BRIEFING

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Drawbacks of adopting a “similar” LCA methodology for U.S. sustainable aviation fuel (SAF)

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INTRODUCTION

The Biden administration’s Sustainable Aviation Fuel (SAF) Grand Challenge calls for vastly expanding domestic production of SAF to 3 billion gallons per year in 2030 and to 100% of aviation fuel demand—an estimated 35 billion gallons per year—in 2050.[1] At present, the primary policy lever to meet these targets is a provision in the Inflation Reduction Act (IRA) that grants tax credits of up to $1.75 per gallon for SAF sold or used in 2023 or 2024. Between 2025 and 2027, SAF is eligible for up to $1.75 per gallon from another tax credit that applies to all “drop-in” liquid hydrocarbon fuels. To qualify for these credits, an alternative aviation fuel must be associated with 50% fewer greenhouse gas (GHG) emissions over its life cycle than conventional, petroleum-based jet fuel. However, the 50% GHG reduction threshold is only as robust as the methods and data used to measure it. More than a year after the IRA was passed, the administration has yet to decide upon the methodology or methodologies that may be used to determine which SAFs will count toward the Grand Challenge and receive valuable financial support.

The IRA states that a fuel’s reduction in GHG emissions is to be defined and certified by the Treasury Department in accordance with standards adopted by the International

1 U.S. Department of Energy, U.S. Department of Transportation, and U.S. Department of Agriculture, “Memorandum of Understanding Sustainable Aviation Fuel Grand Challenge,” September 8, 2021, https://www.energy.gov/sites/default/files/2021-09/S1-Signed-SAF-MOU-9-08-21_0.pdf.

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THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Civil Aviation Organization (ICAO) for the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) or "any similar methodology" that satisfies criteria in the Clean Air Act.[2] It is now up to the U.S. Treasury Department and the Internal Revenue Service (IRS) to determine whether any other GHG accounting methods are similar to those used in ICAO's CORSIA and thus could also be used to qualify for tax credits. The decision will profoundly impact the types of SAFs that receive subsidies. Some stakeholders have argued that the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) methodology is sufficiently similar to ICAO's CORSIA model and could be used to determine eligibility for the IRA's tax credits.[3] But there are key differences in the life-cycle emissions calculated using the CORSIA life-cycle assessment (LCA) methodology and the GREET model that appears to be preferred by many in the aviation biofuel industry. The largest differences between these methodologies come from how they estimate the indirect emissions attributable to biofuel policy, particularly on emissions from indirect land-use changes (ILUC) triggered when more acres are put into biofuel production. Regulators calculate these indirect emissions as a way to assess all the unintended risks associated with biofuel policies and increased biofuel demand.

As defined in the Clean Air Act,[4] life-cycle GHG emissions include direct emissions and "significant" indirect emission impacts. Estimating direct emissions is more straightforward than it is for indirect emissions. There is substantial precedent for using flexible supply chain LCA models to estimate the direct, process-based emissions for fuel facilities that have site-specific yields, energy intensities, and inputs. LCA models such as the GREET model, run by the U.S. Department of Energy's Argonne National Laboratory, or the BioGrace model, funded by the European Union, have been used to estimate direct emissions across the entire supply chain for individual fuel producers. Producers of transportation fuels in California use a customized version of GREET to estimate and report their own facility-specific emissions as part of the state's Low Carbon Fuel Standard (LCFS) program. CORSIA also grants fuel producers flexibility in estimating their direct supply chain emissions; producers can choose from a selection of default values for select SAF pathways or submit their own project-level inputs if their process has lower emissions than the default values.[5]

But GREET and CORSIA differ widely in their estimates of indirect emissions. Figure 1 illustrates three separate models used to calculate life-cycle emissions: (1) a supply chain LCA model to calculate direct emissions; (2) an economic model to assess shifts in land use in response to biofuel demand; and (3) an emission factor model to translate how those shifts in land use may affect the amount of GHG emissions being released.

2 Inflation Reduction Act of 2022, Pub. Law No. 117-169, 136 Stat. 1818 (2022) https://www.congress.gov/117/plaws/publ169/PLAW-117publ169.pdf.

3 Airlines for America, "Airlines for America Comments in Response to Notice 2023-06, Request for Comments on Sustainable Aviation Fuel Credit; Registration; Certificates," February 17, 2023; American Petroleum Institute, "API Comments on Sustainable Aviation Fuel Credit; Registration; Certificates; Request for Public Comments (Notice 2023-06)," February 17, 2023; National Corn Growers Association, "NCGA Letter to Janet L. Yellen," September 7, 2023, https://dt176nijwh14e.cloudfront.net/file/625/NCGA%20LTTR%20TO%20YELLEN.pdf; United States Senate, "Senate Treasury Letter Re: IRA Section 40B," June 16, 2023, https://growthenergy.org/wp-content/uploads/2023/06/2023.06.16-Senate-Treasury-Letter-re-IRC-Section-40B-SAF.pdf.

4 42 U.S. Code § 7545(o)(1)(h)

5 International Civil Aviation Organization, "CORSIA Methodology for Calculating Actual Life Cycle Emissions Values," November 2019, https://www.icao.int/environmental-protection/CORSIA/Documents/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions.pdf.

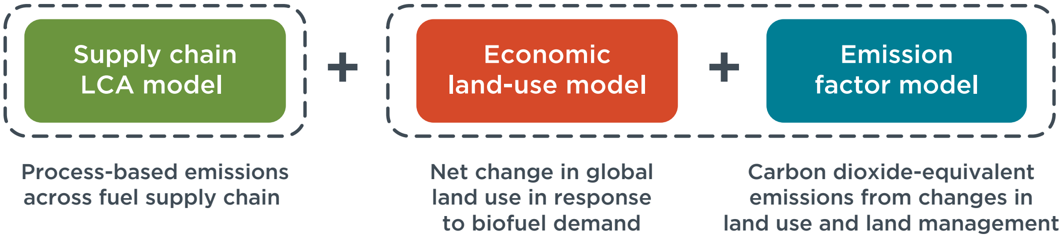

Figure 1. Standard biofuel LCA modeling framework

We summarize the underlying structures and list the discrete models used in both GREET and CORSIA in Table 1. Understanding the structural differences between these two assessment frameworks is key to evaluating their suitability for setting the SAF eligibility threshold in the IRA.

Table 1. Life-cycle modeling in GREET and CORSIA

Type of model	GREET methodology	CORSIA methodology
Supply chain LCA model	GREET *or* project-specific values	Various default *or* project-specific values
Economic land-use model	Global Trade Analysis Project (GTAP-BIO)	Harmonized results from GTAP-BIO and Global Biosphere Management Model (GLOBIOM)
Emission factor model	Carbon Calculator for Land Use and Land Management Change from Biofuels Production (CCLUB)	Agro-ecological Zone Emission Factor model (AEZ-EF)

THE TREATMENT OF ILUC EMISSIONS DIFFERS SUBSTANTIALLY

GREET was designed as an “all-in-one” user interface. It applies its own supply chain model when estimating direct emissions and includes other models for estimating ILUC and the resulting changes in emissions. **Any flaws and/or oversights in the other models are thus also present in GREET**. Both the ILUC and emission factor models cited within GREET have previously been the subject of significant academic debate,[6] and we detail some of this below.

For indirect land-use changes, GREET uses results from the Global Trade Analysis Project’s GTAP-BIO model developed from 2011 to 2013. The run of the GTAP-BIO model cited within GREET analyzes the effect of the U.S. Environmental Protection Agency’s (EPA) Renewable Fuel Standard (RFS), which sets volume targets for alternative road-based transportation fuels, on land use. The cited estimates in GTAP-BIO are significantly lower than the ILUC emissions modeled for previous regulatory

6 Chris Malins and Stephanie Searle, “A Critique of Lifecycle Emissions Modeling in ‘The Greenhouse Gas Benefits of Corn Ethanol—Assessing Recent Evidence’” (Washington, D.C.: ICCT, 2019), https://theicct.org/publication/a-critique-of-lifecycle-emissions-modeling-in-the-greenhouse-gas-benefits-of-corn-ethanol-assessing-recent-evidence/.

assessments for the RFS,[7] California's LCFS,[8] and CORSIA.[9] GREET's use of a single ILUC model, GTAP-BIO, is also not reflective of the continued uncertainty in calculating ILUC emissions within the scientific modeling community.[10]

A key criticism of the GTAP-BIO results cited within GREET is that they contrast with real-world evidence by estimating that some land types sequester rather than release carbon when converted to cropland. This is due to the model's assumption that cropland expansion is likeliest to occur onto "cropland pasture," defined as land that shifted from pastureland to cropland before 1975.[11] This is inconsistent with the definitions used by the EPA and other sources, which define cropland pasture as land that is currently in a pasture state.[12] Further, recent changes to the GTAP-BIO model result in most domestic cropland expansion shifting onto cropland pasture, rather than onto carbon-rich pastureland or forestland, and this further underestimates ILUC emissions.[13] GTAP-BIO has also been criticized for assumptions around the conversion of unmanaged forests to cropland, high rates of yield intensification, and the harvesting of more than one crop each year on the same land, rather than expanding the number of acres planted.[14] The ICCT previously discussed these critiques.[15]

In contrast, ILUC emissions estimated for use within CORSIA are more like those previously estimated through the regulatory analyses developed for the RFS and California LCFS. Recognizing that there is a large variation across models and studies, ICAO undertook a collaborative and transparent stakeholder process to estimate the impact of additional biofuel demand from the aviation sector. Two independent teams—one working with the GTAP-BIO model and the other with the Global Biosphere Management Model (GLOBIOM)—estimated default ILUC emissions for SAF. ICAO's ILUC assessment incorporates and harmonizes the results from the two teams, an approach that can help reduce methodological uncertainty.[16]

7 Environmental Protection Agency, "Regulation of Fuels and Fuel Additives: Changes to the Renewable Fuel Standard Program; Notice of Proposed Rulemaking," 74 Fed. Reg. 24904 (May 26, 2009), https://www.govinfo.gov/content/pkg/FR-2009-05-26/pdf/E9-10978.pdf.

8 California Air Resources Board, "Detailed Analysis for Indirect Land Use Change," January 2015, https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/iluc_assessment/iluc_analysis.pdf.

9 International Civil Aviation Organization, "CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels," June 2022. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2006%20-%20Default%20Life%20Cycle%20Emissions%20-%20June%202022.pdf.

10 Vassilis Daioglou et al., "Progress and Barriers in Understanding and Preventing Indirect Land-Use Change," *Biofuels, Bioproducts and Biorefining*, (June 27, 2020), https://doi.org/10.1002/bbb.2124

11 Chris Malins, Richard Plevin, and Robert Edwards, "How Robust Are Reductions in Modeled Estimates from GTAP-BIO of the Indirect Land Use Change Induced by Conventional Biofuels?" *Journal of Cleaner Production*, 258 (June 10, 2020): 120716, https://doi.org/10.1016/j.jclepro.2020.120716.

12 EPA defines cropland pasture as "managed pasture land used for livestock production, but which can also be converted to cropland production" in its RFS2 Regulatory Impact Analysis.

13 Farzad Taheripour, Hao Cui, and Wallace E. Tyner, "An Exploration of Agricultural Land Use Change at the Intensive and Extensive Margins: Implications for Biofuels Induced Land Use Change," in *Bioenergy and Land Use Change* (Washington, DC: American Geophysical Union and Hoboken, NJ: John Wiley & Sons, Inc., 2018).

14 Malins, Plevin, and Edwards, "How Robust Are Reductions in Modeled Estimates."

15 Malins and Searle, "A Critique of Lifecycle Emissions Modeling."

16 National Academies of Sciences, Engineering and Medicine, "Current Methods for Life Cycle Analyses of Low-Carbon Transportation Fuels in the United States," (Washington, DC: National Academies Press, 2022), https://doi.org/10.17226/26402.

THE IMPACT OF DIFFERENT EMISSION FACTOR MODELS

Another key reason for the greater consistency between the ICAO CORSIA results for indirect emissions and previous regulatory assessments is ICAO's choice of underlying emission model, the Agro-ecological Zone Emission Factor (AEZ-EF), which is the same one used by the California Air Resources Board. The GREET methodology instead uses the Carbon Calculator for Land Use and Land Management Change from Biofuels Production (CCLUB). The AEZ-EF model draws upon measured carbon stock levels for different combinations of region and land categories and estimates a decline in carbon stocks when cropland pasture is converted into dedicated cropland. Conversely, CCLUB generally estimates an increase in carbon stocks from the conversion of cropland pasture to cultivated cropland. This specific methodological difference drives a large share of the differences between the ILUC emissions cited within GREET and those estimated by ICAO for use in CORSIA. Figure 2 shows the ILUC results for corn ethanol and soy biodiesel from the most recent GREET model relative to those models adopted under CORSIA, the RFS2, and California LCFS.

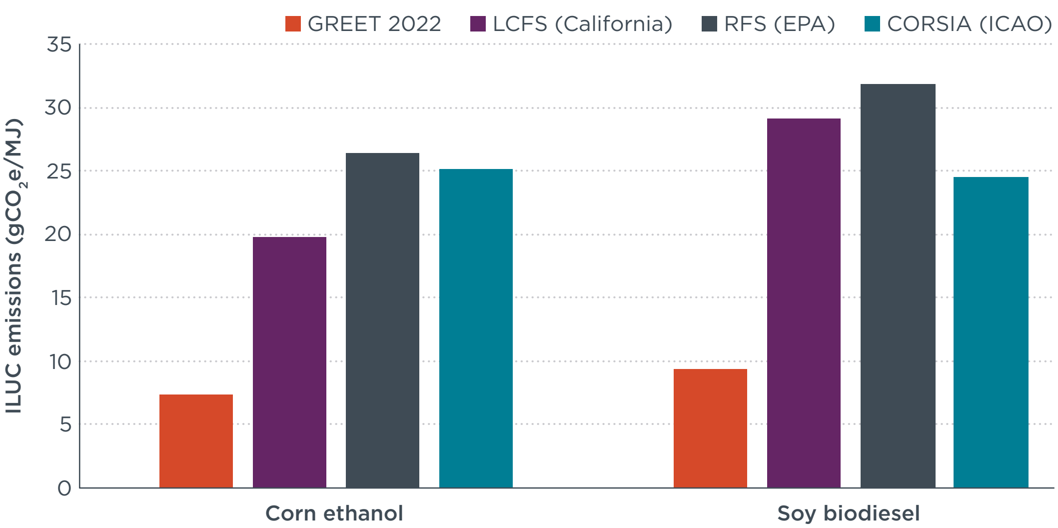

Figure 2. Emissions attributable to indirect land use changes from growing corn for ethanol and soy for biodiesel, as estimated by GREET 2022 and models used in California, U.S., and international standards

TREATMENT OF OFFSETS FROM SOIL ORGANIC CARBON MANAGEMENT

GREET can be configured to assess the change in a soil's carbon content—known as soil organic carbon or SOC—from agricultural practices at the project level. Credits or offsets from direct emissions may be calculated for practices including crop tillage, cover cropping, and manure management. GREET estimates SOC changes using CCLUB. Within CCLUB, projections for the change in carbon stock per hectare of land are based on regional soil data. To assign SOC changes over time to a given fuel, GREET estimates the change in SOC over 30 years and then attributes that unit of change to fuel produced in the present day. CORSIA does not provide an option for including changes in SOC in its direct LCA methodology.

If the Treasury Department approves an LCA methodology for the IRA that includes credits from soil carbon management, the system would be similar to carbon offset programs that reward changes in behavior without the safeguards traditionally associated with such programs. These safeguards include protections to ensure a proper baseline, the permanence of the sequestered carbon, and additionality; the latter means the reductions in carbon must be in addition to what would have happened without the offset. SOC credits are difficult to verify at the farm level and may be reflective of existing land-management practices. For example, no-till systems were already used on 37% of U.S. cropland acres in 2017.[17] Additionally, different systems for field management and different crops have significantly variable effects on annual SOC content, and this increases uncertainty when attempting to select a baseline year.

The science around the permanence of SOC changes and how to translate these effects into policymaking is not well understood.[18] Assumptions that SOC practices must be maintained indefinitely to avoid reversal or that agricultural practices such as tillage result in significant losses in soil carbon conflict with the intrinsic complexity of soil carbon mechanics.[19] The ability to monitor soil carbon stocks over long time frames and at various depths also presents challenges for quantifying SOC changes as a carbon offset. It remains unclear whether the Treasury Department has the capacity to verify SOC credits using measurement, reporting, and verification (MRV) tools or if these changes will be modeled and applied uniformly across variable land types.

CORSIA IS FLEXIBLE AND NOT OUTDATED

Some have criticized the CORSIA approach and its default values by arguing that life-cycle inventory data and methods used to assess biofuels are outdated and that recent data suggest improvements in GHG emissions.[20] In particular, there are claims that CORSIA's LCA of corn ethanol, which can be upgraded into jet fuel, is outdated. This argument overlooks the option in CORSIA to develop project-specific LCA values for a fuel pathway's direct emissions. Aviation fuel producers able to demonstrate that their processes have supply chain emissions that are lower than the default LCA value can submit documentation to calculate an updated carbon intensity value under CORSIA's actual life-cycle methodology guidance.[21] CORSIA's flexibility allows users to choose from several different models to conduct the estimates of direct emissions. For example, Argonne National Laboratory has developed a standalone version of its GREET model to assist with conducting a project-specific LCA.[22]

Note, too, that the majority of the estimated declines in emissions for corn ethanol come from changes to ILUC emissions; these analyses include a 2018 paper written by consulting firm ICF that was commissioned by the U.S. Department of

17 Carl Zulauf and Ben Brown. "Tillage Practices, 2017 US Census of Agriculture." farmdoc daily (9):136, Department of Agriculture and Consumer Economics, University of Illinois at Urbana-Champaign, July 25, 2019. https://farmdocdaily.illinois.edu/2019/07/tillage-practices-2017-us-census-of-agriculture.html.

18 Katherine A. Dynarski, Deborah A. Bossio, and Kate M. Scow, "Dynamic Stability of Soil Carbon: Reassessing the 'Permanence' of Soil Carbon Sequestration," *Frontiers in Environmental Science* 8 (November 13, 2020), https://www.frontiersin.org/articles/10.3389/fenvs.2020.514701.

19 Dynarski, Bossio, and Scow, "Dynamic Stability of Soil Carbon."

20 American Farm Bureau Federation et al., "Congressional SAF Letter," August 6, 2021, https://growthenergy.org/wp-content/uploads/2021/08/Ag-and-Biofuels-Congressional-SAF-Letter_FINAL.pdf.

21 ICAO, "CORSIA Methodology

22 Uisung Lee et al., "GREET Aviation Module Instruction Manual," (Argonne National Laboratory, March 2022).

Agriculture[23] and a subsequent journal article published by the same research team.[24] In 2021, another paper suggested that the LCAs for corn ethanol from regulations such as the RFS and California LCFS are overestimated; this team estimated that the total LCA value for corn ethanol was equivalent to 51.4 grams of carbon dioxide per megajoule (gCO_2e/MJ).[25]

The proposed LCA values for crop-based fuel pathways in GREET are among the lowest across the literature and across regulatory assessments. Figure 3 shows the life-cycle GHG emissions for corn ethanol-to-jet (ETJ) in GREET 2022—which includes SOC crediting for on-farm management practices using GREET's Feedstock Carbon Intensity Calculator (FD-CIC)[26]—relative to CORSIA and to EPA's RFS. The EPA conducted an in-depth regulatory impact analysis (RIA) in 2010 and found that corn ethanol would generate life-cycle emissions of 73.3 gCO_2e/MJ in 2022.[27] This includes 46.2 gCO_2e/MJ in direct, process-based emissions. Because the RFS assessment was conducted for the road sector, an emission factor of 9 gCO_2e/MJ was added to the direct emissions shown in the figure to account for emissions from ethanol-to-jet upgrading.

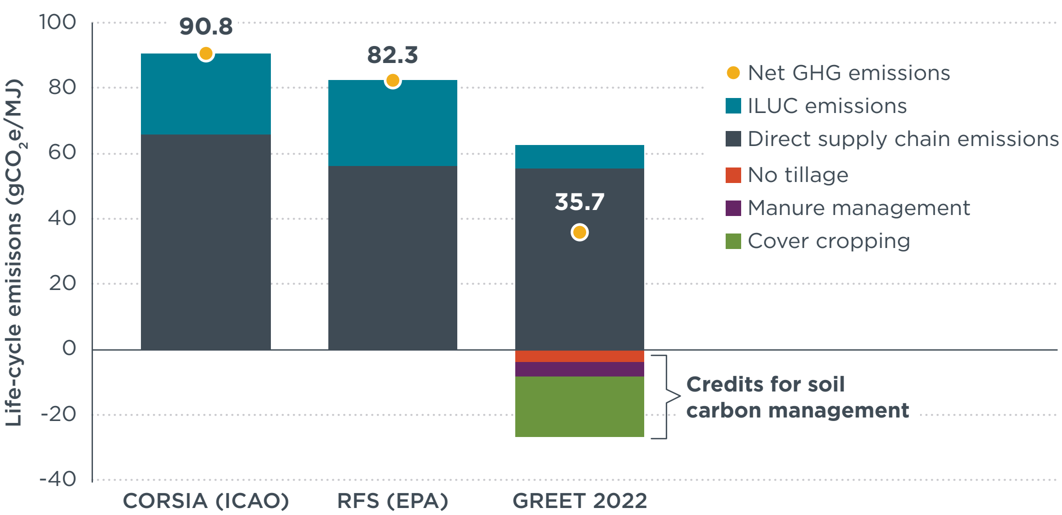

Figure 3. Life-cycle emissions estimates for corn ethanol-to-jet

As shown in the brown bars, the supply chain LCA emissions used in GREET and CORSIA are closely aligned. However, emissions from ILUC and SOC credits from land-management practices differ widely across models. This is due to the underlying assumptions in GTAP-BIO and CCLUB discussed above. Because these cannot be easily verified by regulators like the Treasury Department or easily demonstrated by producers, the use of GREET would widely diverge from the CORSIA approach and existing U.S. fuel policies. Adopting GREET as a "similar" LCA methodology for SAFs in the IRA could incentivize fuel pathways with uncertain GHG reduction benefits.

23 J. Rosenfeld et al., "A Life-Cycle Analysis of the Greenhouse Gas Emissions from Corn-Based Ethanol," Report prepared by ICF under USDA Contract No. AG-3142-D-17-0161, September 5, 2018, https://www.usda.gov/sites/default/files/documents/LCA_of_Corn_Ethanol_2018_Report.pdf.

24 Jan Lewandrowski et al., "The Greenhouse Gas Benefits of Corn Ethanol – Assessing Recent Evidence," *Biofuels* 11, no. 3 (2020): 362, https://doi.org/10.1080/17597269.2018.1546488.

25 Melissa J Scully et al., "Carbon Intensity of Corn Ethanol in the United States: State of the Science," *Environmental Research Letters* 16, no. 4 (April 1, 2021): 043001, https://doi.org/10.1088/1748-9326/abde08.

26 Xinyu Liu, Hoyoung Kwon, and Michael Wang, "Feedstock Carbon Intensity Calculator (FD-CIC) Users' Manual and Technical Documentation," U.S. Department of Energy Office of Scientific and Technical Information, 2021, https://www.osti.gov/servlets/purl/1823646.

27 U.S. Environmental Protection Agency, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis," February 2010, https://nepis.epa.gov/Exe/ZyPDF.cgi/P1006DXP.PDF?Dockey=P1006DXP.PDF.