

February 12, 2025

Demo for Biofuels in R&D GREET®

3:00-4:00 p.m. CT

Instructors

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Branden Leonhardt, Department of Energy

Argonne National Laboratory Subject Matter Experts

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 - a. Model a CIDI-ICE Car Using Conventional Diesel, Soybean Biodiesel, Soybean Renewable Diesel, and 35% Soybean Biodiesel
4. Renewable Natural Gas Scenarios
 - a. Model a Refuse Truck with LNG from Different RNG Waste Sources



Outline Steps for Biofuels Scenarios



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Main Outputs for SI-ICE LDVs and CIDI-ICE LDVs



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RSELSIICEV Select Fuels

Home Inputs Back to Top WTP Results WTP Changes

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles
 Select Fuels Go
 Select Fuels Go
 SI - Gasoline Go
 SI - CA gasoline
 SI - E10
 SI - EtOH FFV
 SI - BtOH FFV
 SI - MeOH FFV
 SI - CNG Vehicle
 SI - LNG Vehicle
 SI - LPG Vehicle
 SI - Dedi. MeOH Vehicle
 SI - Dedi. EtOH Vehicle

SI Hybrid Vehicles (HEV) Go
 CIDI Hybrid Vehicles (HEV) Go
 BEV and FCV Go

SI Plug-in Hybrids (PHEV) Go
 CIDI Plug-in Hybrids (PHEV) Go
 GCI ICE Vehicles Go

Performance-enhancing Fuels
 Select Fuels

Select units from a pink drop down menu for the Results
 Emission Unit: g
 Operational Unit: mile
 Energy Unit: Btu
 Emission Unit: g
 Energy Functional Unit: mmBtu

Per Energy in Fuels

Vehicle Operation	Btu/mmBtu or Gallon/mmBtu or g/mmBtu					
	Total	Feedstock	Fuel	Vehicle Operation	Total	
Total Energy	4,289	5,450	50,498	220,096	1,000,000	1,270,595
Fossil Fuels	4,003	5,042	47,218	195,069	933,326	1,175,613
Coal	19	30	0	49	0	11,391
Natural Gas	147	538	0	685	0	159,788
Petroleum	36	269	4,003	4,308	8,474	1,004,435
Water Consumption	0.1	0.2	0	0	15	38
CO2 (w/ C in VOC & CO)	-4	63	329	388	-839	14,592
CH4	0.315	0.173	0.015	0.503	73.544	40,320
N2O	0.000	0.012	0.004	0.016	0.066	2.787
GHGs	6	71	330	407	1,371	16,554
VOC: Total	0.013	0.114	0.230	0.356	2.988	26.524
CO: Total	0.026	0.043	2.741	2.810	6.071	10.068
NOx: Total	0.039	0.071	0.082	0.193	9.137	16.540
PM10: Total	0.002	0.010	0.035	0.047	0.443	2.360
PM2.5: Total	0.002	0.006	0.007	0.015	0.372	1.502

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio

Note: press F9 to ensure the results of R&D GREET are up to date



Microsoft Excel ribbon showing tabs: File, Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. The Home tab is active, displaying options for Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, and Analyze Data.

RSELCIDIICEV Select Fuels

WTW Results Menu

Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles	Select Fuels	Go
SIDI ICE Vehicles	Select Fuels	Go
CIDI ICE Vehicles	Select Fuels	Go

Select units from a pink drop down menu for the Results

Per Energy in Fuels

Emission Unit: g Energy Unit: Btu Emission Unit: g

Functional Unit: mile Energy Functional Unit: mmBtu

Item	Vehicle Operation		Total		Btu/mmBtu or Gallon/mmBtu or g/mmBtu		Vehicle Operation		Total	
	Vehicle	Operation	Vehicle	Total	Feedstock	Fuel	Vehicle	Operation	Vehicle	Total
Total Energy	4,289	5,450	50,498	220,096	1,000,000	1,270,595				
Fossil Fuels	4,003	5,042	47,218	195,069	933,326	1,175,613				
Coal	0	49	4,492	6,898	0	11,391				
Natural Gas	147	538	0	685	34,251	159,788				
Petroleum	36	269	4,003	4,308	8,474	1,004,435				
Water Consumption	0.1	0.2	0	0	15	53				
CO2 (w/ C in VOC & CO)	-4	63	329	388	-839	90,455				
CH4	0.315	0.173	0.015	0.503	73.544	117.279				
N2O	0.000	0.012	0.004	0.016	0.066	3.764				
GHGs	6	71	330	407	1,371	94,977				
VOC: Total	0.013	0.114	0.230	0.356	2.988	83.110				
CO: Total	0.026	0.043	2.741	2.810	6.071	655.243				
NOx: Total	0.039	0.071	0.082	0.193	9.137	44.886				
PM10: Total	0.002	0.010	0.035	0.047	0.443	10.847				
PM2.5: Total	0.002	0.006	0.007	0.015	0.372	3.602				

Navigation bar with tabs: Overview, Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio. The Results tab is currently selected.

Ethanol Overview



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Find the General Settings to Alter an Ethanol Pathway



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Home Results Petroleum MeOH & Ethanol Electric Vehicles Car_TS Tab LDV1_TS Tab LDV2_TS Tab
 Natural Gas Hydrogen Bio Oil Pyrolysis WTP Vehicles Tab HDV_TS Tab HDV_WTW Tab
 Fuel Economy

Scenario Control Variables and Input Assumptions

1. Key Options for Simulation

1.1) Target Year for Simulation: 2022

1.2) Point-Estimation or Probability-Estimation Option: Load Stochastic Toolkit

Link with GREET2: Reactivate GREET2 Links, Deactivate GREET2 Links

Load Stochastic Toolkit ... To load the stochastic toolkit
 Unload Stochastic Toolkit ... To unload the stochastic toolkit

2. Vehicle Types for Simulation

1 -- Passenger Cars; 2 -- Light-Duty Trucks 1 (LDT1) (Sports utility vehicles [SUV]); 3 -- Light-Duty Trucks 2 (LDT2) (Pickup Truck [PUT])

3. Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Share of crude oil sources

1 -- Basis of share of crude oil sources: 1 -- EIA projection, 2 -- User defined

	U.S. Domestic	Canada (Oil Sands)	Canada (Conv. Crude)	Mexico	Middle East	Lat
EIA projection	80.8%	6.6%	5.0%	1.9%	2.3%	
User defined	0.0%	100.0%	0.0%	0.0%	2.3%	
Used in calculation	80.8%	6.6%	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	14,596	

U.S. Domestic crude	Shale Oil (Bakken)	Shale Oil (Eagle Ford)	Rest of U.S. domestic crude
API gravity	42	48	32.0
Vol. Share (%)	8.7%	8.0%	83.3%

Overview Inputs Results Petroleum Co-processing NG MeOH FTD FtOH Electric Generation mixes Bio



Microsoft Excel ribbon: Formulas, Data, Review, View, Automate, Help. Includes Function Library (Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More Functions), Defined Names (Name Manager, Define Name, Use in Formula, Create from Selection), Formula Auditing (Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula), and Calculation (Watch Window, Calculation Options).

NavInputsZoomEthanol | 8. Fuel Ethanol Pathway

8. Fuel Ethanol Pathway

8.1) Ethanol Production Feedstocks for General Purpose: Corn, Cellulosic Biomass, and Sugarcane

Share of Each Feedstock	Corn	Willow	Poplar	Switchgrass	Miscanthus
	100.0%	0.0%	0.0%	0.0%	0.0%

8.2) Farming Energy Use and Fertilizer use

8.2.a) Allocation of corn farming energy between corn grain and corn stover

1. Attributional 2. Energy allocation 3. Mass allocation 4. Market-value allocation

8.2.b) Logging residue scenarios (Logging residue is related to forest residue feedstock options)

1 -- Logging residue is treated as a waste, 2 -- Logging residue is treated as a co-product

8.2.c) Forest residue collection and harvesting energy use

	Logging residues	Forest thinnings
Diesel consumption for collection and preprocessing (Btu/dry ton)	118,006	146,353
Forest Residues Shares (by dry wt.)	50%	50%

8.2.d) Farming energy use and fertilizer use summary

	Corn (per bushel)	Willow (per d.ton harvested)	Poplar (per d.ton harvested)	Clean Pine (per d.tonharvested)	Switchgrass (per d.ton harvested)	Miscanthus (per d.ton harvested)
Farming Energy Use: Btu	8,891	185,416	268,597	144,177	59,361	
Fertilizer Use						
Grams of Nitrogen	396	1,462	1,970	2,840	4,291	
Grams of P2O5	133	650	591	1,523	2,030	
Grams of K2O	138	1,002	522	401	2,815	
Grams of CaCO3	1,471	0	23,237	16,619	5,144	
Pesticide Use						
Grams of Herbicide	7.66	16.08	61.70	0.00	46.71	
Grams of Insecticide	0.04	0.00	11.76	0.00	0.00	

8.3) CO2 Emission Estimates from Land Use Changes and Land Management Changes of Farming: grams/gal of ethanol

8.3.a) Land Use Change Scenario Options

Select	Scenario	Case Code	Case Description
Select Corn Ethanol Case	Corn Ethanol 2011	yield_increase	Annual yield increase considered over simulation
Select Domestic Emissions Modeling Scenario	Century	yield_constant	Yield assumed constant over simulation
Select International Emissions Modeling Scenario	Winrock		
Domestic Emissions Modeling Scenario	yield_constant		
Soil depth considered in modeling	100 cm		
Harvested Wood Product (HWP) Scenario	HEATH		

Run LUC

Navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

fx Insert Function | AutoSum | Recently Used | Financial | Logical | Text | Date & Time | Lookup & Reference | Math & Trig | More Functions | Define Name | Use in Formula | Create from Selection | Trace Precedents | Trace Dependents | Remove Arrows | Show Formulas | Error Checking | Evaluate Formula | Watch Window | Calculation Options | Calculation

NavInputsZoomEthanol

8. Fuel Ethanol Pathway

8.7.c) Selection of Plant Type

- 1 -- Industrial average
- 2 -- User defined average
- 3 -- Plant Specific: Dry Mill with DGS as a process fuel
- 4 -- Plant Specific: Dry Mill with only DDGS as co-product and NG as process fuel
- 5 -- Plant Specific: Dry Mill with only DDGS as co-product and Coal as process fuel
- 6 -- Plant Specific: Dry Mill with only DDGS as co-product and Biomass as process fuel
- 7 -- Plant Specific: Dry Mill with only WDGS as co-product and NG as process fuel
- 8 -- Plant Specific: Dry Mill with only WDGS as co-product and Coal as process fuel
- 9 -- Plant Specific: Dry Mill with only WDGS as co-product and Biomass as process fuel
- 10 -- Plant Specific: Wet Mill with NG as process fuel
- 11 -- Plant Specific: Wet Mill with Coal as process fuel
- 12 -- Plant Specific: Wet Mill with Biomass as process fuel

8.7.c.i) Energy demands for corn oil extraction

For process level allocation	Heat (Btu/gal EtOH)	Electricity (Btu/gal EtOH)
Energy for ethanol processing (distillation, dewatering, etc., allocated to ethanol only)	4,010	22
Energy for corn oil extraction (allocated to corn oil only)		50
Energy for DGS drying (allocated to DGS only; allocated to ethanol only w/ marginal method)	10,116	632
Allocated between ethanol, corn oil and DGS	8,354	1,444

8.7.c.ii) 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 Mill with pr
	Dry Milling Plant w/o Corn Oil extraction	Dry Milling Plant w/ Corn Oil extraction	Wet Milling Plant	Dry Milling Plant	Wet Milling Plant	
Share of Corn Ethanol Plant Types	4.5%	85.5%	10.0%	100.0%	0.0%	
Total energy use for ethanol production: Btu/gallon	25,034	24,628	47,409	34,290	47,409	
Energy use: NG, coal, and biomass, Btu/gallon	22,908	22,480	47,409	31,594	47,409	
Share: NG	99.6%	99.6%	72.5%	0.0%	72.5%	
Coal	0.4%	0.4%	27.5%	0.0%	27.5%	
Biomass	0.0%	0.0%	0.0%	100.0%	0.0%	
Electricity demand, kWh/gallon	0.62	0.63	0.00	0.79	0.00	
Share of Biomass used as process fuel:						
Willow	0.0%	0.0%	0.0%	0.0%	0.0%	
Poplar	0.0%	0.0%	0.0%	0.0%	0.0%	
Switchgrass	0.0%	0.0%	0.0%	0.0%	0.0%	
Miscanthus	0.0%	0.0%	0.0%	0.0%	0.0%	
Corn Stover	0.0%	0.0%	0.0%	0.0%	0.0%	
Forest Residue	100.0%	100.0%	100.0%	100.0%	100.0%	
Percentage of co-produced DGS used as process fuel	0.0%	0.0%		0.0%		

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Further Explore Ethanol Scenarios



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Ethanol tabs

Primary
Ethanol

Some Secondary

Ag_Inputs
RNG
NG

Inputs
Results
Fuel_Prod_TS
Fuel_Specs
Electricity
Car_TS
Vehicles
EF
T&D
T&D Flowcharts



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Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon tabs: Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: A1, fx, Corn, Cellulosic Biomass, and Sugarcane to Ethanol; Corn to Butanol and Acetone

Worksheet tabs: Home, Inputs, Results

1) Scenario Control and Key Input Parameters

	Corn	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Forest Residue	Sorghum
Shares of Feedstocks for Ethanol for General Purpose	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Shares of Feedstocks for Gasoline Blended Ethanol	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

1.1) Feedstock Farming

N content of above and below ground biomass: grams/bushel for corn, grams/ton for cellulosic biomass, and grams/tonne for sugarcane

	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Grain Sorghum	Sweet Sorghum	Forage Sorghum
Corn Farming	141.6	0.0	0.0	486.9	584.2	0.0	149.0	0

N2O Emissions: N in N2O as % of N in N fertilizer and biomass

	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Sorghum	Sugarcane	N fertilizer in the US
Corn Farming	1.264%	1.264%	1.264%	1.264%	1.264%	1.264%	1.264%	1.374%

N2O Emissions Management Practices (only for corn)

BAU Business-As-Usual scenario in which an empirical EF is applied
 4R Right time, Right place, Right form, and Right rate nitrogen management scheme in which a nitrogen balance approach is used to estimate
 EEf Use of enhanced efficiency nitrogen fertilizer that reduces direct N2O emission from synthetic fertilizer by 30%

Corn and Corn Stover Farming Assumptions

Allocation of corn farming energy between corn grain and corn stover: 1. Attributional 2. Energy allocation 3. Mass allocation 4. Market-value allocation

	Biomass Yield	Energy allocation	Mass Allocation	Market-value allocation
Corn grain	176.7 bu/acre	78%	80%	90%
Corn stover	1.27 dry ton/acre	22%	20%	10%

Worksheet tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity



Biodiesel and Renewable Diesel Overview



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General Settings to Alter a Biodiesel or Renewable Diesel Pathway



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Home Results Petroleum MeOH & Ethanol Electric Vehicles Car_TS Tab LDV1_TS Tab LDV2_TS Tab
 Natural Gas Hydrogen Bio Oil Pyrolysis WTP Vehicles Tab HDV_TS Tab HDV_WTW Tab
 Fuel Economy

Scenario Control Variables and Input Assumptions

1. Key Options for Simulation

1.1) Target Year for Simulation: 2022

1.2) Point-Estimation or Probability-Estimation Option: Load Stochastic Toolkit

Link with GREET2: Reactivate GREET2 Links, Deactivate GREET2 Links

Load Stochastic Toolkit ... To load the stochastic toolkit
 Unload Stochastic Toolkit ... To unload the stochastic toolkit

2. Vehicle Types for Simulation

1 -- Passenger Cars; 2 -- Light-Duty Trucks 1 (LDT1) (Sports utility vehicles [SUV]); 3 -- Light-Duty Trucks 2 (LDT2) (Pickup Truck [PUT])

3. Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Share of crude oil sources

1 -- Basis of share of crude oil sources: 1 -- EIA projection, 2 -- User defined

	U.S. Domestic	Canada (Oil Sands)	Canada (Conv. Crude)	Mexico	Middle East	Lati
EIA projection	80.8%	6.6%	5.0%	1.9%	2.3%	
User defined	0.0%	100.0%	0.0%	0.0%	2.3%	
Used in calculation	80.8%	6.6%	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	14,596	

U.S. Domestic crude	Shale Oil (Bakken)	Shale Oil (Eagle Ford)	Rest of U.S. domestic crude
API gravity	42	48	32.0
Vol. Share (%)	8.7%	8.0%	83.3%

Overview Inputs Results Petroleum Co-processing NG MeOH FTD FtOH Electric Generation mixes Bio



Microsoft Excel ribbon showing the **Formulas** tab. The ribbon includes sections for **Function Library** (Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More Functions), **Defined Names** (Name Manager, Define Name, Use in Formula, Create from Selection), **Formula Auditing** (Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula), and **Calculation** (Watch Window, Calculation Options).

NavInputsZoomBioOil | 9. Bio Oil-Based Fuel

9. Bio Oil-Based Fuel						
9.1) Method for dealing with co-products of Bio Oil-based fuel (see co-products in BioOil sheet)						
BioOil Worksheet	Feedstock for biooil-based fuels	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable diesel 3	Renewable gasoline
		1	1	1	6	1
Results	Method for dealing with co-products					
Back to Top	System level allocation for soy and jatropha based fuel	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable gasoline	1- Process Level Allocation/Displacement 2- System Level Energy-Based Allocation
		1	1	1	1	
	Process level allocation for all biooil-based fuels					
	Feedstock	Soybean	Palm Oil	Canola	Jatropha	Camelina
	Oil Extraction Process	4	4	4	2	4
	Fuel	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable diesel 3	Renewable gasoline
	Fuel Production	3	2	2	2	2
	9.2) Farming Energy Use, Fertilizer use, and N2O Emissions from Biomass					
		Soybean (per bushel)	Palm Full Fruit Bunch (FFB) (per wet ton)	Canola (per wet tonne)	Jatropha (per wet kg)	Camelina (per wet kg)
	Farming Energy Use: Btu	13,634	154,528	528,667	1,320	961
	Fertilizer Use					
	Grams of Nitrogen	52.8	5,297.4	51,648.0	34.0	37.0
	Grams of P2O5	207.9	3,565.6	15,919.0	13.0	15.0
	Grams of K2O	348.7	9,830.8	4,163.0	37.4	10.0
	Grams of CaCO3	0.0	0.0	0.0	0.0	0.0
	Pesticide Use					
	Grams of Herbicide	21.16	28.52	417.00	0.00	0.00
	Grams of Insecticide	0.32	137.53	39.00	0.00	0.00
	N content of above and below ground biomass: grams	557	10362	24280	35.0	65.2
	N2O emissions from N fixation: grams N2O	7.3				
	N2O emissions: N in N2O as % of N in N fertilizer	1.374%	1.374%	1.040%	1.374%	1.374%
	N2O emissions: N in N2O as % of N in Biomass	1.264%	1.264%	0.940%	1.264%	1.264%
	9.3) Soyoil Extraction Energy Use: Btu/lb of soyoil					
		3,073				

Navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity



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 Unload Stochastic Toolkit ... To unload the stochastic toolkit

2. Vehicle Types for Simulation

1 -- Passenger Cars; 2 -- Light-Duty Trucks 1 (LDT1) (Sports utility vehicles [SUV]); 3 -- Light-Duty Trucks 2 (LDT2) (Pickup Truck [PUT])

3. Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Share of crude oil sources

1 -- Basis of share of crude oil sources: 1 -- EIA projection, 2 -- User defined

	U.S. Domestic	Canada (Oil Sands)	Canada (Conv. Crude)	Mexico	Middle East	Lati
EIA projection	80.8%	6.6%	5.0%	1.9%	2.3%	
User defined	0.0%	100.0%	0.0%	0.0%	2.3%	
Used in calculation	80.8%	6.6%	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	14,596	

U.S. Domestic crude	Shale Oil (Bakken)	Shale Oil (Eagle Ford)	Rest of U.S. domestic crude
API gravity	42	48	32.0
Vol. Share (%)	8.7%	8.0%	83.3%

Overview Inputs Results Petroleum Co-processing NG MeOH FTD EtOH Electric Generation mixes Bio



Microsoft Excel ribbon showing the 'Formulas' tab. The ribbon includes sections for 'Function Library' (Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More), 'Defined Names' (Name Manager, Define Name, Use in Formula, Create from Selection), 'Formula Auditing' (Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula), and 'Calculation' (Watch Window, Calculation Options).

NavInputsZoomVehicles | 12. Vehicle Operations

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				
	Isobutanol	2	2--20%	3--30%
	ARHC	2	2--20%	3--30%
	MeOH	2	2--20%	3--30%
	Methanol in FFV fuel		85.0%	
	Methanol in dedicated vehicle fuel		90.0%	
	Ethanol in low-level blend of gasoline and ethanol		10.0%	2.0% Share of gasoline by volume added in EtOH as denaturant
	Ethanol in FFV fuel		85.0%	2.0% Share of gasoline by volume added in EtOH as denaturant
	Ethanol in dedicated vehicle fuel		85.0%	2.0% Share of gasoline by volume added in EtOH as denaturant
	Butanol in FFV fuel		100.0%	
	ET 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 EtOH-diesel		10.0%	
	Additives in EtOH-diesel		1.0%	
	Isobutanol in BSI (gasoline) fuel		20.0%	
	ARHC (Aromatics-rich hydrocarbon fuel) in BSI (gasoline) fuel		20.0%	
	Methanol in MM (gasoline) fuel		20.0%	
	Isoalkane in MCCI fuel		20.0%	
	FAE (Fatty alkyl ether) in MCCI fuel		20.0%	
	FAFE (Fatty acid fusel esters) in MCCI fuel		20.0%	
	Renewable diesel in MCCI fuel		10.0%	
12.2) Type of Gasoline or Diesel for Alternative Fuel Blends				
Share of Gasoline out of Gasoline and Blendstock				
	Gasoline for methanol blend		0.0%	
	Gasoline for low-level ethanol blend		0.0%	
	Gasoline for high-level ethanol blend		0.0%	
	Gasoline for butanol blend		0.0%	
	Gasoline for renewable gasoline blend		0.0%	
	Gasoline for Isobutanol blend		0.0%	
	Gasoline for ARHC blend		0.0%	

Vehicles Worksheet

Results

Back to Top

Navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Further Explore Biodiesel and Renewable Diesel Scenarios



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Biodiesel and renewable diesel tabs

Primary
BioOil

Some Secondary

RNG
NG
Ag_Inputs

Inputs
Results
Fuel_Prod_TS
Fuel_Specs
Electricity
Car_TS
Vehicles
EF
T&D
T&D Flowcharts



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AU453 =AU452+SUMPRODUCT(AU449:AU450,Fuel_Specs!\$B\$148:\$B\$149)+SUMPRODUCT(AU441:AU443,Fuel_Specs!\$B\$154:\$B\$156)+SUMPRODUCT(AU447:AU448,Fuel_Specs!\$B\$157:\$B\$158)

	A	B	C	D	E	F	G	H	
1	Soybeans, Palm, Canola, Jatropha and Camelina to Biodiesel, Renewable Diesel, and Renewable Gasoline								
2				Home	Inputs	Results			
5	1) Scenario Control and Key Input Parameters (from the Inputs sheet)								
6			Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable gasoline			
7	Feedstock for biooil-based fuels		1	1	1	1		: Soybean, 2: Palm FFB, 3: Canola, 4: Jatropha,	
9	Allocation Method								
10	Method for dealing with co-products		Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable gasoline			
11			1	1	1	1		1- Process Level Allocation/Displacement	
12	System level allocation for soy and jatropha based fuel							2- System Level Energy-Based Allocation	
13	Process level allocation for all biooil-based fuels								
14	Feedstock		Soy oil	Palm Oil	Canola	Jatropha	Camelina	Tallow	
15	Oil Extraction Process		4	4	4	2	4	4	
16	Fuel		Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable gasoline	Glycerin		
17	Fuel Production		3	2	2	2	3		
19	Palm Fatty Acid Distillate (PFAD)								
20			CPO	PFAD					
21	Oil Extraction Process		4	6					
22	Fuel refining		RBD/PFAD						
23	CPO refining		2						
24	Fuel production		Renewable diesel 2	Biodiesel					
25	Fuel Production		2	2					
27	Feedstock Properties								
28			Soybean	Palm Full Fruit Bunch (FFB)	Canola	Jatropha	Camelina	Carinata	
29	Density Unit		lb/bushel						
30	Density		52.2						
31	Lipid Content		19.1%	22.4%	44.0%	35.0%	36.0%	41.0%	

NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity Hydrogen **BioOil** Algae Macroalgae Was



Renewable Natural Gas Overview



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General Settings to Alter a Renewable Natural Gas Pathway



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Home Results Petroleum MeOH & Ethanol Electric Vehicles Car_TS Tab LDV1_TS Tab LDV2_TS Tab
 Natural Gas Hydrogen Bio Oil Pyrolysis WTP Vehicles Tab HDV_TS Tab HDV_WTW Tab
 Fuel Economy

Scenario Control Variables and Input Assumptions

1. Key Options for Simulation

1.1) Target Year for Simulation: 2022

1.2) Point-Estimation or Probability-Estimation Option

Link with GREET2
 Reactivate GREET2 Links
 Deactivate GREET2 Links

Load Stochastic Toolkit ... To load the stochastic toolkit
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2. Vehicle Types for Simulation

1 -- Passenger Cars; 2 -- Light-Duty Trucks 1 (LDT1) (Sports utility vehicles [SUV]); 3 -- Light-Duty Trucks 2 (LDT2) (Pickup Truck [PUT])

3. Petroleum-Based Fuels

3.1) Petroleum Recovery Options

3.1.a) Share of crude oil sources

1 -- Basis of share of crude oil sources: 1 -- EIA projection, 2 -- User defined

	U.S. Domestic	Canada (Oil Sands)	Canada (Conv. Crude)	Mexico	Middle East	Lat
EIA projection	80.8%	6.6%	5.0%	1.9%	2.3%	
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U.S. Domestic crude	Shale Oil (Bakken)	Shale Oil (Eagle Ford)	Rest of U.S. domestic crude
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Vol. Share (%)	8.7%	8.0%	83.3%

Overview Inputs Results Petroleum Co-processing NG MeOH FTD FtOH Electric Generation mixes Bio



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4. Natural Gas to Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG)

114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145

4.1) Simulation Options for NG-Based Fuel Pathways

Natural Gas			
Results			
Back to Top			
	Compressed Natural Gas	NG-based Liquefied Petroleum Gas (NGL)	Liquefied Natural Gas as a Transportation Fuel
Feedstock Source	1	1	1

Note: Feedstock Sources: 1 -- North American NG, 4 -- Renewable natural gas

4.2) Share of Conventional and Shale Gas for North America NG Supply

Conventional Gas	25%
Shale Gas	75%

4.3) CH4 leakage rate for each stage in conventional NG and shale gas pathways

	Unit	Used in calculation: BU/TD Hybrid		BU/TD Hybrid	
		Conventional NG	Shale gas	Conventional NG	Shale gas
Recovery - CH4 Leakage and Venting	vol. % of CH4 over NG through	0.51%	0.51%	0.51%	0.51%
Recovery - Completion CH4 Venting	vol. % of CH4 over NG through	0.00%	0.01%	0.00%	0.01%
Recovery - Workover CH4 Venting	vol. % of CH4 over NG through	0.00%	0.00%	0.00%	0.00%
Recovery - Liquid Unloading CH4 Venting	vol. % of CH4 over NG through	0.02%	0.02%	0.02%	0.02%
Well Equipment - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.33%	0.33%	0.33%	0.33%
Gathering and Boosting - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.15%	0.15%	0.15%	0.15%
Processing - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.03%	0.03%	0.03%	0.03%
Transmission and Storage - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.31%	0.31%	0.31%	0.31%
Distribution - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.09%	0.09%	0.09%	0.09%
Total	vol. % of CH4 over NG through	0.94%	0.94%	0.94%	0.94%

4.4) Flaring energy and CO2 emission rate for recovery and processing in conventional NG and shale gas pathways

	Unit	Used in calculation: EPA		BU/TD Hybrid	
		Conventional NG	Shale gas	Conventional NG	Shale gas
Recovery - Flaring	Btu NG/mmBtu NG	1,879	1,878	1,879	1,878
Recovery - Venting	g CO2/mmBtu NG	115	115	115	115
Processing - Flaring	Btu NG/mmBtu NG	3,083	3,083	3,083	3,083
Processing - Venting	g CO2/mmBtu NG	463	463	463	463

4.5) Share of Petroleum and NG for Production of Liquefied Petroleum Gas (LPG)

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio ... +



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Home Results Petroleum MeOH & Ethanol Electric Vehicles Car_TS Tab LDV1_TS Tab LDV2_TS Tab
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Overview Inputs Results Petroleum Co-processing NG MeOH FTD FtOH Electric Generation mixes Bio



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5. Natural Gas, Biomass and Coal to Methanol (MeOH), Dimethyl Ether (DME), Fischer-Tropsch Diesel (FTD), and Fischer-Tropsch Naphtha (FTN)

5.1) Simulation Options for MeOH, DME, FTD and FTN Pathways

	Feedstock Source	Plant Design Type When Natural Gas is Feedstock	Plant Design Type When Flared Gas is Feedstock	Plant Design Type When Landfill Gas is Feedstock	Plant Design Type When Biomass is Feedstock	Plant Design Type When Coal is Feedstock
Methanol	1	1	1	0	0	0
Dimethyl Ether	1	0	0	0	0	0
Fischer-Tropsch Diesel	1	0	2	2	0	0
Fischer-Tropsch Naphtha	1	2	0	0		
Marine Fischer-Tropsch Diesel	1					

Note: Feedstock Sources:
 1 -- North American NG
 2 -- Non-North American NG
 3 -- Non-North American flared gas
 4 -- Renewable NG
 5 -- Biomass
 6 -- Coal via gasification (only for MeOH, DME, and FTD)
 7 -- Coal/Biomass (only for FTD)
 8 -- NG/Biomass (only for FTD)
 9 -- Black Liquor (only for MeOH and DME)
 10 -- Methanol (only for DME)
 11 -- CO2 (e-fuel)

Note: Plant Design Types:
 0 -- No co-products
 1 -- Steam co-production
 2 -- Electricity co-production

5.2) Share of Petroleum and NG for Production of FT Naphtha

	NG	Petroleum
Naphtha	100.0%	0.0%

5.3) Share of Willow, Poplar, Switchgrass, Miscanthus, Corn Stover, Forest Residue out of Total Biomass for Methanol, Dimethyl Ether, and Fischer-Tropsch Diesel Production

	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Forest Residue
Methanol	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dimethyl Ether	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fischer-Tropsch Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Marine Fischer-Tropsch Diesel	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

5.4) CO2 Sequestration Options for MeOH, DME and FTD Plants

	Feedstock	NG	DME	Biomass	Coal	Coal/Biomass	NG/Biomass
--	-----------	----	-----	---------	------	--------------	------------

Inputs Results Petroleum Co processing NG MeOH FTD EtOH Electric Generation mixes Bio electricity

Further Explore Renewable Natural Gas Scenarios



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Renewable natural gas fuels tabs

Primary
Waste
RNG

Some Secondary

NG
BioOil
MeOH_FTD
EtOH
Co-processing
OilGasCoalInfra

Inputs
Results
Fuel_Prod_TS
Fuel_Specs
Electricity
Car_TS
Vehicles
EF
T&D
T&D Flowcharts



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A1 Business-As-Usual Waste Management Modeling

Business-As-Usual Waste Management Modeling

Quick Access for Waste Stream Modeling

Landfill Gas Results

Animal Waste Inputs Results

Wastewater Sludge Inputs Results

Municipal Solid Waste (MSW)

Select Modeling Approach

Modeling Approach

Default Approach
- Primarily EPA WARM Approach

Waste Composition Waste Properties Management Practices Management Scenarios

IPCC Approach

Inputs

Results

Intermediate Results
- Component-level results with the default approach

U.S. Average Landfilling Incineration Composting Anaerobic Digestion

1) Scenario Control and Key Input Parameters

1.1) Key Assumptions regarding animal waste management

Source of Assumptions: U.S.

BioOil Algae Macroalgae Waste RNG Pyrolysis_IDL IBR E_fuel Fuel_Prod_TS EF_TS AgMining_EF_TS

This pathway uses RNG as a process fuel or feedstock. The LCA results of RNG are subject to further revision to address technical uncertainties, especially related to counterfactual scenario assumptions for wastes that are used for RNG production.

address producti

Note: this tab addresses the counterfactual issues related to the major waste streams



Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon tabs: Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: A1, Renewable Natural Gases Based Fuel

Worksheet: Renewable Natural Gases Based Fuel

Navigation: Home (blue), Inputs (yellow), Results (green)

1) Scenario Control and Key Input Parameters

1.1) Share of Fuels from Each Waste

	NG as Intermediate			
	Fuel	MeOH	CNG	LNG
Landfill Gas	100%	100%	100%	100%
Bio-gas from AD of Animal Waste	0%	0%	0%	0%
Bio-gas from AD of Wastewater Sludge	0%	0%	0%	0%
Bio-gas from AD of MSW	0%	0%	0%	0%

1.2) Assumptions Regarding NG Processing

	LFG-based Micro Turbine	Manure-based Micro Turbine	WWTP-based Micro Turbine	MSW-based Micro Turbine	Engine	Micro Turbine	MCFC	PAFC
CHP Generator Electrical Efficiency	33%	33%	33%	33%	30%	32.9%	48%	35%
Heat Recovery Efficiency from CHP generator	70%	70%	70%	70%	70%	70%	50%	50%
Boiler Efficiency	80%							
NG Processing Efficiency (powered by Electricity)	94.4%							
NG Processing CH4 Leakage	2%							
NG Small Scale Liquefaction Efficiency (powered by R)	89.0%							
CNG Refueling Options	1	1 -- On-Site, 2 -- Off-Site						
Allocation Handling Method	2	1 -- Displacement, 2-- Energy Allocation						
Biogenic CO2 emission credits	-59,413 (gCO2e/mmBtu biogas combustion)							

1.3) Assumptions for Anaerobic Digestion of Animal Waste

Source of Assumptions: U.S. - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other

U.S.

Navigation: BioOil, Algae, Macroalgae, Waste, **RNG**, Pyrolysis_IDL, IBR, E_fuel, Fuel_Prod_TS, EF_TS, AgMining_EF_TS



Microsoft Excel interface showing the 'Renewable Natural Gases Based Fuel' worksheet. The ribbon includes Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, and Help. The active cell is A1, containing the text 'Renewable Natural Gases Based Fuel'.

1.3) Assumptions for Anaerobic Digestion of Animal Waste
 Source of Assumptions: **U.S.** - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other options include U.S., IPCC, and User-defined.

U.S.	Beef	Dairy Cow	Dairy Heifer	Swine	Layer	Broiler and Turkey
Share of Livestocks	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%

Moisture Content of Animal Waste: 88%

Wet Animal Waste Input (ton/mmBtu): 1.59

Transportation Vehicles: 1 - 1--Heavy Heavy-Duty Truck, 2--Medium Heavy-Duty Truck

AD Type: Mixed Plug Flow

Animal waste inputs (lb TS) → Anaerobic digestion

0.471 lb C/lb TS	0.097 lb C/lb TS	0.130 lb CH4/lb TS	2,786 Btu/lb TS
0.041 lb N/lb TS	0.097 lb C/lb TS	0.356 lb CO2/lb TS	

Use RNG for on-site heat and power generation? **2** 1. Yes; 2. No.

Heat Load Share by CHP: 100%

Min	0%
Max	100%
User Input	100%
Biogas Share to CHP	0%
Min	40%
Self-sustaining Min	40%
Max	99%
User Input	40%

Process Flow Diagram:

- Anaerobic digestion (0.471 lb C/lb TS, 0.041 lb N/lb TS)
 - 20.6% → Biogas Produced (0.097 lb C/lb TS, 0.130 lb CH4/lb TS, 2,786 Btu/lb TS)
 - 99.0% → 1st Clean Up (0.128 lb CH4/lb TS, 2,758 Btu/lb TS)
 - 0.0% → Boiler (0 lb CH4/lb TS, 0 Btu thermal/lb TS)
 - 1.0% → Leakage (0.001 lb CH4/lb TS)
 - 0.0% → CH4 Emissions (0.0001 lb C/lb TS, 0.0001 lb CH4/lb TS)
 - 62.0% → Converted into CO2 (0.1716 lb C/lb TS, 0.6291 lb CO2/lb TS)
 - 20.6% → Biogenic CO2 in Biogas (0.097 lb C/lb TS, 0.356 lb CO2/lb TS)
 - 58.7% → AD Residue Applied to Soil (0.649 lb residue/lb TS, 0.277 lb C/lb TS, 0.041 lb N/lb TS)

Electricity for Biogas Processing: 82 Btu elec/lb TS

Navigation tabs: BioOil, Algae, Macroalgae, Waste, **RNG**, Pyrolysis_IDL, IBR, E_fuel, Fuel_Prod_TS, EF_TS, AgMining_EF_TS



Ethanol Scenarios



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Ethanol

Oxygenate

- Added to gasoline to promote gasoline burning cleanly
- When the additive accounts for **less than 12%** of the fuel
- Burned in low-level ethanol “blend” vehicles: SI-ICE and SIDI-ICE vehicles

Blend

- Used for biofuel purposes
- When the additive accounts for **more than 12%**
- Burned in a flex fuel vehicle (FFV) or a dedicated ethanol vehicle
- An increasing octane number of the fuel produces better knock resistance and may allow for better engine efficiency



100% Ethanol

Model a Dedicated Ethanol (EtOH) Spark-Ignition
Internal Combustion Engine (SI-ICE) Light-Duty Car
Fueled by 100% Ethanol



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NavInputsZoomVehicles | 12. Vehicle Operations

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			
Isobutanol	2	2--20%, 3--30%	
ARHC	2	2--20%, 3--30%	
MeOH	2	2--20%, 3--30%	
Methanol in FFV fuel		85.0%	
Methanol in dedicated vehicle fuel		90.0%	
Ethanol in low-level blend of gasoline and ethanol		10.0%	2.0% Share of gasoline by volume added in EtOH as denaturant
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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 EtOH-diesel		10.0%	
Additives in EtOH-diesel		1.0%	
Isobutanol in BSI (gasoline) fuel		20.0%	
ARHC (Aromatics-rich hydrocarbon fuel) in BSI (gasoline) fuel		20.0%	
Methanol in MM (gasoline) fuel		20.0%	
Isoalkane in MCCI fuel		20.0%	
FAE (Fatty alkyl ether) in MCCI fuel		20.0%	
FAFE (Fatty acid fusel esters) in MCCI fuel		20.0%	
Renewable diesel in MCCI fuel		10.0%	
12.2) Type of Gasoline or Diesel for Alternative Fuel Blends			
Share of Gasoline out of Gasoline and Blendstock			
Gasoline for methanol blend		0.0%	
Gasoline for low-level ethanol blend		0.0%	
Gasoline for high-level ethanol blend		0.0%	
Gasoline for butanol blend		0.0%	
Gasoline for renewable gasoline blend		0.0%	
Gasoline for Isobutanol blend		0.0%	
Gasoline for ARHC blend		0.0%	

Vehicles Worksheet
Results
Back to Top

Type 100%

2
Press F9

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Default Agricultural Feedstock in Ethanol as a Blend



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Microsoft Excel ribbon: Home, Insert, Draw, Page Layout, Formulas, Data, Review, View, Automate, Help. Ribbon tabs: Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: A1, fx, Corn, Cellulosic Biomass, and Sugarcane to Ethanol; Corn to Butanol and Acetone

Worksheet tabs: Home, Inputs, Results

1) Scenario Control and Key Input Parameters

	Corn	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Forest Residue	Sorghum
Shares of Feedstocks for Ethanol for General Purpose	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Shares of Feedstocks for Gasoline Blended Ethanol	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

1.1) Feedstock Farming

N content of above and below ground biomass: grams/bushel for corn, grams/ton for cellulosic biomass, and grams/tonne for sugarcane

	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Grain Sorghum	Sweet Sorghum	Forage Sorghum
Corn Farming	0.0	0.0	486.9	584.2	0.0	149.0	0	0

N2O Emissions: N in N2O as % of N in N fertilizer and biomass

	Willow	Poplar	Switchgrass	Miscanthus	Corn Stover	Sorghum	Sugarcane	N fertilizer in the US
Corn Farming	1.264%	1.264%	1.264%	1.264%	1.264%	1.264%	1.264%	1.374%

N2O Emissions Management Practices (only for corn)

BAU Business-As-Usual scenario in which an empirical EF is applied
 4R Right time, Right place, Right form, and Right rate nitrogen management scheme in which a nitrogen balance approach is used to estimate
 EEf Use of enhanced efficiency nitrogen fertilizer that reduces direct N2O emission from synthetic fertilizer by 30%

Corn and Corn Stover Farming Assumptions

Allocation of corn farming energy between corn grain and corn stover: 1 Attributional 2. Energy allocation 3. Mass allocation 4. Market-value allocation

	Biomass Yield	Energy allocation	Mass Allocation	Market-value allocation
Corn grain	176.7 bu/acre	78%	80%	90%
Corn stover	1.27 dry ton/acre	22%	20%	10%

Worksheet tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity



Well-to-Wheel (WTW) GHG Emissions



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U375

Home Inputs Back to Top WTP Results WTP Changes

WTW Results Menu

1 Select a vehicle type from a pink drop down menu, then press "Go"

- SI ICE Vehicles
 - SI - Dedi. EtOH Vehicle Go
 - SIDI ICE Vehicles Go
 - CIDI ICE Vehicles Go
- SI Hybrid Vehicles (HEV) Go
- CIDI Hybrid Vehicles (HEV) Go
- BEV and FCV Go
- SI Plug-in Hybrids (PHEV) Go
- CIDI Plug-in Hybrids (PHEV) Go
- GCI ICE Vehicles Go
- Performance-enhancing Fuels Select Fuels

Unit Selection Select units from a pink drop down menu for the Results

2

Per Vehicle Distance Travelled
 Energy Unit: Btu Emission Unit: g
 Service Functional Unit: mile

Per Energy in Fuels
 Energy Unit: Btu Emission Unit: g
 Energy Functional Unit: MJ

375 Dedi. EtOH Vehicle: E100, Corn

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
376 Total Energy	-1,478.004	4,902.004	4,008.497	7,432.498	349	1,159	948	1,757
377 Fossil Fuels	417	1,721						
378 Coal	9	148						
379 Natural Gas	265	1,518						
380 Petroleum	143	55						
381 Water Consumption	1.4	0.2						
382 CO ₂ w/ C in VOC & CO	-229	111						
383	0.071	0.315						
384 N ₂ O	0.147	0.003	0.004	0.154	0.035	0.001	0.001	0.036
385 GHG	-186	121	302	236.75	-44	29	71	56
386 VOC	0.020	0.219	0.206	0.445	0.005	0.052	0.049	0.105
387 CO ₂	0.079	0.090	2.741	2.910	0.019	0.021	0.648	0.688
388 NO _x : Total	0.208	0.138	0.082	0.429	0.049	0.033	0.019	0.101
389 PM10: Total	0.011	0.051	0.035	0.097	0.003	0.012	0.008	0.023
390 PM2.5: Total	0.009	0.014	0.007	0.030	0.002	0.003	0.002	0.007

WTW GHG emissions
 237 g CO₂e/mile or 56 g CO₂e/MJ

Press F9

Dedicated ethanol vehicle fueled by 100% ethanol

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity



E80 in an FFV

Model a Flex Fuel Spark-Ignition Internal
Combustion Engine Vehicle (SI-ICE FFV) Light-Duty
Car Fueled by E80



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Microsoft Excel ribbon showing the 'Formulas' tab. The 'Function Library' includes Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, and More. The 'Defined Names' group includes Name Manager, Define Name, Use in Formula, and Create from Selection. The 'Formula Auditing' group includes Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, and Evaluate Formula. The 'Calculation' group includes Watch Window and Calculation Options.

NavInputsZoomVehicles | 12. Vehicle Operations

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			
Isobutanol	2	2--20%, 3--30%	
ARHC	2	2--20%, 3--30%	
MeOH	2	2--20%, 3--30%	
Methanol in FFV fuel		85.0%	
Methanol in dedicated vehicle fuel		90.0%	
Ethanol in low-level blend of gasoline and ethanol		10.0%	2.0% Share of gasoline by volume added in EtOH as denaturant
Ethanol in FFV fuel		85.0%	2.0% Share of gasoline by volume added in EtOH as denaturant
Ethanol in dedicated vehicle fuel		85.0%	Share of gasoline by volume added in EtOH as denaturant
Butanol 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 EtOH-diesel		10.0%	
Additives in EtOH-diesel		1.0%	
Isobutanol in BSI (gasoline) fuel		20.0%	
ARHC (Aromatics-rich hydrocarbon fuel) in BSI (gasoline) fuel		20.0%	
Methanol in MM (gasoline) fuel		20.0%	
Isoalkane in MCCI fuel		20.0%	
FAE (Fatty alkyl ether) in MCCI fuel		20.0%	
FAFE (Fatty acid fusel esters) in MCCI fuel		20.0%	
Renewable diesel in MCCI fuel		10.0%	
12.2) Type of Gasoline or Diesel for Alternative Fuel Blends			
Share of Gasoline out of Gasoline and Blendstock			
Gasoline for methanol blend		0.0%	
Gasoline for low-level ethanol blend		0.0%	
Gasoline for high-level ethanol blend		0.0%	
Gasoline for butanol blend		0.0%	
Gasoline for renewable gasoline blend		0.0%	
Gasoline for Isobutanol blend		0.0%	
Gasoline for ARHC blend		0.0%	
Gasoline for Methanol Blend		0.0%	

1
Type 80%

Note: if we were using E11, we could model this in a low-level blend ethanol vehicle

2
Press F9

Navigation tabs: Inputs (highlighted), Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Well-to-Wheel (WTW) GHG Emissions



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Microsoft Excel interface showing the 'Results_EnergyFunctionalUnit' worksheet. The spreadsheet displays input options for vehicle types and units, and a detailed table of WTW GHG emissions.

WTW Results Menu

- SI ICE Vehicles: Go
- SI - EtOH FFV: Go
- SID/ICE Vehicles: Go
- CIDI ICE Vehicles: Go
- SI Hybrid Vehicles (HEV): Go
- CIDI Hybrid Vehicles (HEV): Go
- BEV and FCV: Go
- SI Plug-in Hybrids (PHEV): Go
- CIDI Plug-in Hybrids (PHEV): Go
- GCI ICE Vehicles: Go
- Performance-enhancing Fuels: Select Fuels

Unit Selection

Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled
 Energy Unit: Btu Emission Unit: g Service Functional Unit: mile

Per Energy in Fuels
 Energy Unit: Btu Emission Unit: g Energy Functional Unit: MJ

EtOH FFV: E80, Corn

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	-1,086	4,014						
Fossil Fuels	383	1,537						
Coal	12	121						
Natural Gas	249	1,300						
Petroleum	122	117						
Water Consumption	1.1	0.2						
CO2 (w/ C in VOC & CO)	-172	101						
CH4	0.148	0.287	0.015	0.450	0.033	0.063	0.003	0.099
N2O	0.115	0.003	0.004	0.124	0.025	0.001	0.001	0.027
GHGs	-137	110	325	298	-30	24	72	66
VOC: Total	0.019	0.198	0.206	0.423	0.004	0.044	0.045	0.094
CO: Total	0.069	0.079	2.741	2.889	0.015	0.017	0.606	0.638
NOx	0.174	0.121	0.082	0.377	0.038	0.027	0.018	0.083
PM	0.009	0.042	0.035	0.085	0.002	0.009	0.008	0.019
PM2.5	0.008	0.012	0.007	0.027	0.002	0.003	0.002	0.006
SOx: Total	0.036	0.036	0.001	0.072	0.008	0.008	0.000	0.016
BC Total	0.001	0.001	0.003	0.005	0.000	0.000	0.001	0.001
OC Total	0.001	0.002	0.002	0.005	0.000	0.000	0.000	0.001

WTW GHG emissions
 298 g CO₂e/mile or 66 g CO₂e/MJ

Flex fuel vehicle (FFV) fueled by E80

Navigation tabs: Overview, Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity, Hydrogen



Dedicated EtOH vehicle fueled by 100% ethanol

Flex fuel vehicle fueled by E80

Select a vehicle type from a pink drop down menu, then press "Go"

Select units from a pink drop down menu for the Results

WTW GHG emissions
237 g CO₂e/mile

Select a vehicle type from a pink drop down menu, then press "Go"

Select units from a pink drop down menu for the Results

WTW GHG emissions
298 g CO₂e/mile

Biodiesel and Renewable Diesel Scenarios



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Conventional Diesel

Model a Compression-Ignition Direct-Injection
Internal Combustion Engine (CIDI-ICE) Light-Duty
Car Fueled by Conventional Diesel



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CIDI-ICE vehicle

CIDI-ICE

Compression-ignition direct-injection
internal combustion engine

1. Air is fed into the engine's intake
2. The compression of the air produces heat
3. This heat burns the fuel



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Well-to-Wheel (WTW) GHG Emissions



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W827 fx

Home Inputs Back to Top WTP Results WTW Changes

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles Go SI Hybrid Vehicles (HEV) Go

SIDI ICE Vehicles Go CIDI Hybrid Vehicles (HEV) Go

CIDI ICE Vehicles Go BEV and FCV Go

CIDI - Diesel Go

SI Plug-in Hybrids (PHEV) Go

CIDI Plug-in Hybrids (PHEV) Go

N/A

GCI ICE Vehicles Go

Performance-enhancing Fuels Select Fuels

Unit Selection Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled Per Energy in Fuels

Energy Unit: Btu Emission Unit: g Energy Unit: Btu Emission Unit: g

Service Functional Unit: mile Energy Functional Unit: MJ

CIDI Vehicle: Conventional and LS Diesel

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	223	419						
Fossil Fuels	208	413						
Coal	20	10						
Natural Gas	151	278						
Petroleum	37	125						
Water Consumption	0.1	0.0						
CO ₂ (w/ C in VOC & CO)	18	27						
CH ₄	0.325	0.065	0.092	0.481	0.007	0.017	0.024	0.128
N ₂ O	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.000
GHGs	28	29	284	341	7	8	76	91
VOC	0.013	0.013	0.148	0.175	0.004	0.004	0.040	0.047
CO ₂	0.027	0.017	3.531	3.574	0.007	0.004	0.942	0.954
NO _x	0.040	0.025	0.097	0.162	0.011	0.007	0.026	0.043
PM ₁₀ : Total	0.002	0.003	0.034	0.038	0.001	0.001	0.009	0.010
PM _{2.5} : Total	0.002	0.002	0.007	0.011	0.000	0.001	0.002	0.003

WTW GHG emissions
341 g CO₂e/mile or 91 g CO₂e/MJ

CIDI vehicle fueled by conventional diesel

Press F9

Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity Hydroger

Soybean Biodiesel

Model a Compression-Ignition Direct-Injection
Internal Combustion Engine (CIDI-ICE) Light-Duty
Car Fueled by Biodiesel Produced by Soybeans



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Default Content (%) of Biodiesel Used in CIDI Fuel



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Workbook name: NavInputsZoomVehicles | Worksheet: 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			
Isobutanol	2	2--20%,	3--30%
ARHC	2	2--20%,	3--30%
MeOH	2	2--20%,	3--30%
Methanol in FFV fuel		85.0%	
Methanol in dedicated vehicle fuel		90.0%	
Ethanol in low-level blend of gasoline and ethanol		10.0%	2.0%
Ethanol in FFV fuel		85.0%	2.0%
Ethanol in dedicated vehicle fuel		85.0%	2.0%
Butanol 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 EtOH-diesel		10.0%	
Additives in EtOH-diesel		1.0%	
Isobutanol in BSI (gasoline) fuel		20.0%	
ARHC (Aromatics-rich hydrocarbon fuel) in BSI (gasoline) fuel		20.0%	
Methanol in MM (gasoline) fuel		20.0%	
Isoalkane in MCCI fuel		20.0%	
FAE (Fatty alkyl ether) in MCCI fuel		20.0%	
FAFE (Fatty acid fusel esters) in MCCI fuel		20.0%	
Renewable diesel in MCCI fuel		10.0%	
12.2) Type of Gasoline or Diesel for Alternative Fuel Blends			
Share of Gasoline out of Gasoline and Blendstock			
Gasoline for methanol blend		0.0%	
Gasoline for low-level ethanol blend		0.0%	
Gasoline for high-level ethanol blend		0.0%	
Gasoline for butanol blend		0.0%	
Gasoline for renewable gasoline blend		0.0%	
Gasoline for Isobutanol blend		0.0%	
Gasoline for ARHC blend		0.0%	

Navigation sidebar:

- Vehicles Worksheet
- Results
- Back to Top

Worksheet navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Default Agricultural Feedstock for Biodiesel



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Microsoft Excel ribbon showing the **Formulas** tab. The ribbon includes sections for **Function Library** (Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More Functions), **Defined Names** (Name Manager, Define Name, Use in Formula, Create from Selection), **Formula Auditing** (Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula), and **Calculation** (Watch Window, Calculation Options).

NavInputsZoomBioOil | 9. Bio Oil-Based Fuel

9. Bio Oil-Based Fuel						
9.1) Method for dealing with co-products of Bio Oil-based fuel (see co-products in BioOil sheet)						
BioOil Worksheet	Feedstock for biooil-based fuels	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable diesel 3	Renewable gasoline
Results		1	1	1	6	1
Back to Top	Method for dealing with co-products					
	System level allocation for soy and jatropha based fuel	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable gasoline	1- Process Level Allocation/Displacement 2- System Level Energy-Based Allocation
		1	1	1	1	
	Process level allocation for all biooil-based fuels					
	Feedstock	Soybean	Palm Oil	Canola	Jatropha	Camelina
	Oil Extraction Process	4	4	4	2	4
	Fuel	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable diesel 3	Renewable gasoline
	Fuel Production	3	2	2	2	2
	9.2) Farming Energy Use, Fertilizer use, and N2O Emissions from Biomass					
		Soybean (per bushel)	Palm Full Fruit Bunch (FFB) (per wet ton)	Canola (per wet tonne)	Jatropha (per wet kg)	Camelina (per wet kg)
	Farming Energy Use: Btu	13,634	154,528	528,667	1,320	961
	Fertilizer Use					
	Grams of Nitrogen	52.8	5,297.4	51,648.0	34.0	37.0
	Grams of P2O5	207.9	3,565.6	15,919.0	13.0	15.0
	Grams of K2O	348.7	9,830.8	4,163.0	37.4	10.0
	Grams of CaCO3	0.0	0.0	0.0	0.0	0.0
	Pesticide Use					
	Grams of Herbicide	21.16	28.52	417.00	0.00	0.00
	Grams of Insecticide	0.32	137.53	39.00	0.00	0.00
	N content of above and below ground biomass: grams	557	10362	24280	35.0	65.2
	N2O emissions from N fixation: grams N2O	7.3				
	N2O emissions: N in N2O as % of N in N fertilizer	1.374%	1.374%	1.040%	1.374%	1.374%
	N2O emissions: N in N2O as % of N in Biomass	1.264%	1.264%	0.940%	1.264%	1.264%
	9.3) Soyoil Extraction Energy Use: Btu/lb of soyoil					
		3,073				

Navigation tabs: Inputs (highlighted), Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Default GHG Emissions from Domestic and International Induced Land Use Changes



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Function Library

Name Manager Define Name Use in Formula Create from Selection

Defined Names

Trace Precedents Trace Dependents Remove Arrows

Show Formulas Error Checking Evaluate Formula

Formula Auditing

Watch Window Calculation Options

Calculation

AU453 =AU452+SUMPRODUCT(AU449:AU450,Fuel_Specs!\$B\$148:\$B\$149)+SUMPRODUCT(AU441:AU443,Fuel_Specs!\$B\$154:\$B\$156)+SUMPRODUCT(AU447:AU448,Fuel_Specs!\$B\$157:\$B\$158)

A B C D E F G H

1 Soybeans, Palm, Canola, Jatropha and Camelina to Biodiesel, Renewable Diesel, and Renewable Gasoline

2

3 Home Inputs Results

4

5 1) Scenario Control and Key Input Parameters (from the Inputs sheet)

6 Feedstock for biooil-based fuels Biodiesel Renewable diesel 1 Renewable diesel 2 Renewable gasoline 1: Soybean, 2: Palm FFB, 3: Canola, 4: Jatropha,

7 1

8

9 Allocation Method

10 Method for dealing with co-products

11 Biodiesel Renewable diesel 1 Renewable diesel 2 Renewable gasoline 1- Process Level Allocation/Displacement

12 System level allocation for soy and jatropha based fuel 1 1 1 1 2- System Level Energy-Based Allocation

13 Process level allocation for all biooil-based fuels

14 Feedstock Soy oil Palm Oil Canola Jatropha Camelina Tallow Sc

15 Oil Extraction Process 4 4 4 2 4 4

16 Fuel Biodiesel Renewable diesel 1 Renewable diesel 2 Renewable gasoline Glycerin

17 Fuel Production 3 2 2 2 3

18

19 Palm Fatty Acid Distillate (PFAD)

20 Oil Extraction Process CPO PFAD

21 4 6

22 Fuel refining RBD/PFAD

23 CPO refining 2

24 Fuel production Renewable diesel 2 Biodiesel

25 Fuel Production 2 2

26

27 Feedstock Properties

28 Soybean Palm Full Fruit Bunch (FFB) Canola Jatropha Camelina Carinata

29 Density Unit lb/bushel

30 Density 52.2

31 Lipid Content 19.1% 22.4% 44.0% 35.0% 36.0% 41.0%

< > ... NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity Hydrogen BioOil Algae Macroalgae Was ... +



Microsoft Excel ribbon showing the **Formulas** tab. The **Function Library** includes categories like Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, and More Functions. Other groups include Name Manager, Defined Names, Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula, Watch Window, and Calculation Options.

AU453 $=AU452+SUMPRODUCT(AU449:AU450, Fuel_Specs!\$B\$148:\$B\$149)+SUMPRODUCT(AU441:AU443, Fuel_Specs!\$B\$154:\$B\$156)+SUMPRODUCT(AU447:AU448, Fuel_Specs!\$B\$157:\$B\$158)$

Soybeans, Palm, Canola, Jatropha and Camelina to Biodiesel, Renewable Diesel, and Renewable Gasoline						
GHG Emissions from Potential Induced Land Use Changes: grams/gal of biodiesel						
		Soy Biodiesel	Soy Renewable Diesel			
	ILUC Case					
	Inclusion of GHG Emissions from Induced Land Use Change	2	2	0: GHG Emissions from ILUC are not included.		
	Domestic	66	67	1: Domestic GHG Emissions from ILUC are included.		
	Foreign	1,085	1,103	2: Domestic and Foreign GHG Emissions from ILUC are included.		
GHG Emissions from Land Use Change						
			Palm FFB (g CO ₂ e/ton)	Canola (g CO ₂ e/MT)	Jatropha (g CO ₂ e/kg)	Camelina (g CO ₂ e/kg)
	Unit					Carinata (g CO ₂ e/kg)
	GHG Emissions from LUC		0	0	0	0
Assumptions for tallow and UCO feedstock						
	UCO process method:	1	1: industry average, 2: settling only			
		Rendering	BD Production	Rendering		
	Feedstock	Rendering fat	Tallow/UCO/PFAD	Rendering UCO		
	Feedstock use (lb/lb)	2.3	1.05	1.35		
	Total energy consumption (Btu/lb)	3,195	2,292	1,015		
	Process fuel share (%)					
	NG	67.2%	52.2%	89.5%		
	Residual Oil	0.0%	0.0%			
	Fat	13.2%	0.0%			
	Methanol	0.0%	41.1%			
	Electricity	19.6%	6.7%	10.5%		
	Meat and bone meal yield (lb/lb)	1.04				
	Glycerin co-products (lb/lb)		0.07			
	Yield after allocation	0.903	0.997	0.741		
Assumptions for yellow grease for marine fuel production						
		Yellow grease	Yellow grease + HFO			
	Feedstock use (Btu/Btu)	1.21	1.02			

Excel navigation bar showing tabs: NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity, Hydrogen, **BioOil**, Algae, Macroalgae, Was... +

Well-to-Wheel (WTW) GHG Emissions



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Function Library: Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More Functions, Defined Names, Formula Auditing, Calculation

RNAVBIODIESEL CIDI : $=\text{"CIDI Vehicle: " \& IF(Inputs!\$F\$650=11, "UCO", IF(Inputs!\$F\$650=2, "Palm FFB", IF(Inputs!\$F\$650=3, "Canola", IF(Inputs!\$F\$650=4, "Jatropha", IF(Inputs!\$F\$650=5, "Camelina", IF(Inputs!\$F\$650=6, "Algae", IF(Inputs!\$F\$650=7, "Tallow", IF(Inputs!\$F\$650=8, "Corn Oil", IF(Inputs!\$F\$650=9, "Carinata", IF(Inputs!\$F\$650=10, "PFAD", "Soybean"))))$

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

- SI ICE Vehicles: Select Fuels, Go
- SIDI ICE Vehicles: Select Fuels, Go
- CIDI ICE Vehicles: Select Fuels, Go
- CIDI - Biodiesel: Select Fuels, Go

Unit Selection Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled: Energy Unit: Btu, Emission Unit: g, Service Functional Unit: mile

Per Energy in Fuels: Energy Unit: Btu, Emission Unit: g, Energy Functional Unit: MJ

CIDI Vehicle: Soybean-based BD20

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	213	637						
Fossil Fuels	199	456						
Coal	19	20						
Natural Gas	135	328						
Petroleum	45	109						
Water Consumption	0.5	0.0						
CO ₂ (w/ C in VOC & CO)	-33	34						
CH ₄	0.268	0.071	0.092	0.430	0.071	0.019	0.024	0.113
N ₂ O	0.015	0.001	0.001	0.017	0.004	0.000	0.000	0.004
GHC	-21	36	284	299	-6	10	76	80
VOC	0.012	0.023	0.143	0.179	0.003	0.006	0.038	0.048
CO ₂	0.028	0.018	3.531	3.577	0.008	0.005	0.942	0.954
NO _x : Total	0.039	0.028	0.097	0.165	0.010	0.008	0.026	0.044
PM ₁₀ : Total	0.002	0.003	0.034	0.038	0.001	0.001	0.009	0.010
PM _{2.5} : Total	0.002	0.002	0.007	0.011	0.000	0.001	0.002	0.003

WTW GHG emissions
299 g CO₂e/mile or 80 g CO₂e/MJ

CIDI vehicle fueled by 20% biodiesel (BD20)

Press F9

Overview **Inputs** Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio

CIDI fueled by conventional diesel

CIDI fueled by soybean biodiesel (BD20)

Excel interface showing the 'CIDI Vehicle: Conventional and LS Diesel' scenario. The 'Inputs' tab is active, and the 'Results' tab is selected at the bottom. A blue callout box highlights the WTW GHG emissions as 341 g CO₂e/mile.

Item	Feedstock		Fuel		Vehicle Operation	
	Btu/mile or Gallon/mile or g/MJ	Btu/MJ or Gallon/MJ or g/MJ	Btu/mile or Gallon/mile or g/MJ	Btu/MJ or Gallon/MJ or g/MJ	Btu/mile or Gallon/mile or g/MJ	Btu/MJ or Gallon/MJ or g/MJ
Total Energy	223	4	112	948		
Fossil Fuels	208	4	110	948		
Coal	20		3	0		
Natural Gas	151	2	74	0		
Petroleum	37	12	33	948		
Water Consumption	0.1	0.0	0	0		
CO ₂ (w/ C in VOC & CO)	18	27	5	75		
CH ₄	0.325	0.065	0.092	0.481	0.087	0.017
N ₂ O	0.000	0.001	0.001	0.002	0.000	0.000
GHGs	28	29	284	341	7	8
VOC: Total	0.013	0.013	0.148	0.173	0.004	0.004
CO: Total	0.027	0.017	3.531	3.574	0.007	0.004
NOx: Total	0.040	0.025	0.097	0.162	0.011	0.007
PM10: Total	0.002	0.003	0.034	0.038	0.001	0.001
PM2.5: Total	0.002	0.002	0.007	0.011	0.000	0.001

Excel interface showing the 'CIDI Vehicle: Soybean-based BD20' scenario. The 'Inputs' tab is active, and the 'Results' tab is selected at the bottom. A blue callout box highlights the WTW GHG emissions as 299 g CO₂e/mile.

Item	Feedstock		Fuel		Vehicle Operation	
	Btu/mile or Gallon/mile or g/MJ	Btu/MJ or Gallon/MJ or g/MJ	Btu/mile or Gallon/mile or g/MJ	Btu/MJ or Gallon/MJ or g/MJ	Btu/mile or Gallon/mile or g/MJ	Btu/MJ or Gallon/MJ or g/MJ
Total Energy	213	63	170	948		
Fossil Fuels	199	45	122	770		
Coal	19	2	5	0		
Natural Gas	135	32	87	0		
Petroleum	45	10	29	770		
Water Consumption	0.5	0.0	0	0		
CO ₂ (w/ C in VOC & CO)	-33	34	-9	75		
CH ₄	0.268	0.071	0.092	0.430	0.071	0.019
N ₂ O	0.015	0.001	0.001	0.017	0.004	0.000
GHGs	-21	36	284	299	-6	10
VOC: Total	0.012	0.023	0.143	0.179	0.003	0.006
CO: Total	0.028	0.018	3.531	3.577	0.008	0.005
NOx: Total	0.039	0.028	0.097	0.165	0.010	0.008
PM10: Total	0.002	0.003	0.034	0.038	0.001	0.001
PM2.5: Total	0.002	0.002	0.007	0.011	0.000	0.001



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Soybean Renewable Diesel

Model a Compression-Ignition Direct-Injection
Internal Combustion Engine (CIDI-ICE) Light-Duty
Car Fueled by Renewable Diesel Produced by
Soybeans



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Default Content (%) of Renewable Diesel Used in CIDI Fuel



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Microsoft Excel ribbon showing the 'Formulas' tab. The ribbon includes sections for 'Function Library' (Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, More), 'Defined Names' (Name Manager, Define Name, Use in Formula, Create from Selection), 'Formula Auditing' (Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula), and 'Calculation' (Watch Window, Calculation Options).

Workbook name: NavInputsZoomVehicles | Worksheet: 12. Vehicle Operations

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			
Isobutanol	2	2--20%,	3--30%
ARHC	2	2--20%,	3--30%
MeOH	2	2--20%,	3--30%
Methanol in FFV fuel		85.0%	
Methanol in dedicated vehicle fuel		90.0%	
Ethanol in low-level blend of gasoline and ethanol		10.0%	2.0%
Ethanol in FFV fuel		85.0%	2.0%
Ethanol in dedicated vehicle fuel		85.0%	2.0%
Butanol 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 EtOH-diesel		10.0%	
Additives in EtOH-diesel		1.0%	
Isobutanol in BSI (gasoline) fuel		20.0%	
ARHC (Aromatics-rich hydrocarbon fuel) in BSI (gasoline) fuel		20.0%	
Methanol in MM (gasoline) fuel		20.0%	
Isoalkane in MCCI fuel		20.0%	
FAE (Fatty alkyl ether) in MCCI fuel		20.0%	
FAFE (Fatty acid fusel esters) in MCCI fuel		20.0%	
Renewable diesel in MCCI fuel		10.0%	
12.2) Type of Gasoline or Diesel for Alternative Fuel Blends			
Share of Gasoline out of Gasoline and Blendstock			
Gasoline for methanol blend		0.0%	
Gasoline for low-level ethanol blend		0.0%	
Gasoline for high-level ethanol blend		0.0%	
Gasoline for butanol blend		0.0%	
Gasoline for renewable gasoline blend		0.0%	
Gasoline for Isobutanol blend		0.0%	
Gasoline for ARHC blend		0.0%	

Navigation sidebar:

- Vehicles Worksheet
- Results
- Back to Top

Worksheet navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Default Agricultural Feedstock for Renewable Diesel



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NavInputsZoomBioOil | 9. Bio Oil-Based Fuel

9. Bio Oil-Based Fuel

647 **9. Bio Oil-Based Fuel**

648 **9.1) Method for dealing with co-products of Bio Oil-based fuel (see co-products in BioOil sheet)**

649 **BioOil**

650 **Worksheet**

651

652 **Results**

653

654 **Back to Top**

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	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable diesel 3	Renewable gasoline
Feedstock for biooil-based fuels	1	1	1	6	1

1: Soybean, 2: Pa

Method for dealing with co-products

	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable gasoline
System level allocation for soy and jatropha based fuel	1	1	1	1

1- Process Level Allocation/Displacement
2- System Level Energy-Based Allocation

Process level allocation for all biooil-based fuels

Feedstock	Soybean	Palm Oil	Canola	Jatropha	Camelina	Tallow
Oil Extraction Process	4	4	4	2	4	4
Fuel	Biodiesel	Renewable diesel 1	Renewable diesel 2	Renewable diesel 3	Renewable gasoline	
Fuel Production	3	2	2	2	2	

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9.2) Farming Energy Use, Fertilizer use, and N2O Emissions from Biomass

	Soybean (per bushel)	Palm Full Fruit Bunch (FFB) (per wet ton)	Canola (per wet tonne)	Jatropha (per wet kg)	Camelina (per wet kg)	Carinata (p
Farming Energy Use: Btu	13,634	154,528	528,667	1,320	961	
Fertilizer Use						
Grams of Nitrogen	52.8	5,297.4	51,648.0	34.0	37.0	
Grams of P2O5	207.9	3,565.6	15,919.0	13.0	15.0	
Grams of K2O	348.7	9,830.8	4,163.0	37.4	10.0	
Grams of CaCO3	0.0	0.0	0.0	0.0	0.0	
Pesticide Use						
Grams of Herbicide	21.16	28.52	417.00	0.00	0.00	
Grams of Insecticide	0.32	137.53	39.00	0.00	0.00	
N content of above and below ground biomass: grams	557	10362	24280	35.0	65.2	
N2O emissions from N fixation: grams N2O	7.3					
N2O emissions: N in N2O as % of N in N fertilizer	1.374%	1.374%	1.040%	1.374%	1.374%	
N2O emissions: N in N2O as % of N in Biomass	1.264%	1.264%	0.940%	1.264%	1.264%	

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9.3) Soyoil Extraction Energy Use: Btu/lb of soyoil

	3,073
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Navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Well-to-Wheel (WTW) GHG Emissions



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RNAVRENDIESEL1CIDI : `= "CIDI Vehicle: "&IF(Inputs!E690=1,IF(Inputs!G650=2,"Palm FFB",IF(Inputs!G650=3,"Canola",IF(Inputs!G650=4,"Jatropha",IF(Inputs!G650=5,"Camelina",IF(Inputs!G650=6,"Algae",IF(Inputs!G650=7,"Tallow",IF(Inputs!G650=8,"Corn Oil","Soybean"))))))),IF(Inputs!E690=3,IF(Inputs!I650=2,"Palm FFB",IF(Inputs!`

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

- SI ICE Vehicles: Select Fuels, Go
- SIDI ICE Vehicles: Select Fuels, Go
- CIDI ICE Vehicles: Select Fuels, Go
- CIDI - RD from Bio Oil: Select Fuels, Go

Unit Selection Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled: Energy Unit: Btu, Emission Unit: g, Service Functional Unit: mile

Per Energy in Fuels: Energy Unit: Btu, Emission Unit: g, Energy Functional Unit: MJ

943 CIDI Vehicle: Soybean-based RDII 100

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
946 Total Energy	171	1,6						
947 Fossil Fuels	161	7						
948 Coal	14							
949 Natural Gas	68	6						
950 Petroleum	79							
951 Water Consumption	2.2							
952 CO2 (w/ C in VOC & CO)	-260							
953 CH4	0.021	0.138	0.092	0.251	0.006	0.037	0.024	0.067
954 N2O	0.082	0.001	0.001	0.084	0.022	0.000	0.000	0.022
955 GHG	-237	88	275	125	-63	23	73	33
956 VOC	0.008	0.067	0.143	0.219	0.002	0.018	0.038	0.058
957 CO:	0.036	0.030	3.531	3.597	0.010	0.008	0.942	0.960
958 NOx: Total	0.035	0.051	0.097	0.183	0.009	0.014	0.026	0.049
959 PM10: Total	0.003	0.003	0.034	0.040	0.001	0.001	0.009	0.011
960 PM2.5: Total	0.003	0.002	0.007	0.012	0.001	0.001	0.002	0.003

WTW GHG emissions
125 g CO₂e/mile or 33 g CO₂e/MJ

CIDI vehicle fueled by renewable diesel (RD100)

Press F9

Navigation: Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity, Hydroger

CIDI fueled by soybean biodiesel (BD20)

CIDI fueled by soybean renewable diesel (RD100)

RNAVBODIESEL1CIDI

= "CIDI Vehicle: "&IF(Inputs!\$F\$650=11, "UCO Inputs!\$F\$650=4, "Jatropha", IF(Inputs!\$F\$650= "Tallow", IF(Inputs!\$F\$650=8, "Corn Oil", IF(I

Item	Feedstock	Fuel	Btu/mile or Gallon/mile or g/mile	Btu/MJ or Gallon/MJ or g/MJ	Fuel	Operation	Vehicle
916 Total Energy	213	63			170	948	
917 Fossil Fuels	199	45			122	770	
918 Coal	19	2			5	0	
919 Natural Gas	135	32			87	0	
920 Petroleum	45	10			29	770	
921 Water Consumption	0.5	0.0			0	0	
922 CO2 (w/ C in VOC & CO)	-33	34			9	75	
923 CH4	0.268	0.071			0.019	0.024	
924 N2O	0.015	0.001			0.000	0.000	
925 GHGs	-21	36			10	76	
926 VOC: Total	0.012	0.023			0.006	0.038	
927 CO: Total	0.028	0.018			0.005	0.942	
928 NOx: Total	0.039	0.028			0.008	0.026	
929 PM10: Total	0.002	0.003			0.001	0.009	
930 PM2.5: Total	0.002	0.002			0.001	0.002	

WTW GHG emissions: 299 g CO₂e/mile

RNAVRENDIESEL1CIDI

= "CIDI Vehicle: "&IF(Inputs!E690=1, IF(Input \$G\$650=4, "Jatropha", IF(Inputs!\$G\$650=5, "Cam IF(Inputs!\$G\$650=8, "Corn Oil", "Soybean")))

Item	Feedstock	Fuel	Btu/mile or Gallon/mile or g/mile	Btu/MJ or Gallon/MJ or g/MJ	Fuel	Operation	Vehicle
946 Total Energy	171	1,6			448	948	
947 Fossil Fuels	161	7			205	0	
948 Coal	14	2			20	0	
949 Natural Gas	68	6			174	0	
950 Petroleum	79	0			11	0	
951 Water Consumption	2.2	0.0			0	0	
952 CO2 (w/ C in VOC & CO)	-260	83			22	73	
953 CH4	0.021	0.138			0.037	0.024	
954 N2O	0.082	0.001			0.022	0.000	
955 GHGs	-237	88			23	73	
956 VOC: Total	0.008	0.067			0.018	0.038	
957 CO: Total	0.036	0.030			0.010	0.942	
958 NOx: Total	0.035	0.051			0.009	0.026	
959 PM10: Total	0.003	0.003			0.001	0.009	
960 PM2.5: Total	0.003	0.002			0.001	0.002	

WTW GHG emissions: 125 g CO₂e/mile



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Compare biodiesel and renewable diesel

Renewable diesel can be used in 100% blends - “drop-in” or a complete replacement of conventional diesel

Biodiesel (BD20) still contains 80% conventional fossil diesel, which explains the higher emissions produced from biodiesel



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Soybean 35% Biodiesel

Model a Compression-Ignition Direct-Injection
Internal Combustion Engine (CIDI-ICE) Light-Duty
Car Fueled by 35% Biodiesel Produced by Soybeans



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NavInputsZoomVehicles | 12. Vehicle Operations

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

Isobutanol	2	2--20%, 3--30%
ARHC	2	2--20%, 3--30%
MeOH	2	2--20%, 3--30%

Methanol in FFV fuel	85.0%
Methanol in dedicated vehicle fuel	90.0%
Ethanol in low-level blend of gasoline and ethanol	10.0%
Ethanol in FFV fuel	85.0%
Ethanol in dedicated vehicle fuel	85.0%
Butanol in FFV fuel	100.0%
ET 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 EtOH-diesel	10.0%
Additives in EtOH-diesel	1.0%
Isobutanol in BSI (gasoline) fuel	20.0%
ARHC (Aromatics-rich hydrocarbon fuel) in BSI (gasoline) fuel	20.0%
Methanol in MM (gasoline) fuel	20.0%
Isoalkane in MCCI fuel	20.0%
FAE (Fatty alkyl ether) in MCCI fuel	20.0%
FAFE (Fatty acid fusel esters) in MCCI fuel	20.0%
Renewable diesel in MCCI fuel	10.0%

12.2) Type of Gasoline or Diesel for Alternative Fuel Blends
Share of Gasoline out of Gasoline and Blendstock

Gasoline for methanol blend	0.0%
Gasoline for low-level ethanol blend	0.0%
Gasoline for high-level ethanol blend	0.0%
Gasoline for butanol blend	0.0%
Gasoline for renewable gasoline blend	0.0%
Gasoline for Isobutanol blend	0.0%
Gasoline for ARHC blend	0.0%
Gasoline for Methanol blend	0.0%

Vehicles Worksheet

Results

Back to Top

1

Type 35%

2

Press F9

Navigation bar with tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

Default Energy Content of Soy Oil



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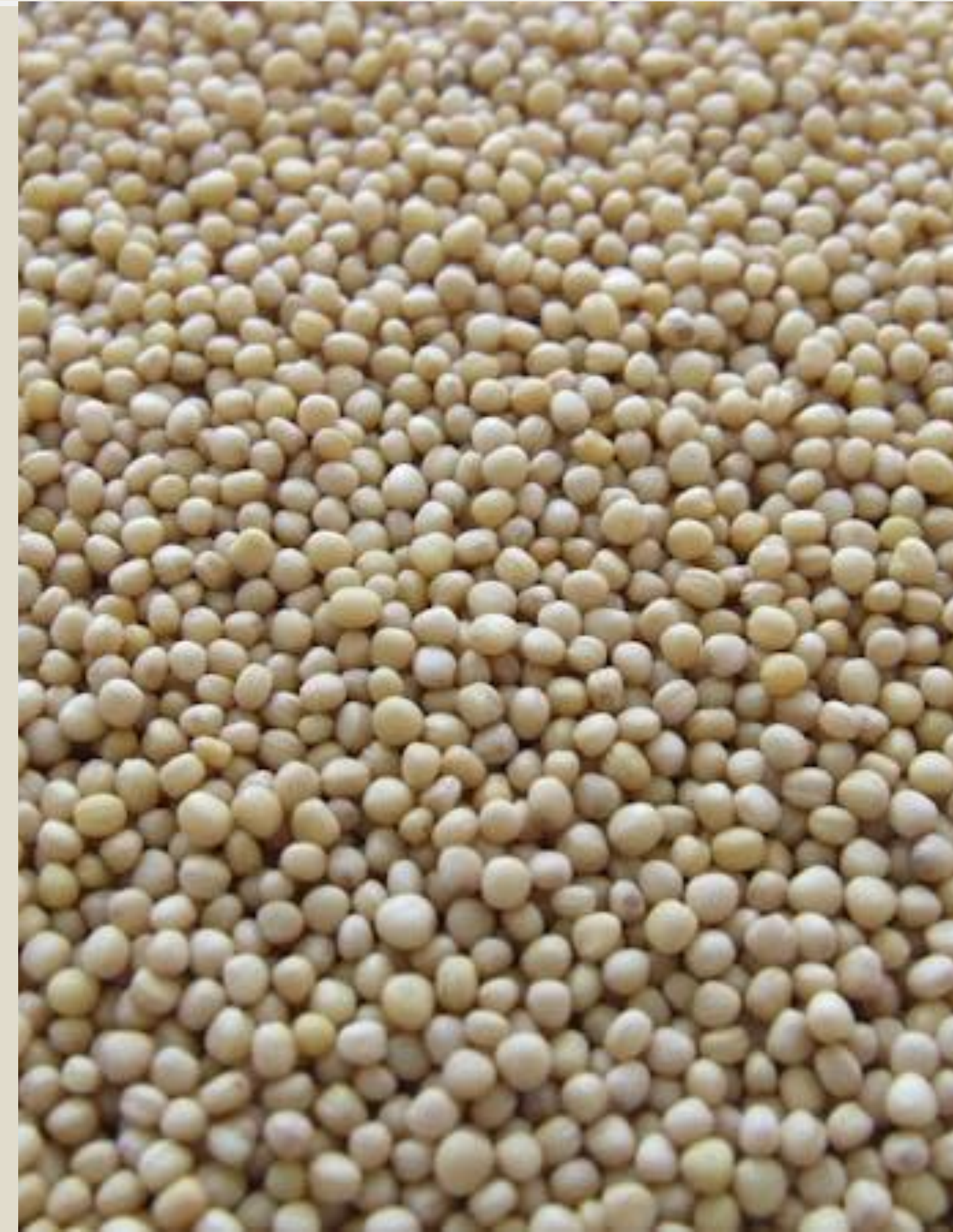
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Default energy content of soy oil

Estimates the soy oil conversion efficiency to BD/RD by energy

Accounts for total energy consumption in some cases

Estimates the energy-based allocation factor between soy oil and soybean meal during the soybean crushing and oil extraction step



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fx Insert Function AutoSum Recently Used Financial Logical Text Date & Time Lookup & Reference Math & Trig More Functions

Function Library

Name Manager Define Name Use in Formula Create from Selection

Defined Names

Trace Precedents Trace Dependents Remove Arrows Show Formulas Error Checking Evaluate Formula

Formula Auditing

Watch Window Calculation Options

Calculation

AU453 =AU452+SUMPRODUCT(AU449:AU450,Fuel_Specs!\$B\$148:\$B\$149)+SUMPRODUCT(AU441:AU443,Fuel_Specs!\$B\$154:\$B\$156)+SUMPRODUCT(AU447:AU448,Fuel_Specs!\$B\$157:\$B\$158)

A B C D E F G H

1 Soybeans, Palm, Canola, Jatropha and Camelina to Biodiesel, Renewable Diesel, and Renewable Gasoline

2

3 Home Inputs Results

4

5 1) Scenario Control and Key Input Parameters (from the Inputs sheet)

6 Biodiesel Renewable diesel 1 Renewable diesel 2 Renewable gasoline

7 Feedstock for biooil-based fuels 1 1 1 1 1: Soybean, 2: Palm FFB, 3: Canola, 4: Jatropha,

8

9 Allocation Method

10 Method for dealing with co-products

11 Biodiesel Renewable diesel 1 Renewable diesel 2 Renewable gasoline 1- Process Level Allocation/Displacement

12 System level allocation for soy and jatropha based fuel 1 1 1 1 2- System Level Energy-Based Allocation

13 Process level allocation for all biooil-based fuels

14 Feedstock Soy oil Palm Oil Canola Jatropha Camelina Tallow Sc

15 Oil Extraction Process 4 4 4 2 4 4

16 Fuel Biodiesel Renewable diesel 1 Renewable diesel 2 Renewable gasoline Glycerin

17 Fuel Production 3 2 2 2 3

18

19 Palm Fatty Acid Distillate (PFAD)

20 Oil Extraction Process CPO PFAD

21 4 6

22 Fuel refining RBD/PFAD

23 CPO refining 2

24 Fuel production Renewable diesel 2 Biodiesel

25 Fuel Production 2 2

26

27 Feedstock Properties

28 Soybean Palm Full Fruit Bunch (FFB) Canola Jatropha Camelina Carinata

29 Density Unit lb/bushel

30 Density 52.2

31 Lipid Content 19.1% 22.4% 44.0% 35.0% 36.0% 41.0%

< > ... NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity Hydrogen BioOil Algae Macroalgae Was ... +



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A1 Soybeans, Palm, Canola, Jatropha and Camelina to Biodiesel, Renewable Diesel, and Renewable Gasoline

	A	B	C	D	E	F	G	H
1	Soybeans, Palm, Canola, Jatropha and Camelina to Biodiesel, Renewable Diesel, and Renewable Gasoline							
254	3. Allocation Method for Dealing with Co-products (based on Energy Value and Market Value)							
255	3.1 Energy content (Btu/lb) and market value of co-product (\$/lb)							
256			Energy content					Market value
257			(Btu/lb)					(\$/lb)
258	Soybean (dry matter)		7,924					
259	Palm FFB (dry matter)		5,510					
260	Canola (dry matter)		10,469					
261	Jatropha (dry matter)		8,631					
262	Camelina (dry matter)		14,792					
263	Carinata (dry matter)		15,921					
264	Biodiesel		16,269					0.494
265	Renewable diesel I		18,729					0.568
266	Renewable diesel II		18,908					0.574
267	Renewable gasoline		18,590					0.564
268	Soy oil		15,993					0.350
269	Soy meal (dry matter)		5,742					0.213
270	Palm Oil		15,993					0.455
271	PKE (dry matter)		2,666					0.063
272	Canola Oil		15,993					0.477
273	Canola Meal (dry matter)		5,742					0.116
274	Jatropha oil		15,993					0.384
275	Jatropha Meal		7,739					
276	Jatropha Husk		6,664					
277	Jatropha Shell		8,169					
278	Camelina Oil		15,993					0.384
279	Camelina Meal (dry matter)		5,742					0.118
280	Carinata Oil		16,075					0.349
281	Carinata Meal (dry matter)		7,610					0.159
282	Tallow		15,802					0.314
283	Yellow Grease		15,652					
284	Meat bone and meal (dry matter)		2,666					0.165
285	Glycerine		7,979					0.100

Well-to-Wheel (WTW) GHG Emissions



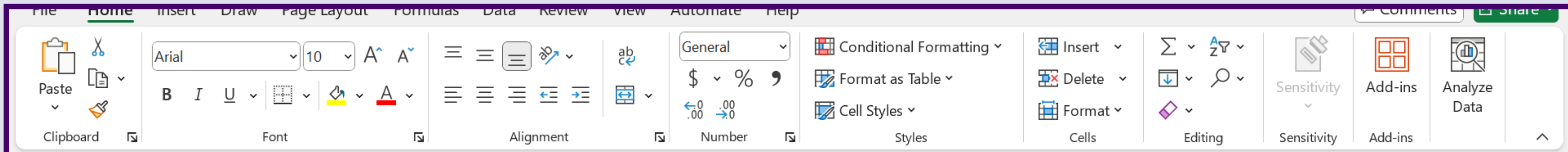
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AK925

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles Select Fuels	Go	SI Hybrid Vehicles (HEV) Select Fuels	Go	SI Plug-in Hybrids (PHEV) Select Fuels	Go	Performance-enhancing Fuels Select Fuels
SIDI ICE Vehicles Select Fuels	Go	CIDI Hybrid Vehicles (HEV) Select Fuels	Go	CIDI Plug-in Hybrids (PHEV) N/A	Go	
CIDI ICE Vehicles CIDI - Biodiesel	Go	BEV and FCV Select Fuels	Go	GCI ICE Vehicles Select Fuels	Go	

Unit Selection Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled Energy Unit: Btu Emission Unit: g Service Functional Unit: mile	Per Energy in Fuels Energy Unit: Btu Emission Unit: g Energy Functional Unit: MJ
---	---

CIDI Vehicle: Soybean-based BD35

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	205	8						
Fossil Fuels	192							
Coal	18							
Natural Gas	123							
Petroleum	51							
Water Consumption	0.8							
CO2 (w/ C in VOC & CO)	-73							
CH4	0.224	0.075	0.092	0.391	0.060	0.020	0.024	0.104
N2O	0.027	0.001	0.001	0.028	0.007	0.000	0.000	0.008
GHGs	-58	41	284	266	-16	11	76	71
VOC: Total	0.012	0.031	0.143	0.186	0.003	0.008	0.038	0.050
CO: Total	0.030	0.019	3.531	3.580	0.008	0.005	0.942	0.955
NOx: Total	0.039	0.031	0.097	0.167	0.010	0.008	0.026	0.045
PM10: Total	0.002	0.003	0.034	0.039	0.001	0.001	0.009	0.010
PM2.5: Total	0.002	0.002	0.007	0.011	0.001	0.001	0.002	0.003
SOx: Total	0.011	0.011	0.001	0.023	0.003	0.003	0.000	0.006
BC Total	0.001	0.000	0.002	0.003	0.000	0.000	0.001	0.001
OC Total	0.001	0.000	0.001	0.002	0.000	0.000	0.000	0.001

WTW GHG emissions
266 g CO₂e/mile or 71 g CO₂e/MJ

Press F9

CIDI vehicle fueled by 35% biodiesel (BD35)

Navigation tabs: Inputs, Results, Petroleum, Co_processing, NG, MeOH_FTD, EtOH, Electric, Generation_mixes, Bio_electricity

CIDI fueled by soybean renewable diesel

CIDI fueled by 35% soybean biodiesel (BD35)

The image shows two side-by-side screenshots of a spreadsheet application. The left screenshot displays a 'WTW Results Menu' with various vehicle types and fuel selection options. Below the menu, a table shows 'WTW GHG emissions' for 'Soybean-based BD35' as 125 g CO₂e/mile. The right screenshot shows a similar 'WTW Results Menu' and a detailed table of 'WTW GHG emissions' for 'Soybean-based BD35' as 266 g CO₂e/mile. Both screenshots include a 'Per Energy in Fuels' section with units for Energy and Emission.

WTW GHG emissions
125 g CO₂e/mile

WTW GHG emissions
33 g CO₂e/MJ

WTW GHG emissions
266 g CO₂e/mile

WTW GHG emissions
71 g CO₂e/MJ



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Challenge: Which Stage of the Vehicle Cycle Accounts for Biogenic CO₂ Credits?



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WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

SI ICE Vehicles Select Fuels Go

SIDI ICE Vehicles Select Fuels Go

CIDI ICE Vehicles Select Fuels Go

CIDI - Biodiesel

SI Hybrid Vehicles (HEV) Select Fuels Go

CIDI Hybrid Vehicles (HEV) Select Fuels Go

BEV and FCV Select Fuels Go

SI Plug-in Hybrids (PHEV) Select Fuels Go

CIDI Plug-in Hybrids (PHEV) Select Fuels Go

Performance-enhancing Fuels Select Fuels

Unit Selection Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled Energy Unit: Btu Emission Unit: g Service Functional Unit: mile

Per Energy in Fuels Energy Unit: Btu Emission Unit: g Energy Functional Unit: MJ

CIDI Vehicle: Soybean-based BD35

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	205	805	2,553	4,563	55	215	948	1,217
Fossil Fuels						131	633	815
Coal						8	0	12
Natural Gas						98	0	130
Petroleum						26	633	672
Water Cooling						0	0	0
CO2 (w/ CH4)						10	75	66
N2O	-0.027	0.001	0.001	0.028	-0.007	0.000	0.000	0.008
GHGs	-58	41	284	266	-16	11	76	71
VOC: Total	0.012	0.031	0.143	0.186	0.003	0.008	0.038	0.050
CO: Total	0.030	0.019	3.531	3.580	0.008	0.005	0.942	0.955
NOx: Total	0.039	0.031	0.097	0.167	0.010	0.008	0.026	0.045
PM10: Total	0.002	0.003	0.034	0.039	0.001	0.001	0.009	0.010
PM2.5: Total	0.002	0.002	0.007	0.011	0.001	0.001	0.002	0.003
SOx: Total	0.011	0.011	0.001	0.023	0.003	0.003	0.000	0.006
BC Total	0.001	0.000	0.002	0.003	0.000	0.000	0.001	0.001
OC Total	0.001	0.000	0.001	0.002	0.000	0.000	0.000	0.001

Feedstock GHG emissions
 -58 g CO₂e/mile or -16 g CO₂e/MJ

CIDI vehicle fueled by 35% biodiesel (BD35)

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Biogenic credits and emissions

The “Feedstock” stage accounts for the biogenic carbon uptake credit provided due to biomass feedstock production

Biogenic CO₂ emissions are included in the “Vehicle Operation”

The net effect of biogenic CO₂ emissions and the biogenic carbon uptake credit is small



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Renewable Natural Gas Scenarios



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RNG from Landfill Gas

Model a Refuse Truck Fueled by Liquified Natural
Gas Produced from RNG from Landfill Gas



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Home Inputs Back to Top WTP Results WTP Changes

WTW Results Menu Select a vehicle type from a pink drop down **1** then press "Go"

Heavy-Duty Vehicles
 Refuse Trucks
 SI Vehicle: LNG

2 Unit Selection: Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled or Cargo Distance Transported
 Energy Unit: Btu Emission Unit: g
 Service Functional Unit for Heavy-Duty Vans and Trucks: mile
 Service Functional Unit for Buses: mile

Per Energy in Fuels
 Energy Unit: Btu Emission Unit: g
 Energy Functional Unit: MJ **3**

Per Vehicle Distnace Travelled

Energy Unit	Btu	mBtu
	1.000	0.001
Emission Unit	g	mg
	1.000	1000
Functional Unit	mile	km
	1.000	1.609

SI Refuse Trucks: LNG, NA NG

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	2,623	3,787	0	6,410	0.000	0.000	0.000	0.000
Fossil Fuels	2,609	3,787	0	6,396	0.000	0.000	0.000	0.000
Coal	19	0	0	19	0.000	0.000	0.000	0.000
Natural Gas	2,576	3,500	0	6,076	0.000	0.000	0.000	0.000
Petroleum	14	1	0	15	0.000	0.000	0.000	0.000
Water Consumption	0	0	0	0	0.000	0.000	0.000	0.000
CO2 (w/ C in VOC & CO)	164	2	0	166	0.000	0.000	0.000	0.000
CH4	4	0	0	4	0.000	0.000	0.000	0.000
N2O	0	0	0	0	0.000	0.000	0.000	0.000
GHGs	295	352	2,013	2,661	9	10	59	78
VOC: Total	0.045	0.032	0.096	0.173	0.007	0.001	0.003	0.011
CO: Total	0.017	0.204	23.000	23.742	0.016	0.006	0.676	0.697
NOx: Total	0.030	0.265	0.090	0.985	0.019	0.008	0.003	0.029
PM10: Total	0.012	0.015	0.154	0.181	0.000	0.000	0.005	0.005
PM2.5: Total	0.011	0.014	0.024	0.049	0.000	0.000	0.001	0.001
SOx: Total	0.355	0.051	0.000	0.407	0.010	0.002	0.000	0.012
BC Total	0.002	0.001	0.003	0.006	0.000	0.000	0.000	0.000
OC Total	0.005	0.009	0.004	0.018	0.000	0.000	0.000	0.001
VOC: Urban	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

WTW GHG emissions
 2661 g CO₂e/mile or 78 g CO₂e/MJ

Refuse truck fueled by LNG from North American NG

4 Press F9

Plastics CESA Animal_Feed EtOH-Diesel Additives OilGasCoalInfra ElecInfra Woody HDV_TS HDV_WTW SA



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fx Insert Function Σ AutoSum Recently Used Financial Logical Text Date & Time Lookup & Reference Math & Trig More Functions Name Manager Define Name Use in Formula Create from Selection Trace Precedents Trace Dependents Remove Arrows Show Formulas Error Checking Evaluate Formula Watch Window Calculation Options

NG_LNG_FeedstockShare 1

4. Natural Gas to Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG)

4.1) Simulation Options for NG-Based Fuel Pathways

Feedstock Source	Compressed Natural Gas	NG-based Liquefied Petroleum Gas (NGL)	Liquefied Natural Gas as a Transportation Fuel
	1	1	1

Note: Feedstock Sources: 1 -- North American NG, 4 -- Renewable natural gas

4.2) Share of Conventional and Shale Gas for North America NG Supply

Conventional Gas	25%
Shale Gas	75%

4.3) CH4 leakage rate for each stage in conventional NG and shale gas pathways

	Unit	Used in calculation: BU/TD Hybrid		BU/TD Hybrid	
		Conventional NG	Shale gas	Conventional NG	Shale gas
Recovery - CH4 Leakage and Venting	vol. % of CH4 over NG through	0.51%	0.51%	0.51%	0.51%
Recovery - Completion CH4 Venting	vol. % of CH4 over NG through	0.00%	0.01%	0.00%	0.01%
Recovery - Workover CH4 Venting	vol. % of CH4 over NG through	0.00%	0.00%	0.00%	0.00%
Recovery - Liquid Unloading CH4 Venting	vol. % of CH4 over NG through	0.02%	0.02%	0.02%	0.02%
Well Equipment - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.33%	0.33%	0.33%	0.33%
Gathering and Boosting - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.15%	0.15%	0.15%	0.15%
Processing - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.03%	0.03%	0.03%	0.03%
Transmission and Storage - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.31%	0.31%	0.31%	0.31%
Distribution - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.09%	0.09%	0.09%	0.09%
Total	vol. % of CH4 over NG through	0.94%	0.94%	0.94%	0.94%

4.4) Flaring energy and CO2 emission rate for recovery and processing in conventional NG and shale gas pathways

	Unit	Used in calculation: EPA		BU/TD Hybrid	
		Conventional NG	Shale gas	Conventional NG	Shale gas
Recovery - Flaring	Btu NG/mmBtu NG	1,879	1,878	1,879	1,878
Recovery - Venting	g CO2/mmBtu NG	115	115	115	115
Processing - Flaring	Btu NG/mmBtu NG	3,083	3,083	3,083	3,083
Processing - Venting	g CO2/mmBtu NG	463	463	463	463

4.5) Share of Petroleum and NG for Production of Liquefied Petroleum Gas (LPG)

Ready Calculate Accessibility: Investigate



Microsoft Excel interface showing a spreadsheet for "Renewable Natural Gases Based Fuel". The ribbon includes options for Clipboard, Font, Alignment, Number, Styles, Cells, and Editing.

The spreadsheet content is as follows:

Renewable Natural Gases Based Fuel

1) Scenario Control and Key Input Parameters

1.1) Share of Fuels from Each Waste

	NG as Intermediate Fuel	MeOH	CNG	LNG
Landfill Gas	100%	100%	100%	100%
Bio-gas from AD of Animal Waste	0%	0%	0%	0%
Bio-gas from AD of Wastewater Sludge	0%	0%	0%	0%
Bio-gas from AD of MSW	0%	0%	0%	0%

1.2) Assumptions Regarding NG Processing

	LFG-based Micro Turbine	Manure-based Micro Turbine	WWTP-based Micro Turbine	MSW-based Micro Turbine	Engine	Micro Turbine	MCFC	PAFC
CHP Generator Electrical Efficiency	33%	33%	33%	33%	30%	32.9%	48%	35%
Heat Recovery Efficiency from CHP generator	70%	70%	70%	70%	70%	70%	50%	50%
Boiler Efficiency	80%							
NG Processing Efficiency (powered by Electricity)	94.4%							
NG Processing CH4 Leakage	2%							
NG Small Scale Liquefaction Efficiency (powered by R)	89.0%							
CNG Refueling Options	1	1 -- On-Site, 2 -- Off-Site						
Allocation Handling Method	2	1 -- Displacement, 2-- Energy Allocation						
Biogenic CO2 emission credits	-59,413 (gCO2e/mmBtu biogas combustion)							

1.3) Assumptions for Anaerobic Digestion of Animal Waste

Source of Assumptions: U.S. - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other

U.S.

Navigation tabs at the bottom: BioOil, Algae, Macroalgae, Waste, **RNG**, Pyrolysis_IDL, IBR, E_fuel, Fuel_Prod_TS, EF_TS, AgMining_EF_TS



Well-to-Wheel (WTW) GHG Emissions



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Home Inputs Back to Top WTP Results WTP Changes

WTW Results Menu Select a vehicle type from a pink drop down **1** then press "Go"

Heavy-Duty Vehicles
 Refuse Trucks
 SI Vehicle: LNG

2 Unit Selection: Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled or Cargo Distance Transported
 Energy Unit: Btu Emission Unit: g
 Service Functional Unit for Heavy-Duty Vans and Trucks: mile
 Service Functional Unit for Buses: mile

Per Energy in Fuels
 Energy Unit: Btu Emission Unit: g
 Energy Functional Unit: MJ **3**

Per Vehicle Distnace Travelled

Energy Unit	Btu	mBtu
	1.000	0.001
Emission Unit	g	mg
	1.000	1000
Functional Unit	mile	km
	1.000	1.609

SI Refuse Trucks: LNG, LFG

Item	Btu/mile or Gallon/mile or g/mile				Btu/MJ or Gallon/MJ or g/MJ			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
2722 Total Energy	0	-26,443	32,272	5,829	0	777	0.048	174
2723 Fossil Fuels	0	5,200			0			
2725 Coal	0	2,000			0			
2726 Natural Gas	0	3,000			0			
2727 Petroleum	0	1,000			0			
2728 Water Consumption	0				0			
2729 CO2 (w/ C in VOC & CO)	0	4,000			0			
2730 CH4	0				0			
2731 N2O	0	0	0	-0.029	0.000	-0.001	0.000	-0.001
2732 GHGs	0	821	2,013	2,835	0	24	59	83
2733 VOC: Total	0.000	-0.735	0.096	-0.639	0.000	-0.022	0.003	-0.019
2734 CO: Total	0.000	-1.189	23.000	21.811	0.000	-0.035	0.676	0.641
2735 NOx: Total	0.000	-0.228	0.090	-0.138	0.000	-0.007	0.003	-0.004
2736 PM10: Total	0.000	-0.123	0.154	0.031	0.000	-0.004	0.005	0.001
2737 PM2.5: Total	0.000	-0.142	0.024	-0.118	0.000	-0.004	0.001	-0.003
2738 SOx: Total	0.000	0.241	0.000	0.241	0.000	0.007	0.000	0.007
2739 BC Total	0.000	-0.157	0.003	-0.154	0.000	-0.005	0.000	-0.005
2740 OC Total	0.000	-0.002	0.004	0.003	0.000	0.000	0.000	0.000
2741 VOC: Urban	0.000	0.288	0.088	0.376	0.000	0.014	0.002	0.016

WTW GHG emissions
 2835 g CO₂e/mile or 83 g CO₂e/MJ

Refuse truck fueled by LNG from RNG from landfill gas

4 Press F9

Plastics CESA Animal_Feed EtOH-Diesel Additives OilGasCoalInfra ElecInfra Woody HDV_TS HDV_WTW SA



Refuse truck fueled by LNG from North American NG

Refuse truck fueled by LNG from RNG produced from landfill gas

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

Heavy-Duty Vehicles
 Refuse Trucks
 SI Vehicle: LNG

Unit Selection: Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled or Cargo Distance Transported
 Energy Unit: Btu Emission Unit: g
 Service Functional Unit for Heavy-Duty Vans and Trucks: mile
 Service Functional Unit for Buses: mile

Per Energy in Fuels
 Energy Unit: Btu Emission Unit: g
 Energy Functional Unit: MJ

Trucks: LNG, NA NG

	Btu/mile or Gallon	WTW GHG emissions		Btu/MJ or Gallon	WTW GHG emissions	
	Feedstock			Fuel		
	2,623			111		
	2,609			110		
	19			1		
	2,576			104		
	14			6		
	0			0		
	164			5		
	4	4	3	12.071	0.128	0.131
	0	0	0	-0.006	0.000	0.000
	295	352	2,013	2,661	9	10
	0.245	0.032	0.096	0.372	0.007	0.001
	0.537	0.204	23.000	23.742	0.016	0.006
	0.630	0.265	0.090	0.985	0.019	0.008
	0.012	0.015	0.154	0.181	0.000	0.000
	0.011	0.014	0.024	0.049	0.000	0.000
	0.355	0.051	0.000	0.407	0.010	0.002
	0.002	0.001	0.003	0.006	0.000	0.000
	0.005	0.009	0.004	0.018	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

Plastics CESA Animal_Feed EtOH-Diesel Additives OilGasCoallnfra ElecInfra Woody HDV_TS

WTW Results Menu Select a vehicle type from a pink drop down menu, then press "Go"

Heavy-Duty Vehicles
 Refuse Trucks
 SI Vehicle: LNG

Unit Selection: Select units from a pink drop down menu for the Results

Per Vehicle Distance Travelled or Cargo Distance Transported
 Energy Unit: Btu Emission Unit: g
 Service Functional Unit for Heavy-Duty Vans and Trucks: mile
 Service Functional Unit for Buses: mile

Per Energy in Fuels
 Energy Unit: Btu Emission Unit: g
 Energy Functional Unit: MJ

Trucks: LNG, LFG

	Btu/mile or Gallon	WTW GHG emissions		Btu/MJ or Gallon	WTW GHG emissions	
	Feedstock			Fuel		
	0			-777		
	0			154		
	0			60		
	0			90		
	0			4		
	0			0		
	0			12		
	0	14	3	17.585	0.000	0.421
	0	0	0	-0.028	0.000	-0.001
	0	821	2,013	2,835	0	24
	0.000	-0.735	0.096	-0.639	0.000	-0.022
	0.000	-1.189	23.000	21.811	0.000	-0.035
	0.000	-0.228	0.090	-0.138	0.000	-0.007
	0.000	-0.123	0.154	0.031	0.000	-0.004
	0.000	-0.142	0.024	-0.118	0.000	-0.004
	0.000	0.241	0.000	0.241	0.000	0.007
	0.000	-0.157	0.003	-0.154	0.000	-0.005
	0.000	-0.002	0.004	0.003	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

Plastics CESA Animal_Feed EtOH-Diesel Additives OilGasCoallnfra ElecInfra Woody HDV_TS

RNG from AD

Model a Refuse Truck Fueled by Liquified Natural Gas Produced from RNG from Anaerobic Digestion (AD) from Animal Manure



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NG_LNG_FeedstockShare 1

4. Natural Gas to Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG)

4.1) Simulation Options for NG-Based Fuel Pathways

Natural Gas	Compressed Natural Gas	NG-based Liquefied Petroleum Gas (NGL)	Liquefied Natural Gas as a Transportation Fuel	Note: Feedstock Source
1	1	1	1	1 -- North American NG, 4 -- Renewable natural gas

4.2) Share of Conventional and Shale Gas for North America NG Supply

Conventional Gas	25%
Shale Gas	75%

4.3) CH4 leakage rate for each stage in conventional NG and shale gas pathways

	Unit	Used in calculation: BU/TD Hybrid		BU/TD Hybrid		Conversion
		Conventional NG	Shale gas	Conventional NG	Shale gas	
Recovery - CH4 Leakage and Venting	vol. % of CH4 over NG through	0.51%	0.51%	0.51%	0.51%	
Recovery - Completion CH4 Venting	vol. % of CH4 over NG through	0.00%	0.01%	0.00%	0.01%	
Recovery - Workover CH4 Venting	vol. % of CH4 over NG through	0.00%	0.00%	0.00%	0.00%	
Recovery - Liquid Unloading CH4 Venting	vol. % of CH4 over NG through	0.02%	0.02%	0.02%	0.02%	
Well Equipment - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.33%	0.33%	0.33%	0.33%	
Gathering and Boosting - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.15%	0.15%	0.15%	0.15%	
Processing - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.03%	0.03%	0.03%	0.03%	
Transmission and Storage - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.31%	0.31%	0.31%	0.31%	
Distribution - CH4 Venting and Leakage	vol. % of CH4 over NG through	0.09%	0.09%	0.09%	0.09%	
Total	vol. % of CH4 over NG through	0.94%	0.94%	0.94%	0.94%	

4.4) Flaring energy and CO2 emission rate for recovery and processing in conventional NG and shale gas pathways

	Unit	Used in calculation: EPA		BU/TD Hybrid		Conversion
		Conventional NG	Shale gas	Conventional NG	Shale gas	
Recovery - Flaring	Btu NG/mmBtu NG	1,879	1,878	1,879	1,878	
Recovery - Venting	g CO2/mmBtu NG	115	115	115	115	
Processing - Flaring	Btu NG/mmBtu NG	3,083	3,083	3,083	3,083	
Processing - Venting	g CO2/mmBtu NG	463	463	463	463	

4.5) Share of Petroleum and NG for Production of Liquefied Petroleum Gas (LPG)

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity



Microsoft Excel interface showing a spreadsheet for "Renewable Natural Gases Based Fuel".

Formula bar: A1: Renewable Natural Gases Based Fuel

Navigation buttons: Home, Inputs, Results

1) Scenario Control and Key Input Parameters

1.1) Share of Fuels from Each Waste

	NG as Intermediate Fuel	MeOH	CNG	LNG
Landfill Gas	100%	100%	100%	100%
Bio-gas from AD of Animal Waste	0%	0%	0%	0%
Bio-gas from AD of Wastewater Sludge	0%	0%	0%	0%
Bio-gas from AD of MSW	0%	0%	0%	0%

Type 0%

1.2) Assumptions Regarding NG Processing

	LFG-based Micro Turbine	Manure-based Micro Turbine	WWTP-based Micro Turbine	MSW-based Micro Turbine	Engine	Micro Turbine	MCFC	PAFC
CHP Generator Electrical Efficiency	33%	33%	33%	33%	30%	32.9%	48%	35%
Heat Recovery Efficiency from CHP generator	70%	70%	70%	70%	70%	70%	50%	50%
Boiler Efficiency	80%							
NG Processing Efficiency (powered by Electricity)	94.4%							
NG Processing CH4 Leakage	2%							
NG Small Scale Liquefaction Efficiency (powered by R)	89.0%							
CNG Refueling Options	1	1 -- On-Site, 2 -- Off-Site						
Allocation Handling Method	2	1 -- Displacement, 2-- Energy Allocation						
Biogenic CO2 emission credits	-59,413 (gCO2e/mmBtu biogas combustion)							

1.3) Assumptions for Anaerobic Digestion of Animal Waste

Source of Assumptions: U.S. - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other

U.S.

Navigation tabs: BioOil, Algae, Macroalgae, Waste, **RNG**, Pyrolysis_IDL, IBR, E_fuel, Fuel_Prod_TS, EF_TS, AgMining_EF_TS



Microsoft Excel ribbon: Insert Function, AutoSum, Recently Used, Financial, Logical, Text, Date & Time, Lookup & Reference, Math & Trig, Functions, Name Manager, Define Name, Use in Formula, Create from Selection, Defined Names, Trace Precedents, Trace Dependents, Remove Arrows, Show Formulas, Error Checking, Evaluate Formula, Formula Auditing, Watch Window, Calculation Options, Calculation.

Formula bar: H7, 0%

Worksheet tabs: Home, Inputs, Results

Worksheet content:

Renewable Natural Gases Based Fuel

1) Scenario Control and Key Input Parameters

1.1) Share of Fuels from Each Waste

	NG a
Landfill Gas	
Bio-gas from AD of Animal Waste	
Bio-gas from AD of Wastewater Sludge	
Bio-gas from AD of MSW	

1.2) Assumptions Regarding NG Processing

	Engine	Micro Turbine	MCFC	PAFC
CHP Generator Electrical Efficiency	30%	32.9%	48%	35%
Heat Recovery Efficiency from CHP generator	70%	70%	50%	50%
Boiler Efficiency	80%			
NG Processing Efficiency (powered by Electricity)	94.4%			
NG Processing CH4 Leakage	2%			
NG Small Scale Liquefaction Efficiency (powered by R)	89.0%			

CNG Refueling Options: 1 -- On-Site, 2 -- Off-Site

Allocation Handling Method: 1 -- Displacement, 2-- Energy Allocation

Biogenic CO2 emission credits: -59,413 (gCO2e/mmBtu biogas combustion)

1.3) Assumptions for Anaerobic Digestion of Animal Waste

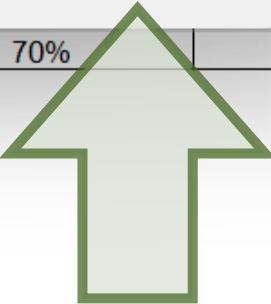
Source of Assumptions: U.S. - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other

Worksheet tabs: Electric, Generation_mixes, Bio_electricity, Hydrogen, BioOil, Algae, Macroalgae, Waste, **RNG**, Pyrolysis_IDL

Microsoft Excel

This pathway uses RNG as a process fuel or feedstock. The LCA results of RNG are subject to further revisions to address technical uncertainties, especially related to counterfactual scenario assumptions for wastes that are used for RNG production.

OK



Excel ribbon: Formulas > Function Library > Insert Function > AutoSum > Recently Used > Financial > Logical > Text > Date & Time > Lookup & Reference > Math & Trig > More Functions > Name Manager > Define Name > Use in Formula > Create from Selection > Defined Names > Trace Precedents > Trace Dependents > Remove Arrows > Formula Auditing > Show Formulas > Error Checking > Evaluate Formula > Watch Window > Calculation Options > Calculation

Worksheet: N16

Columns: A, B, C, D, E, F, G, H, I, J, K, L

Row 1: Renewable Natural Gases Based Fuel

Row 2: 1) Scenario Control and Key Input Parameters

Row 3: Home (blue), Inputs (yellow), Results (green)

Row 4: 1.1) Share of Fuels from Each Waste

	NG as Intermediate Fuel	MeOH	CNG	LNG
Landfill Gas	100%	100%	100%	0%
Bio-gas from AD of Animal Waste	0%	0%	0%	100%
Bio-gas from AD of Wastewater Sludge	0%	0%	0%	0%
Bio-gas from AD of MSW	0%	0%	0%	0%

Row 11: 1.2) Assumptions Regarding NG Processing

	LFG-based Micro Turbine	Manure-based Micro Turbine	WWTP-based Micro Turbine	MSW-based Micro Turbine	Engine	Micro Turbine	MCFC	PAFC
CHP Generator Electrical Efficiency	33%	33%	33%	33%	30%	32.9%	48%	35%
Heat Recovery Efficiency from CHP generator	70%	70%	70%	70%	70%	70%	50%	50%
Boiler Efficiency	80%							
NG Processing Efficiency (powered by Electricity)	94.4%							
NG Processing CH4 Leakage	2%							
NG Small Scale Liquefaction Efficiency (powered by R)	89.0%							

Row 21: CNG Refueling Options Allocation Handling Method

1	1 -- On-Site, 2 -- Off-Site
2	1 -- Displacement, 2-- Energy Allocation

Row 24: Biogenic CO2 emission credits: -59,413 (gCO2e/mmBtu biogas combustion)

Row 26: Anaerobic Digestion of Animal Waste

Row 27: Source of Assumptions: U.S. - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other

Row 28: U.S.

Annotations: "Type 100%" points to the 100% value in the LNG column of the first table. "Press F9" points to the CNG Refueling Options section.

Bottom tabs: Electric, Generation_mixes, Bio_electricity, Hydrogen, BioOil, Algae, Macroalgae, Waste, RNG, Pyrolysis_IDL



Default Livestock Producing the Animal Waste in Anaerobic Digestion



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Renewable Natural Gases Based Fuel

1.3) Assumptions for Anaerobic Digestion of Animal Waste

Source of Assumptions: **U.S.** - If U.S. is selected (default), the assumptions for the U.S. reference system are shown while those for the IPCC and the User-defined are hidden. Other

U.S.

	Beef	Dairy Cow	Dairy Heifer	Swine	Layer	Broiler and Turkey
Share of Livestocks	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%

Moisture Content of Animal Waste: 88%

Wet Animal Waste Input (ton/mmBtu): 1.59

Transportation Vehicles: 1 1--Heavy Heavy-Duty Truck, 2--Medium Heavy-Duty Truck

AD Type: **Mixed Plug Flow**

Animal waste inputs (lb TS) → Anaerobic digestion

0.471 lb C/lb TS	0.097 lb C/lb TS	0.130 lb CH4/lb TS	2,786 Btu/lb TS
0.041 lb N/lb TS	0.097 lb C/lb TS	0.356 lb CO2/lb TS	

Use RNG for on-site heat and power generation? **2** 1. Yes; 2. No.

Heat Load Share by CHP: 100%

Min: 0%

Max: 100%

User Input: 100%

Biogas Share to CHP: 0%

Min: 40%

Self-sustaining Min: 40%

Max: 99%

User Input: 40%

Electricity for Biogas Processing: 82 Btu elec/lb TS

1st Clean Up: 99.0%
0.128 lb CH4/lb TS
2,758 Btu/lb TS

Boiler: 0.0%
0 lb CH4/lb TS
0 Btu thermal/lb TS

Leakage: 1.0%
0.001 lb CH4/lb TS

CH4 Emissions: 0.0%
0.0001 lb C/lb TS
0.0001 lb CH4/lb TS

AD Residue Applied to Soil: 58.7%
0.649 lb residue/lb TS
0.277 lb C/lb TS
0.041 lb N/lb TS

Converted into CO2: 62.0%
0.1716 lb C/lb TS
0.6291 lb CO2/lb TS

Navigation: BioOil | Algae | Macroalgae | Waste | **RNG** | Pyrolysis_IDL | IBR | E_fuel | Fuel_Prod_TS | EF_TS | AgMining_EF_TS



Well-to-Wheel (WTW) GHG Emissions



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Compare RNG from landfill gas and RNG from AD

In GREET, animal manure-based RNG has deeply negative GHG emissions

Assumption in GREET

Typical manure management practices are replaced with AD facilities with RNG upgrading

These manure management practices emit a lot of fugitive methane, so, by ending these practices one receives a significant GHG emissions (negative) credit



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