

NOVEMBER 8, 2022, FOR THE GREET WORKSHOP

BATTERY AND ELECTRIC VEHICLE DEEP DIVES

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Demonstrations using GREET 1 & 2

- Vehicle Cycle – Battery Electric Vehicle (GREET 1 and 2)
 - BEV 400 vs. BEV 200
 - And comparison against all other powertrains

- Total Life Cycle - Plugin Hybrid Electric Vehicle (GREET 1 and 2)
 - PHEV 20 using US grid vs. California electrical grid
 - And comparison against all other powertrains


- Vehicle and Total Energy Cycle - Plugin Hybrid Electric Vehicle (GREET . NET)
 - Examine PHEV 40 using US and California grid


Demonstrations – Vehicle Cycle, Vehicle Selection

- Use GREET 2, but make sure GREET 1 is open
- Select [Vehi_Inputs] Tab
- Select 1 – Passenger Cars
- Select 1 – Passenger Cars 1
- Press F9

Scenario Control Variables and Input Assumptions Related to Vehicle and its Components

1. Selection of Vehicle Types for Simulation

 1 -- Passenger Cars
2 -- Sport Utility Vehicles
3 -- Pick-Up Trucks

 When the "Passenger Cars" option is selected, select one of the following two vehicles for ICEVs
 1 -- Passenger Cars 1, 2 -- Passenger Cars 2

When the "Sport Utility Vehicles" option is selected, select one of the following two vehicles for ICEVs
 1 -- Sport Utility Vehicles 1, 2 -- Sport Utility Vehicles 2

When the "Pick-Up Trucks" option is selected, select one of the following two vehicles for ICEVs
 1 -- Pick-Up Trucks 1, 2 -- Pick-Up Trucks 2

Demonstrations – Vehicle Cycle, Examine BEV Specs

- In GREET 2, look at [\[Car\]](#) Tab, check values

Scenario Control Variables and Input Assumptions Related to Passenger Car and its Components

1. Specification of Total Vehicle Weight, pounds

	ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material	PHEV: Lightweight Material	EV: Conventional Material	EV: Lightweight Material	FCV: Conventional Material	FCV: Lightweight Material
Passenger Car 1	3,183	2,692	3,429	2,839	3,858	3,121	4,150	3,287	3,644	2,930
Passenger Car 2	3,170	2,476	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Selected Passenger Car	3,183	2,692	3,429	2,839	3,858	3,121	4,150	3,287	3,644	2,930

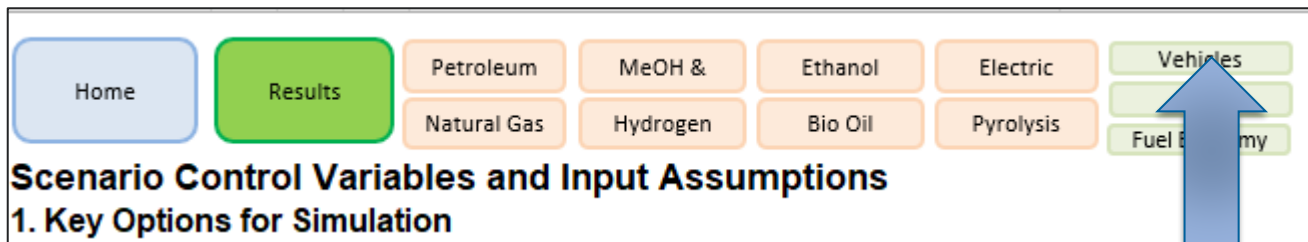
2. Vehicle Battery and Fluids Weight, pounds per vehicle

2.1) Battery Weight

	ICEV: Conventional Material	ICEV: Lightweight Material	HEV: Conventional Material	HEV: Lightweight Material	PHEV: Conventional Material	PHEV: Lightweight Material	EV: Conventional Material	EV: Lightweight Material	FCV: Conventional Material	FCV: Lightweight Material
Passenger Car 1 - Lead-Acid	36.0	23.4	22.1	14.4	22.1	14.4	22.1	14.4	22.1	14.4
Passenger Car 1 - Ni-MH			89.1	75.3	635.3	495.8	2,853.2	2,162.3	105.6	94.1
Passenger Car 1 - Li-Ion			43.2	36.5	341.9	266.9	1,174.0	889.7	48.8	43.5
Passenger Car 2 - Lead-Acid	27.3	24.9	0	0	0	0	0	0	0	0
Passenger Car 2 - Ni-MH			0	0	0	0	0	0	0	0
Passenger Car 2 - Li-Ion			0	0	0	0	0	0	0	0
Selected Passenger Car - Lead-Acid	36.0	23.4	22.1	14.4	22.1	14.4	22.1	14.4	22.1	14.4
Selected Passenger Car - Ni-MH			89.1	75.3	635.3	495.8	2,853.2	2,162.3	105.6	94.1
Selected Passenger Car - Li-Ion			43.2	36.5	341.9	266.9	1,174.0	889.7	48.8	43.5

Demonstrations – Vehicle Cycle, Examine BEV Specs

- Go to GREET 1, [\[Inputs\]](#) Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Check Rated All-Electric Range for BEVs



Demonstrations – Vehicle Cycle, Examine BEV Specs

- Go to GREET 1, [Inputs] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Check Rated All-Electric Range for BEVs (make it 200)

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%

Vehicles
Worksheet

Results

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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%	
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%	
Isokane 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%	

Share of gasoline by volume added in EtOH as denaturant

Share of gasoline by volume added in EtOH as denaturant

Share of gasoline by volume added in EtOH as denaturant

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-gasoline blend	0.0%
Diesel for isokane diesel blend	100.0%
Diesel for FAE (Fatty alkyl ether) diesel blend	100.0%
Diesel for FAFE (Fatty acid fusel esters) diesel blend	100.0%
Share of LSD out of LSD and CD	
Diesel for Fischer-Tropsch diesel blend	100.0%
Diesel for biodiesel blend	100.0%
Diesel for renewable diesel blend	100.0%
Diesel for EtOH-diesel blend	100.0%

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

PHEVs	40
BEVs	200

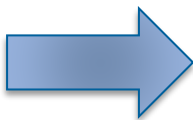
(Note: PHEVs with RAER longer than or equal to 30 miles are series hybrid while PHEVs with RAER shorter than 30 miles are power-split hybrid.)

Check for BEV

Demonstrations – Vehicle Cycle, Examine Vehicle Cycle Results

- Go to GREET 2, [\[Vehi_Sum\]](#) Tab
- Examine Results
- Focus on BEV Results

1.7) EV: Conventional Material



	mmBtu or grams per vehicle lifetime				
	Components	ADR	Batteries	Fluids	Total (No Credits)
Total energy	65.634	14.416	95.238	2.824	178.111
Fossil fuels	58.098	12.649	83.616	2.769	157.131
Coal	22.243	3.007	23.853	0.099	49.202
Natural gas	27.315	9.549	48.731	2.071	87.666
Petroleum	8.539	0.092	11.032	0.600	20.264
Water consumption	7,371	731	12,846	55	21,003
CO2	4,278,434	874,883	6,061,561	82,340	11,297,218
CO2 (VOC, CO, CO2)	4,316,239	881,150	6,082,984	167,461	11,447,834
CH4	10,557.987	2,300.628	27,630.581	469.440	40,958.636
N2O	182.366	22.148	173.138	4.198	381.850
GHGs	4,720,270	955,755	6,995,338	182,596	12,853,960

Demonstrations – Vehicle Cycle, Change BEV Specs

- Go to GREET 1, [Inputs] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Change Rated All-Electric Range to 400 for BEVs
- Press F9

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%
FT diesel in CDI fuel	100.0%
Biodiesel in CDI fuel	20.0%
Renewable diesel in CDI fuel	100.0%
Renewable gasoline in SI fuel	100.0%
Ethanol in EIOH-diesel	10.0%
Additives in EIOH-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%
Isokane in MCCI fuel	20.0%
FAE (Fatty alkyl ether) in MCCI fuel	20.0%
FAFE (Fatty acid fuel esters) in MCCI fuel	20.0%
Renewable diesel in MCCI fuel	10.0%

2.0% Share of gasoline by volume added in EIOH as denaturant
2.0% Share of gasoline by volume added in EIOH as denaturant
2.0% Share of gasoline by volume added in EIOH as denaturant

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-gasoline blend	0.0%
Diesel for isokane diesel blend	100.0%
Diesel for FAE (Fatty alkyl ether) diesel blend	100.0%
Diesel for FAFE (Fatty acid fuel esters) diesel blend	100.0%
Share of LSD out of LSD and CD	
Diesel for Fischer-Tropsch diesel blend	100.0%
Diesel for biodiesel blend	100.0%
Diesel for renewable diesel blend	100.0%
Diesel for EIOH-diesel blend	100.0%

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

PHEVs	40
BEVs	400

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

Change to 400 (BEVs)



Demonstrations – Vehicle Cycle, Examine Vehicle Cycle Results

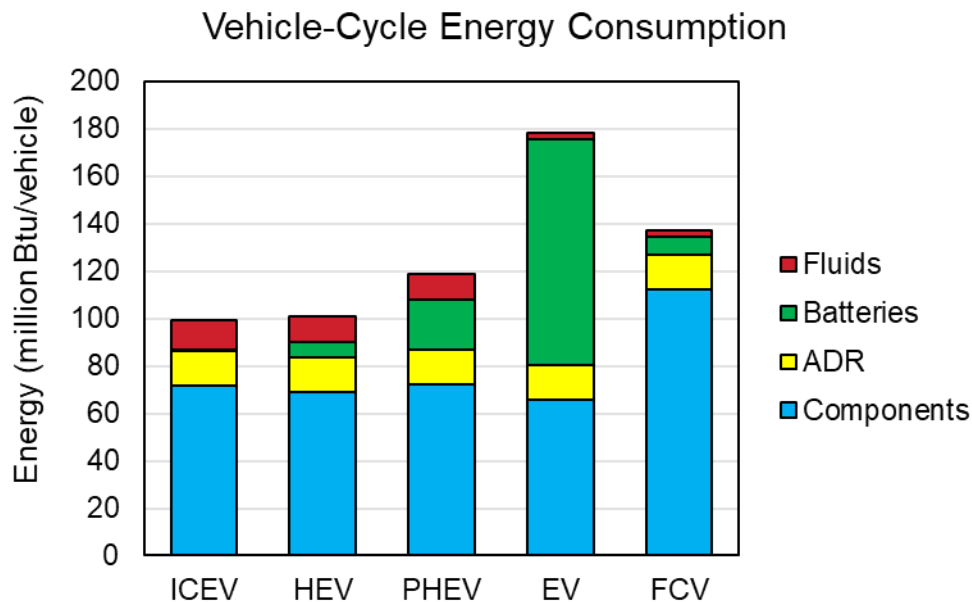
- Go to GREET 2, [\[Vehi_Sum\]](#) Tab
- Examine Results
- Focus on BEV Results



1.7) EV: Conventional Material					
	mmBtu or grams per vehicle lifetime				
	Components	ADR	Batteries	Fluids	Total (No Credits)
Total energy	65.619	14.416	83.898	2.824	166.757
Fossil fuels	58.089	12.649	74.652	2.769	148.159
Coal	22.254	3.007	19.996	0.099	45.355
Natural gas	27.304	9.549	44.460	2.071	83.385
Petroleum	8.531	0.092	10.196	0.600	19.419
Water consumption	7,370	731	10,279	55	18,436
CO2	4,278,431	874,883	5,316,925	82,340	10,552,580
CO2 (VOC, CO, CO2)	4,316,270	881,150	5,334,443	167,461	10,699,324
CH4	10,556.381	2,300.628	25,843.984	469.440	39,170.433
N2O	181.696	22.148	147.087	4.198	355.129
GHGs	4,720,078	955,755	6,172,516	182,596	12,030,946

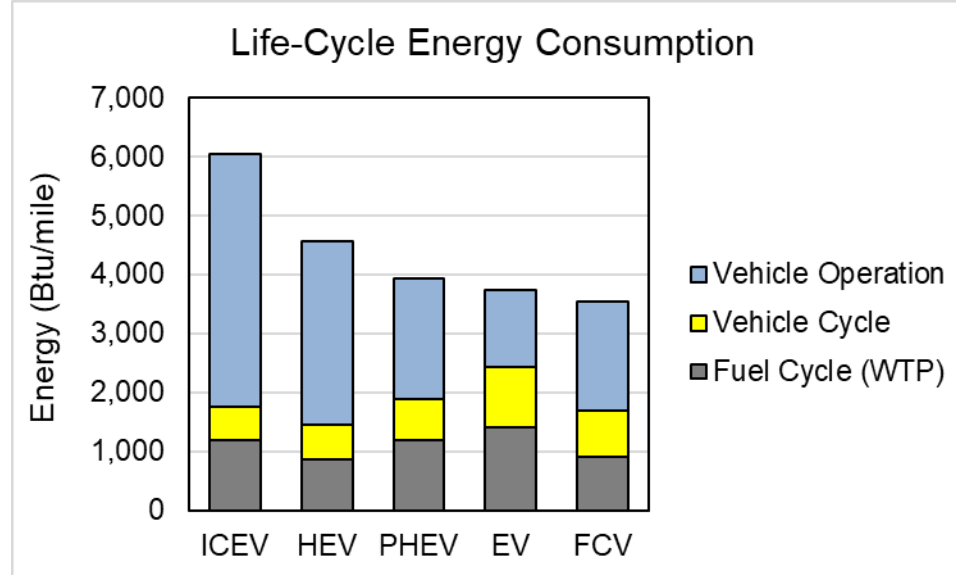
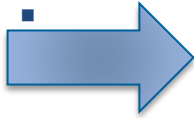
Demonstrations – Vehicle Cycle, Examine Vehicle Cycle Results

- Go to GREET 2, [\[Vehi_Sum\]](#) Tab
- Examine Results (BEV 200; can do the same for BEV 400)
- Graph below based on results in [\[Vehi_Sum\]](#) tab



Demonstrations – Life Cycle, Examine Life Cycle Results

- Go to GREET 2, [\[TEC_Results\]](#) Tab
- Examine Results (BEV 200; can do the same for BEV 400)
- Graph below based on results in [\[TEC_Results\]](#) tab



Demonstrations – Vehicle Cycle, Change PHEV Battery Size

- Go to GREET 2, [Car] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Change Li-Ion Battery weights of PHEV to 7 and 4 kWh
- Press F9

4.2) Passenger Car Battery Size in Peak Battery Energy (High Power Applications), kWh

	Ni-MH	Li-Ion
PHEV: Conventional Material	18	18
PHEV: Lightweight Material	11	11
EV: Conventional Material	28	28
EV: Lightweight Material	17	17

Change to 7

Change to 4

Demonstrations – Total Life Cycle, Examine Electrical Grid Specs

- Go to GREET 1, [Inputs] Tab
- Click “Electric” button, or go to section 10 “Electric Generation”
- Check Electricity Generation Mix
- Should be 1 for US Grid Mix

10. Electric Generation

Electric Worksheet

Results

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

2

1 -- GREET-calculated factors via emission factors in EF Sheet
2 -- Emission factors from EPA and EIA database in g/kWh

10.2) Electricity Generation Mix

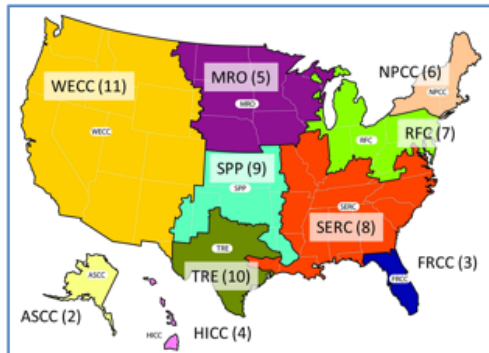
10.2.a) Selection of Electricity Generation Mix for Transportation Use

Mix for transportation use

1

Mix for stationary use

1



(U.S. EPA)

- 1 U.S. Mix
- 2 ASCC Mix
- 3 FRCC Mix
- 4 HICC Mix
- 5 MRO Mix
- 6 NPCC Mix
- 7 RFC Mix
- 8 SERC Mix
- 9 SPP Mix
- 10 TRE Mix
- 11 WECC Mix
- 12 CA Mix
- 13 User Defined Mix
- 14 NG Power Plants
- 15 Coal Power Plants
- 16 Nuclear Power Plants
- 17 Hydro Power Plants
- 18 NGCC Turbine
- 19 Geothermal

Demonstrations – Vehicle Cycle, Examine PHEV Specs

- Go to GREET 1, [Inputs] Tab
- Click “Vehicles” button, or go to section 12 “Vehicle Operations”
- Check Rated All-Electric Range for PHEVs (make it 20)

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%

Vehicles Worksheet

Results

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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%	
Gasoline for Methanol-gasoline blend	0.0%	
Diesel for isoalkane diesel blend	100.0%	
Diesel for FAE (Fatty alkyl ether) diesel blend	100.0%	
Diesel for FAFE (Fatty acid fusel esters) diesel blend	100.0%	
Share of LSD out of LSD and CO		
Diesel for Fischer-Tropsch diesel blend	100.0%	
Diesel for biodiesel blend	100.0%	
Diesel for renewable diesel blend	100.0%	
Diesel for EtOH-diesel blend	100.0%	

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

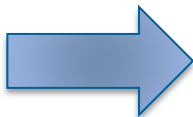
PHEVs	20
BEVs	300

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

Make PHEV as 20

Demonstrations – Total Life Cycle, Examine Total Energy Cycle Results with US Grid

- Go to GREET 2, [\[TEC_Results\]](#) Tab
- Examine Results
- Focus on PHEV Results



Grid-Connected SI PHEV: CG and RFG, Conventional Material				
Item	Btu/mile or g/mile			
	WTP	Vehicle Cycle	Vehicle Operation	Total
Total energy	1,030	638	2,621	4,288
Fossil fuels	886	570	2,388	3,844
Coal	168	189	141	498
Natural gas	549	279	158	986
Petroleum	169	102	2,090	2,361
Water consumption	0.185	0.061	0.000	0.246
CO2 (VOC, CO, CO2)	81	41	172	293
CH4	0.368	0.106	0.005	0.479
N2O	0.007	0.001	0.003	0.011
GHGs	94	45	172	311

Demonstrations – Total Life Cycle, Change Electrical Grid Assumption

- Go to GREET 1, [Inputs] Tab
- Click “Electric” button, or go to section 10 “Electric Generation”
- Change Electricity Generation Mix to 12 (California Mix)
- Press F9

10. Electric Generation

Electric Worksheet

Results

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

2

1 -- GREET-calculated emission factors via emission factors in EF Sheet
2 -- Emission factors from EPA and EIA database in g/kWh

10.2) Electricity Generation Mix

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

Mix for transportation use	12
Mix for stationary use	1

Change to 12

(U.S. EPA)

- 1 U.S. Mix
- 2 ASCC Mix
- 3 FRCC Mix
- 4 HICC Mix
- 5 MRO Mix
- 6 NPCC Mix
- 7 RFC Mix
- 8 SERC Mix
- 9 SPP Mix
- 10 TRE Mix
- 11 WECC Mix
- 12 CA Mix
- 13 User Defined Mix
- 14 NG Power Plants
- 15 Coal Power Plants
- 16 Nuclear Power Plants
- 17 Hydro Power Plants
- 18 NGCC Turbine
- 19 Geothermal

Demonstrations – Total Life Cycle, Examine Total Energy Cycle Results with California Grid

- Go to GREET 2, [\[TEC_Results\]](#) Tab
- Examine Results
- Focus on PHEV Results



Grid-Connected SI PHEV: CG and RFG, Conventional Material				
Item	Btu/mile or g/mile			
	WTP	Vehicle Cycle	Vehicle Operation	Total
Total energy	928	638	2,621	4,186
Fossil fuels	773	570	2,342	3,685
Coal	50	189	28	266
Natural gas	560	279	226	1,065
Petroleum	164	102	2,088	2,354
Water consumption	0.191	0.061	0.000	0.253
CO2 (VOC, CO, CO2)	62	41	172	274
CH4	0.344	0.106	0.005	0.454
N2O	0.007	0.001	0.003	0.011
GHGs	74	45	172	291

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Questions?

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