

### GREET tutorial:





The purpose of this tutorial is to provide a step-by-step guide for checking GHG emission results for bio-ethanol production. It was designed with reference to the official training materials provided by Argonne National Laboratory. For the latest updates, please refer to this link:

[https://greet.anl.gov/greet\\_train\\_the\\_trainer](https://greet.anl.gov/greet_train_the_trainer)

#### Step 1 - Download R&D GREET 2024 Rev. 1

1. Go to Argonne's GREET Website: [https://greet.anl.gov/greet\\_1\\_series](https://greet.anl.gov/greet_1_series).
1. Enter your information and select Submit.
2. Click on **R&D GREET\_2024 Rev1.zip** and download the file.
3. Once the model is downloaded, extract the contents to any folder that is not the Downloads folder.
4. Right-click on each of the Excel files in your newly extracted folder, select properties, check "Unblock," then select "Apply".

When you open the folder, you will find the following files:

Name	Type	Compressed size	Password ...	Size
 CCLUB_2024_Rev1	Microsoft Excel Macro-En...	16,266 KB	No	17,126 KB
 R&D GREET1_2024_Rev1	Microsoft Excel Macro-En...	23,372 KB	No	24,570 KB
 R&D GREET2_2024_Rev1	Microsoft Excel Macro-En...	5,152 KB	No	5,596 KB
 STOCHASTIC	Microsoft Excel Add-In	527 KB	No	1,718 KB

- R&D GREET 1: fuel cycle (or WTW) model of vehicle technologies and transportation fuels.
- R&D GREET 2: vehicle manufacturing cycle model of vehicle technologies.
- CCLUB: land-use and land-management changes.
- Stochastic Toolkit: running stochastic analyses and determining error bars on LCA estimates.

We will use **R&D GREET 1\_2024\_Rev1.xlsm**. Note: The Excel model should be opened as a macro-enabled file to ensure proper functionality.

## Step 2 - GREET 1 Model Structure

### 1. The overview sheet

When you open the Excel file, the first sheet is the **Overview**, containing the GREET copyright statement. It also presents a brief summary of each worksheet and is intended to provide a brief introduction to the functions of each sheet.

To become familiar with this sheet, watch the YouTube video “[Bridges Case Study Resources - Aviation Fuel](#)” from 02:35 to 06:33.

In this tutorial, we will utilize the following sheets:

- The **Input** Sheet: presents key variables for various well-to-pump (WTP) and pump-to-wheels (PTW) scenarios, and specifies key parametric assumptions for GREET simulations.
- The **Result** Sheet: presents results for vehicle/fuel options included in the GREET model. The sheet consists of three sections: well-to-pump, well-to-wheels, and well-to-wheels energy Use and Emissions sections.
- The **EtOH** Sheet: calculates energy use and emission rates for ethanol production from various biomass feedstocks, covering farming, transportation, ethanol production, transportation, distribution, and storage of the ethanol fuel.

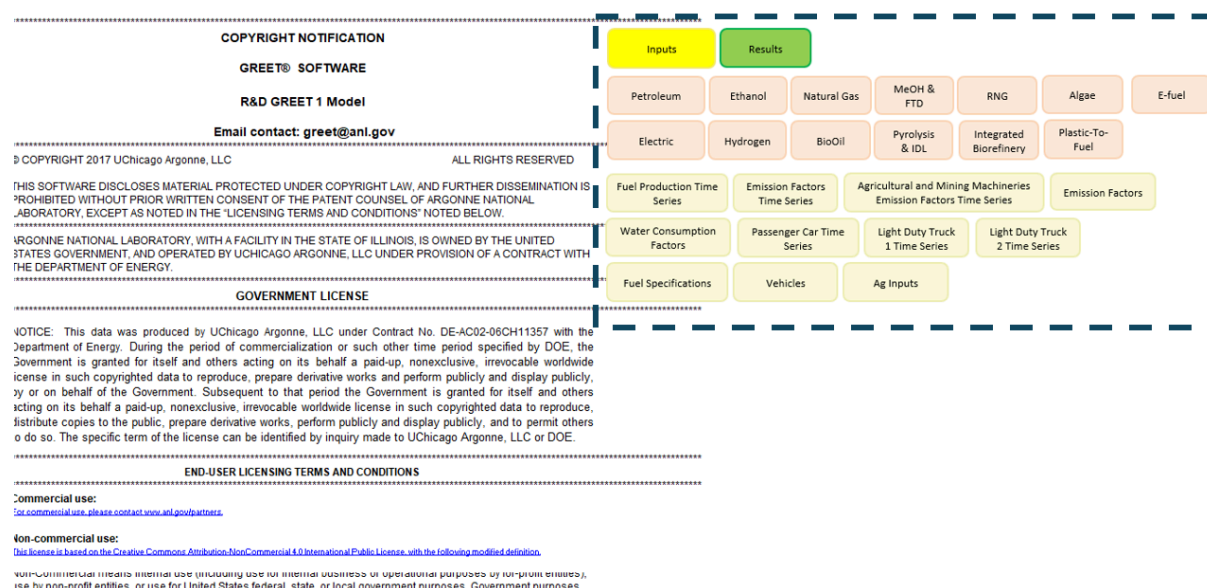


Figure 1: The overview of sheets in the GREET model.

Note: For more details on each sheet, please refer to the **Operating Manual for GREET**, which can be downloaded here: [https://greet.anl.gov/greet\\_1\\_series](https://greet.anl.gov/greet_1_series) (see the Documents section).

### Step 3 - Find the General Settings to Alter an Ethanol Pathway

#### 1. Target year for simulation

When you open the 'Input' sheet, the first parameter you can modify is the '**Target Year for Simulation.**'

Since this GREET version is 2024, the default target year is set to 2024. You can also select the future year (e.g., 2030 or 2050) to simulate future scenarios, which are based on assumed changes in parameters such as the electricity generation mix, vehicle efficiency, and carbon capture implementation. These assumptions can be manually adjusted by users as needed.

In this tutorial, we use the default **2024** as the target year.

**Scenario Control Variables and Input Assumptions**

1. Key Options for Simulation

1.1) Target Year for Simulation: 2024

1.2) Point-Estimation or Probability-Estimation Option: Point-Estimation

2. Vehicle Types for Simulation: 1

3. Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Share of crude oil sources

	1	2	3	4	5
EIA projection	80.8%	8.6%	5.0%	1.9%	2.3%
User defined	80.8%	8.6%	5.0%	1.9%	2.3%
Used in calculation	80.8%	8.6%	5.0%	1.9%	2.3%
API gravity	34.0	18.1	26.5	26.5	31.8
S Content (wt %)	1.4	2.9	1.9	2.2	2.3
Average transportation distances (mi)	See T&D_Flowcharts tab	1,708	1,708	797	14,586

3.1.b) Efficiency for Petroleum Recovery

Conventional Crude Recovery: 98.0%

3.1.c) Key parameters of Oil Sands Recovery Methods and Products

	Bitumen	Diluent
Dilbit Composition		
Volumetric Shares	70%	30%

Recovered Diluent in Refineries: 100% by volume

	Surface Mining + Bitumen	Surface Mining + SCO	In-Situ + Bitumen	In-Situ + SCO
Share of oil sands recovery methods and products				
Volumetric Shares	5.0%	39.6%	48.1%	6.3%
Mass Shares	5.4%	36.2%	52.7%	5.7%
Energy Shares	5.3%	37.1%	51.8%	5.8%

Figure 2: The selection of 'Target Year of Simulation'.

#### 2. Ethanol production pathway

Next, click '**Ethanol**'. This will take you to the section in the Input sheet where you can modify parameters for ethanol production.



Next, scroll down to Section ‘8.7.c Selection of Plant Type’.

In this section, you can modify the configuration of the ethanol production plant. You can choose the type of **process fuel** used (e.g., natural gas, coal, or biomass) and specify whether the plant co-produces Distillers Dried Grains with Solubles (**DDGS**)—a high-protein animal feed derived from the fermentation residues.

**Dry mill** and **wet mill** refer to two different ethanol production technologies: a dry mill grinds the entire corn kernel and primarily produces ethanol and DDGS, while a wet mill separates the corn into its components (starch, fiber, oil, and protein) before fermentation and yields multiple co-products such as corn gluten meal, corn oil, and ethanol. Generally, the dry mill is a modern fuel ethanol plant design that is used for almost all corn-based ethanol in North America.

Here, let’s select **4 - Plant Specific: Dry Mill with only DDGS as co-product and NG as process fuel**.

8.7.c) Selection of Plant Type											
4			1 -- Industrial average			7 -- Plant Specific: Dry Mill with only DDGS as co-product and NG as process fuel			13 -- 1.5 Gen Dry Milling Plant w/ Corn Oil extraction		
			2 -- User defined average			8 -- Plant Specific: Dry Mill with only DDGS as co-product and Coal as process fuel					
			3 -- Plant Specific: Dry Mill with DGS as a process fuel			9 -- Plant Specific: Dry Mill with only DDGS as co-product and Biomass as process fuel					
			4 -- Plant Specific: Dry Mill with only DDGS as co-product and NG as process fuel			10 -- Plant Specific: Wet Mill with NG as process fuel					
			5 -- Plant Specific: Dry Mill with only DDGS as co-product and Coal as process fuel			11 -- Plant Specific: Wet Mill with Coal as process fuel					
			6 -- Plant Specific: Wet Mill with only DDGS as co-product and Biomass as process fuel			12 -- Plant Specific: Wet Mill with Biomass as process fuel					
8.7.c) Energy demands for corn oil extraction											
For process level allocation											
Energy for ethanol processing (distillation, dewatering, etc., allocated to ethanol only)			Heat (Btu/gal EtOH)			Electricity (Btu/gal EtOH)					
			4,910			22					
Energy for corn oil extraction (allocated to corn oil only)											
Energy for DGS drying (allocated to DGS only; allocated to ethanol only w/ marginal method)			30,448			632					
Allocated between ethanol, corn oil and DGS			8,364			3,444					
8.7.c) Share of Corn Ethanol Plant Types, Energy Use for Ethanol Production, and Share of Process Fuels for Each Plant Type											
Industry Average											
User Defined Average											
			Dry Milling Plant w/ Corn Oil extraction	Dry Milling Plant w/ Corn Oil extraction	Wet Milling Plant	Dry Milling Plant	Wet Milling Plant	Dry Mill with DGS as a process fuel	Dry Mill with only DDGS as co-product and NG as process fuel	Dry Mill with only DDGS as co-product and Coal as process fuel	Dry Mill with only DDGS as co-product and Biomass as process fuel
Share of Corn Ethanol Plant Types			4.6%	88.6%	10.0%	100.0%	0.0%	100.0%	100.0%	100.0%	100.0%
Total energy use for ethanol production (Btu/gal)			25,624	24,828	47,400	38,620	47,400	22,560	20,664	38,620	35,800
Energy use: NG, coal, and biomass (Btu/gal)			20,800	20,800	47,400	38,620	47,400	21,000	27,570	35,824	35,800
Share: NG			89.6%	89.6%	72.6%	100.0%	0.0%	100.0%	100.0%	100.0%	0.0%
Coal			0.4%	0.4%	27.6%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
Biomass			0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electricity demand, kWh/gal			0.42	0.42	0.00	0.72	0.00	0.75	0.74	0.79	0.00
Share of Biomass used as process fuel:											
Willow			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Poplar			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Switchgrass			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Miscanthus			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Corn Stover			100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Forest Residue			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Percentage of co-produced DGS used as process fuel			0.0%	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%
Co-Product Yield: Dry DGS to animal feed (dry lb/gal EtOH)			2.44	2.28	3.70	3.70	5.63	5.63	5.63	5.63	0.00
Co-Product Yield: Wet DGS to animal feed (dry lb/gal EtOH)			1.45	1.48	1.93	1.93	1.93	1.93	1.93	1.93	0.00
Co-Product Yield: CGM to animal feed (Actual lb/gal EtOH)			1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	0.00
Co-Product Yield: CGF to animal feed (Actual lb/gal EtOH)			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 5: Selecting the ethanol plant type.

### 3. Further Explore Ethanol Scenarios

Click ‘**EtOH**’. This will open the *EtOH* sheet, where you can further adjust ethanol production scenarios and calculate the associated energy use and emission rates.

Here are **four sections** for this sheet:

- 1) Scenario control and key input parameters. The values in this section derive primarily from the Inputs sheet. Thus, this section is the interactive link between the Inputs sheet and this sheet.
- 2) Shares of combustion processes for each stage, which are used for emission calculations;
- 3) Calculation of energy use and emissions for individual stages. In this section, GREET calculates energy use and emissions for each individual stage by considering energy and material use, energy efficiency, fuel use by type, fuel use by combustion technology, etc.
- 4) Summary of energy use and emissions. Other GREET sheets use the summary results from this sheet for individual vehicle/fuel WTW calculations.

**1.1) Feedstock Farming** - This section defines the feedstock farming options. In **‘N2O Emissions Management Practices’**, you can choose among three options: BAU (Business-As-Usual), 4R (improved fertilizer management), or EEf (enhanced efficiency fertilizer technology). Here, we will use the default **BAU scenario**.



9) Summary of Energy Consumption, Water Consumption, and Emissions: Bu or Gallons or Grams per mmbtu of Fuel Throughput at Each Stage																													
Energy	Dry Milling Corn Ethanol w/o Corn Oil Extraction				Dry Milling Corn Ethanol w/ Corn Oil Extraction				Wet Milling Corn Ethanol				Corn Ethanol: Combined Dry and Wet Milling Ethanol				Integrated Corn/Stover Ethanol (Combined Gallon)				Integrated Corn/Stover Ethanol (Associated with Corn Ethanol)				Integrated Corn/Stover Ethanol (Associated with Corn Ethanol)				Summ
	Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol		Ethanol						
	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor	Corn	Loss Factor					
Total Energy	1,257.13	1,001			1,257.13	1,001			1,257.13	1,001			1,257.13	1,001			1,257.13	1,001			1,257.13	1,001			1,257.13	1,001			
Fossil fuels	88,256	69,157			88,256	69,157			88,256	69,157			88,256	69,157			88,256	69,157			88,256	69,157			88,256	69,157			
Coal	4,351	22,540			4,351	22,540			4,351	22,540			4,351	22,540			4,351	22,540			4,351	22,540			4,351	22,540			
Natural gas	50,877	68,159			50,877	68,159			50,877	68,159			50,877	68,159			50,877	68,159			50,877	68,159			50,877	68,159			
Petroleum	35,818	23,581			35,818	23,581			35,818	23,581			35,818	23,581			35,818	23,581			35,818	23,581			35,818	23,581			
Water consumption	300,211	387,451			300,211	387,451			300,211	387,451			300,211	387,451			300,211	387,451			300,211	387,451			300,211	387,451			
VOC	3,481	58,597			3,481	58,597			3,481	58,597			3,481	58,597			3,481	58,597			3,481	58,597			3,481	58,597			
CO2	22,379	22,379			22,379	22,379			22,379	22,379			22,379	22,379			22,379	22,379			22,379	22,379			22,379	22,379			
NOx	58,813	45,364			58,813	45,364			58,813	45,364			58,813	45,364			58,813	45,364			58,813	45,364			58,813	45,364			
PM10	2,848	1,230			2,848	1,230			2,848	1,230			2,848	1,230			2,848	1,230			2,848	1,230			2,848	1,230			
PM2.5	2,468	1,147			2,468	1,147			2,468	1,147			2,468	1,147			2,468	1,147			2,468	1,147			2,468	1,147			
SOx	12,666	8,289			12,666	8,289			12,666	8,289			12,666	8,289			12,666	8,289			12,666	8,289			12,666	8,289			
HC	2,482	1,074			2,482	1,074			2,482	1,074			2,482	1,074			2,482	1,074			2,482	1,074			2,482	1,074			
CH4	0,487	0,787			0,487	0,787			0,487	0,787			0,487	0,787			0,487	0,787			0,487	0,787			0,487	0,787			
N2O	13,046	71,047			13,046</																								

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## 1. Vehicle operations setting

**Scenario Control Variables and Input Assumptions**

### 1. Key Options for Simulation

- 1.1) Target Year for Simulation  
**2024**
- 1.2) Point Estimation or Probability Estimation Option  
**Load Stochastic Toolkit**

### 2. Vehicle Types for Simulation

- Passenger Cars
- Light-Duty Trucks 1 (LDLT1) (Sports utility vehicles [SUV])
- Light-Duty Trucks 2 (LDLT2) (Pickup Truck [PUT])

### 3. Petroleum-Based Fuels

#### 3.1.a) Share of crude oil sources

Basis of share of crude oil sources:	EIA projection	User defined	Mexico	Middle East	Latin America	Africa	Others
U.S. Domestic Crude Oil	80.8%	80.8%	1.9%	2.3%	1.9%	0.9%	0.6%
Canada (Oil Sands)	6.6%	6.6%	5.0%	2.3%	1.9%	0.9%	0.6%
API gravity	34.0	18.1	25.5	25.5	31.8	38.3	32.0
S Content (wt %)	1.4	2.0	1.9	2.2	2.3	3.0	1.8
Average transportation distances (mi)	See T&O_Flowcharts tab	1,708	1,708	787	14,590	4,020	6,108

#### 3.1.b) Efficiency for Petroleum Recovery

Conventional Crude Recovery: **98.0%**

#### 3.1.c) Key parameters of Oil Sands Recovery Methods and Products

Dilbit Composition	Bitumen	Diluent
Volumetric Shares	75% by volume	30%

Recovered Diluent in Refineries: **100%** by volume

Share of oil sands recovery methods and products	Surface Mining + Bitumen	Surface Mining + SCO	In-Situ + Bitumen	In-Situ + SCO
Volumetric Shares	5.0%	35.2%	49.1%	6.3%
Mass Share (%)	5.4%	35.2%	57.4%	6.7%
Energy Shares	5.3%	37.1%	51.8%	5.9%

### 12. Vehicle Operations

#### 12.1) Share of Alternative Fuel in Conventional Fuel and Alternative Fuel Blend: Volumetric Percentage

BSI (Boosted Spark Ignition) or MM (Multi-mode) fuel blend level selection

Fuel Type	ARHC	MeOH	%
Iso-butanol	-	-	2–20%, 3–30%
ARHC	-	-	2–20%, 3–30%
MeOH	-	-	2–20%, 3–30%

#### 12.2) Type of Gasoline or Diesel for Alternative Fuel Blends

Fuel Type	%
Methanol in FFV fuel	80.0%
Methanol in dedicated vehicle fuel	80.0%
Ethanol in low-level blend of gasoline and ethanol	10.0%
Ethanol in mid-level blend of gasoline and ethanol	80.0%
Ethanol in dedicated vehicle fuel	100.0%
FT diesel in FFV fuel	100.0%
FT diesel in CIDI fuel	100.0%
Biodiesel in CIDI fuel	20.0%
Renewable diesel in CIDI fuel	100.0%
Renewable gasoline in SI fuel	100.0%
Ethanol in EIOH-diesel	10.0%
Additive in EIOH-diesel	1.0%
Iso-butanol in BSI (gasoline) fuel	20.0%
ARHC (Aromatics-rich hydrocarbon fuels) in BSI (gasoline) fuel	20.0%
Methanol in MM (gasoline) fuel	20.0%
Isoketane in MCCI fuel	20.0%
FAE (Fatty acid ethyl ester) in MCCI fuel	20.0%
FAFE (if fatty acid fuel esters) in MCCI fuel	20.0%
Renewable diesel in MCCI fuel	10.0%

#### 12.2) Type of Gasoline or Diesel for Alternative Fuel Blends

Blend Component	%
Gasoline for methanol blend	0.0%
Gasoline for low-level ethanol blend	0.0%
Gasoline for high-level ethanol blend	0.0%
Gasoline for n-butanol blend	0.0%
Gasoline for renewable gasoline blend	0.0%
Gasoline for Iso-butanol blend	0.0%
Gasoline for ARHC blend	0.0%
Gasoline for Methanol-gasoline blend	0.0%
Diesel for Isoketane diesel blend	100.0%
Diesel for FAE (Fatty acid ethyl ester) diesel blend	100.0%
Diesel for FAPE (Fatty acid propyl ester) diesel blend	100.0%
Share of LSO out of LEO and CO	0.0%
Diesel for Fischer-Tropsch diesel blend	100.0%
Diesel for Biodiesel blend	100.0%
Diesel for renewable diesel blend	100.0%
Diesel for EIOH-diesel blend	100.0%

#### 12.3) Key Parameters for Grid-Connected (Plug-In) Hybrid Electric Passenger Vehicle Technologies

Note: PHEVs with RAER longer than or equal to 30 miles are series hybrid while PHEVs with RAER shorter than 30 miles are power-split hybrid.)

PHEV Type	RAER Range (miles)
PHEV A	30

Figure 8: Setting the dedicated vehicle fuel.

## 2. Select the vehicle type and check the result

Then, go to the **'Results'** page. Under SI ICE Vehicles, select **'SI – Dedi. EtOH Vehicle'** as the vehicle type, and set the **emission unit** to **grams (g)** and the **energy functional unit** to **megajoules (MJ)**. Finally, click **'Go'** to review the WTW energy consumption, water consumption, and GHG emissions results for the selected scenario. These results cover the different life cycle stages of ethanol, including feedstock cultivation, fuel production, and vehicle operation.



