GREET SAF Overview

Steffen Mueller; PhD
Principal Economist
University of Illinois Chicago
Energy Resources Center

New Orleans, LA
November 2023

ENERGY RESOURCES CENTER

Presentation Overview

- GREET Introduction
- Important GREET Modules for SAF
  - GREET Aviation Module
  - GREET Feedstock Carbon Intensity Module: FD-CIC
- Impact of Climate Smart Agriculture on SAF Feedstock Emissions
- Impact of Carbon Capture and Sequestration on SAF Feedstock Emissions
- Modeling Comparison GREET / CORSIA

GREET Introduction

Presentation focuses on two GREET Modules important for SAF:

- FD-CIC Tool for Feedstock Farming
- Aviation Module

How to access GREET:

1. Go to: greet.anl.gov
2. Create account
3. Download Module
4. May have to adjust macro settings

GREET®

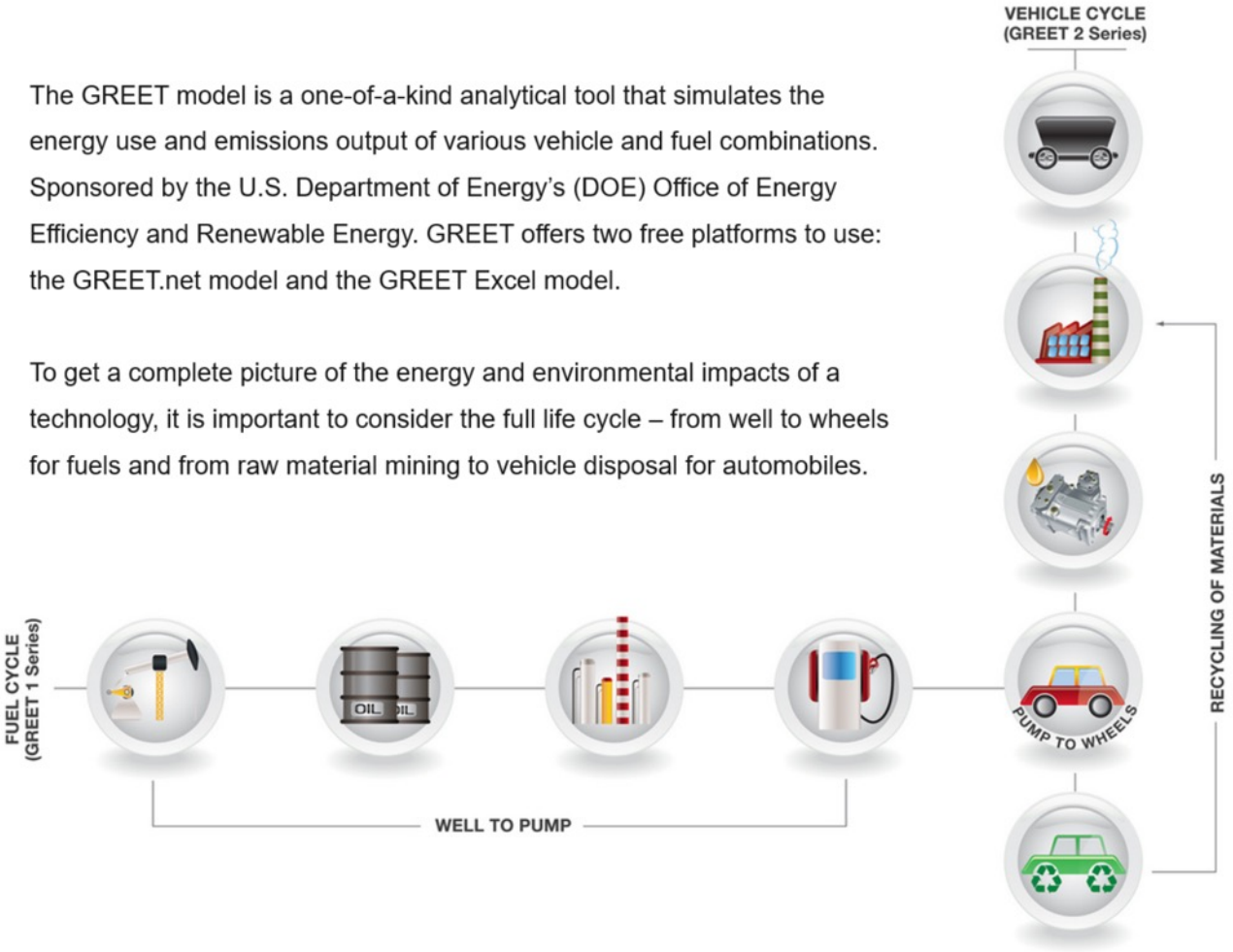
- Publications
- Databases
- GREET Model Platforms
  - GREET .Net
  - GREET Excel
    - Fuel-Cycle Model
    - Vehicle-Cycle Model
- GREET Tools
  - WTW Calculator
  - AFLEET Tool
  - AWARE-US Model
  - FD-CIC Tool
  - Refinery Products VOC
  - GREET Building Module
  - GREET Aviation Module
  - GREET Marine Module
  - GREET-H_2 Module
  - Decarbonization Model
  - ICAO-GREET Model

GREET® Model

The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model

The GREET model is a one-of-a-kind analytical tool that simulates the energy use and emissions output of various vehicle and fuel combinations. Sponsored by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy. GREET offers two free platforms to use: the GREET.net model and the GREET Excel model.

To get a complete picture of the energy and environmental impacts of a technology, it is important to consider the full life cycle – from well to wheels for fuels and from raw material mining to vehicle disposal for automobiles.



GREET News

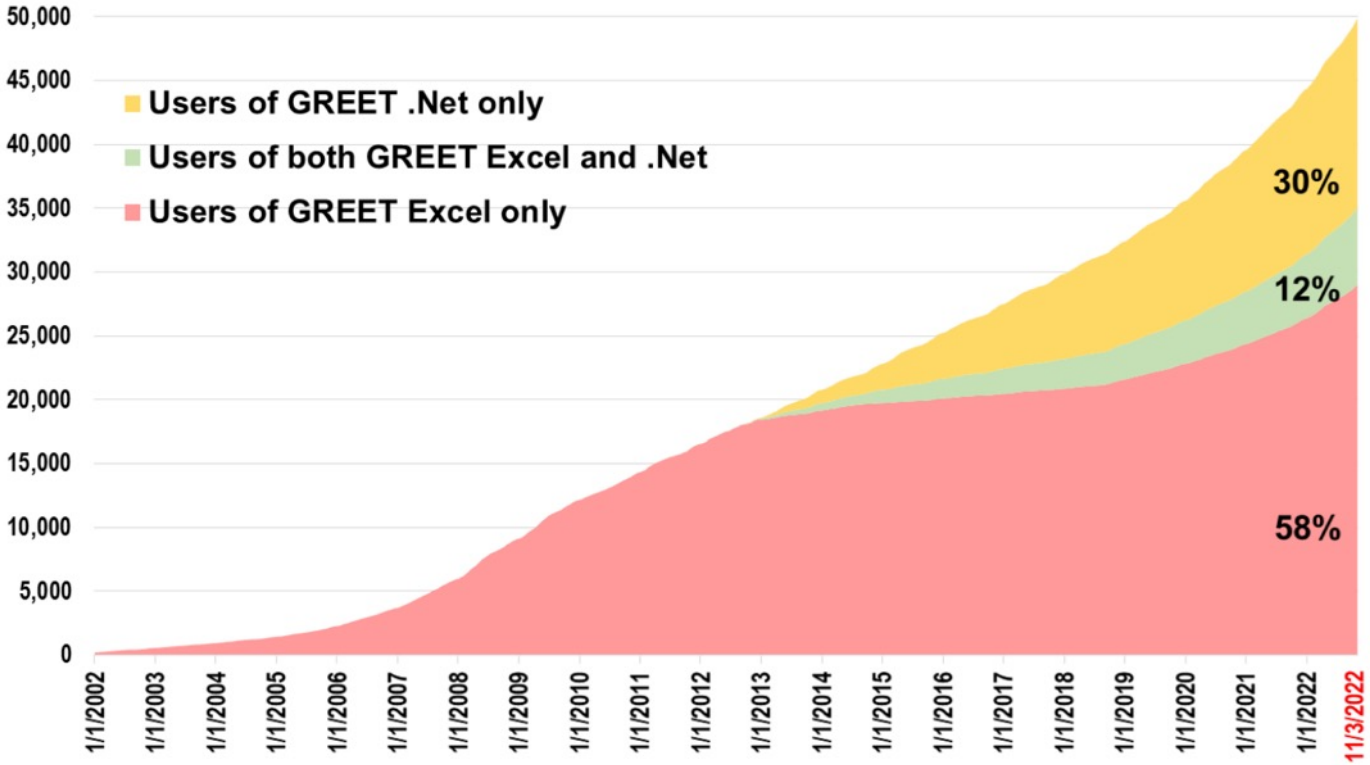
GREET 2022 rev1 Release

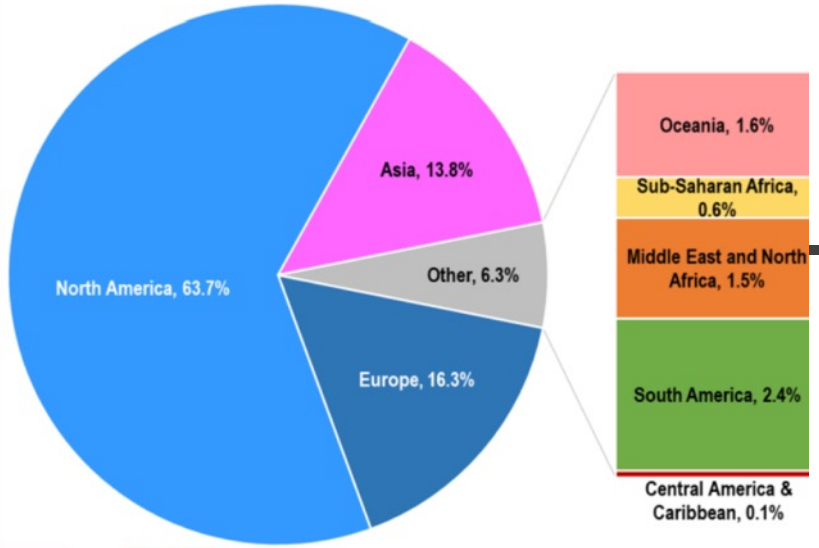
The Argonne National Laboratory's Systems Assessment Center is pleased to announce the 2022 rev

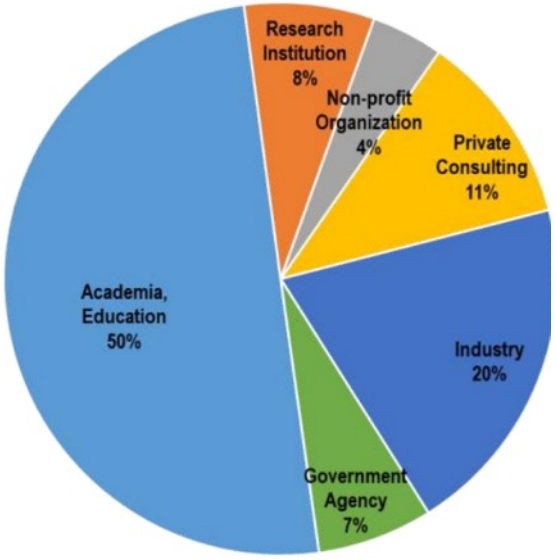
Informing Policies and Regulations

- **California-GREET** is an adaptation of Argonne's GREET model
- **Oregon Clean Fuels Program** also uses an adaptation of Argonne's GREET model
- **U.S. EPA** uses GREET with other sources for **Renewable Fuels Standard** pathway evaluations
- **National Highway Traffic Safety Administration** for fuel economy regulation
- **Federal Aviation Administration** and **International Civil Aviation Organization** using GREET to evaluate aviation fuel pathways
- **USDRIVE** Well-to-Wheels Report
- **U.S. Maritime Administration -** renewable marine energy options for IMO GHG intensity and sulfur limits
- **U.S. Dept. of Agriculture bioenergy LCA** and carbon intensity of farming practices
- **Canadian Clean Fuel Standard** for Environment and Climate Change Canada fuel pathways
- LCA results for use in different provisions of the 2021 Bipartisan Infrastructure Bill and the 2022 Inflation Reduction Act

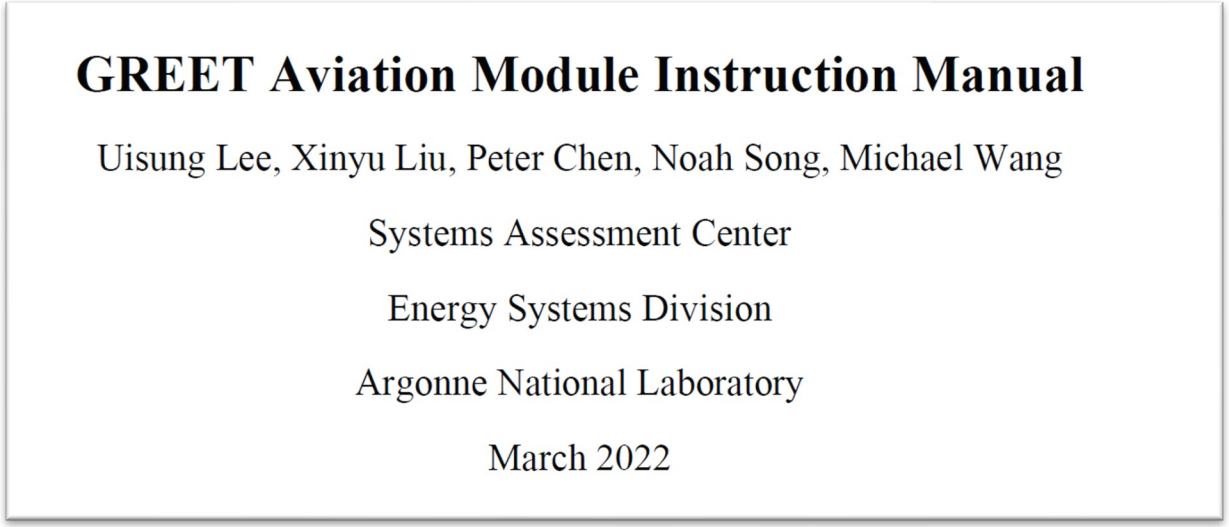
There are ~50,000 registered GREET users globally







GREET Aviation Module



GREET Aviation Module Instruction Manual

Uisung Lee, Xinyu Liu, Peter Chen, Noah Song, Michael Wang

Systems Assessment Center

Energy Systems Division

Argonne National Laboratory

March 2022

GREET Aviation Module

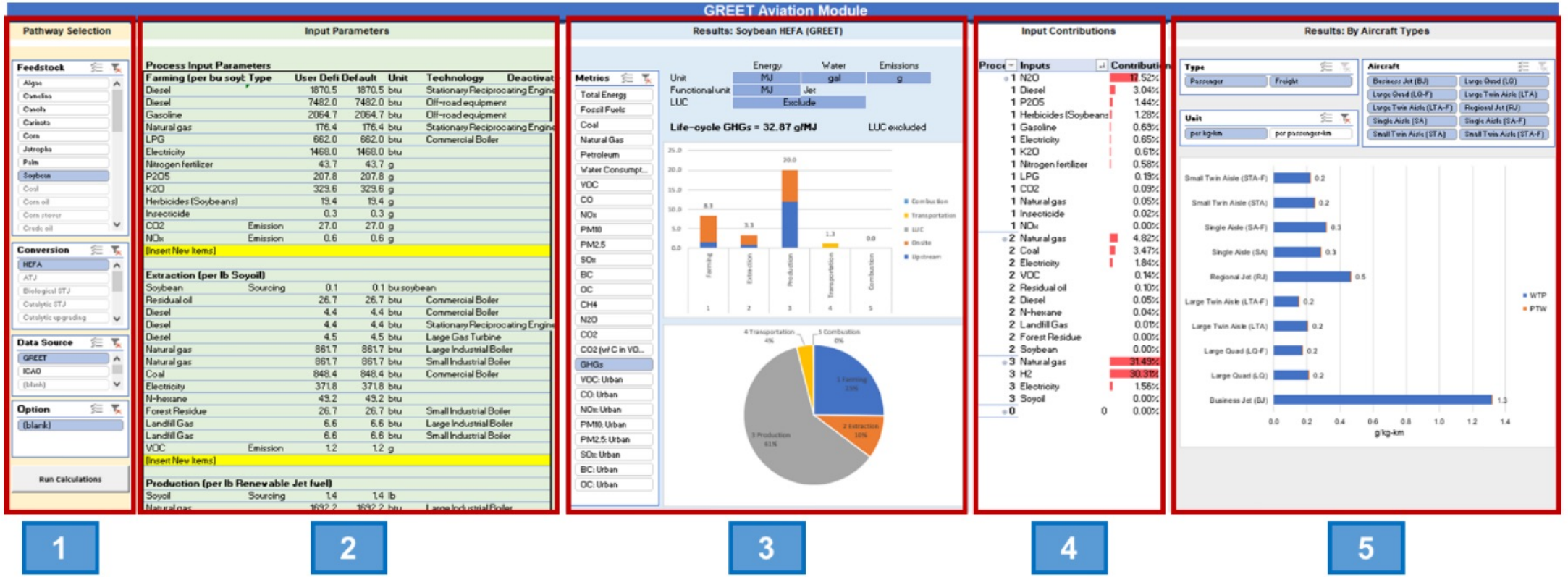
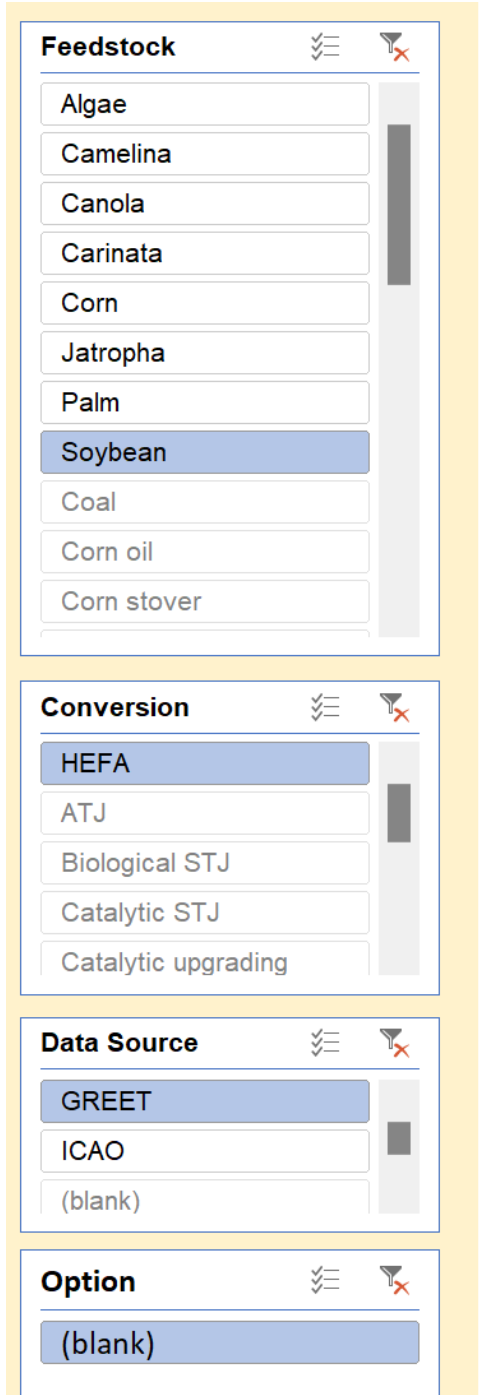
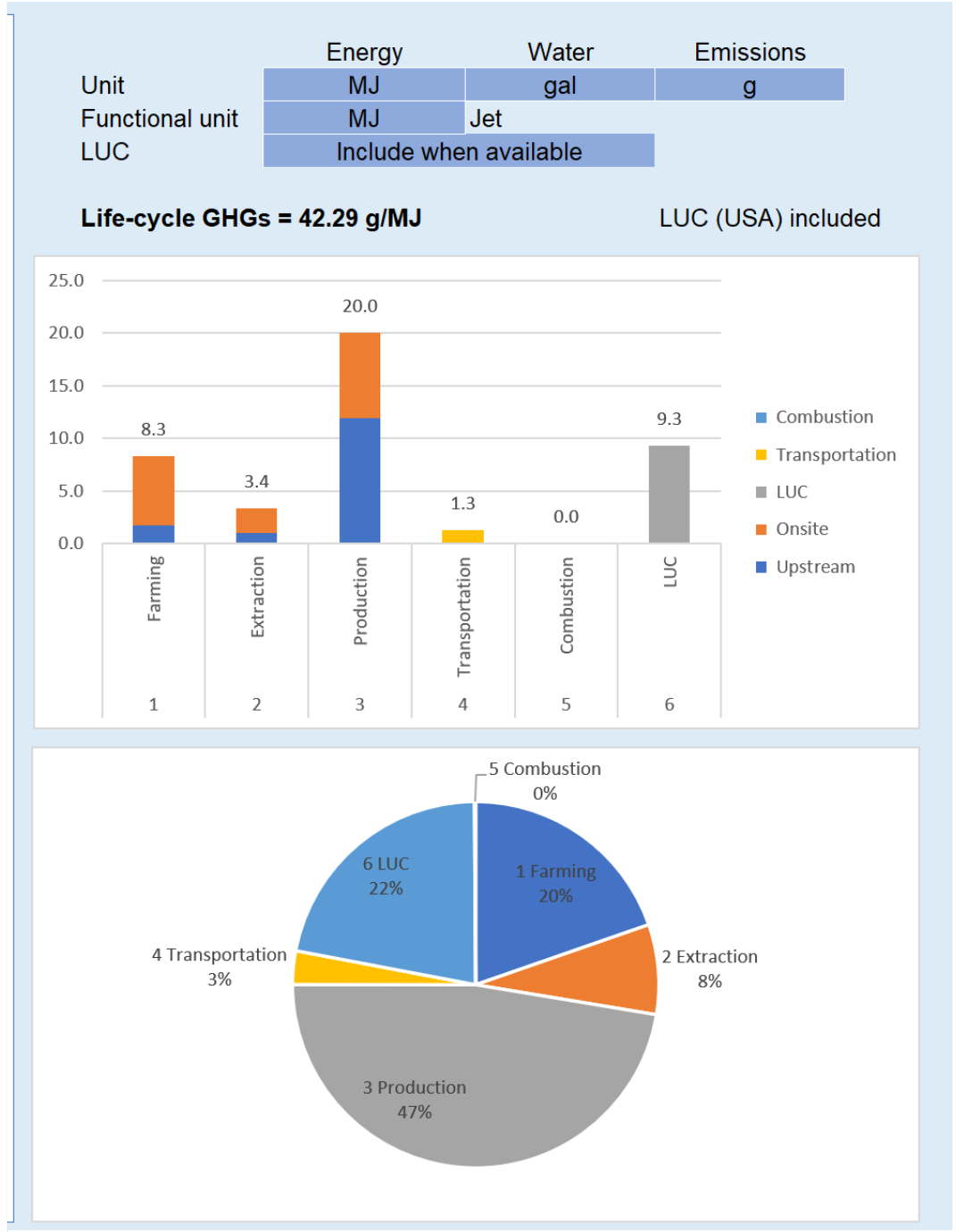


Figure 3. The Dashboard of the GREET Aviation Module. (1) Pathway Selection, (2) Input Parameters, (3) Results (by MJ or gal fuel produced and used), (4) Input Contribution, (5) Results (by aircraft types).

Big Levers for CI reduction:

- Feedstock Farming
- Fuel Production (including CCSU opportunities)
- iLUC



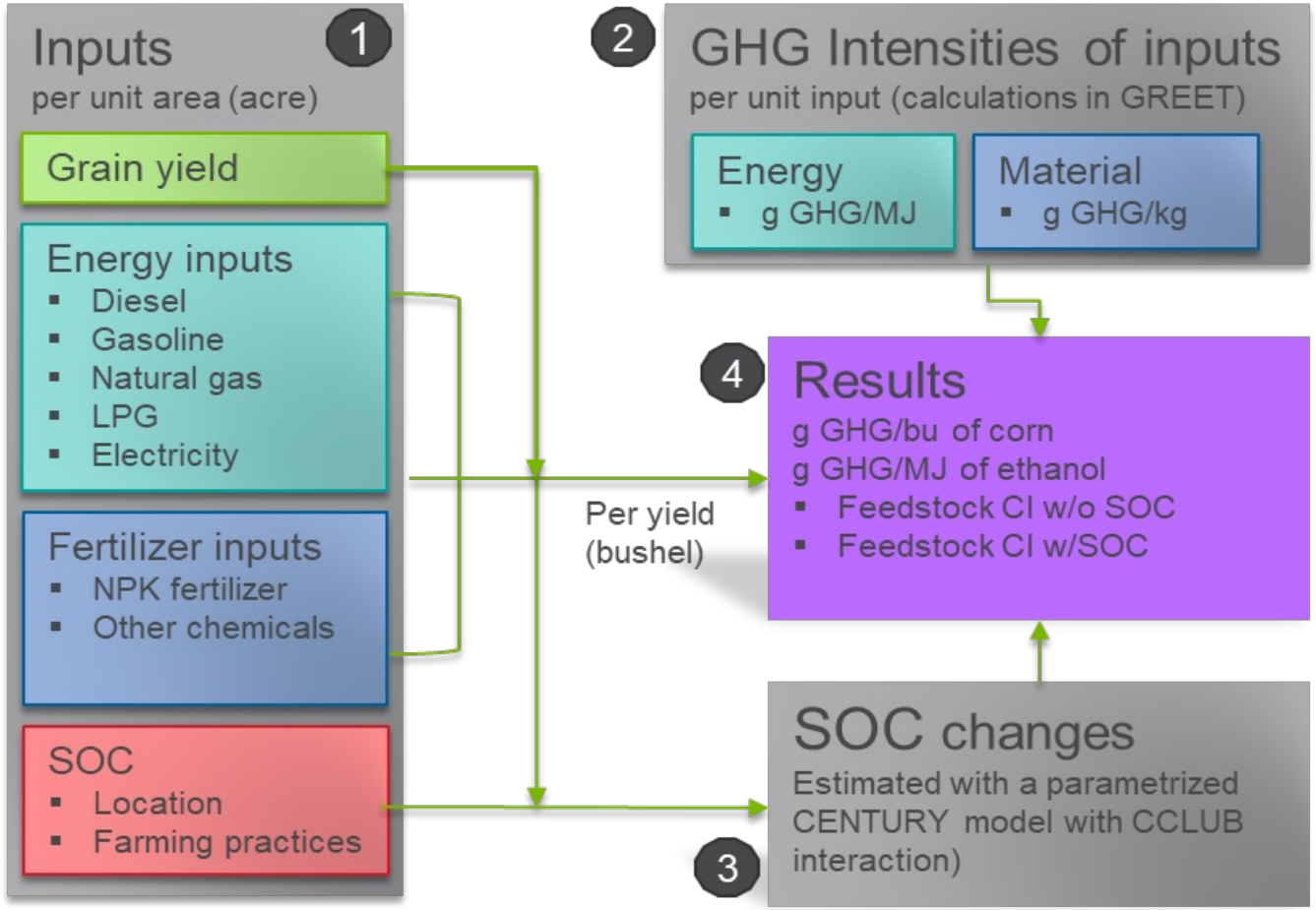


GREET Feedstock Carbon Intensity Module: FD-CIC

Direct Land Use Change Modeling & Carbon Accounting

ARGONNE FEEDSTOCK Carbon Intensity CALCULATOR INTERFACE (FD-CIC)

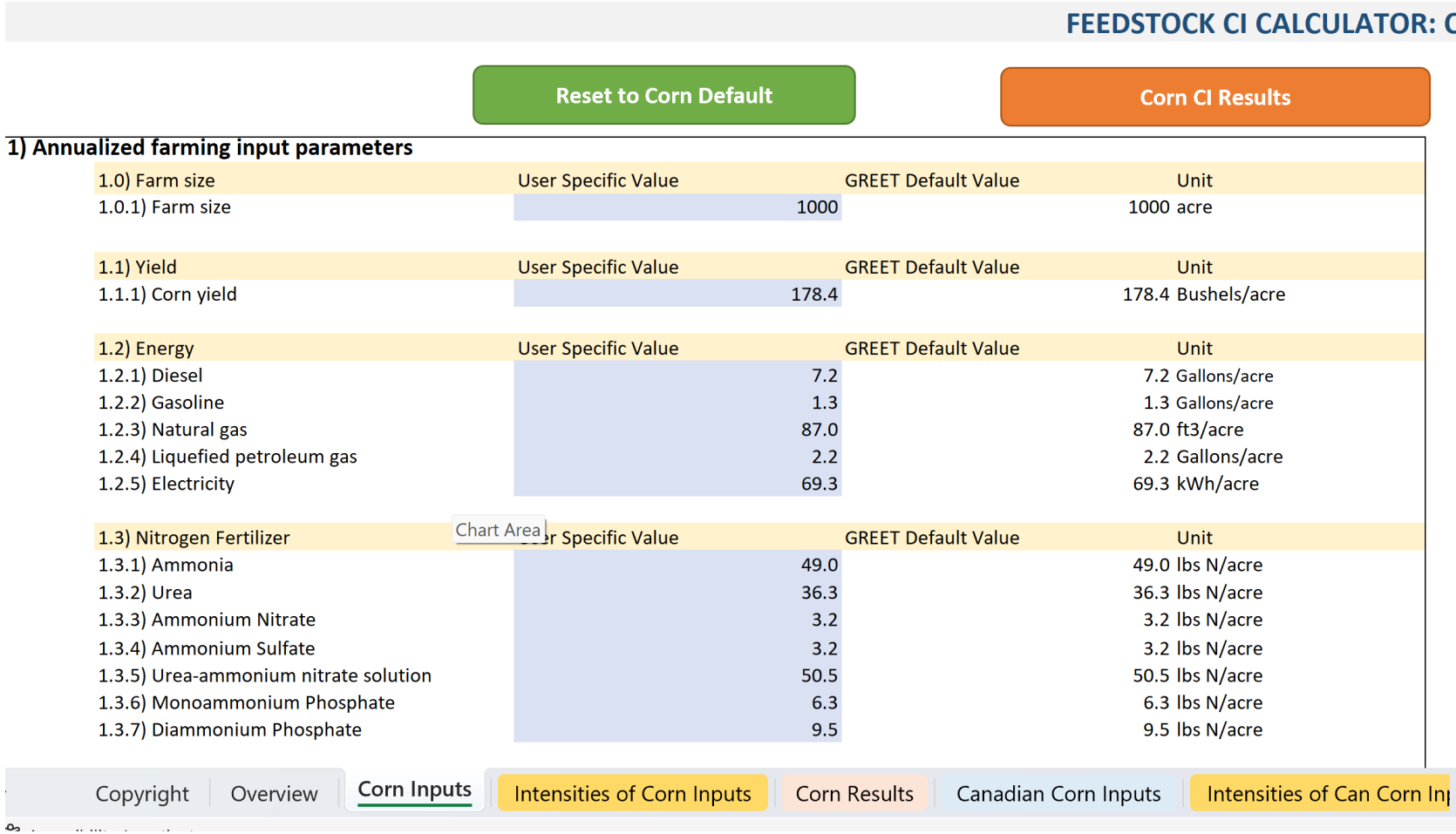
Provides the GHG emissions from different agricultural feedstock production: corn, rice, soy, sorghum, others:
– carbon intensity per unit of biomass produced
– Several land management practices options for users to explore their impacts on feedstock CI at the field level



Source: Argonne GREET Group

Farm Level GHG Emissions via GREET FD-CIC

- Multiple Feedstocks: Corn, soy, rice, etc.
- Hidden cell ranges and worksheets: unhide available
- SOC calculated on a county-by-county basis for areas where USDA reports corn yields



FEEDSTOCK CI CALCULATOR: C

Reset to Corn Default | Corn CI Results

1) Annualized farming input parameters

1.0) Farm size	User Specific Value	GREET Default Value	Unit
1.0.1) Farm size	1000	1000	acre
1.1) Yield	**User Specific Value**	**GREET Default Value**	**Unit**
1.1.1) Corn yield	178.4	178.4	Bushels/acre
1.2) Energy	**User Specific Value**	**GREET Default Value**	**Unit**
1.2.1) Diesel	7.2	7.2	Gallons/acre
1.2.2) Gasoline	1.3	1.3	Gallons/acre
1.2.3) Natural gas	87.0	87.0	ft3/acre
1.2.4) Liquefied petroleum gas	2.2	2.2	Gallons/acre
1.2.5) Electricity	69.3	69.3	kWh/acre
1.3) Nitrogen Fertilizer	**User Specific Value**	**GREET Default Value**	**Unit**
1.3.1) Ammonia	49.0	49.0	lbs N/acre
1.3.2) Urea	36.3	36.3	lbs N/acre
1.3.3) Ammonium Nitrate	3.2	3.2	lbs N/acre
1.3.4) Ammonium Sulfate	3.2	3.2	lbs N/acre
1.3.5) Urea-ammonium nitrate solution	50.5	50.5	lbs N/acre
1.3.6) Monoammonium Phosphate	6.3	6.3	lbs N/acre
1.3.7) Diammonium Phosphate	9.5	9.5	lbs N/acre

Chart Area

Copyright | Overview | Corn Inputs | Intensities of Corn Inputs | Corn Results | Canadian Corn Inputs | Intensities of Can Corn In

Impact of Climate Smart Agriculture on Cradle-to-Farm Gate Emissions

Climate Smart Ag: Field Energy Considerations

Table S6 Energy use for common farming operations (University of Nebraska-Lincoln Institute of Agriculture and Natural Resources 2019)

Operation	Plow	Chisel	Disk	Ridge Plant	Strip-till	No-till
Total diesel fuel (gal/acre)	5.28	3.34	2.71	2.69	1.75	1.35
Tillage category	CT	RT	RT	RT	NT	NT

Shifting agricultural practices to produce sustainable, low carbon intensity feedstocks for biofuel production - Supporting Information

Xinyu Liu[1], Hoyoung Kwon[1], Daniel Northrup[2], and Michael Wang[1]

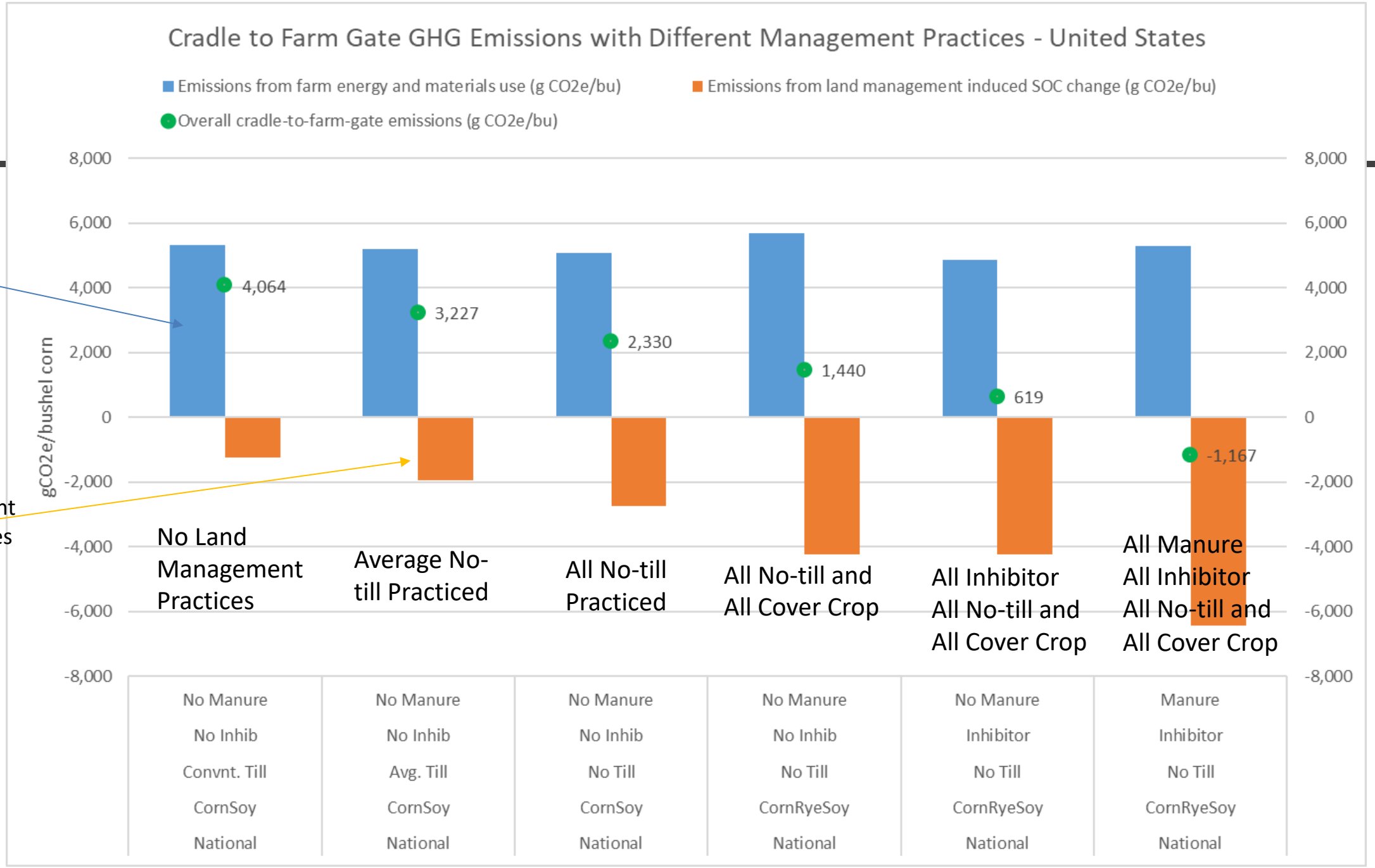
Fertilizer Inputs

Table S2 Fertilizer inputs used to grow corn in nine states in 2010 and their carbon intensity (unit: g CO_2e/bushel of corn) (United States Department of Agriculture Economic Research Service 2010). A bushel of corn is equivalent to 0.0254 metric ton.

	N	P	K	Lime	N	P	K	Lime
	g nutrient/bushel of corn				g CO_2e/bushel of corn			
National	434	153	169	1513	1630	214	97	15
Illinois	410	226	246	2080	1562	317	141	20
Indiana	471	185	311	2512	1846	259	179	24
Iowa	421	129	153	1292	1668	181	88	12
Michigan	425	113	267	1894	1895	158	153	18
Minnesota	354	106	119	1129	1535	149	68	11
Nebraska	450	81	14	588	1822	114	8	6
Ohio	478	181	236	1694	1839	254	135	16
South Dakota	553	162	40	0	1897	227	23	0
Wisconsin	388	112	153	2161	1505	156	88	21

Farm Energy Varies with Different Field Passes for Different Management Practices

Each additional land management practice increases GHG offsets



Carbon Capture Sequestration and Utilization (CCSU)

Carbon Capture Sequestration Treatment in GREET

- GREET electricity requirement for CCS: 130 kWh/ton CO_2
- includes compression for CO_2 transportation via pipeline
- CO_2 capture rate of 97.5%.
- electricity can be sourced from various US electricity grid aggregations (NERC regions) or renewables, or custom parameterization

Direct Injection by Individual Plants or CO_2 Pipeline

MARQUIS

CARBON & SUSTAINABILITY

Red Trail Energy Begins Carbon Capture And Storag

JULY 17, 2022 BY RED TRAIL ENERGY LLC

The first carbon capture and storage project allowed under state primacy in the U.S. has commenced operations. Red Trail Energy LLC announces it officially began carbon capture and storage (CCS) at its ethanol facility located near Richardton, North Dakota, on June 16.

ADM News Products & Services

ADM and Carbon Capture and Storage

CCS is an important technology to help us meet the growing demand for low-carbon energy and ingredient solutions.

Trailblazer Pipeline Company LLC One Step Closer to Transporting Carbon Dioxide Following FERC Order

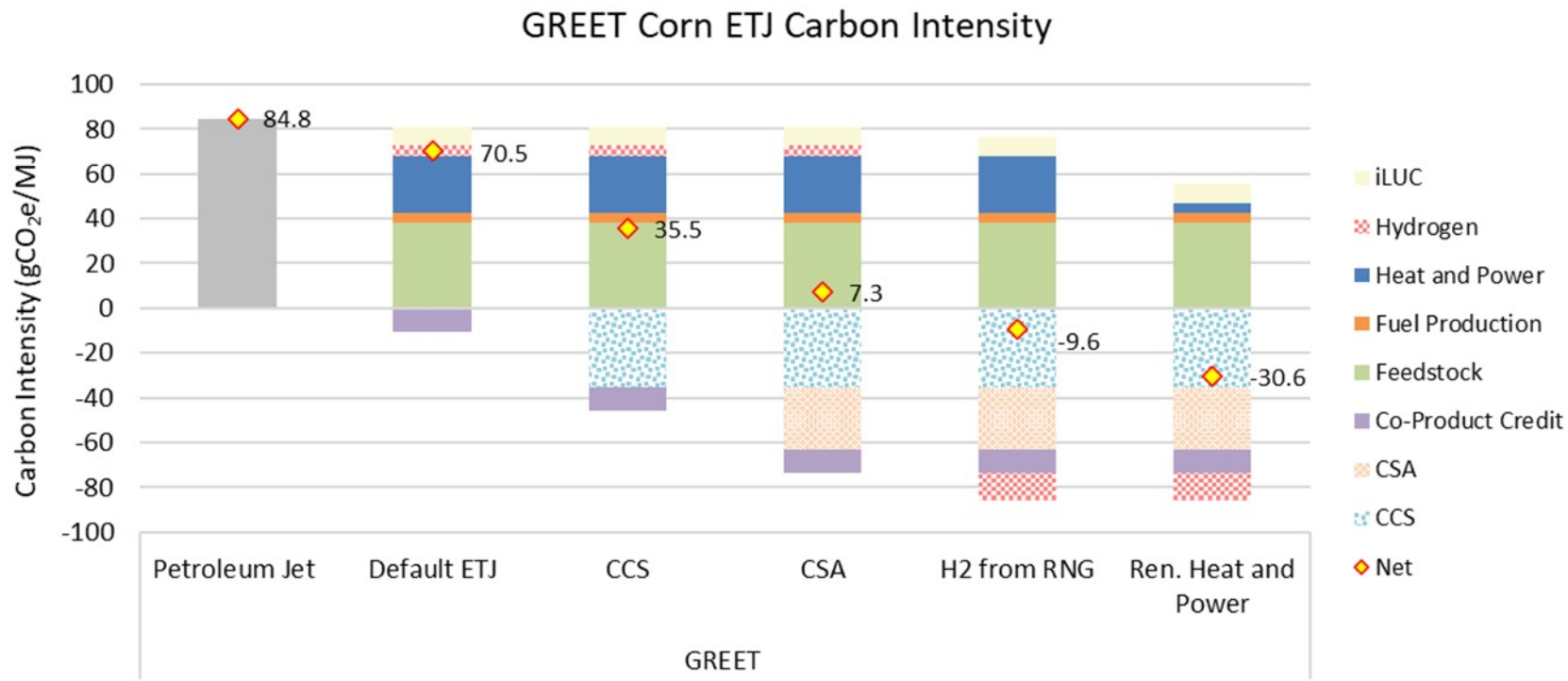
October 30, 2023

Reading Time : **3 min**

SAF GHG Emissions in GREET and CORSIA

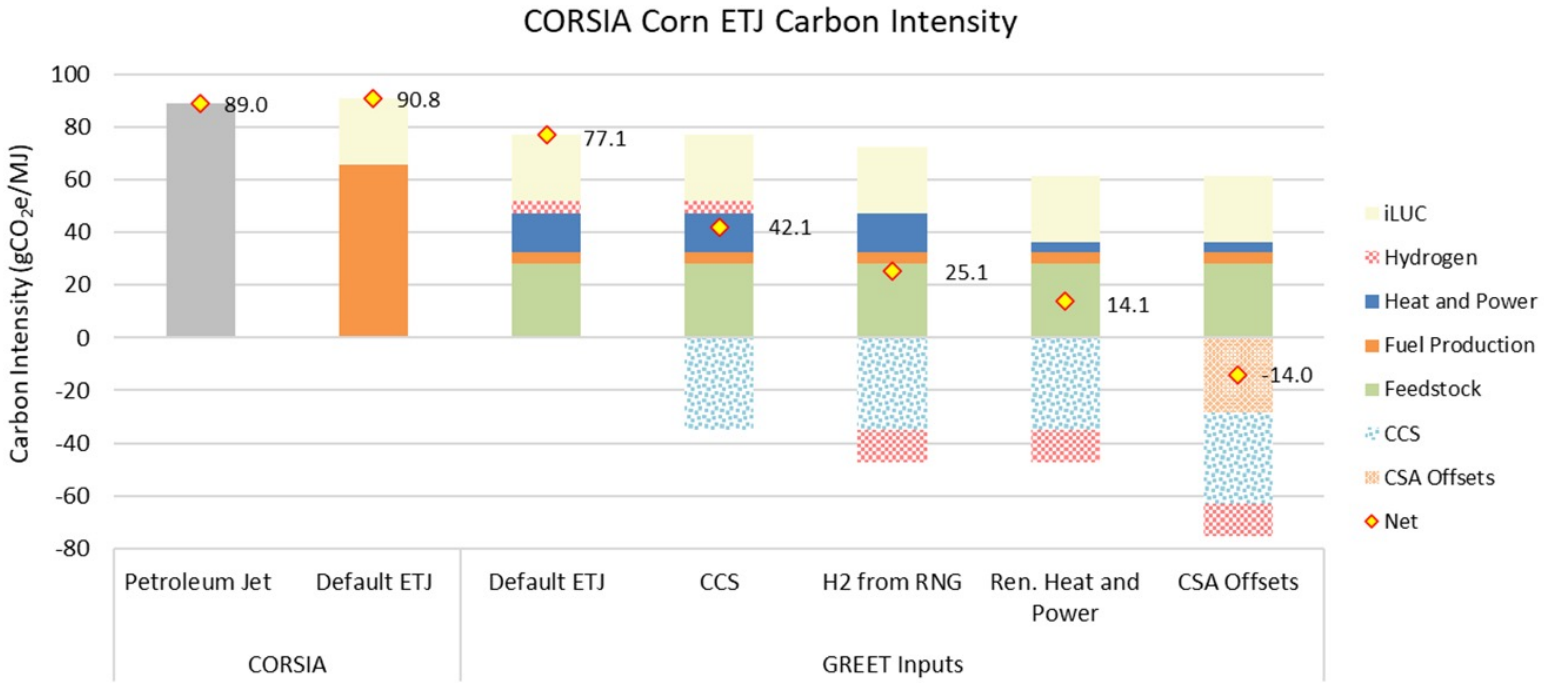
Example GREET: Corn Ethanol to Jet

- GREET default inputs
- Petroleum Aviation Fuel Baseline: 84.8 gCO2/MJ
- CCLUB iLUC (8.28 g CO_2e/MJ Jet)
- CCS from fertilizer plant provides opportunity for further reduction: saving of upstream fertilizer production emissions (up to 3-4 gCO_2/MJ)



Example CORSIA: Corn Ethanol to Jet

- GREET inputs with energy allocation
- Petroleum Aviation Fuel Baseline: 89 gCO2/MJ
- Default CORSIA iLUC (25.1 gCO_2e/MJ, U.S. Ethanol to Jet)
- CCS from fertilizer plant provides opportunity for further reduction: saving of upstream fertilizer production emissions (up to 3-4 gCO_2/MJ)



Questions ???