Ability of Low Carbon Intensity Corn for SAF to Serve Global Markets

Presented at: 2024 ISCC NATC Meeting

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Chicago, IL
November 2024

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Presentation Overview

- Quick Review: Life Cycle Greenhouse Gas Modeling of Biofuels Pathways
- Corn Ethanol to Jet Opportunities under CORSIA
  - New Study on US Corn Ethanol Carbon Intensities under CORSIA
  - New Publications on Induced Land Use Change

Quick Review: LCA of Biofuels Pathways

Greenhouse gases, Regulated Emissions, and Energy use in Technologies

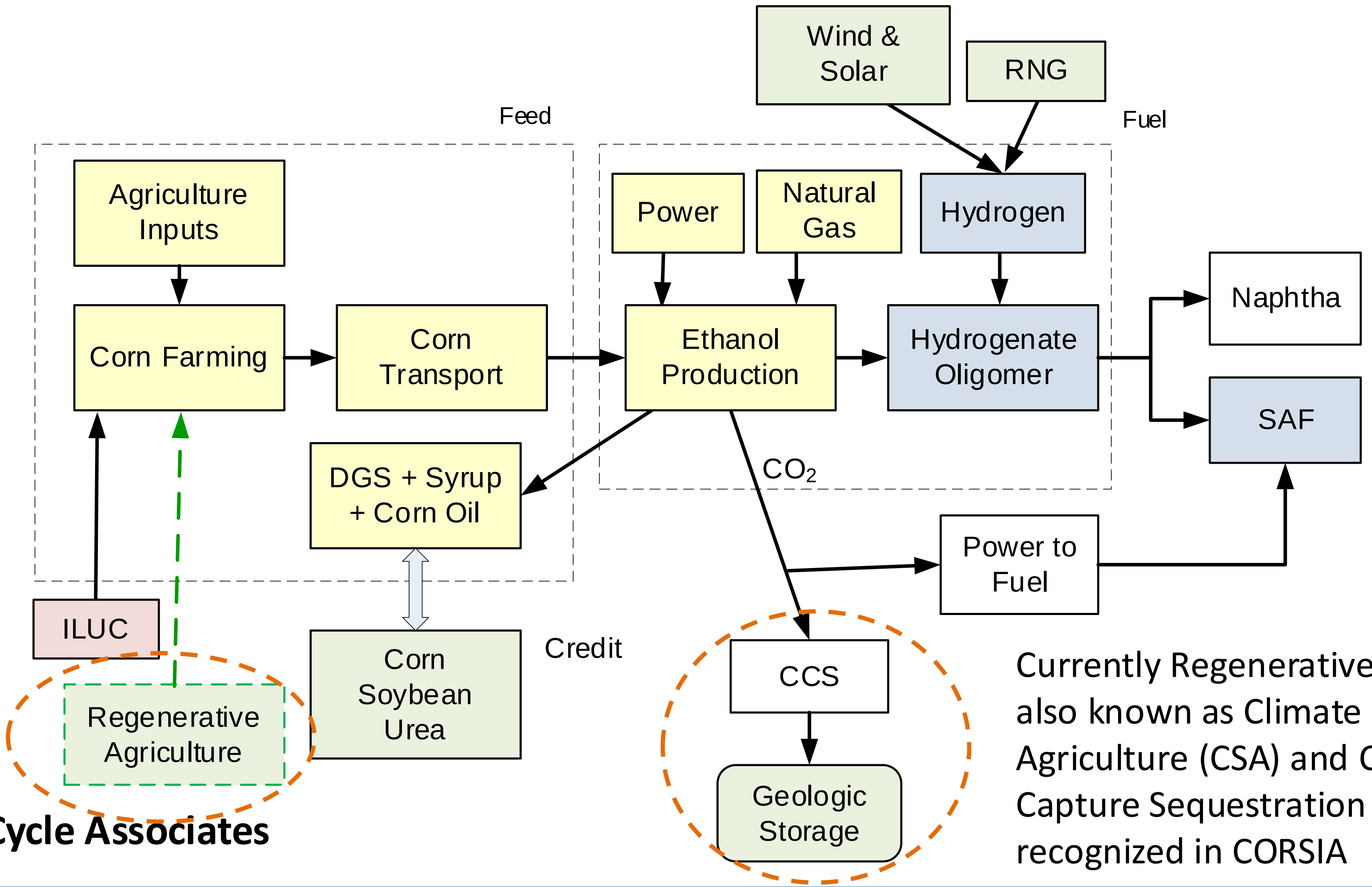
- Life cycle analysis (LCA) is a framework for assessing the environmental impacts associated with all stages of the supply chain of a technology or product
- For transportation, a main LCA metric is the Carbon Intensity (CI) or “gCO2e emitted per megajoule” of the produced fuel (e.g. ethanol, ETBE, blended fuels such as E10, E!5, SAF)
- Important LCA model in the United States and increasingly globally: The U.S. Department of Energy’s Argonne National Laboratory GREET® (Greenhouse gases, Regulated Emissions, and Energy use in Technologies) life cycle analysis (LCA) model
- Emissions along the fuel’s production pathway are added up including:
  - Main product emissions with credits for co-products
  - Emissions from direct and indirect effects
- Ethanol to jet pathway = emissions from ethanol production + emissions from conversion of ethanol into jet fuel + emissions from induced land use change (iLUC)

LCA Modeling:
Corn to Ethanol and Ethanol to SAF

Emissions along the fuel's production pathway are added up including:

- Main product and co-product
- Direct and indirect effects

<u>iLUC or induced land use change is highly debated indirect effect. Accounts for emissions associated with land use responses from a biofuels policy</u>



Currently Regenerative Agriculture also known as Climate Smart Agriculture (CSA) and Carbon Capture Sequestration (CCS) are not recognized in CORSIA

Source: Life Cycle Associates

Main Drivers of Differences in Biofuel Carbon Score

- Carbon score unit is grams CO_2 emitted per megajoule of fuel (gCO_2/MJ)
  - Petroleum based aviation fuels have carbon score between 84-89 gCO_2/MJ
  - Ethanol-to-Jet or Soy-to-Jet can be much lower depending on production method
- Key Drivers of Carbon Score for Biofuels/SAF
  - How the crop feedstock is grown. Opportunities to reduce carbon score via Climate Smart Agriculture (CSA)
    - E.g. Cover crops, optimized nitrogen use, conservation tillage, N-inhibitors
  - How Corn is Converted into Ethanol:
    - Carbon Capture Sequestration & Utilization (CCSU) of fermentation CO_2 at the ethanol plant
    - Drying of animal feed co-product (dried distillers grains - DDG) or not drying (wet distiller grains – WDG)
  - Updates to induced land use change (iLUC) modeling
    - Updated GTAP/Purdue University iLUC model

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Example CI Values

Note: For Illustration Only; Do not Cite or Reference

Pathway	gCO_2e/MJ	Notes
Petroleum Based Gasoline and Jet Fuel	88-110	Depending on Crude Oil Source & Refinery Type
US Produced Corn Ethanol Feedstock	~ 15-65 (45 current average)	Depending on Ethanol Plant, CCSU, Corn Agriculture etc.
Upgrade of Ethanol into Jet	add ~ 10-30	Depending on Technology
Induced Land Use Change for ETJ	11-25	Depending on Model and Amortization Period

Corn Ethanol to Jet Opportunities under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

Current US Corn Ethanol to Jet under CORSIA

Core LCA (ethanol + Upgrade to SAF)	+	Induced Land Use Change	=	Life Cycle Emissions Factor LSF
65.7 gCO_2e/MJ	+	25.1 gCO_2e/MJ	=	90.8 gCO_2e/MJ

For US Corn Ethanol to Jet Pathway:

- Conversion Efficiencies (Core LCA) are Dramatically Improving
- Updates to high iLUC value are in progress

ICAO document

CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels

Recent US Corn Ethanol CI Study

- An independent study conducted by MEO Carbon Solutions (affiliated with ISCC) and the University of Illinois at Chicago
- Study Question: Can corn ethanol provide High Volumes of SAF that the World Aviation Sector needs.
- **Study Objective:** Using certified volumes of US ethanol shipments as feedstock, determine if SAF produced by the Alcohol to Jet pathway would achieve a sufficient CI reduction, as compared to petroleum Jet Fuel, to qualify for CORSIA offsets
  - Study utilizes public CI data from plants with existing ethanol shipments into the California Low Carbon Fuels Standard market
  - New Study uses up-to-date data on US Ethanol CI and up to date data on conversion technologies for ethanol to jet production
- Represents up to 4 billion gallons of certified name plate capacity
- Note: actual deliveries into CA are lower at around 1.3 billion gallon

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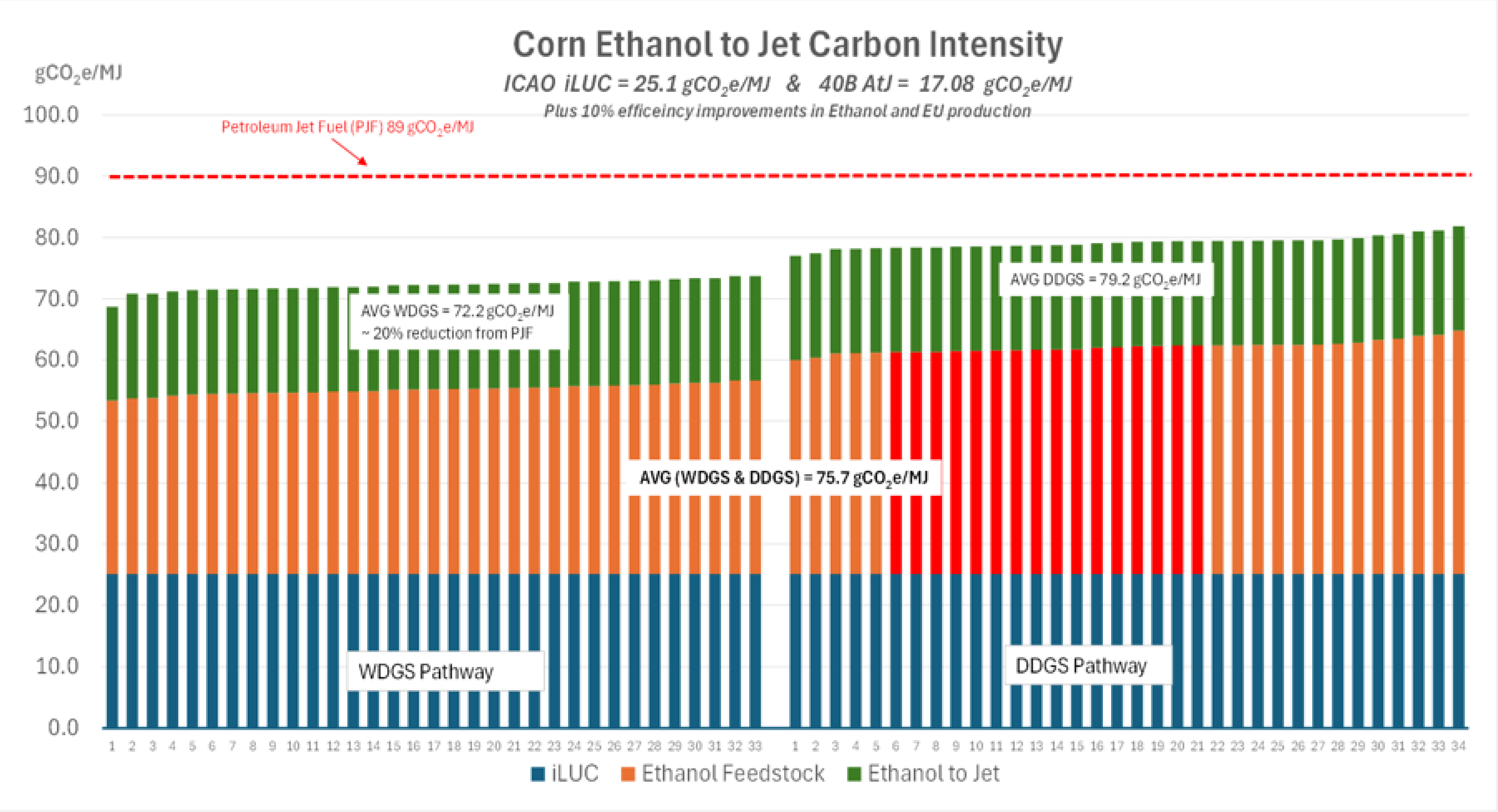
Key Results

- If corn ethanol plants currently delivering ethanol into CA LCFS were to produce SAF under CORSIA using latest SAF technologies, all SAF would easily meet 10% CORSIA GHG reduction requirement.
- Note: this includes CORSIA iLUC of 25.1 gCO_2/MJ



New Publications on Induced Land Use Change

What is the message?

iLUC Science is Evolving

sustainability

MDPI

Article

Biofuels Induced Land Use Change Emissions: The Role of Implemented Land Use Emission Factors

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Author Contributions: Conceptualization, F.T. and S.M.; methodology, F.T., S.M. and M.W.; results, all authors; analysis, all authors; writing, all authors. All authors have read and agreed to the published version of the manuscript.

Funding: This study received financial support from the United States Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, ASCENT project 01 through the FAA Award (number 13-C-AJFEPU) under the supervision of A. Oldani and P. Lobo.

Table 3. Estimated ILUC emissions values for various SAF pathways using different emissions accounting models for 25- and 30-year amortization time periods (gCO_2e/MJ).

Pathways	Amortization Time Horizon			
	25 Years		30 Years	
	AEZ-EF	CCLUB	AEZ-EF	CCLUB
Soy oil HEFA	20.0	15.0	16.6	12.5
Corn ATJ	22.5	14.4	18.7	12.0
Corn ETJ	24.9	15.6	20.8	13.0
Miscanthus FTJ	−37.3	−12.8	−31.1	−10.7
Switchgrass FTJ	−8.2	1.0	−6.8	0.9
Poplar FTJ	−9.6	7.0	−8.0	5.9
Miscanthus ATJ iBuOH	−58.5	−26.1	−48.7	−21.8
Switchgrass ATJ iBuOH	−18.9	−14.1	−15.7	−11.8
Grain ATJ	22.5	14.4	18.7	12.0
Grain ETJ	24.9	15.6	20.8	13.0

Corn Ethanol to Jet iLUC under US Inflation Reduction Act

Argonne NATIONAL LABORATORY

Development of R&D GREET 2023 Rev1 to Estimate Greenhouse Gas Emissions of Sustainable Aviation Fuels for 40B Provision of the Inflation Reduction Act

Table 6. Adjusted indirect effects of the four SAF pathways (in g CO_2e/MJ of liquid fuels)

	Pathway			
	Corn ATJ-E	**Soy HEFA**	**Canola HEFA**	**Sugarcane ATJ-E**
ILUC	9.0	12.2	18.1	10.6
Non-Feedstock Crops	3.8	3.5	5.9	-3.0
Livestock	-1.4	1.4	0.1	-1.6
Rice Methane	-0.3	-0.8	-0.3	-0.1
Total	**11.1**	**16.2**	**23.7**	**5.9**

Note: 11.1 gCO2/MJ adjusted to the CORSIA Amortization Period would return 13.3 gCO2/MJ

Latest US Corn Ethanol to Jet iLUC publications show Reduction of ~10gCO_2e/MJ in iLUC over CORSIA iLLUC Value

Note: Same amortization period

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Summary

- Carbon Intensity of US produced corn ethanol feedstock is continuously decreasing
- Carbon Intensity of technologies that convert ethanol feedstock into SAF is continuously decreasing (e.g. since original CORSIA calculations)
- Study shows that with updated technologies many ethanol plants will meet CORSIA GHG reduction requirements
- The Science of Induced land use change (iLUC) is evolving and now shows a trend towards much lower iLUC values for SAF
- With these trends US Ethanol can be a high-volume low GHG, sustainable fuels platform.

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