Supplementary Information

Prospective life-cycle assessment of CORSIA Sustainable Aviation Fuels under evolving electricity and hydrogen carbon intensities

Uisung Lee[1], Matteo Prussi[2*], Alessandro Martulli[3], Michael Wang[1], Robert Malina[3]

[1] Life Cycle Analysis Group, Energy Systems and Infrastructure Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Lemont, 60439, IL, United States.

[2] Department of Energy (DENERG), Politecnico di Torino, C.so Duca degli Abruzzi, Turin, 10129, Italy.

[3] Centre for Environmental Sciences (CMK), Hasselt University, Diepenbeek, Belgium.

*Corresponding author's e-mail: matteo.prussi@polito.it;

S1. Key modeling settings and scenario inputs

This Supplementary Information (SI) summarizes the key modeling conditions used in Argonne R&D GREET® 2023 Rev1 for the selected pathways, and documents all non-default assumptions and parameter overrides relative to GREET defaults applied in this study. To avoid duplication, numerical values already reported in the main manuscript (e.g., Figure 2) are referenced rather than repeated. Unless otherwise noted, all other parameters were kept at R&D GREET default values for the selected pathways.

- Model: Argonne R&D GREET® 2023 Rev1 [S1].
- Co-product handling: Energy allocation at a process level (consistent with the International Civil Aviation Organization [ICAO] Carbon Offsetting and Reduction Scheme for International Aviation [CORSIA] life-cycle assessment [LCA] methodology) [S2].
- Global warming potential (GWP): Greenhouse gases were characterized using Intergovernmental Panel on Climate Change (IPCC) AR5 (5^{th} assessment report) 100-year global warming potential (GWP100) values (consistent with ICAO CORSIA) [S3]. Hydrogen indirect warming effect is excluded.

Regional electricity cases (Figure 3): Grid electricity CI was set to the regional 2022 electricity carbon intensity (CI) values (from GREET+ [S4] (

- Table S1).
- Prospective electricity and hydrogen CIs (Figures 2 and 4): Electricity CI and hydrogen CI were updated over time following the scenario trajectories shown in Figure 2 (as described in Section 3.3), with values between anchor years determined via linear interpolation.
- System boundary: Fuel-cycle boundary; infrastructure/embodied emissions (e.g., manufacturing of power plants, wind/solar equipment, electrolyzers) are excluded.
- Induced land use change (ILUC) impact: Excluded (see Section 3.1).

Facility-level mitigation cases (Figure 5): Mitigation cases were implemented as input CI substitutions (electricity, hydrogen, and/or process heat) and/or addition of carbon capture and sequestration (CCS) at the ethanol plant, without changing process yields. Key assumptions and implementation details are summarized in

- Table S2.

Table S1. Appendix A Grid emissions per country [4]

Country / Region	CI (gCO_2e/kWh)	CI (gCO_2e/MJ)
Canada	154	43
Mexico	589	164
Brazil	138	38
Central/South America A	385	107
Central/South America B	410	114
EU	283	79
China	699	194
India	1000	278
Japan	625	174
Korea	570	158
Southeast Asia/Oceania	797	221
Middle East/North Africa	839	233
Central/South Africa	832	231
United Kingdom	256	71
Norway	6.3	2

Table S2. Key assumptions for facility-level mitigation cases used for Figure 5 (relative to baseline)

Mitigation option	Changes	Notes
Renewable electricity	Electricity CI set to 0 for the targeted unit process	Electricity demand and yields unchanged
Renewable hydrogen	Hydrogen CI set to 0 for the targeted unit process	H_2 demand and yields unchanged
Waste heat utilization	Process heat from fossil NG displaced by waste heat with CI = 0	Implemented as heat-supply substitution; yields unchanged
CCS at ethanol plant	Fermentation CO_2 captured and sequestered; electricity use added	CCS electricity uses the same scenario-year grid CI; CCS benefit allocated by energy allocation between ethanol and distillers grains with solubles (DGS) (see Section 3.4)

References

[S1] Argonne National Laboratory: GREET Model (R&D Version 2023) [Computer software]. https://greet.es.anl.gov/. Accessed September 8, 2025 (2023)

[S2] International Civil Aviation Organization (ICAO): CORSIA Supporting Document: CORSIA Eligible Fuels – Life Cycle Assessment Methodology (2022). https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/CORSIA_Supporting_Document_CORSIA%20Eligible%20Fuels_LCA_Methodology_V5.pdf

[S3] Intergovernmental Panel on Climate Change (IPCC): Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA (2013). https://www.ipcc.ch/report/ar5/wg1/

[S4] Lu, Z., Wang, M.: Greet+ model 2024 (2024) https://doi.org/10.11578/GREET-PLUS-2024/DC.20241105.1 . Accessed September 8, 2025