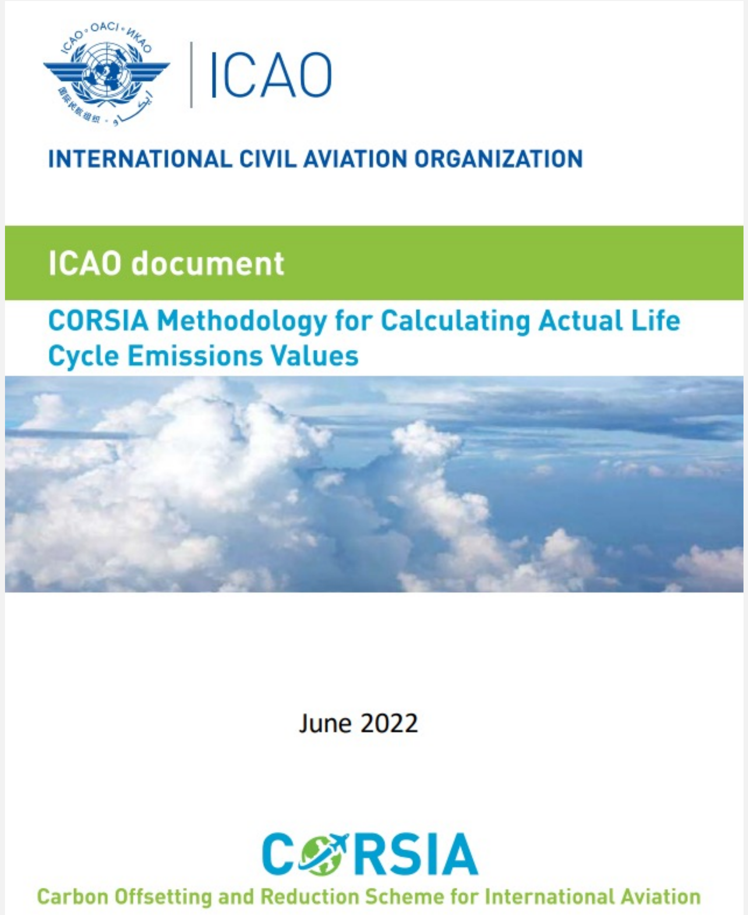
Electricity **accounting** and sourcing

ICAO Document 07 – CORSIA Methodology for Calculating Actual Life Cycle Emissions Values

“The calculated LS_f values will include emissions generated during ongoing operational activities (e.g., operation of a fuel production facility, feedstock cultivation and extraction, transportation of feedstock, intermediate products and finished aviation fuels, and other operational activities for life cycle stages 1-6 described in paragraph 2), as well as **upstream emissions associated with the material and utility inputs for operational activities, such as processing chemicals, electricity, and natural gas.** ***Emissions generated during one-time construction or manufacturing activities (e.g., fuel production facility construction, equipment manufacturing) will not be included.”***

Embodied emissions of electricity generation are currently not accounted for. Does this matter?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Drivers of relevance of embodied emissions for a SAF pathway

Embodied electricity emissions impact for a SAF pathway = Electricity requirements for a SAF pathway X Embodied emissions of electricity used within the pathway

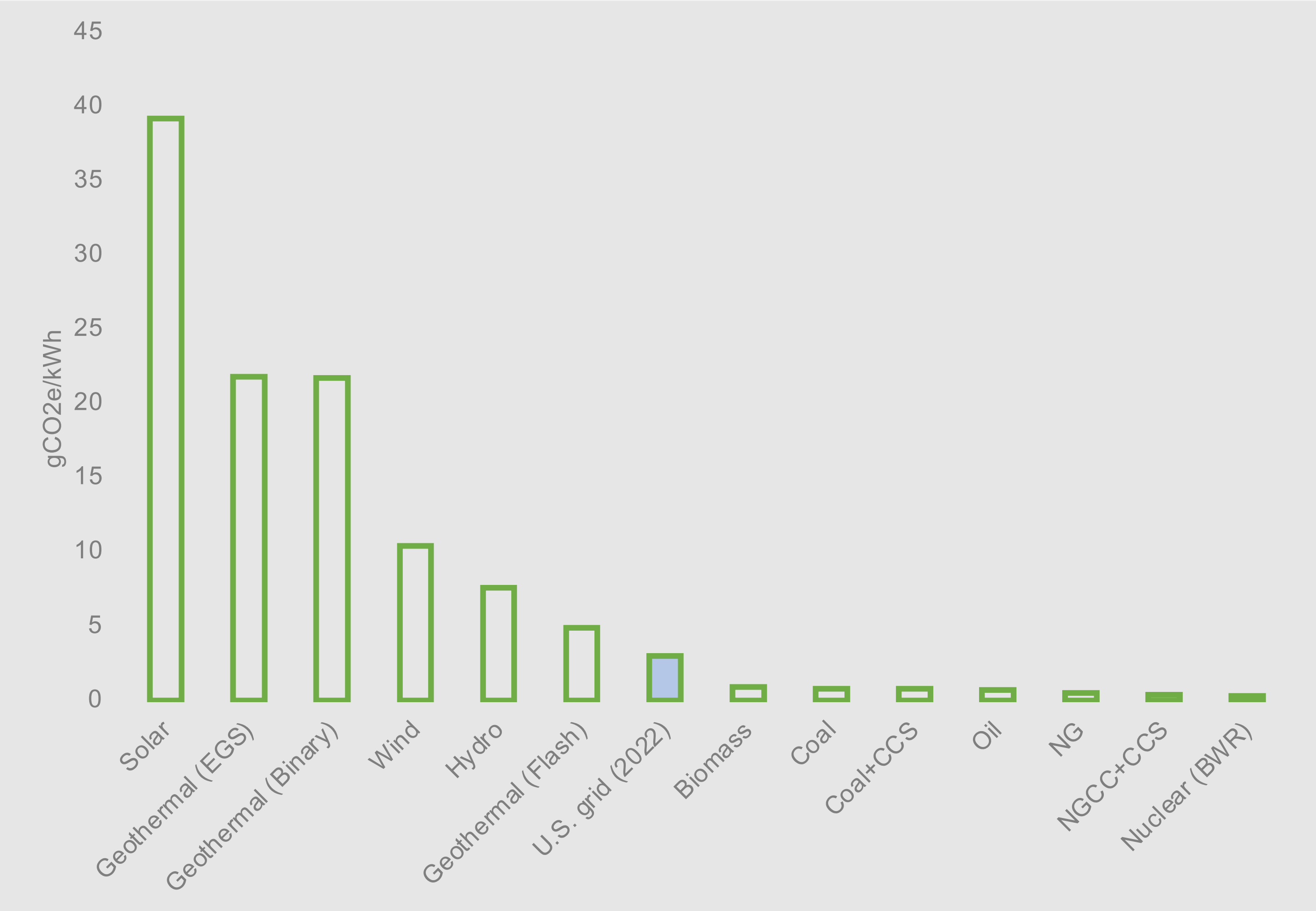
Electricity requirements for SAF pathways

Increasing Electricity Use →

	Existing CORSIA	Electrified CORSIA	"Pure" PtL
Resource Use Types	• Biogenic C w/ combustion farming • Natural gas heat • SMR H_2 • Combustion transport & distribution	• Biogenic C w/ electrified farming • Electric heat • Electrolytic H_2 • Electrified transport & distribution	• Electrified DAC or Waste CO_2 • Electric heat • Electrolytic H_2 • Electrified transport & distribution
% Electricity of Energy Input	**0-4%**	**4-30+%**	**→100%**

Visual taken from a joint presentation with N. Keogh and Florian Allroggen (both MIT) at the CRC Lifecycle analysis workshop held at Argonne National Laboratory in October 2023.

Magnitude of embodied emissions per electricity source



For comparison purposes, average US electricity grid CO_2 emissions per kWh in 2022 were approx. 371 g (including embodied emissions).

US Data, from GREET model.

Results for example traditional SAF and PtL pathways

Emissions (gCO_2e/MJ jet fuel)

Process	Feedstock	CORSIA LCA	Grid Elec. Use	Solar w/ Embodied	Solar w/o Embodied
HEFA	Rapeseed	40.4	1.6	**0.1**	0
	UCO	13.9	1.5	**0.1**	0
ETJ	Corn grain	65.7	7.3	**0.6**	0
iBuOHtJ		55.8	6.7	**0.6**	0
SIP	Sugarbeet	32.4	0 (Net elec. export)		
	Sugarcane	32.8			
F-T	Corn stover	7.2	N/A – Heat & Electricity covered by internal gen.		
Pure PtL	-	-	-	**35.8**	0

Data taken from a joint presentation with N. Keogh and Florian Allroggen (both MIT) at the CRC Lifecycle analysis workshop held at Argonne National Laboratory in October 2023.

- Including embodied emissions in "traditional SAF" has a relatively small impact on SAF lifecycle emissions.
- **For PtL fuels, embodied emissions can have a relatively high impact on SAF lifecycle emissions.**
- Criterion/criteria needed that determine for a SAF pathway if embodied emissions are to be included or not.

Grid electricity does not include embodied emissions in CORSIA

Embodied carbon based on current U.S. values from GREET

Electricity accounting and **sourcing**

Electricity sourcing and tracing is not possible using physical tracing (used for biogenic feedstocks) for facilities connected to the grid

Electricity sourcing will have to rely on **factual (no grid connection) or contractual (grid connection) sourcing arrangements** for a specific CEF production facility

Similar considerations as for RFNBOs in the EU.

Potential dimensions of electricity sourcing

Connectedness	*Proof of physical connection between CEF production facility and power generation (incl. sufficient capacity?)*
Temporal matching	• *On what time scale do the contractual sourcing arrangements have to match the electricity demand of the CEF production facility (e.g. hourly, monthly, annual)?*
Additionality	*Can CEF producers leverage existing power generation resources or proof use of new capacity?*

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2. **Carbon accounting and sourcing**
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Potential carbon cycles

Fossil

Fossil crude oil, subsequently refined to Jet A.

Biogenic

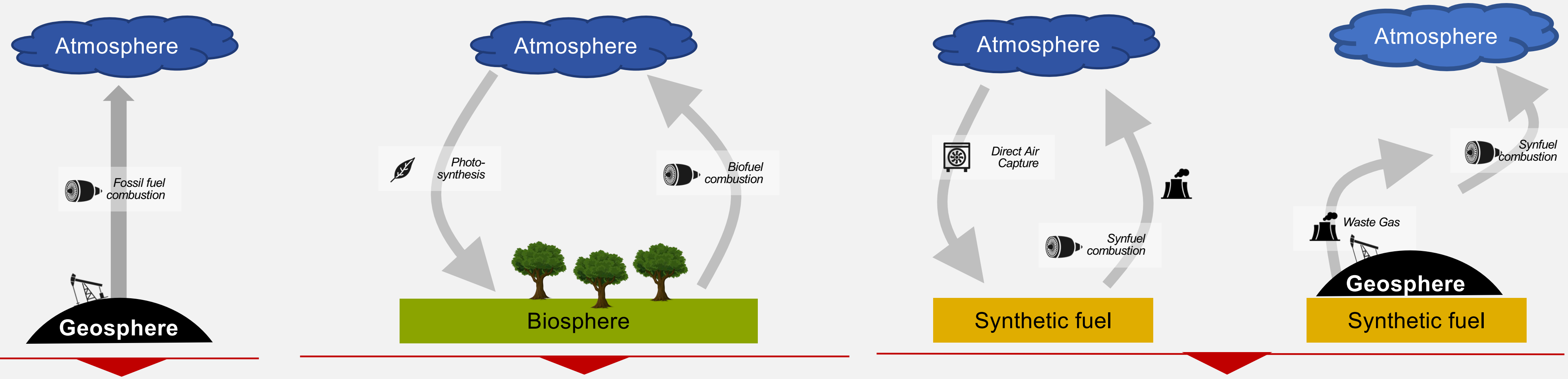
Carbon sourced from biomass (e.g., energy crops, biogenic wastes and by-products etc.)

Atmospheric C

Carbon captured directly from the atmosphere

"Waste" carbon streams

Carbon "re-used" for SAF production.



Under current method:
Combustion emissions counted. ✓

Under current method:
Biogenic CO_2 emissions from fuel combustion are excluded from the calculation of CO_2e emissions. ✓

Under current method: *"Only" biogenic CO_2 emissions are excluded*
Revisions needed: *Fuels made from C captured directly from the atmosphere not associated with combustion CO_2 or from directly reused emitted industrial carbon.* ⚠

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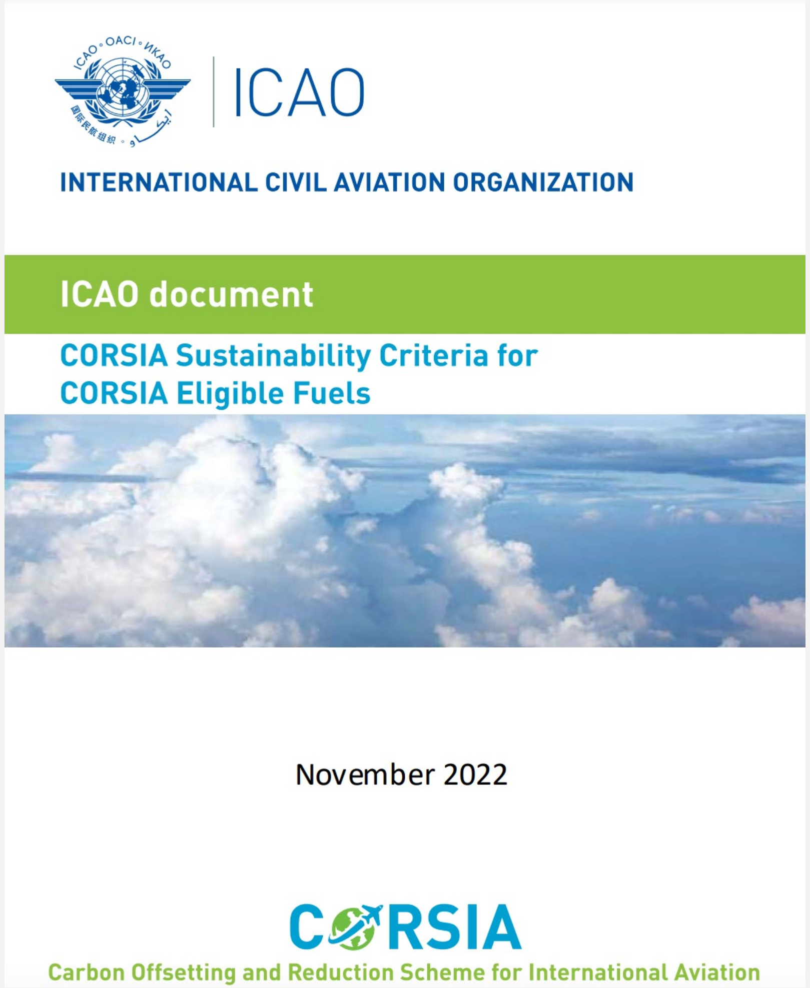
PtL-related development needs for sustainability criteria



- The CORSIA sustainability criteria for SAF focus on (biomass) feedstock production and feedstock conversion, in particular.
- **There are currently no sustainability provisions that apply to electricity production within CORSIA**.
- For PtL fuels that require large amounts of electricity, is an extension of the applicability of sustainability criteria to electricity generation needed? **What about potential land-use issues of solar-powered PV, for example?**

Some relevant papers

- Prussi, M., Lee, U., Wang, M., Malina, R., Valin, H., Taheripour, F., Velarde, C., Staples, M.D., Lonza, L. and Hileman, J.I., 2021. CORSIA: The first internationally adopted approach to calculate life-cycle GHG emissions for aviation fuels. *Renewable and Sustainable Energy Reviews*, 150, p.111398.

- Malina, R., Abate, M.A., Schlumberger, C.E. and Pineda, F.N., 2022. The role of sustainable aviation fuels in decarbonizing air transport. World Bank Flagship Report. Washington, DC.

- Staples, M.D., Malina, R. and Barrett, S.R., 2017. The limits of bioenergy for mitigating global life-cycle greenhouse gas emissions from fossil fuels. *Nature Energy, 2(2*), pp.1-8.

- Staples, M. D., R. Malina, P. Suresh, J. I. Hileman, and S. R. Barrett. 2018. Aviation CO2 Emissions Reductions from the Use of Alternative Jet Fuels. *Energy Policy* 114 (March): 342–54.

- Wang, J., M. D. Staples, W. Tyner, W. Zhao, R. Malina, H. Olcay, F. Allroggen, and S. Barrett. 2021. Quantitative Policy Analysis for Sustainable Aviation Fuel Production Technologies. *Frontiers in Energy Researc*h December: 751722.

- Seber, G., Escobar, N., Valin, H. and Malina, R., 2022. Uncertainty in life cycle greenhouse gas emissions of sustainable aviation fuels from vegetable oils. *Renewable and Sustainable Energy Reviews*, 170, p.112945.

- Winchester, N., Malina, R., Staples, M.D. and Barrett, S.R., 2015. The impact of advanced biofuels on aviation emissions and operations in the US. *Energy Economics*, 49, pp.482-491.

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Thank you for your attention!

June 19, 2024

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