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Demonstration of GREET1.7 Simulations

II. Simulations through the Excel Spreadsheet

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***GREET User Workshop
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Three Cases Will be Demoad through GREET Excel Spreadsheet Model

■ Petroleum Based Pathways (Demo 1)

- Feedstock Selection: Conventional Crude vs. Canadian Oil Sands
- Fuel Selection: RFG w/ corn-ethanol as oxygenate vs. LSD
- Vehicle Selection: SI GV vs. GI SI HEV vs. CI DI DV vs. GI CIDI HEV

■ Hydrogen Production Pathways (Demo 2)

- Feedstock Selection: NA NG
- Location Selection: Central vs. Distributed
- Fuel Selection: GH2 vs. LH2
- Vehicle Selection: FCV

■ Ethanol Production Pathways (Demo 3)

- Feedstock Selection: Corn vs. Farmed Trees vs. Herbaceous Biomass
- Fuel Selection: E85
- Vehicle Selection: E85 FFV

Browse the Overview Sheet prior to the Specific GREET Simulation

Color Scheme for the GREET Model

Clear cells are primarily for calculations and secondary assumptions

Yellow cells are key input assumptions that users can change for their own simulations

Green cells are key input assumptions with probability distribution functions built in

Blue cells are GREET forecast cells for running stochastic simulations

Gray cells are placeholder pathways. Even though simulations of these pathways are completed in GREET, no thorough research was conducted to examine key input assumptions for the pathway

Cells with red triangle in the upper right corner contain comments. Users are advised to read the comments

Brief Descriptions of GREET 1.7 Worksheets

Sheet	Description
Inputs	Key input parameters that users can specify for GREET simulations. If users use the GREET GUI program, the GUI input values interact mostly with values in this sheet.
EF_TS	Time-series tables for emission factors of combustion technologies applied to stationary sources
EF	Emission factors of combustion technologies by fuel type. This sheet interacts with EF_TS sheet.
Fuel_Specs	Specifications of individual fuels and global warming potentials of GHGs
T&D	Calculations of energy use and emissions for transportation and distribution of energy feedstocks and fuels
Urban_Shares	Share of urban emissions out of total emissions of criteria pollutants for major GREET simulated activities
Fuel_Prod_TS	Time-series tables for key parametric assumptions for well-to-pump fuel production processes. This sheet interacts with other fuel production sheets
Petroleum	Calculations of well-to-pump energy use and emissions for petroleum-based fuels (including production of oxygenates)
NG	Calculations of well-to-pump energy use and emissions for NG-based fuels (plus flared gas to liquid fuels; landfill gas to methanol; and biomass to methanol, DME, and FT fuels)
Hydrogen	Calculations of well-to-pump energy use and emissions for hydrogen production pathways
Ag_Inputs	Calculations of energy use and emissions for manufacturing agricultural inputs including fertilizers, herbicides, and insecticides
EtOH	Calculations of well-to-pump energy use and emissions for producing ethanol from corn and cellulosic biomass
E-D_Additives	Calculations of well-to-pump energy use and emissions for additives to blend ethanol in diesel fuel
BD	Calculations of well-to-pump energy use and emissions for biodiesel from soybeans
Coal	Calculations of energy use and emissions for coal mining
Uranium	Calculations of energy use and emissions for uranium ore mining and uranium fuel production
LF_Gas	Calculations of energy use and emissions for landfill gas recovery
Electric	Calculations of energy use and emissions for electricity generation
Car_LDT1_TS	Time-series tables of fuel economy and emission rates/changes associated with vehicle operations for passenger cars and light duty truck 1
LDT2_TS	Time-series tables of fuel economy and emission rates/changes associated with vehicle operations for light duty truck 2
Vehicles	Calculations of energy use and emissions for vehicle operations
Results	Well-to-pump and well-to-wheels energy use and emissions results for vehicle/fuel technology combinations
Graphs	Graphic presentation of energy use and emissions for various vehicle/fuel technology combinations
Dist_Specs	Detailed specifications of the input parameters built with distribution functions. The user is cautioned against making any changes to this sheet.

Select Key Scenario Options in the Inputs Sheet

The screenshot shows the 'Inputs' sheet in Microsoft Excel. A red oval highlights the 'Scenario Control Variables and Input Assumptions' section, which includes the following content:

1. Selection of Key Options for Simulation

1.1) Target Year for Simulation
2010

1.2) Point-Estimation or Probability-Estimation Option
no
yes ... To run probability-based simulations
no ... Not to run probability-based simulations (instead, to run point-estimation simulations)

1.3) Time Series Simulation Option
1
1 -- GREET default time-series (TS) values; 2 -- User inputs (adjust all years in TS Tables); 3 -- User inputs (adjust future years in TS Table)

2. Selection of Vehicle Types for Simulation

1
1 -- Passenger Cars
2 -- Light-Duty Trucks 1
3 -- Light-Duty Trucks 2

3. Key Input Parameters for Simulating Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Efficiency for Petroleum Recovery

3.1.a-i) Conventional Crude Recovery
98.0%

3.1.a-ii) Oil Sands Recovery and Upgrading

	Bitumen recovery	Bitumen Upgrading	H2 Use for Upgrading: SCF/mmBtu product
Surface Mining	94.8%	98.6%	290.3
In Situ Production	84.3%	98.6%	111.6

3.1.b) Selection of Oil Sands Recovery Methods

Surface Mining	50.0%
In Situ Production	50.0%

Changing Default in TS Table Requires a Careful Selection of Time Series Simulation Option

The screenshot shows an Excel spreadsheet with the following content:

Scenario Control Variables and Input Assumptions

1. Selection of Key Options for Simulation

1.1) Target Year for Simulation: 2010

1.2) Point-Estimation or Probability-Estimation Option: no

1.3) Time Series Simulation Option: 1

2. Selection of Vehicle Types for Simulation: 1

3. Key Input Parameters for Simulating Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Efficiency for Petroleum Recovery

3.1.a-i) Conventional Crude Recovery: 98.0%

3.1.a-ii) Oil Sands Recovery and Upgrading

5-year period	Crude Recovery Efficiency	Relative Efficiency (to yr 2010)
1990	98.0%	100.0%
1995	98.0%	100.0%
2000	98.0%	100.0%
2005	98.0%	100.0%
2010	98.0%	100.0%
2015	98.0%	100.0%

3.1.b) Selection of Oil Sands Recovery Methods

Surface Mining	50.0%
In Situ Production	50.0%

Method 2: If the user prefers to select the yellow cell to change the default value in GREET, the user must select option 2, 3 or 4 (section 1.3 in the Inputs sheet) before to do so.

CAUTION: Option 1 does not allow the user to change the GREET default via method 2!

Method 1 (Recommended): The user can always change the default value in the TS table no matter which option (section 1.3 in the Inputs sheet) you select.

Select Key Input Parameters in the Inputs Sheet: Petroleum-Based Gasoline and Diesel (Demo 1)

3. Key Input Parameters for Simulating Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Efficiency for Petroleum Recovery

3.1.a-i) Conventional Crude Recovery

98.0%

3.1.a-ii) Oil Sands Recovery and Upgrading

	Bitumen recovery	Bitumen Upgrading	H2 Use for Upgrading: SCF/mmBtu product
Surface Mining	94.8%	98.6%	290.3
In Situ Production	84.3%	98.6%	111.8

3.1.b) Selection of Oil Sands Recovery Methods

Surface Mining	50.0%
In Situ Production	50.0%

3.1.c) Share of Oil Sands Products in Crude Oil Feed to Refineries

0%

3.1.d) Feedstock of H2 Production for Use in Oil Sands Recovery

1 1-- NA NG; 2-- Nuclear (Thermo-Chemical Water Cracking); 3-- Electrolysis (Nuclear HTGR); 4-- Coal

3.1.e) Feedstock of Steam Production for Use in Oil Sands Recovery

1 1-- NA NG; 2-- Nuclear (HTGR); 3-- Coal

3.2) Gasoline Fuel Options

3.2.a) Share of Reformulated Gasoline in Total Gasoline Use, by volume

50%

3.2.b) Gasoline Specifications and Refining Efficiencies for Gasoline

	O2 content by wt.	Oxygenate type	Sulfur level, ppm	Refining Efficiency	Note:
Conventional Gasoline	0.0%	5	26	86.0%	1-- MTBE
RFG: Gasoline Blendstock	2.3%	4	26	85.5%	2-- ETBE
CARFG: Gasoline Blendstock	2.0%	4	11	85.5%	

3.2.c) Ethanol Production Options for Gasoline if ETBE or Ethanol is Selected as the Oxygenate

	Corn	Woody Biomass	Herbaceous Biomass
Share of Ethanol Feedstock	100.0%	0.0%	0.0%

3.3) Diesel and Other Petroleum-Based Fuel Options

3.3.a) Share of Low-Sulfur Diesel in Total Diesel Use, by volume

100%

3.3.b) Fuel Specifications and Refining Efficiencies

	Selection for U.S. or CA Use	Sulfur Level, ppm	Refining Efficiency	Note:
Conventional Diesel	1	200	89.0%	1-- Fuel for U.S. use
Low-Sulfur Diesel	1	11	87.0%	2-- Fuel for California use
Crude Oil Naphtha	1	1	91.0%	
Crude Oil Liquefied Petroleum Gas	1		93.5%	

Specify conventional crude recovery efficiency (via Fuel Prod TS sheet)

Specify oil sands recovery parameters (some via Fuel Prod TS sheet)

Specify share of reformulated gasoline and conventional gasoline (via Fuel Prod TS sheet)

Specify gasoline refinery parameters (some via Fuel Prod TS sheet)

Specify share of conventional diesel and low sulfur diesel (via Fuel Prod TS sheet)

Specify diesel refinery parameters (some via Fuel Prod TS sheet)

Select Key Input Parameters in the Inputs Sheet: NG-to-H2 Pathways (Demo 2)

5. Key Input Parameters for Simulating Hydrogen Production

5.1) Share of H2 Production by Location

	Gaseous H2	Liquid H2
Central Plants	0%	0%
Refueling Stations	100%	100%

5.2) Share of H2 Feedstock Sources in Central Plants

	Gaseous H2	Liquid H2
NG	100%	100%
Solar Photovoltaics	0%	0%
Nuclear (Thermo-Chemical Cracking of Water)	0%	0%
Electrolysis (Nuclear HTGR)	0%	0%
Coal	0%	0%
Biomass	0%	0%

5.3) Share of H2 Feedstock Sources at Refueling Stations

	Gaseous H2	Liquid H2
NG	100%	100%
Electrolysis	0%	0%
EtOH	0%	0%
MeOH	0%	0%

5.4) H2 Feedstock Options for H2 Production

	Gaseous H2	Liquid H2	Note:
Central Plants	1	1	1 -- North American NG
Refueling Stations	1	1	2 -- Non-North American NG
			3 -- Non-North American flared gas

5.5) CO2 Sequestration Options for Central Plant H2 Production

	Gaseous H2	Liquid H2	Note:
NG-Based H2 Plants	1	1	1 -- Without CO2 sequestration
Coal-Based H2 Plants	1	1	2 -- With CO2 sequestration
Biomass-Based H2 Plants	1	1	

5.6) Selection of H2 Plant Design Types

	NG as Feedstock	FG as Feedstock	Coal as Feedstock	Biomass as Feedstock	Note:
Central Plant G-H2	0	0	0	0	0 -- No co-products
Refueling Station G-H2	0	0	0	0	1 -- Steam co-production
Central Plant L-H2	0	0	0	0	2 -- Electricity co-production
Refueling Station L-H2	0	0	0	0	

5.7) Electric Generation Source for H2 Production via Electrolysis at Refueling Stations

	Gaseous H2	Liquid H2	1 -- Oil Power Plants	4 -- Nuclear Power Plants	7 -- NOCC Turbine	10 -- User Defined Mix kWh
			2 -- NG Power Plants	5 -- Hydro Power Plants	8 -- NEUS: Mix kWh	

Specify H2 production location, feedstock, plant design, and other key options. (some via Fuel Prod TS sheet)

12. GREET Default Key Assumptions for Well-to-Pump Activities

12.1) Energy Efficiency of Steam Boilers for Steam Generation (for steam co-generation in many WTP facilities)

	80.0%
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12.2) Natural Gas Recovery and Processing Efficiencies

NG recovery efficiency	97.2%	North American NG
	97.2%	Non-North American NG
NG processing efficiency	97.2%	North American FG
	97.2%	Non-North American NG
	97.2%	Non-North American FG

12.17) Hydrogen Production Efficiencies

12.17.a) Central Plant H2 Production Efficiencies

	Gaseous H2	H2 Production for LH	
NA NG feedstock	71.5%	71.5%	Without steam or electricity export
	69.5%	69.5%	With steam or electricity export (excluding energy in co-products)
	145,000	145,000	With steam or electricity export: net steam export credit: Btu of steam per mMBtu of H2 produced
	12.75	12.7	With steam or electricity export: net electricity export credit: kWh per mMBtu of H2 produced
NA NG feedstock	71.5%	71.5%	Without steam or electricity export
	69.5%	69.5%	With steam or electricity export (excluding energy in co-products)
	145,000	145,000	With steam or electricity export: net steam export credit: Btu of steam per mMBtu of H2 produced
	12.75	12.7	With steam or electricity export: net electricity export credit: kWh per mMBtu of H2 produced
NNA FG feedstock	71.5%	71.5%	Without steam or electricity export
	69.5%	69.5%	With steam or electricity export (excluding energy in co-products)
	145,000	145,000	With steam or electricity export: net steam export credit: Btu of steam per mMBtu of H2 produced
	12.75	12.7	With steam or electricity export: net electricity export credit: kWh per mMBtu of H2 produced
Coal feedstock	61.0%	61.0%	Gasification in central plants: without steam or electricity co-generation
	53.3%	53.3%	Gasification for H2 production in central plants: without steam or electricity co-generation
	53.3%	53.3%	Gasification for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)
	48.90	48.9	Synthesis process for H2 production in central plants: without steam or electricity co-generation (without accounting Btu in steam or electricity)
	51.0%	51.0%	Synthesis process for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)
	47.5%	47.5%	Synthesis process for H2 production in central plants: with steam or electricity co-generation (without accounting Btu in steam or electricity)
			Net Steam export credit: Btu of steam per mMBtu of H2 produced
			Net electricity export credit: kWh per mMBtu of H2 produced

Specify key parameters related to NG recovery and processing (via Fuel Prod TS sheet)

Specify H2 production efficiency and other H2 production parameters (via Fuel Prod TS sheet)

Select Key Input Parameters in the Inputs Sheet: Ethanol Production Pathways (Demo 3)

8. Key Input Parameters for Fuel Ethanol Pathway Simulations

8.1) Selection of Ethanol Production Feedstocks: Combination of Corn, Woody Biomass, and Herbaceous Biomass

Share of Each Feedstock	Corn	Farmed Trees	Herbaceous Biomass	Corn Stover	Forest Residue
	100.0%	0.0%	0.0%	0.0%	0.0%

8.2) Selection of Corn Ethanol Plant Types

Dry Milling Plant	85.0%
Wet Milling Plant	15.0%

8.3) Selection of Method for Estimating Credits of Co-Products of Corn Ethanol

1 -- displacement method
Other values -- market value-based method

8.4) CO2 Emissions from Potential Land Use Changes of Farming: grams-bushel for corn and grams-dry ton for biomass and corn stover

	Corn	Farmed Trees	Herbaceous Biomass	Corn Stover	Forest Residue
Data cells	195	-112,500	-48,500	0	0
Calculation cells	195	-112,500	-48,500	0	0

8.5a) H2O Emissions: H in H2O as % of H in H Fertilizer

	Corn Farming	Biomass Farming	Corn Stover
	2.0%	1.5%	2.0%

8.5b) H2O Credit from Corn Stover Removal

N in N2O Avoided per Unit of Corn Stover Removed	N Content of Corn Stover	N in N2O Avoided per Unit of N in Stover Removed
-0.00563%	0.45%	-1.25%

8.6) Farming Energy Use and Fertilizer use

	Corn (per bushel)	Farmed Trees (per d ton)	H. Biomass (per d ton)	Corn Stover (per d ton)	Forest Residue (per d ton)
Farming Energy Use: Btu	22,500	234,770	217,230	235,244	612,700
Fertilizer Use					
Grams of Nitrogen	420.0	709.0	10,635	3,175	
Grams of P2O5	149.0	189.0	142.0	1,633	
Grams of K2O	174.0	331.0	226.0	8,346	
Grams of CaCO ₂	1202.0	0.0	0.0		
Pesticide Use					
Grams of Herbicide	8.10	24.00	28.00	0.00	
Grams of Insecticide	0.68	2.00	0.00	0.00	

8.7) Key Assumptions for Simulating Additional Energy Use and Fertilizer Use for Corn Stover-Based Ethanol Pathway

Corn Yield, bushels/acre	158.0
Ratio of Harvest vs. Planted Acre	90%
Collection Rate of Corn Stover	50.0%
Corn Stover Removed, dry (ton/acre)	1.884

8.8) Key Assumptions for Simulating Corn-Based Ethanol Production

8.8.a) Ethanol Yield: gallons bushel

Dry Milling Plant	2.72
Wet Milling Plant	2.62

8.8.b) Energy Use for Ethanol Production: Btu/gallon

Dry Milling Plant	36,000
Wet Milling Plant	45,850

8.8.c) Share of Process Fuels in Corn-Based Ethanol Plants

	Coal	NG
Dry Milling Plant	20%	80%
Wet Milling Plant	40%	60%

8.9) Key Assumptions for Simulating Cellulosic Ethanol Production

8.9.a) Selection of Technologies for Biomass-Based Ethanol Plant

Farmed Trees Plant	1	1 -- Fermentation
Herbaceous Biomass Plant	1	1 -- Fermentation
Corn Stover Plant	1	2 -- Gasification
Forest Residue Plant	2	2 -- Gasification

8.9.b) Ethanol Yield: Gallons per Dry Ton of Biomass

	Fermentation	Gasification
Farmed Trees Plant	90.0	
Herbaceous Biomass Plant	95.0	
Corn Stover Plant	95.0	
Forest Residue Plant		90.4

8.9.c) Amount of Electricity Co-Produced in Cellulosic Ethanol Plants for Export: kWh per gallon of ethanol (negative values mean net export from ethanol plants)

	Fermentation	Gasification
Farmed Trees Plant	-1.145	
Herbaceous Biomass Plant	-0.572	
Corn Stover Plant	-0.572	
Forest Residue Plant		0.000

8.10) Moisture Content of Biomass When Being Transported

Farmed Trees	25%
Herbaceous Biomass	15%
Corn Stover	15%

Specify key parameters and key options for ethanol production pathways: e.g., feedstock selection, plant design options, farming energy use, fertilizer and pesticide use, etc. (some via Fuel Prod TS sheet)

Those Input Parameters with Time-Series Tables Must be Specified in the Fuel Prod TS, EF TS, Car LDT1 TS, and/or LDT2 TS Sheets

	A	B	C	D	E	F
1	Time-Series Tables for Key Parameters		Production Options			
2						
3		Year 2010				
4						
5						
6	Co		and Fuel Refining from Conventional C			
7						
8		Fixed (original for 2010)	98.0%			
9		Interpolated Default or user input	98.0%			
10						
11						
12						
13						
14						
15						
16						
17						
18						

5-year period	Crude Recovery Efficiency	Relative Efficiency (to yr 2010)
1990	98.0%	100.0%
1995	98.0%	100.0%
2000	98.0%	100.0%
2005	98.0%	100.0%
2010	98.0%	100.0%
2015	98.0%	100.0%
2020	98.0%	100.0%

The cell immediately above the green cell, which presents the mean of the distribution curve for such parameter, is used for stochastic simulations.

The cell in yellow contains the value that is interpolated from the time-series table and that represents the value of the parameter corresponding to the year targeted for simulation. The yellow cell also serves as a user input cell.

The cell immediately above the yellow cells, which is colored in green, has built-in probability distribution for stochastic simulations.

The time-series look-up table contains GREET default values for such parameter in five-year internal from 1990 to 2020.

Select Key Input Parameters in the Inputs Sheet: Vehicle Fuel Economy and Emission Factors

Microsoft Excel - greet1_7.xls

Specify baseline GV and DV fuel economy and emission factors (via Car_LDT1_TS or LDT2_TS sheet)

13. Fuel Economy and Emission Rates of Baseline Vehicles, Gasoline-Equivalent MPG and grams/mile emissions

	Gasoline Car	Gasoline LDT1	Gasoline LDT2	Diesel Car	Diesel LDT1	Diesel LDT2
Gasoline Equivalent MPG	24.80	19.40	16.70	33.7	26.4	21.9
Exhaust VOC	0.1220	0.144	0.211	0.0880	0.130	0.175
Evaporative VOC	0.0580	0.069	0.080	0.000	0.000	0.000
CO	3.7450	3.916	4.280	0.5390	0.412	0.285
NOx	0.1410	0.229	0.442	0.1410	0.291	0.442
Exhaust PM10	0.0081	0.012	0.015	0.0090	0.014	0.019
Brake and Tire Wear PM10	0.0205	0.021	0.021	0.0205	0.021	0.021
Exhaust PM2.5	0.0075	0.0112	0.0140	0.0084	0.0129	0.018
Brake and Tire Wear PM2.5	0.0073	0.0073	0.0073	0.0073	0.0073	0.007
CH4	0.0146	0.016	0.025	0.0026	0.003	0.003
N2O	0.0120	0.012	0.012	0.0120	0.012	0.012

14. Fuel Economy and Emission Changes by Alternative-Fueled Vehicles and Advanced Vehicle Technologies

14.1) Passenger Car and LDT1 Technologies: SI Technologies Are Relative to GVs Fueled with CG and RFG, and CIDI Technologies Are Relative to CIDI Vehicles with CD and LS Diesel (except for fuel economy)

	CIDI Vehicle: CD and Low-Sulfur Diesel	CIDI Vehicle: Dimethyl Ether	CIDI Vehicle: FT Diesel	CIDI Vehicle: BD 20	CIDI Vehicle: E-Diesel	Grid-Independent SI HEV: CG and RFG	Grid-Independent SI HEV: CARFG	Grid-Independent SI HEV: Low-Level E10H Blend with
Gasoline Equivalent MPG	136.0%	136.0%	136.0%	136.0%	136.0%	160.0%	160.0%	160.0%
Exhaust VOC	100.0%	100.0%	100.0%	100.0%	100.0%	54.0%	54.0%	54.0%
Evaporative VOC	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%	100.0%
CO	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
NOx	100.0%	100.0%	100.0%	100.0%	100.0%	84.0%	84.0%	84.0%
Exhaust PM10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Brake and Tire Wear PM10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Exhaust PM2.5	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Brake and Tire Wear PM2.5	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
CH4	200.0%	100.0%	100.0%	100.0%	100.0%	47.0%	47.0%	47.0%
N2O	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

14.2) LDT2 Technologies: SI Technologies Are Relative to GVs Fueled with CG and RFG, and CIDI Technologies Are Relative to CIDI Vehicles Fueled with CD and LS Diesel

	Gasoline Vehicle: CARFG	Gasoline Vehicle: Low-Level E10H Blend with Gasoline	BI-fuel CHGV on C1G	Dedicated CHGV
Gasoline Equivalent MPG	100.0%	100.0%	91.0%	95.0%
Exhaust VOC	100.0%	100.0%	90.0%	90.0%
Evaporative VOC	100.0%	100.0%	50.0%	50.0%

Specify relative changes of fuel economy and emission factors of alternative-fueled vehicles and advanced vehicles (via Car_LDT1_TS or LDT2_TS sheet)

Select Key Input Parameters in the Inputs Sheet: Other Key Inputs, e.g., Electricity Generation Mix

10. Key Input Parameters for Simulating Electric Generation

10.1) Selection of GREET-Calculated or User-Inputted Emission Factors for Power Plants

1 -- GREET-calculated emissions factors via emission factors in *EF Sheet*
2 -- User-inputted emission factors in gMWh directly from *Electric Sheet*

10.2) Electricity Generation Mix

10.2.a) Selection of Marginal Electricity Generation Mix for Transportation Use

Marginal mix for transportation use 1 1 -- U.S. mix 2 -- NE U.S. mix
Average mix for stationary use 1 3 -- CA mix 4 -- User defined

10.2.b) Electric Generation Mixes: Data Table for Use in GREET

	U.S. Mix		NE U.S. Mix		CA Mix		User Defined	
	Marginal	Average	Marginal	Average	Marginal	Average	Marginal	Average
Residual oil	2.7%	2.7%	6.6%	6.6%	0.7%	0.7%	2.7%	2.7%
Natural gas	18.9%	18.9%	20.9%	20.9%	41.5%	41.5%	18.9%	18.9%
Coal	50.7%	50.7%	32.2%	32.2%	14.6%	14.6%	50.7%	50.7%
Nuclear power	18.7%	18.7%	31.0%	31.0%	18.9%	18.9%	18.7%	18.7%
Biomass	1.3%	1.3%	3.6%	3.6%	1.7%	1.7%	1.3%	1.3%
Others	7.7%	7.7%	5.7%	5.7%	22.6%	22.6%	7.7%	7.7%

10.2.c) Electric Generation Mixes for GREET Simulations

	Marginal Mix for Transportation Use	Average Mix for Stationary Use
Residual oil	2.7%	2.7%
Natural gas	18.9%	18.9%
Coal	50.7%	50.7%
Nuclear power	18.7%	18.7%
Biomass	1.3%	1.3%
Others	7.7%	7.7%

10.3) Shares of Technologies for Natural Gas, Coal, and Biomass Power Plants

NG CC turbine share of total NG power plant capacity	44%
Simple-cycle turbine share of total NG power plant capacity	36%
Advanced coal technology share of total coal power plant capacity	0%
Advanced biomass technology share of total biomass power plant capacity	0%

10.4) Share of Woody Biomass out of Total Woody and Herbaceous Biomass...

100%

10.5) The Types of Electricity Displaced by Co-Produced Electricity in IIG-based, Coal-based, and Biomass-based Fuel Plants for Export to Grid

10.5.a) IIG-Based Fuel Plants (Including IIG to MeOH, DME, FT Diesel, FT Haphtha, and H2)

2 1-- Electricity generation mix (Could be U.S. mix, NE U.S. mix, CA mix, or user defined mix, which is defined for stationary use in section 10.2.a)
2-- NGCC electricity
3-- Coal IGCC electricity
4-- Biomass IGCC electricity

The User May Further Refine Simulations via Specific Processing Sheets: 1) the Petroleum Sheet (Demo 1)

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	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB
31	3) Calculations of En																
32	Conventional Diesel				Low-Sulfur Diesel				Crude Haphtha								
33	Conv. Diesel Refining	Conv. Diesel Refining: Non-Combustion Emissions	Conv. Diesel Transportation and Distribution	Conv. Diesel Storage	LS Diesel Refining	LS Diesel Refining: Non-Combustion Emissions	LS Diesel Transportation Distribution	LS Diesel Storage	Crude Haphtha Refining	Crude Haphtha Refining: Non-Combustion Emissions	Crude Haphtha Transportation and Distribution	Crude Haphtha Storage					
34	Energy efficiency	89.0%			87.0%				91.0%								
35	Urban emission share	65.0%	67.0%	70.0%	65.0%	67.0%	70.0%		65.0%	67.0%	67.0%	67.0%					
36	Loss factor	1.000	1.000	1.000	1.000	1.000	1.000		1.000	1.001	1.000	1.000					
37	Shares of process fuels																
38	Crude oil	0.0%			0.0%				0.0%								
39	Residual oil	3.0%			3.0%				3.0%								
40	Diesel fuel	0.0%			0.0%				0.0%								
41	Gasoline	0.0%			0.0%				0.0%								
42	Natural gas	30.0%			30.0%				30.0%								
43	Coal	13.0%			13.0%				13.0%								
44	Electricity	4.0%			4.0%				4.0%								
45	Refinery still gas	50.0%			50.0%				50.0%								
46	Feed loss	0.0%			0.0%				0.0%								
47	Energy use: Btu/mmmBtu of fu																
48	Crude oil	0			0				0								
49	Residual oil	3,708			4,483				2,967								
50	Diesel fuel	0			0				0								
51	Gasoline	0			0				0								
52	Natural gas	37,079			44,828				29,670								
53	Coal	16,067			19,425				12,857								
54	Electricity	4,944			5,977				3,956								
55	Feed loss	0	44	0	0		44	0	0	841	0						
56	Refinery still gas	61,798			74,713				49,451								
57	Natural gas flared																
58	Total energy	137,387	6,240	0	166,099	6,266	0	109,937	6,912	0							
59	Fossil fuels	135,615	6,185	0	163,956	6,211	0	108,519	6,861	0							
60	Coal	24,780	322	0	29,959	323	0	19,829	307	0							
61	Natural gas	43,460	828	0	52,542	832	0	34,776	785	0							
62	Petroleum	67,375	5,035	0	81,455	5,056	0	53,913	5,769	0							

Overview / Inputs / EF_TS / EF / Fuel_Specs / T&D / Urban_Shares / Fuel_Prod_TS / **Petroleum** / NG / Hydrogen / Ag_Inputs / EtOH / E-D Additives / BD / Coal / Uranium

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The User May Further Refine Simulations via Specific Processing Sheets: 2) the NG and Hydrogen Sheets (Demo 2)

The image displays two overlapping screenshots of a Microsoft Excel spreadsheet titled 'greet1_7.xls'. The top screenshot shows a section titled '3) Calculations of Energy Consumption and Emissions for Each Stage' for 'Natural Gas as a Feedstock to Produce Transportation Fuels'. The bottom screenshot shows a similar section for 'Central Plants: North American Natural Gas to Gaseous Hydrogen'.

Table 1: Natural Gas as a Feedstock to Produce Transportation Fuels

Row	Category	MA BC Recovery	MA BC Processing	MA BC Processing: Non-Combustion Emissions	MA BC Recovery	MA BC Processing
61	Natural Gas as a Processing Fuel produced in North America					
62	MA BC Recovery					
63	MA BC Processing					
64	MA BC Processing: Non-Combustion Emissions					
65	MA BC Recovery					
66	MA BC Processing					
67	MA BC Processing: Non-Combustion Emissions					
68	MA BC Recovery					
69	MA BC Processing					
70	MA BC Processing: Non-Combustion Emissions					
71	MA BC Recovery					
72	MA BC Processing					
73	MA BC Processing: Non-Combustion Emissions					
74	MA BC Recovery					
75	MA BC Processing					
76	MA BC Processing: Non-Combustion Emissions					
77	MA BC Recovery					
78	MA BC Processing					
79	MA BC Processing: Non-Combustion Emissions					
80	MA BC Recovery					
81	MA BC Processing					
82	MA BC Processing: Non-Combustion Emissions					
83	MA BC Recovery					
84	MA BC Processing					
85	MA BC Processing: Non-Combustion Emissions					
86	MA BC Recovery					
87	MA BC Processing					
88	MA BC Processing: Non-Combustion Emissions					
89	MA BC Recovery					
90	MA BC Processing					
91	MA BC Processing: Non-Combustion Emissions					
92	MA BC Recovery					
93	MA BC Processing					
94	MA BC Processing: Non-Combustion Emissions					
95	MA BC Recovery					
96	MA BC Processing					
97	MA BC Processing: Non-Combustion Emissions					
98	MA BC Recovery					
99	MA BC Processing					
100	MA BC Processing: Non-Combustion Emissions					

Table 2: Central Plants: North American Natural Gas to Gaseous Hydrogen

Row	Category	C/H ₂ Production	C/H ₂ Production: Non-Combustion Emissions	Production of Displaced Steam	Electricity Co-Generation in Hydrogen Plant	Generation of Displaced Electricity	C/H ₂ Transmission and Distribution	C/H ₂ Compression	Flared Gas Energy and Emission Credits	Central Plants: Solar Energy to Gaseous Hydrogen	Central Plants: Nuclear Energy to Gaseous Hydrogen (Thermo-Chemical Cracking of Water)
57	Central Plants: North American Natural Gas to Gaseous Hydrogen										
58	C/H ₂ Production										
59	C/H ₂ Production: Non-Combustion Emissions										
60	Production of Displaced Steam										
61	Electricity Co-Generation in Hydrogen Plant										
62	Generation of Displaced Electricity										
63	C/H ₂ Transmission and Distribution										
64	C/H ₂ Compression										
65	Flared Gas Energy and Emission Credits										
66	Central Plants: Solar Energy to Gaseous Hydrogen										
67	C/H ₂ Production										
68	C/H ₂ Transmission and Distribution										
69	C/H ₂ Compression										
70	C/H ₂ Production										
71	C/H ₂ Transmission and Distribution										
72	C/H ₂ Compression										
73	Central Plants: Nuclear Energy to Gaseous Hydrogen (Thermo-Chemical Cracking of Water)										
74	C/H ₂ Production										
75	C/H ₂ Transmission and Distribution										
76	C/H ₂ Compression										
77	C/H ₂ Production										
78	C/H ₂ Transmission and Distribution										
79	C/H ₂ Compression										
80	Energy efficiency	71.5%		80.0%				92.5%		71.5%	100.0%
81	Urban emission share	25.0%		25.0%				70.0%		0.0%	70.0%
82	Loss factor	1.000					1.000	1.000		1.000	1.000
83	Share of feedstock input as feed (the remaining input as process fuel)										
84	Steam or electricity export: Btu (for steam) or kWh (for electricity) per mmBtu of fuel produced										
85	Shares of process fuels										
86	Residual oil	0.0%		0.0%							
87	Diesel fuel	0.0%		0.0%							
88	Gasoline	0.0%		0.0%							
89	Natural gas	98.8%		100.0%							0.0%
90	Coal										
91	N-butane	0.0%		0.0%							
92	Hydrogen										
93	Electricity							100.0%		100.0%	100.0%
94	Feed loss	0.2%		0.0%							
95	Energy use: Btu/mmBtu of fuel throughput (except as noted)										
96	Residual oil	0		0							
97	Diesel fuel	0		0							
98	Gasoline	0		0							
99	Natural gas: process fuel	237,627		1,250,000							
100	Coal: process fuel										
101	Natural gas: feed loss	160,178									
102	Natural gas flared										
103	N-butane										

The User May Further Refine Simulations via Specific Processing Sheets: 3) the EtOH and Ag_Inputs Sheets (Demo 3)

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Production and Transportation of Fertilizers, Herbicides, and Insecticides

1) Shares of Combustion Processes for Each Stage

	Nitrogen Production	P2O5 Production	K2O Production	Urea (CaCO3) Production	Herbicide Production	Insecticide Production
Residual of industrial and commercial boiler	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Diesel commercial boiler	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
Diesel stationary engine	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Diesel turbine	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
NO engine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NO large turbine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NO large industrial boiler	80.0%	80.0%	80.0%	80.0%	80.0%	80.0%
NO small industrial boiler	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
Coal industrial boiler	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

2) Calculation of Energy Use and Emissions of Fertilizer Production: Production Processes Only

	Ammonia (per ton of product)			Urea (per ton of product)			Nitric Acid		
	Production	Process emissions	Transportation to producer products	Production	Process emissions	Transportation	Production	Process emissions	Transportation
Urban emission share	0.0%			0.0%			0.0%		
Share of total NG input as fuel	36.3%			100.0%			100.0%		
Inputs: mmBtu per ton, except as noted									
Total Energy Input	27,446			2,346			0,532		
Natural Gas	26,370			2,146			0,526		
Electricity	1,120			0,129			0,006		
Residual Oil									
Diesel Fuel									
Coal									
Ammonia (ton)				0,567			0,405		
Nitric acid (ton)									
Sulfuric Acid (ton)									
Phosphoric rock (ton)									
Calculated Energy Use: mmBtu/ton	28,572			2,477			0,538		

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3) Calculations of Energy Consumption and Emissions for Each Stage

	Corn Farming				Corn Ethanol Production				Co-P				
	Corn Farming	Corn Farming Fertilizer Use by Nutrient (grams bushel)	Corn Farming Pesticide Use (grams bushel)	Corn Transportation	Total: Corn Farming and Transportation	Dry Mill Ethanol Production	Dry Mill Ethanol Production: Non-Combustion Emissions	Wet Mill Ethanol Production		Wet Mill Ethanol Production: Non-Combustion Emissions			
Production inputs	Etbushel	Nitrogen	P2O5	K2O	CaCO3	Herbicide	Insecticide	Per bushel	Per bushel	Etbushel	Per gallon	Per gallon	Per gallon
Urban emission share	0.0%	420.0	149.0	174.0	1202.0	8.10	0.68			36,000	0.0%	45,950	0.0%
Loss factor													
Shares of process fuels													
Residual oil	0.0%												
Diesel fuel	38.3%												
Gasoline	12.3%												
Natural gas	21.5%										71.8%	60.0%	
Coal	0.0%										17.9%	40.0%	
Liquefied petroleum gas	18.8%										10.3%	0.0%	
Electricity	9.0%												
Feed loss	0.0%												
Energy Use: Btu/mmBtu of fuel throughput, except as noted								Per bushel			Per gallon		
Residual oil	0									0	0	0	
Diesel fuel	8,616									0	0	0	
Gasoline	2,768									0	0	0	
Natural gas	4,838									25,834	27,570	18,380	
Coal	0									6,458	18,380	0	
Liquefied petroleum gas	4,230									0	0	0	
Biomass: tons										0,000	0,000	0,000	
Electricity	2,025									3,708	0	3,708	
Total energy	28,838	19,280	1,980	1,465	9,272	2,141	214	5,990	69,180	97,084	101,349	49,261	
Fossil fuels	26,115	19,039	1,897	1,359	8,542	2,050	205	5,973	67,190	42,789	49,261	18,516	
Coal	3,750	1,188	414	523	3,595	453	47	163	10,192	12,591	15,516	0	
Natural gas	8,886	17,078	909	409	2,792	570	57	314	32,015	28,559	29,389	0	
Petroleum	14,480	774	573	427	2,155	1,027	101	5,497	25,034	628	377	0	
Total Emissions: grams/mmBtu of fuel throughput, except as noted											Per bushel		Per gallon
CO2		1,340	2,540	0,065	0,021	0,000	0,001	0,198	4,277	0,336	0,336	0,336	0,336

The User May Further Refine Simulations via Specific Processing Sheets: 4) the T&D Sheet

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9) Energy Consumption and Emissions of Feedstock and Fuel Transportation										
82 Feedstock/Fuel	Crude Oil for Use in U.S. Refineries					Crude Oil for Use in California Refineries				
	Ocean Tanker	Barge	Pipeline	Rail	Truck	Ocean Tanker	Barge	Pipeline	Rail	Truck
83 Transportation Mode										
84 Urban Emission Share	5.0%	7.0%	5.0%	5.0%	44.0%	7.0%	5.0%	7.0%	5.0%	54.0%
85 Distance (Miles, one-way)	5,080	500	750	800	30	3,900	200	150	200	30
86 Share of Fuel Type Used:										
87 Diesel	0%	0%	20%	100%	100%	0%	0%	20%	100%	100%
88 Residual Oil	100%	100%	50%			100%	100%	50%		
89 Natural Gas			24%					24%		
90 LPG										
91 DME										
92 FTD										
93 Methanol										
94 Ethanol										
95 Biodiesel										
96 Hydrogen										
97 Electricity			6%	0%				6%	0%	
98 Energy Intensity: Btu/ton-mile										
99 Origin to Destination	22	403	253	370	1,028	22	403	253	370	1,028
100 Back-Haul	20	307			1,028	20	307			1,028
101 Energy Consumption: Btu/mmBtu of fuel transported										
102 Total energy	6,299	10,613	6,192	9,523	1,984	4,836	4,245	1,238	2,381	1,984
103 Fossil energy	6,266	10,592	6,079	9,497	1,978	4,826	4,237	1,216	2,374	1,978
104 Coal	97	163	584	260	54	74	65	117	65	54
105 Natural gas	200	337	1,643	499	104	154	135	329	125	104
106 Petroleum	5,969	10,092	3,852	8,739	1,820	4,598	4,037	770	2,185	1,820
107 Total Emissions: grams/mmBtu fuel transported										
108 VOC	0.572	0.453	0.216	0.657	0.063	0.439	0.181	0.043	0.164	0.063
109 CO	2.528	1.239	1.091	1.824	0.279	1.941	0.495	0.218	0.456	0.279
110 NOx	14.452	10.490	4.655	12.563	0.827	11.095	4.196	0.931	3.141	0.827
111 PM10	0.446	0.293	0.185	0.348	0.026	0.342	0.117	0.037	0.087	0.026
112 PM2.5	0.326	0.143	0.095	0.282	0.017	0.250	0.057	0.019	0.071	0.017
113 SOx	4.125	2.727	0.932	0.149	0.048	3.167	1.091	0.186	0.037	0.048
114 CH4	0.578	0.949	0.892	0.862	0.175	0.444	0.379	0.178	0.215	0.175
115 N2O	0.012	0.021	0.011	0.018	0.004	0.009	0.008	0.002	0.005	0.004
116 CO2	530	900	482	742	155	407	360	96	186	155
117 Urban Emissions: grams/mmBtu of fuel transported										
118 VOC	0.038	0.047	0.018	0.054	0.027	0.038	0.016	0.004	0.013	0.032
119 CO	0.135	0.099	0.064	0.116	0.119	0.141	0.030	0.017	0.029	0.145
120 NOx	0.738	0.753	0.255	0.683	0.348	0.785	0.220	0.069	0.171	0.423
121 PM10	0.023	0.022	0.006	0.020	0.007	0.024	0.007	0.002	0.005	0.009
122 PM2.5	0.017	0.014	0.005	0.017	0.005	0.017	0.004	0.001	0.004	0.005

Overview / Inputs / EF_TS / EF / Fuel Specs / T&D / Urban_Shares / Fuel_Prod_TS / Petroleum / NG / Hydrogen / Ag_Inputs / EtOH / E-D Additives / BD / Coal / Uranium

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The Results Sheet Summarizes the WTP and WTW Results

27 **2. Well-to-Wheels Energy Consumption and Emissions: per Mile**

28

29 Gasoline Vehicle: CG and RFG

30

31 Item	Btu/mile or grams/mile				Percentage of each stage		
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation
32 Total Energy	175	1,141	4,581	5,897	3.0%	19.4%	77.7%
33 Fossil Fuels	169	993	4,388	5,550	3.0%	17.0%	79.1%
34 Coal	33	190	0	223	14.6%	85	
35 Natural Gas	81	355	0	435	18.5%	81	
36 Petroleum	56	448	4,388	4,892	1.1%	9	
37 CO2	3	75	352	430	0.7%	17	
38 CH4	0.418	0.093	0.015	0.525	79.5%	17	
39 N2O	0.000	0.010	0.012	0.023	1.5%	45	
40 GHGs	13	81	449	543	2.8%	16	
41 VOC: Total	0.016	0.110	0.180	0.306	5.1%	26	
42 CO: Total	0.030	0.044	3.745	3.819	0.8%	1	
43 NOx: Total	0.112	0.131	0.141	0.384	29.2%	34	
44 PM10: Total	0.009	0.052	0.029	0.089	9.7%	58	
45 PM2.5: Total	0.004	0.019	0.015	0.038	10.4%	50	
46 SOx: Total	0.038	0.085	0.006	0.129	29.5%	66	
47 VOC: Urban	0.003	0.068	0.112	0.183	1.5%	37	
48 CO: Urban	0.001	0.018	2.329	2.349	0.1%	0	
49 NOx: Urban	0.005	0.049	0.088	0.141	3.5%	34	
50 PM10: Urban	0.000	0.009	0.018	0.027	0.8%	34	
51 PM2.5: Urban	0.000	0.005	0.009	0.015	1.0%	36	
52 SOx: Urban	0.003	0.033	0.004	0.040	8.4%	82	

53

54 Gasoline Vehicle: CARFG

38 CH4	0.507	0.094	0.015	0.616	82.3%	15
39 N2O	0.001	0.010	0.012	0.023	4.5%	44
40 GHGs	74	82	511	667	14.4%	16
41 VOC: Total	0.020	0.110	0.180	0.311	6.6%	35
42 CO: Total	0.035	0.044	3.745	3.824	0.9%	1
43 NOx: Total	0.126	0.131	0.141	0.398	31.6%	33
44 PM10: Total	0.019	0.052	0.029	0.100	18.8%	52
45 PM2.5: Total	0.010	0.019	0.015	0.044	22.0%	44
46 SOx: Total	0.041	0.085	0.006	0.132	31.1%	64
47 VOC: Urban	0.003	0.068	0.112	0.183	1.5%	37
48 CO: Urban	0.001	0.018	2.329	2.349	0.1%	0
49 NOx: Urban	0.005	0.049	0.088	0.141	3.5%	34.4%
50 PM10: Urban	0.000	0.009	0.018	0.027	0.8%	34.2%
51 PM2.5: Urban	0.000	0.005	0.009	0.015	1.0%	36.8%
52 SOx: Urban	0.003	0.033	0.004	0.040	8.4%	82.6%

53

WTW GHG Emissions (g/mi)

