

February 3, 2025

Demo for R&D GREET[®] 2: Vehicle/Material Cycle Analysis

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

Instructors

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Branden Leonhardt, Department of Energy

Argonne National Laboratory Subject Matter Experts

Rakesh Iyer, Jarod Kelly



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Table of contents

1. Navigate in R&D GREET 2
2. Steps to Model a Scenario in R&D GREET 2
3. Example Scenarios
 - a. Model a 2017 SI-ICE Vehicle
 - b. Compare a 2022 SUV BEV and an 2022 SUV ICEV
 - c. Change the Materials Used in Vehicle Assembly
 - i. Increased Share of Recycled Steel
 - ii. Replace Steel with Aluminum



Navigate in R&D GREET 2



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Sync the Results Between R&D GREET 1 and R&D GREET 2



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FileHomeInsertDrawPage LayoutFormulasDataReviewViewAutomateHelp

R&D GREET 1

PasteClipboard

B

I

U

Font

Alignment

Number

Styles

Conditional Formatting

Format as Table

Cell Styles

Insert

Delete

Format

Editing

Sensitivity

Add-ins

Analyze Data

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Inputs

Results

Petroleum

Ethanol

Natural Gas

MeOH &

RNG

Electric

Hydrogen

BioOil

Pyrolysis & IDL

Integrated Biorefinery

Fuel Production Time Series

Emission Factors Time Series

Agricultural and Mining Machinery Emission Factors Time Series

Water Consumption Factors

Passenger Car Time Series

Light Duty Truck 1 Time Series

Light Duty Truck 2 Time Series

Fuel Specifications

Vehicles

Ag Inputs

Open R&D GREET 1

Overview

Inputs

Results

Petroleum

Co_processing

NG

MeOH_FTD

EtOH

Electric

Generation_mixes

Bio

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Overview

Inputs

Results

Petroleum

Co_processing

NG

MeOH_FTD

EtOH

Electric

Generation_mixes

Bio

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R&D GREET 1

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1 2 A B C D E F G H I J K

1 Home Results Petroleum MeOH & Ethanol Electric Vehicles Car_TS Tab LDV1_TS Tab LDV2_TS Tab

2 Natural Gas Hydrogen Bio Oil Pyrolysis WTP

3 Fuel Economy Vehicles Tab HDV_TS Tab HDV_WTW Tab

4

5

6 **Scenario Control Variables and Input Assumptions**

7 **1. Key Options for Simulation**

8 1.1) Target Year for Simulation

9 2022

10 Restore Time Series Table Value

11 1.2) Point-Estimation or Probability-Estimation Option

12 Load Stochastic Toolkit

13 Load Stochastic Toolkit ... To load the stochastic toolkit

14 Unload Stochastic Toolkit ... To unload the stochastic toolkit

15 **2. Vehicle Types for Simulation**

16 1

17 1 -- Passenger Cars; 2 -- Light-Duty Trucks 1 (LDT1) (Sports utility vehicles [SUV]); 3 -- Light-Duty Trucks 2 (LDT2) (Pickup Truck [PUT])

18 **3. Petroleum-Based Fuels**

19 Petroleum Worksheet

20 Results

21 Back to Top

22 3.1) Petroleum Recovery Options

23 3.1.a) Share of crude oil sources

24 1

25 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	Latin America
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	

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Main Way to Navigate Through R&D GREET 2



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Font

Alignment

Number

Styles

Conditional Formatting

Format as Table

Cell Styles

Insert

Delete

Format

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Right click

Overview Vehi_Inputs Mat_Inputs Car SUV PUT Steel C.Iron W.AI C.AI Lead Nickel Cobalt Copper Zinc N ... +



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Main Categories of Tabs in R&D GREET 2



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Main tabs in R&D GREET 2

Categories of Tabs in R&D GREET 2

- Materials
- Vehicle-related Details
- Impact Calculation Tabs for Vehicle Components
- Vehicle Fluids
- ADR (assembly, disposal, and recycling)
- Trailer Components
- Trailer Fluids
- Sum of all Vehicle-cycle Results
- Sum of Full Life-cycle Results



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Steps to Model a Scenario in R&D GREET 2



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Steps to model an LDV scenario in R&D GREET 2



Go to the “TEC_Results” Tab

Are the results for your scenario generated by default?

Go to the “Inputs (R&D GREET 1),” “Vehi_Inputs,” or “Mat_Inputs” Tab

Have I made the necessary changes on all these tabs?

If Yes,

Make your changes and go to the “TEC_Results” tab to see your results

If No,

Determine whether the changes are related to the vehicle/material type, vehicle fluids/processing, or battery

Dive into the formulas on the “TEC_Results” tab

Vehicle/material Type

Go to the “vehicle/material-specific” tab

Vehicle Fluids/processing

Go to “Vehi_Fluids,” “Vehi_ADR,” “Vehi_Sum,” “Vehi_Comp_Sum,” or technology-specific tab

Battery

Go to one of the “Battery_Assembly/Sum/Materials/Recycling” tab



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Steps to model an MHDV scenario in R&D GREET 2



Go to the “MHDV_TEC_Results” Tab

Are the results for your scenario generated by default?

Go Through the Full LDV Chart and the “MHDV_Inputs” Tab

Have I made the necessary changes on all these tabs?

If Yes,

Make your changes and go to the “MHDV_TEC_Results” tab to see your results

If No,

Determine whether the changes are related to the material parameters, vehicle fluids/processing, or battery

Dive into the formulas on the “MHDV_TEC_Results” tab

Material Parameters

Go to the “MHDV_Mat_Parameters” or “vehicle-specific” tab

Vehicle Fluids/processing

Go to the “MDHV_Fluids/Trailer_Fluids” “MHDV_ADR/Trailer_ADR,” “MHDV_Sum” or MHDV_Comp_Sum/Trailer_Comp_Sum” tab

Battery

Go to the “MHDV_Battery_Sum” tab



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Vehicle Outputs



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Light-duty Vehicle Outputs



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Formula bar: A1

Worksheet: A1:B6

Cell A1 content:

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Sheet tabs: t_Inputs, Car, SUV, PUT, Steel, C.Iron, W.AI, C.AI, Lead, Nickel, Cobalt, Copper, Zinc, M, +, : < 85%

Activate dialog box:

Activate:

- Manganese
- FC Materials
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- Silicon
- Mat_Sum
- Vehi_Fluids
- Battery_Assembly
- Vehi_ADR
- Battery_Sum
- Battery_Materials
- Anode
- LiMn2O4
- Li_Chemicals
- Other_Cathodes
- Battery_Recyc
- Vehi_Comp_S
- Vehi_Sum
- TEC_Results
- Electrolyzers
- Wind_Turbine

OK Cancel

Annotations: 1 (purple circle), 2 (purple circle), 3 (purple circle), Green arrow pointing down, Red box around TEC_Results, Red box around OK button.



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Medium and Heavy-duty Vehicle Outputs



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Activate dialog box:

Activate: ? X

- Hydropower
- Nuclear_Power
- Tractor
- GREET1_Import_Export
- GREET2_Factors_T&D
- GREET_Building_Import_Export
- MHDV_Inputs
- MHDV_Mat_Parameters
- Class 6 PnD Trucks
- Class 8 Day-cab Trucks
- Class 8 Sleeper-cab Trucks
- MHDV_Fluids
- MHDV_Trailer_Fluids
- MHDV_ADR
- MHDV_Trailer_ADR
- MHDV_Battery_Sum
- MHDV_Comp_Sum
- MHDV_Trailer_Comp_Sum
- MHDV_Sum
- MHDV_TEC_Results

OK Cancel

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- 1: Red box around the list of items.
- 2: Green arrow pointing to the list of items.
- 3: Green arrow pointing to the OK button.



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Adjust General Battery Settings



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Adjust More-specified Simulation Settings



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Example Scenarios



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2017 SI-ICE

Model a 2017 Spark-Ignition Internal Combustion Engine (SI-ICE) Light-duty Vehicle (LDV) Fueled by Gasoline in R&D GREET



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Overview

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Results

Petroleum

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Generation_mixes

Bio

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Inputs

Results

Petroleum

Ethanol

Natural Gas

MeOH &

RNG

Electric

Hydrogen

BioOil

Pyrolysis & IDL

Integrated Biorefiner

Fuel Production Time Series

Emission Factors Time Series

Agricultural and Mining Machinery Emission Factors Time Series

Water Consumption Factors

Passenger Car Time Series

Light Duty Truck 1 Time Series

Light D Tim

Note:

this scenario is modeling a car built in 2017

R&D GREET 1

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Year2022

Scenario Control Variables and Input Assumptions

1. Key Options for Simulation

1.1) Target Year for Simulation

2022

1.2) Point-Estimate

2. Vehicle Types for Simulation

3. Petroleum-Based Fuels

3.1) Petroleum Refinement

3.1.a) Share of share of crude oil sources

3.1.b) Efficiency for Petroleum Refinement

HomeResultsPetroleumMeOH & EthanolElectricVehiclesCar_TS TabLDV1_TS TabLDV2_TS TabNatural GasHydrogenBio OilPyrolysisVehicles TabHDV_TS TabHDV_WTW Tab

WTPFuel Economy

Link with GREET2

Reactivate GREET2 LinksDeactivate GREET2 Links

201120122013201420152016201720182019202020212022

Used in calculation

API gravity

S Content (wt %)

Average transportation distances (mi)

U.S. Domestic crude

API gravity

Vol. Share (%)

U.S. Domestic

Canada (Oil Sands)

Canada (Conv. Crude)

Mexico

Middle East

Latin America

80.8%

6.6%

5.0%

1.9%

2.3%

0.0%

100.0%

0.0%

0.0%

2.3%

80.8%

6.6%

5.0%

1.9%

2.3%

34.0

18.1

26.5

26.5

31.8

1.4

2.9

1.9

2.2

2.3

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

42

48

32.0

8.7%

8.0%

83.3%

OverviewInputsResultsPetroleumCo_processingNGMeOH_FTDtEtOHElectricGeneration_mixesBio

ReadyCalculateAccessibility: Investigate

Excel ribbon: Clipboard, Font, Alignment, Number, Styles, Cells, Editing, Sensitivity, Add-ins, Analyze Data.

Formula bar: G11, NOx

Fuel Economy and Emission Rates of Passenger Cars: Baseline Vehicles and New Vehicles

1) Fuel Economy and Emission Rates of Passenger Cars Baseline Vehicles: gasoline-equivalent MPG and grams/mile emission (fuel economy is adjusted for on-road performance using the EPA mpg-based method, and using 43%city/57%highway VMT split)

Model Year: 2017
Lag year: 0

Gasoline Car: Values from non-stochastic simulations and for adjustments to distribution functions
Model year is 5 years earlier than simulated technology year

Gasoline Car: stochastic simulation

Default values from times series or user input

Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O
MY 1990	22.10	1.071	2.641	13.152	2.908	0.021	0.031	0.018	0.004	0.004	0.010	0.179	0.040
MY 1995	21.70	0.658	2.626	9.472	1.860	0.014	0.031	0.012	0.004	0.003	0.006	0.110	0.027
MY 2000	22.00	0.244	2.611	5.791	0.812	0.006	0.031	0.006	0.004	0.001	0.003	0.041	0.014
MY 2005	23.40	0.115	0.166	3.871	0.203	0.002	0.031	0.002	0.004	0.000	0.001	0.022	0.006
MY 2010	26.08	0.074	0.164	2.986	0.090	0.002	0.031	0.002	0.004	0.001	0.001	0.016	0.006
MY 2015	26.16	0.069	0.161	2.741	0.082	0.004	0.031	0.003	0.004	0.002	0.001	0.015	0.004
MY 2020	29.80	0.040	0.114	1.466	0.039	0.004	0.031	0.004	0.004	0.003	0.001	0.008	0.004
MY 2025	29.42	0.029	0.101	1.016	0.021	0.004	0.031	0.004	0.004	0.003	0.001	0.005	0.004
MY 2030	33.07	0.029	0.099	1.011	0.021	0.004	0.031	0.003	0.004	0.003	0.001	0.005	0.004
MY 2035	35.88	0.028	0.098	1.006	0.021	0.004	0.031	0.003	0.004	0.003	0.001	0.005	0.004
MY 2050	41.96	0.027	0.096	0.993	0.020	0.004	0.031	0.003	0.004	0.002	0.001	0.005	0.004

Diesel Car: Values from non-stochastic simulations and for adjustments to distribution functions
Model year is 5 years earlier than simulated technology year

Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O
MY 1990	31.58	0.143	0.005	3.531	0.097	0.003	0.031	0.003	0.004	0.002	0.000	0.092	0.004
MY 1995	31.58	0.143	0.005	3.531	0.097	0.003	0.031	0.003	0.004	0.002	0.000	0.092	0.004

Note: this scenario is modeling a car built in 2017

Navigation: Home, Inputs, Results

Worksheet tabs: RNG, Pyrolysis_IDL, IBR, E_fuel, Fuel_Prod_TS, EF_TS, AgMining_EF_TS, EF, WCF, Fuel_Specs, Car_TS, LDT1_...

Status bar: Ready, Calculate, Accessibility: Investigate, 85%

Well-to-Pump (WTP) and Well-to-Wheel (WTW) GHG Emissions



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Inputs Results

Petroleum Ethanol Natural Gas MeOH & RNG

Electric Hydrogen BioOil Pyrolysis & IDL Integrated Biorefiner

Fuel Production Time Series Emission Factors Time Series Agricultural and Mining Machinery Emission Factors Time Series

Water Consumption Factors Passenger Car Time Series Light Duty Truck 1 Time Series Light D Tim

Fuel Specifications Vehicles Ag Inputs

Overview Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio



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Add-ins

Analyze Data

Analyze Data

Comments

Share

RSELSIICEV

fx

Select Fuels

Home

Inputs

Back to Top

WTP Results

WTP Changes

WTW Results Menu

SI ICE Vehicles

Select Fuels

Go

SIDI ICE Vehicles

Select Fuels

Go

CIDI ICE Vehicles

Select Fuels

Go

Unit Selection

Per Vehicle Distance Travelled

Energy Unit: Btu

Emission Unit: g

Service Functional Unit: mile

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

GCI ICE Vehicles

Select Fuels

Go

Performance-enhancing Fuels

Select Fuels

Gasoline Vehicle: Gasoline

Item	Btu/mile or Gallon/mile or g/mile				Btu/mmBtu or Gallon/mmBtu or g/mmBtu			
	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	217	944	4,289	5,450	50,498	220,096	1,000,000	1,270,595
Fossil Fuels	203	837	4,003	5,042	47,218	195,069	933,326	1,175,613
Coal	19	30	0	49	4,492	6,898	0	11,391
Natural Gas	147	538	0	685	34,251	125,536	0	159,788
Petroleum	36	269	4,003	4,308	8,474	62,635	933,326	1,004,435
Water Consumption	0.1	0.2	0	0	15	38	0	53
CO2 (w/ C in VOC & CO)	-4	63	329	388	-839	14,592	76,702	90,455
CH4	0.315	0.173	0.015	0.503	73.544	40.320	3.414	117.279
N2O	0.000	0.012	0.004	0.016	0.066	2.787	0.911	3.764
GHGs	6	71	330	407	1,371	16,554	77,053	94,977
VOC: Total	0.013	0.114	0.230	0.356	2.988	26.524	53.597	83.110
CO: Total	0.026	0.043	2.741	2.810	6.071	10.068	639.104	655.243
NOx: Total	0.039	0.071	0.082	0.193	9.137	16.540	19.209	44.886
PM10: Total	0.002	0.010	0.035	0.047	0.443	2.360	8.044	10.847
PM2.5: Total	0.002	0.006	0.007	0.015	0.372	1.502	1.729	3.602

Overview

Inputs

Results

Petroleum

Co-processing

NG

MeOH-ETD

EtOH

Electric

Generation mixes

Bio



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RSELSIICEV Select Fuels

1 2 3 4 5 6 7 8 9 10 11 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

Home Inputs Back to Top WTP Results WTP Changes

WTW Results Menu

1 Select Fuels

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

Go Go Go

SI - Gasoline

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

Gasoline Vehicle: Gasoline

Item

Total Energy

Fossil Fuels

Coal

Natural Gas

Petroleum

Water Consumption

CO2 (w/ C in VOC & CO)

CH4

N2O

GHGs

VOC: Total

CO: Total

NOx: Total

PM10: Total

PM2.5: Total

SI Hybrid Vehicles (HEV)

Select Fuels

CIDI Hybrid Vehicles (HEV)

Select Fuels

BEV and FCV

Select Fuels

SI Plug-in Hybrids (PHEV)

Select Fuels

CIDI Plug-in Hybrids (PHEV)

N/A

GCI ICE Vehicles

Select Fuels

Performance-enhancing Fuels

Select Fuels

Select units from a pink drop down menu for the Results

Per Energy in Fuels

Emission Unit: g

Energy Unit: Btu

Emission Unit: g

Energy Functional Unit: mmBtu

		Btu/mmBtu or Gallon/mmBtu or g/mmBtu			
Vehicle Operation	Total	Feedstock		Vehicle Operation	
		Fuel			Total
4,289	5,450	50,498	220,096	1,000,000	1,270,595
4,003	5,042	47,218	195,069	933,326	1,175,613
0	49	4,492	6,898	0	11,391
0	685	34,251	125,536	0	159,788
4,003	4,308	8,474	62,635	933,326	1,004,435
0	0	15	38	0	53
329	388	-839	14,592	76,702	90,455
0.015	0.503	73.544	40.320	3.414	117.279
0.004	0.016	0.066	2.787	0.911	3.764
330	407	1,371	16,554	77,053	94,977
0.230	0.356	2.988	26.524	53.597	83.110
2.741	2.810	6.071	10.068	639.104	655.243
0.082	0.193	9.137	16.540	19.209	44.886
0.035	0.047	0.443	2.360	8.044	10.847
0.007	0.015	0.372	1.502	1.729	3.602

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



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Analyze Data

Results_EnergyFunctionalUnitmmBtu

1	Home	WTW Results Menu		Select a vehicle type from a pink drop down menu, then press "Go"											
2	Inputs	SI ICE Vehicles		Go	SI Hybrid Vehicles (HEV)		Go	SI Plug-in Hybrids (PHEV)		Go	Performance-enhancing Fuels				
3		SI - Gasoline			Select Fuels			Select Fuels			Select Fuels				
4		SIDI ICE Vehicles		Go	CIDI Hybrid Vehicles (HEV)		Go	CIDI Plug-in Hybrids (PHEV)		Go					
5		Select Fuels			Select Fuels			N/A							
6	Back to Top	CIDI ICE Vehicles		Go	BEV and FCV		Go	GCI ICE Vehicles		Go					
7	WTP Results	Select Fuels			Select Fuels			Select Fuels							
8	WTP Changes	Unit Selection		Select units from a pink drop down menu for the Results											
9		Per Vehicle Distance Travelled				Per Energy in Fuels									
10		Energy Unit: Btu Emission Unit: g				Energy Unit: Btu Emission Unit: g									
11		Service Functional Unit: mile				Energy Functional Unit: mmBtu									
43	Gasoline Vehicle: Gasoline														
44		Btu/mile or Gallon/mile or g/mile				Btu/mmBtu or Gallon/mmBtu or g/mmBtu									
45	Item	Feedstock	Fuel	Vehicle Operation	Total	Feedstock	Fuel	Vehicle Operation	Total						
46	Total Energy	217	944	4,289	5,450	50,498	220,096	1,000,000	1,270,595						
47	Fossil Fuels	203	837	4,003	5,042	47,218	195,069	933,326	1,175,613						
48	Coal	19	30	0	49	4,492	6,898	0	11,391						
49	Natural Gas	147	538	0	685	34,251	125,536	0	159,787						
50	Petroleum	36	269	4,003	4,308	8,474	62,635	933,326	1,004,425						
51	Water Consumption	0.1	0.2	0	0	15	38	0	53						
52	CO2 (w/ C in VOC & CO)	-4	63	329	388	-839	14,592	76,702	90,455						
53	CH4	0.315	0.173	0.015	0.503	73.544	40.320	3.414	117.279						
54	N2O	0.00	0.012	0.004	0.016	0.066	2.787	0.911	3.764						
55	GHGs	6	71	330	407	1,371	16,554	77,053	94,977						
56	VOC: Total	0.013	0.114	0.230	0.356	2.988	26.524	53.597	83.110						
57	CO: Total	0.026	0.043	2.741	2.810	6.071	10.068	639.104	655.243						
58	NOx: Total	0.039	0.071	0.082	0.193	9.137	16.540	19.209	44.886						
59	PM10: Total	0.002	0.010	0.035	0.047	0.443	2.360	8.044	10.847						
60	PM2.5: Total	0.002	0.006	0.007	0.015	0.372	1.502	1.729	3.602						

OverviewInputsResultsPetroleumCo_processingNGMeOH_FTD EtOHElectricGeneration_mixesBio...



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Analyze Data

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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 menu, then press "Go"

SI ICE Vehicles

SI - Gasoline

Go

SIDI ICE Vehicles

Select Fuels

Go

CIDI 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

SI Hybrid Vehicles (HEV)

Select Fuels

Go

CIDI Hybrid Vehicles (HEV)

Select Fuels

Go

BEV - Electricity

Select Fuels

Go

SI Plug-in Hybrids

Select Fuels

Go

CIDI Plug-in Hybrids

Select Fuels

Go

GCI ICE Vehicles

Select Fuels

Go

Gasoline Vehicle: Gasoline

Item	Feedstock	Fuel	Vehicle Operation	Total
Total Energy	271	971	4,289	5,531
Fossil Fuels	256	865	4,003	5,124
Coal	32	43	0	75
Natural Gas	174	540	0	714
Petroleum	49	281	4,003	4,334
Water Consumption	0.1	0.2	0	0
CO2 (w/ C in VOC & CO)	1	64	329	394
CH4	0.325	0.176	0.015	0.515
N2O	0.000	0.012	0.004	0.016
GHGs	11	73	330	414
VOC: Total	0.000	0.014	0.230	0.357
CO: Total	0.000	0.007	0.010	0.017
NOx: Total	0.000	0.015	0.018	0.033
PM10: Total	0.000	0.001	0.002	0.003
PM2.5: Total	0.000	0.001	0.002	0.003

WTP GHG emissions per fuel consumed

WTP GHG emissions per fuel consumed

WTP GHG emissions per distance

WTP GHG emissions per distance

WTP GHG emissions 83.3 g CO₂e/mile

MeOH_FTD

EtOH

Electric

Generation_mixes

Bio_electricity

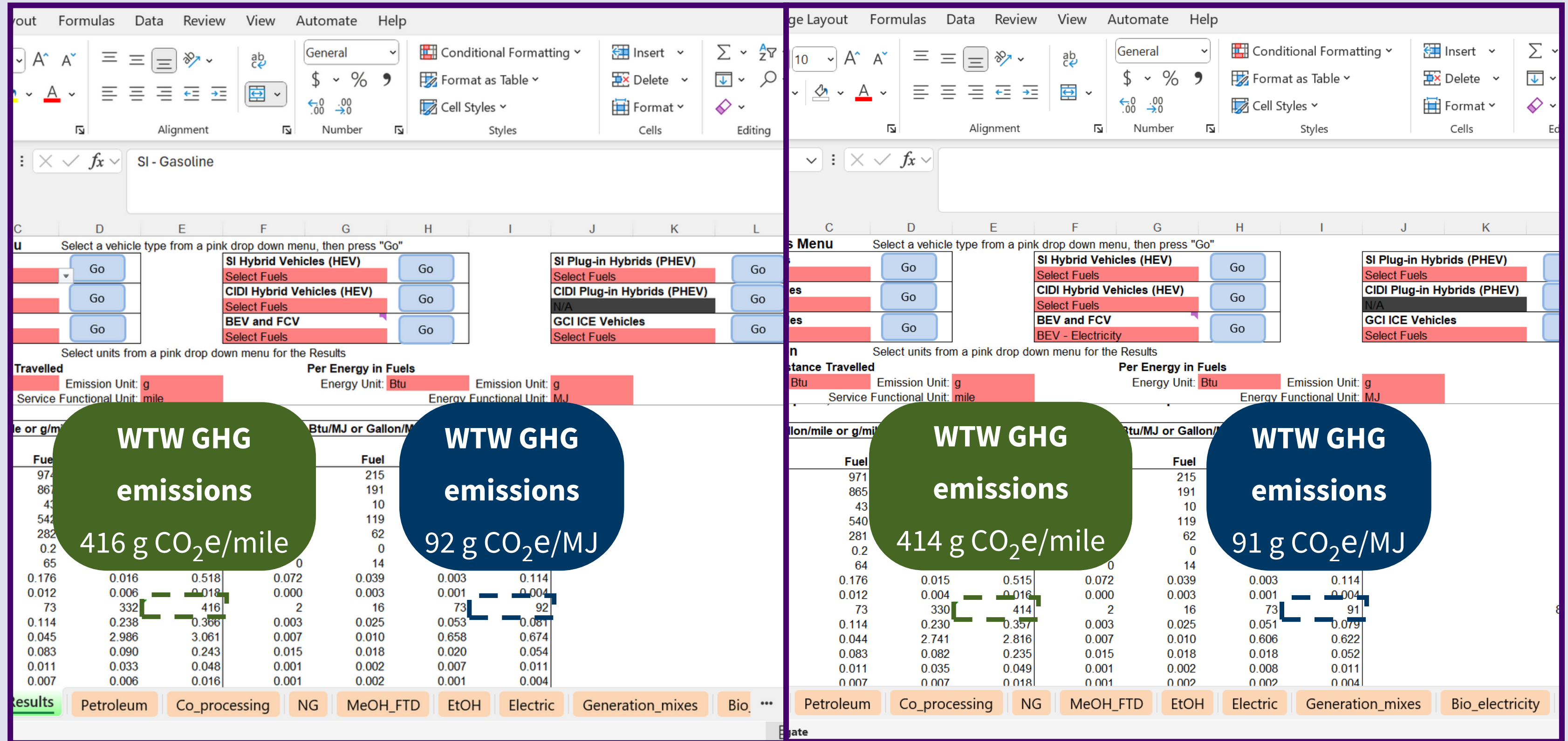
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SI-ICE LDV vehicle on the road in 2017

SI-ICE LDV built in 2017





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7.2) Energy Use of Vehicle Assembling, Disposal and Recycling: mmBtu per vehicle

0.287	Paint Production
2.759	Vehicle Assembly - Painting
0.990	Vehicle Assembly - HVAC & Lighting
2.982	Vehicle Assembly - Heating
0.205	Vehicle Assembly - Material Handling
0.273	Vehicle Assembly - Welding
0.409	Vehicle Assembly - Compressed Air
1.496	Vehicle Disposal

8. Lifetime VMT of a Vehicle, miles

	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
ICEV: Conventional Material	173,151	173,151	173,151	173,151	173,151	173,151	173,151	173,151	173,151

9. Ratios of Fuel Economy of Chosen Conventional Vehicles Relative to Their Baseline Vehicles

	HEV: Conventional Material	PHEV: Conventional Material	EV: Conventional Material	FCV: Conventional Material
ICEV: Conventional Material	100%	99%	106%	105%

10. Ratios of Fuel Economy of Lightweight Material Vehicles Relative to Their Conventional Material Vehicles

	HEV: Lightweight Material	PHEV: Lightweight Material	EV: Lightweight Material	FCV: Lightweight Material
ICEV: Lightweight Material	113%	114%	111%	112%

Note:

emissions results will be amortized across the total number of miles driven by the vehicle in its lifetime to convert the units to g/mile



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Manganese

FC Materials

Cement_Concrete

Silicon

Mat_Sum

Vehi_Fluids

Battery_Assembly

Vehi_ADR

Battery_Sum

Battery_Materials

Anode

LiMn2O4

Li_Chemicals

Other_Cathodes

Battery_Recyc

Vehi_Comp_S

Vehi_Sum

TEC_Results

Electrolyzer

Wind_Turbine

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Nickel

Cobalt

Copper

Zinc

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R&D GREET 2

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Energy Use and Emissions of Well-to-Pump, Vehicle Cycle and Vehicle Operation									
1) Well-to-Pump, Vehicle Cycle and Vehicle Operation Energy Use and Emissions: Btu or g per mile									
Energy Unit: Btu		Emission Unit: g							
Service Functional Unit: mile									
Gasoline Vehicle: CG and RFG, Conventional Material									
Item	Btu/mile or g/mile				Vehicle Cycle Credits	Percentage of each stage			
	WTP	Vehicle Cycle	Vehicle Operation	Total		WTP	Vehicle Cycle	Vehicle Operation	Total
Total energy	1,242	0	0	0	0	20.5%	8.8%	70.7%	100.0%
Fossil fuels	1,121	0	0	0	0	20.0%	8.6%	71.4%	100.0%
Coal	75	0	0	0	0	32.2%	67.8%	0.0%	100.0%
Natural gas	714	0	0	0	0	76.1%	23.9%	0.0%	100.0%
Petroleum	331	0	0	0	0	7.5%	2.3%	90.3%	100.0%
Water consumption	0.224	0	0	0	0	83.8%	16.2%	0.0%	100.0%
CO2 (VOC, CO, CO2)	65	0	0	0	0	15.2%	8.0%	76.8%	100.0%
CH4	0.501	0	0	0	0	84.2%	13.4%	2.5%	100.0%
N2O	0.012	0	0	0	0	71.6%	5.6%	22.8%	100.0%
GHGs	83	37	330	451	0	18.5%	8.2%	73.3%	100.0%
VOC: Total	0.127	0.189	0.230	0.546	0	23.3%	34.6%	42.1%	100.0%
CO: Total	0.110	2.741	2.926	5.777	0	1.9%	93.7%	100.0%	100.0%
NOx: Total	0.041	0.082	0.276	0.399	0	10.3%	29.8%	100.0%	100.0%
PM10: Total	0.003	0.035	0.063	0.101	0	3.0%	55.0%	100.0%	100.0%
PM2.5: Total	0.002	0.007	0.024	0.033	0	6.2%	30.5%	100.0%	100.0%
SOx: Total	0.001	0.002	0.190	0.193	0	0.5%	1.0%	100.0%	100.0%
BC: Total	0.003	0.003	0.004	0.010	0	3.0%	59.2%	100.0%	100.0%
OC: Total	0.002	0.002	0.005	0.009	0	2.3%	37.0%	100.0%	100.0%
VOC: Urban	0.161	0.161	0.340	0.662	0	2.7%	47.3%	100.0%	100.0%
CO: Urban	0.002	1.919	1.933	3.854	0	0.1%	99.3%	100.0%	100.0%
NOx: Urban	0.020	0.005	0.058	0.083	0	24.4%	6.3%	69.4%	100.0%

WTW = total - vehicle cycle

Functional Unit	mile	km
	1.000	1.609

WTW GHG emissions
414 g CO₂e/mile

WTP GHG emissions
83 g CO₂e/mile

WTP GHG emissions
18.5%

SI-ICE vehicle built and used in 2017 and fueled by default gasoline

WTW GHG emissions
414 g CO₂e/mile

WTP GHG emissions
83 g CO₂e/mile

WTP GHG emissions
18.5%

WTW = total - vehicle cycle

SI-ICE vehicle built and used in 2017 and fueled by default gasoline

Functional Unit	mile	km
	1.000	1.609

How Do Battery Electric Vehicles (BEVs) Compare to Internal Combustion Engine Vehicles (ICEVs) on a Vehicle Cycle Perspective?



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SUV BEV

Model a 2022 Sport Utility Vehicle (SUV) Battery
Electric Vehicle (BEV) Using an NMC622 Battery in
R&D GREET



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R&D GREET 1

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Veh_Type_Option : 1

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

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

Restore Time Series Table Value

Link with GREET2

Reactivate GREET2 Links

Deactivate GREET2 Links

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 [F

3. Petroleum-Based Fuels

3.1) Petroleum R

3.1.a) Share of crude oil sources

1 2

Basis of share of crude oil sources: 1 -- E

EIA projection	U.S. Domestic	80.8%
User defined		0.0%
Used in calculation		80.8%
API gravity		34.0
S Content (wt %)		1.4
Average transportation distances (mi)	See T&D_Flowcharts tab	1,708 1,708 797

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Note:

this scenario is modeling a car built in 2022



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Delete

Format

Cells

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Sensitivity

Add-ins

Analyze Data

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Fuel Economy and Emission Rates of LDT1 Vehicles: Baseline Vehicles and New Vehicles

1) Fuel Economy and Emission Rates of LDT1 Baseline Vehicles: gasoline-equivalent MPG and grams/mile emissions
(fuel economy is adjusted for ... using the EPA mpg-based method, and using 43%city/57%highway VMT split)
Model Year 2017
Lag year 0
Gasoline LDT1: Values from ... and for adjustments to distribution functions
Model year is 5 years earlier than simulated technology year

26.54	0.044	0.085	1.530	0.050	0.006	0.031	0.005	0.004	0.003	0.001	0.009	0.005	
26.54	0.044	0.085	1.530	0.050	0.006	0.031	0.005	0.004	0.003	0.001	0.009	0.005	
Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O
MY 1990	16.60	1.564	1.774	25.201	4.396	0.027	0.031	0.024	0.004	0.005	0.013	0.262	0.077
MY 1995	16.20	0.937	1.766	16.021	2.911	0.019	0.031	0.016	0.004	0.003	0.009	0.157	0.056
MY 2000	16.30	0.310	1.759	6.841	1.427	0.010	0.031	0.009	0.004	0.002	0.005	0.052	0.034
MY 2005	17.30	0.117	0.130	4.042	0.232	0.003	0.031	0.003	0.004	0.001	0.002	0.024	0.007
MY 2010	20.06	0.075	0.120	3.027	0.107	0.004	0.031	0.003	0.004	0.001	0.002	0.016	0.007
MY 2015	20.06	0.074	0.116	2.882	0.103	0.006	0.031	0.005	0.004	0.003	0.002	0.016	0.005
MY 2020	26.54	0.044	0.085	1.530	0.050	0.006	0.031	0.005	0.004	0.003	0.001	0.009	0.005
MY 2025	26.86	0.031	0.076	0.984	0.025	0.004	0.031	0.004	0.004	0.003	0.001	0.006	0.005
MY 2030	29.69	0.031	0.075	0.982	0.025	0.004	0.031	0.004	0.004	0.003	0.001	0.006	0.005
MY 2035	32.33	0.075	0.075	0.982	0.025	0.004	0.031	0.004	0.004	0.003	0.001	0.006	0.005
MY 2050	37.67	0.073	0.073	0.971	0.024	0.004	0.031	0.004	0.004	0.003	0.001	0.005	0.005

Press F9

31.04	0.141	0.006	2.545	0.035	0.003	0.031	0.003	0.004	0.002	0.000	0.091	0.001	
31.04	0.141	0.006	2.545	0.035	0.003	0.031	0.003	0.004	0.002	0.000	0.091	0.001	
Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O

Home

Inputs

Results

Gasoline LDT1: stochastic simulation distribution

Default values from times series or user input

Distribution Functions of Fuel Economy and Emission Rates

Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)
MY 1990	20.80	1.114	0.545
MY 1995	20.80	0.668	0.426
MY 2000	20.80	0.203	0.112
MY 2005	20.80	0.144	0.069
MY 2010	20.80	0.115	0.067
MY 2015	21.30	0.115	0.067
MY 2020	21.70	0.112	0.067
MY 2025	21.70	0.112	0.067
MY 2030	21.70	0.112	0.067
MY 2035	21.70	0.112	0.067
MY 2050	21.70	0.112	0.067

Diesel LDT1: stochastic simulation distribution

Default values from times series or user input

Distribution Functions of Fuel Economy and Emission Rates

Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)
------------	-------	---------------	-------------

EF_TS

AgMining_EF_TS

EF

WCF

Fuel_Specs

Car_TS

LDT1_TS

LDT2_TS

Vehicles

Urban_Shares

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Number

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Cells

Editing

Sensitivity

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Analyze Data

G11

NOx

Fuel Economy and Emission Rates of Passenger Cars: Baseline Vehicles and New Vehicles

1) Fuel Economy and Emission Rates of Passenger Cars Baseline Vehicles: gasoline-equivalent MPG and grams/mile emission (fuel economy is adjusted for on-road performance using the EPA mpg-based method, and using 43%city/57%highway VMT split)

Model Year: 2017

Lag year: 0

Gasoline Car: Values from non-simulated technology year or adjustments to distribution functions

Model year is 5 years earlier than simulated technology year

Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O
MY 1990	22.10	1.071	2.641	13.152	2.908	0.021	0.031	0.018	0.004	0.004	0.010	0.179	0.040
MY 1995	24.70	0.658	2.626	9.472	1.860	0.014	0.031	0.012	0.004	0.003	0.006	0.110	0.027
MY 2000	22.00	0.244	2.611	5.791	0.812	0.006	0.031	0.006	0.004	0.001	0.003	0.041	0.014
MY 2005	23.40	0.115	0.166	3.871	0.203	0.002	0.031	0.002	0.004	0.000	0.001	0.022	0.006
MY 2010	26.08	0.074	0.164	2.986	0.090	0.002	0.031	0.002	0.004	0.001	0.001	0.016	0.006
MY 2015	26.16	0.069	0.161	2.741	0.082	0.004	0.031	0.003	0.004	0.002	0.001	0.015	0.004
MY 2020	29.80	0.040	0.114	1.466	0.039	0.004	0.031	0.004	0.004	0.003	0.001	0.008	0.004
MY 2025	29.42	0.029	0.101	1.016	0.021	0.004	0.031	0.004	0.004	0.003	0.001	0.005	0.004
MY 2030	33.07	0.029	0.099	1.011	0.021	0.004	0.031	0.003	0.004	0.003	0.001	0.005	0.004
MY 2035	35.88	0.028	0.098	1.006	0.021	0.004	0.031	0.003	0.004	0.003	0.001	0.005	0.004
MY 2050	41.96	0.096	0.096	0.993	0.020	0.004	0.031	0.003	0.004	0.002	0.001	0.005	0.004

Default values from times series or user input

Gasoline Car: stochastic simulation

Distribution Functions of Fuel Economy

Model Year	MPGGE	VOC (Exhaust)
MY 1990	25.20	1.0
MY 1995	25.20	0.8
MY 2000	25.20	0.3
MY 2005	25.20	0.1
MY 2010	25.20	0.1
MY 2015	26.80	0.1
MY 2020	28.40	0.1
MY 2025	28.40	0.1
MY 2030	28.40	0.1
MY 2035	28.40	0.1
MY 2050	28.40	0.1

Diesel Car: stochastic simulation

Distribution Functions of Fuel Economy

Model Year	MPGGE	VOC (Exhaust)
MY 1990	25.20	1.0
MY 1995	25.20	0.8
MY 2000	25.20	0.3
MY 2005	25.20	0.1
MY 2010	25.20	0.1
MY 2015	26.80	0.1
MY 2020	28.40	0.1
MY 2025	28.40	0.1
MY 2030	28.40	0.1
MY 2035	28.40	0.1
MY 2050	28.40	0.1

Press F9

RNGPyrolysis_IDLIBRE_fuelFuel_Prod_TSEF_TSAgMining_EF_TSEFWCFFuel_SpecsCar_TS

Default Range for a BEV



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Relative Fuel Economy for this SUV BEV Compared to a Baseline SI Vehicle Using Gasoline



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Editing

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Analyze Data

C1295: X Y f_x =@INDEX(\$T1295:\$X1305,ROW(B1295)-@ROW(\$T1295:\$X1305)+1,MATCH(BEV_AER,BEV_VMT_AER,0)+1)

1282	MY	2030	152.9%	78.0%	100.0%	100.0%	87.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%					MY	2030	160%	159%	154%	153%
1283	MY	2035	147.4%	78.0%	100.0%	100.0%	87.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%					MY	2035	153%	153%	148%	147%
1284	MY	2050	148.6%	78.0%	100.0%	100.0%	87.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%					MY	2050	154%	154%	149%	149%
1285																								
1286	Battery electric Vehicle (BEV / EV)																							
1287																								
1288	429.5% 0.0% 0.0% 0.0% 0.0% 0.0% 100.0% 0.0% 100.0% 0.0% 0.0% 0.0% 0.0%																							
1289	429.5% 0.0% 0.0% 0.0% 0.0% 0.0% 100.0% 0.0% 100.0% 0.0% 0.0% 0.0% 0.0%																							
1290	Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O										
1291	MY	1990	300.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1292	MY	1995	300.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1293	MY	2000	400.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1294	MY	2005	400.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1295	MY	2010	365.7%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1296	MY	2015	352.8%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1297	MY	2020	429.5%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1298	MY	2025	454.8%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1299	MY	2030	411.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1300	MY	2035	423.5%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1301	MY	2050	399.6%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%										
1302																								
1303	Hydrogen Fuel-Cell Vehicle (FCV)																							
1304																								
1305	203.0% 0.0% 0.0% 0.0% 0.0% 0.0% 100.0% 0.0% 100.0% 0.0% 0.0% 0.0% 0.0%																							
1306	203.0% 0.0% 0.0% 0.0% 0.0% 0.0% 100.0% 0.0% 100.0% 0.0% 0.0% 0.0% 0.0%																							
1307	Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O										
1308	MY	1990	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%										
1309	MY	1995	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%										

Model year is 0 years earlier than simulated technology year

Fuel Economy (MPGGE)

Default values from times series or user input

RAER[mj]				
Model Year	150	200	300	400
MY 1990	300.0%	300.0%	300.0%	300.0%
MY 1995	300.0%	300.0%	300.0%	300.0%
MY 2000	400.0%	400.0%	400.0%	400.0%
MY 2005	400.0%	400.0%	400.0%	400.0%
MY 2010	365.7%	365.7%	365.7%	365.7%
MY 2015	352.8%	352.8%	352.8%	352.8%
MY 2020	459.9%	445.5%	429.5%	388.1%
MY 2025	474.1%	472.1%	454.8%	408.2%
MY 2030	441.1%	426.8%	411.0%	379.1%
MY 2035	443.4%	429.1%	423.5%	378.4%
MY 2050	420.5%	417.5%	399.6%	367.1%

Model year is 0 years earlier than simulated technology year

Default values from times series or user input

E fuelFuel Prod TSEF TSAqMining EF TSEFWCFFuel SpecsCar TSLDT1_TSLDT2_TSVehiclesU...

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Cradle-to-Grave (C2G) GHG Emissions



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InsertFunction

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

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
185	EV, Conventional Material																	
186		Btu/mile or g/mile					Percentage of each stage											
187	Item	WTP	Vehicle Cycle	Vehicle Cycle	Vehicle Cycle	WTP	Vehicle Cycle	Vehicle Operation	Total	Vehicle Cycle Credits								
188	Total energy	1,190	911			36.5%	27.9%	35.5%	100.0%	0.0%								
189	Fossil fuels	945	823			35.5%	30.9%	33.6%	100.0%	0.0%								
190	Coal	352	226			36.9%	23.6%	39.5%	100.0%	0.0%								
191	Natural gas	575	476			36.7%	30.4%	32.8%	100.0%	0.0%								
192	Petroleum	18	121			12.2%	84.2%	3.6%	100.0%	0.0%								
193	Water consumption	0.198	0.079			71.5%	28.5%	0.0%	100.0%	0.0%								
194	CO2 (VOC, CO, CO2)	140	58			70.5%	29.5%	0.0%	100.0%	0.0%								
195	CH4	0.294	0.212			58.0%	42.0%	0.0%	100.0%	0.0%								
196	N2O	0.003	0.002	0.000	0.005	58.5%	41.5%	0.0%	100.0%	0.0%								
197	GHGs	149	66	0	215	69.5%	30.5%	0.0%	100.0%	0.0%								
198	VOC: Total	0.017	0.338	0.000	0.354	4.8%	95.2%	0.0%	100.0%	0.0%								
199	CO: Total	0.060	0.151	0.000	0.212	28.4%	71.6%	0.0%	100.0%	0.0%								
200	NOx: Total	0.106	0.070	0.000	0.176	60.3%	39.7%	0.0%	100.0%	0.0%								
201	PM10: Total	0.015	0.022	0.031	0.069	22.4%	32.1%	45.5%	100.0%	0.0%								
202	PM2.5: Total	0.009	0.010	0.004	0.023	38.2%	43.7%	18.1%	100.0%	0.0%								
203	SOx: Total	0.089	0.280	0.000	0.369	24.1%	75.9%	0.0%	100.0%	0.0%								
204	BC: Total	0.000	0.000	0.000	0.001	34.1%	32.9%	33.0%	100.0%	0.0%								
205	OC: Total	0.002	0.001	0.001	0.004	58.4%	26.0%	15.7%	100.0%	0.0%								
206	VOC: Urban	0.001	0.210	0.000	0.211	0.5%	99.5%	0.0%	100.0%	0.0%								
207	CO: Urban	0.013	0.003	0.000	0.016	81.7%	18.3%	0.0%	100.0%	0.0%								
208	NOx: Urban	0.027	0.005	0.000	0.032	83.4%	16.6%	0.0%	100.0%	0.0%								
209	PM10: Urban	0.003	0.001	0.022	0.026	12.0%	2.0%	86.0%	100.0%	0.0%								
210	PM2.5: Urban	0.003	0.000	0.003	0.006	43.6%	7.3%	49.1%	100.0%	0.0%								
211	SOx: Urban	0.027	0.004	0.000	0.031	86.1%	13.9%	0.0%	100.0%	0.0%								

C2G GHG emissions
215 g CO₂e/mile

C2G = WTW + vehicle cycle

SUV BEV built and used in 2022

<>...

Battery Materials

Anode

LiMn2O4

Li Chemicals

Other Cathodes

Battery Recycling

Vehi Comp Sum

Vehi Sum

TEC_Results

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GHG Emissions from Producing the Vehicle



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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

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=HLOOKUP(\$B\$3,\$N\$5:\$R\$6,2,FALSE)/HLOOKUP(\$D\$4,\$N\$9:\$R\$10,2,FALSE)*Vehi_Sum!L318

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
185	EV, Conventional Material																	
186		Btu/mile or g/mile					Percentage of each stage											
187	Item				Total	Vehicle Cycle Credits		WTP	Vehicle Cycle	Vehicle Operation		Total		Vehicle Cycle Credits				
188	Total energy				3,260	0		36.5%	27.9%	35.5%		100.0%		0.0%				
189	Fossil fuels				2,664	0		35.5%	30.9%	33.6%		100.0%		0.0%				
190	Coal				954	0		36.9%	23.6%	39.5%		100.0%		0.0%				
191	Natural gas				1,566	0		36.7%	30.4%	32.8%		100.0%		0.0%				
192	Petroleum				144	0		12.2%	84.2%	3.6%		100.0%		0.0%				
193	Water consumption				0.277	0		71.5%	28.5%	0.0%		100.0%		0.0%				
194	CO2 (VOC, CO, CO2)				198	0		70.5%	29.5%	0.0%		100.0%		0.0%				
195	CH4	0.294	0.212	0.000	0.506	0		58.0%	42.0%	0.0%		100.0%		0.0%				
196	N2O	0.003	0.002	0.000	0.005	0		58.5%	41.5%	0.0%		100.0%		0.0%				
197	GHGs	149	66	0	215	0		69.5%	30.5%	0.0%		100.0%		0.0%				
198	VOC: Total	0.017	0.338	0.000	0.354	0		4.8%	95.2%	0.0%		100.0%		0.0%				
199	CO: Total	0.060	0.151	0.000	0.212	0		28.4%	71.6%	0.0%		100.0%		0.0%				
200	NOx: Total	0.106	0.070	0.000	0.176	0		60.3%	39.7%	0.0%		100.0%		0.0%				
201	PM10: Total	0.015	0.022	0.031	0.069	0		22.4%	32.1%	45.5%		100.0%		0.0%				
202	PM2.5: Total	0.009	0.010	0.004	0.023	0		38.2%	43.7%	18.1%		100.0%		0.0%				
203	SOx: Total	0.089	0.280	0.000	0.369	0		24.1%	75.9%	0.0%		100.0%		0.0%				
204	BC: Total	0.000	0.000	0.000	0.001	0		34.1%	32.9%	33.0%		100.0%		0.0%				
205	OC: Total	0.002	0.001	0.001	0.004	0		58.4%	26.0%	15.7%		100.0%		0.0%				
206	VOC: Urban	0.001	0.210	0.000	0.211	0		0.5%	99.5%	0.0%		100.0%		0.0%				
207	CO: Urban	0.013	0.003	0.000	0.016	0		81.7%	18.3%	0.0%		100.0%		0.0%				
208	NOx: Urban	0.027	0.005	0.000	0.032	0		83.4%	16.6%	0.0%		100.0%		0.0%				
209	PM10: Urban	0.003	0.001	0.022	0.026	0		12.0%	2.0%	86.0%		100.0%		0.0%				
210	PM2.5: Urban	0.003	0.000	0.003	0.006	0		43.6%	7.3%	49.1%		100.0%		0.0%				
211	SOx: Urban	0.027	0.004	0.000	0.031	0		86.1%	13.9%	0.0%		100.0%		0.0%				

Vehicle cycle GHG emissions

66 g CO₂e/mile

SUV BEV built and used in

2022

<>...

Battery Materials

Anode

LiMn2O4

Li Chemicals

Other Cathodes

Battery Recycling

Vehi Comp Sum

Vehi Sum

TEC_Results

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SUV ICEV

Model a 2022 Sport Utility Vehicle (SUV) Internal
Combustion Engine (ICEV) Using Gasoline in R&D
GREET



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Cradle-to-Grave (C2G) GHG Emissions



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R&D GREET 2

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More Functions

Name Manager

Define Name

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Error Checking

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Calculation Options

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AD18

Energy Use and Emissions of Well-to-Pump, Vehicle Cycle and Vehicle Operation

1) Well-to-Pump, Vehicle Cycle and Vehicle Operation Energy Use and Emissions: Btu or g per mile

Energy Unit: Btu Emission Unit: g

Service Functional Unit: mile

Gasoline Vehicle: CG and RFG, Conventional Material

Item	Btu/mile or g/mile			Percentage of each stage				Vehicle Cycle Credits
	WTP	Vehicle Cycle	Vehicle Operation	WTP	Vehicle Cycle	Vehicle Operation	Total	
Total energy	1,131	587		19.2%	9.9%	70.9%	100.0%	0.0%
Fossil fuels	1,012	538		18.6%	9.9%	71.6%	100.0%	0.0%
Coal	48	143		25.0%	75.0%	0.0%	100.0%	0.0%
Natural gas	668	267		71.5%	28.5%	0.0%	100.0%	0.0%
Petroleum	297	128		6.9%	3.0%	90.2%	100.0%	0.0%
Water consumption	0.220	0.040		84.5%	15.5%	0.0%	100.0%	0.0%
CO2 (VOC, CO, CO2)	57	37		13.8%	8.9%	77.2%	100.0%	0.0%
CH4	0.476	0.088		83.1%	15.4%	1.5%	100.0%	0.0%
N2O	0.012	0.001	0.005	66.5%	6.1%	27.4%	100.0%	0.0%
GHGs	75	40	322	17.1%	9.2%	73.7%	100.0%	0.0%
VOC: Total	0.123	0.334	0.129	21.0%	57.0%	22.0%	100.0%	0.0%
CO: Total	0.067	0.115	1.530	3.9%	6.7%	89.3%	100.0%	0.0%
NOx: Total	0.107	0.042	0.050	53.9%	21.2%	25.0%	100.0%	0.0%
PM10: Total	0.012	0.013	0.037	18.9%	21.5%	59.6%	100.0%	0.0%
PM2.5: Total	0.008	0.007	0.009	33.2%	28.5%	38.3%	100.0%	0.0%
SOx: Total	0.028	0.092	0.002	23.3%	75.2%	1.6%	100.0%	0.0%
BC: Total	0.001	0.000	0.004	20.3%	4.4%	75.3%	100.0%	0.0%
OC: Total	0.002	0.001	0.002	40.9%	12.5%	46.6%	100.0%	0.0%
VOC: Urban	0.066	0.210	0.090	18.0%	57.4%	24.6%	100.0%	0.0%
CO: Urban	0.012	0.002	1.071	1.1%	0.2%	98.7%	100.0%	0.0%
NOx: Urban	0.018	0.005	0.035	30.9%	9.0%	60.1%	100.0%	0.0%

Energy Unit	Btu	mBtu	J	kJ	
	1.000	0.001	1055	1.055	0.0
Emission Unit	g	mg	kg	lb	0.0

C2G GHG emissions

437 g CO₂e/mile

C2G = WTW + vehicle cycle

SUV ICEV built and used in 2022

Battery Materials

Anode

LiMn2O4

Li Chemicals

Other Cathodes

Battery Recycling

Vehi Comp Sum

Vehi Sum

TEC Results

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GHG Emissions from Producing the Vehicle



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ENERGY

2022 SUV BEV

EV, Conventional Material					
Btu/mile or g/mile			Percentage		
Item	Total	Vehicle Cycle Credits	WTP	Vehicle Cycle	Op
Total energy	3,260	0	36.5%	27.9%	
Fossil fuels	2,664	0	35.5%	30.9%	
Coal	954	0	36.9%	23.6%	
Natural gas	1,566	0	36.7%	30.4%	
Petroleum	144	0	12.2%	84.2%	
Water consumption	0.277	0	71.5%	28.5%	
CO2 (VOC, CO, CO2)	198	0	70.5%	29.5%	
CH4	0.506	0	58.0%	42.0%	
N2O	0.003	0	58.5%	41.5%	
GHGs	149	66	69.5%	30.5%	
VOC: Total	0.017	0.338	4.8%	95.2%	
CO: Total	0.060	0.151	28.4%	71.6%	
NOx: Total	0.106	0.070	60.3%	39.7%	
PM10: Total	0.015	0.022	22.4%	32.1%	
PM2.5: Total	0.009	0.010	38.2%	43.7%	
SOx: Total	0.089	0.280	24.1%	75.9%	
BC: Total	0.000	0.000	34.1%	32.9%	
OC: Total	0.002	0.001	58.4%	26.0%	
VOC: Urban	0.001	0.210	0.5%	99.5%	
CO: Urban	0.013	0.003	81.7%	18.3%	
NOx: Urban	0.027	0.005	83.4%	16.6%	
PM10: Urban	0.003	0.001	12.0%	2.0%	
PM2.5: Urban	0.003	0.000	43.6%	7.3%	
SOx: Urban	0.027	0.004	86.1%	13.9%	

**Vehicle cycle
GHG emissions
66 g CO₂e/mile**

2022 SUV ICEV

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	<i>fx</i>	Σ									Define Name Use in Formula Create from Defined Names
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	Function Library										
	AD18										
	A	B	C	D	E	F	G	H			
1	Energy Use and Emissions of Well-to-Pump, Vehicle Cycle and Vehicle Operation										
2	1) Well-to-Pump, Vehicle Cycle and Vehicle Operation Energy Use and Emissions: Btu or g per mile										
3	Energy Unit: Btu		Emission Unit: g								
4			Service Functional Unit: mile								
5	Gasoline Vehicle: CG and RFG, Conventional Material										
6											
	Btu/mile or g/mile					Percentage					
7	Item				Total	Vehicle Cycle Credits	WTP	Vehicle Cycle	Op		
8	Total energy				5,896	0	19.2%	9.9%			
9	Fossil fuels				5,450	0	18.6%	9.9%			
10	Coal				190	0	25.0%	75.0%			
11	Natural gas				934	0	71.5%	28.5%			
12	Petroleum				4,326	0	6.9%	3.0%			
13	Water consumption				0.261	0	84.5%	15.5%			
14	CO2 (VOC, CO, CO2)				415	0	13.8%	8.9%			
15	CH4	0.476	0.088	0.009	0.573	0	83.1%	15.4%			
16	N2O	0.012	0.001	0.005	0.018	0	66.5%	6.1%			
17	GHGs	75	40	322	437	0	17.1%	9.2%			
18	VOC: Total	0.123	0.354	0.129	0.587	0	21.0%	57.0%			
19	CO: Total	0.067	0.115	1.530	1.713	0	3.9%	6.7%			
20	NOx: Total	0.107	0.042	0.050	0.199	0	53.9%	21.2%			
21	PM10: Total	0.012	0.013	0.037	0.062	0	18.9%	21.5%			
22	PM2.5: Total	0.008	0.007	0.009	0.024	0	33.2%	28.5%			
23	SOx: Total	0.028	0.092	0.002	0.122	0	23.3%	75.2%			
24	BC: Total	0.001	0.000	0.004	0.005	0	20.3%	4.4%			
25	OC: Total	0.002	0.001	0.002	0.004	0	40.9%	12.5%			
26	VOC: Urban	0.066	0.210	0.090	0.367	0	18.0%	57.4%			
27	CO: Urban	0.012	0.002	1.071	1.085	0	1.1%	0.2%			
28	NOx: Urban	0.018	0.005	0.035	0.058	0	30.9%	9.0%			
	<	>	...	Battery Materials	Anode	LiMn2O4	Li Chemicals	Other Cathodes	Battery Re		

**Vehicle cycle
GHG emissions
40 g CO₂e/mile**



How Do The Opportunities for Emission Mitigation for the Production of Major Vehicle Materials Affect the Vehicle Cycle Impacts of Vehicles?



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Increase the Share of Recycled Steel



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Scrap vs recycled materials

Scrap

Untreated material

Recycled

Obtained from the treatment of
scrap



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BEV Recycled Steel

Model a 2022 Sport Utility Vehicle (SUV) Battery
Electric Vehicle (BEV) Made with 100% Recycled
Steel and Virgin Aluminum Produced with 100%
Hydropower Electricity



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Why replace a vehicle's steel with aluminum?

Pros of Replacing Steel with Aluminum

- Aluminum is lighter than steel
- Lighter vehicles have an improved fuel economy and consume less fuel over the vehicle's lifetime

Challenges/Cons of using Aluminum

- Virgin aluminum production is highly energy intensive
- Most energy comes from fossil sources - highly carbon intensive
- Most of the aluminum in vehicles is virgin

Therefore, renewable energy is needed to decarbonize virgin aluminum production



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Aluminum background



Virgin Aluminum Production Involves

- Mining and extraction of bauxite ore
- Processing of bauxite to produce aluminum hydroxide
- Conversion of aluminum hydroxide to aluminum oxide (alumina)
- Hall-Heroult process, involving the reduction of alumina through electrolysis (with carbon anodes) to pure aluminum metal

80-90% of the life cycle GHG emissions of aluminum production come from the electrolysis process due to its high energy intensity



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Aluminum options and associated applications for vehicles in R&D GREET

Wrought Aluminum

Used as an aluminum sheet, which could be stamped making the vehicle's body out of aluminum

Extruded or Forced Aluminum Products

Used in the interior body

Cast Aluminum

Used primarily in engine blocks



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R&D GREET 1

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Veh_Type_Option : 1

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

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

Restore Time Series Table Value

Link with GREET2

Reactivate GREET2 Links

Deactivate GREET2 Links

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 [F

3. Petroleum-Based Fuels

3.1) Petroleum R

3.1.a) Share of crude oil sources

1 2

Basis of share of crude oil sources: 1 -- E

EIA projection	U.S. Domestic	80.8%
User defined		0.0%
Used in calculation		80.8%
API gravity		34.0
S Content (wt %)		1.4
Average transportation distances (mi)	See T&D_Flowcharts tab	1,708 1,708 797

Inputs Results Petroleum Co_processing NG MeOH_FTD EtOH Electric Generation_mixes Bio_electricity

Note:
this scenario is modeling a car
built in 2022



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R&D GREET 1

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Analyze Data

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Fuel Economy and Emission Rates of LDT1 Vehicles: Baseline Vehicles and New Vehicles

1) Fuel Economy and Emission Rates of LDT1 Baseline Vehicles: gasoline-equivalent MPG and grams/mile emissions
(fuel economy is adjusted for inflation using the EPA mpg-based method, and using 43%city/57%highway VMT split)
Model Year 2017
Lag year 0
Gasoline LDT1: Values from model and for adjustments to distribution functions
Model year is 5 years earlier than simulated technology year

		26.54	0.044	0.085	1.530	0.050	0.006	0.031	0.005	0.004	0.003	0.001	0.009	0.005
		26.54	0.044	0.085	1.530	0.050	0.006	0.031	0.005	0.004	0.003	0.001	0.009	0.005
	Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O
12	MY 1990	16.60	1.564	1.774	25.201	4.396	0.027	0.031	0.024	0.004	0.005	0.013	0.262	0.077
13	MY 1995	16.20	0.937	1.766	16.021	2.911	0.019	0.031	0.016	0.004	0.003	0.009	0.157	0.056
14	MY 2000	16.30	0.310	1.759	6.841	1.427	0.010	0.031	0.009	0.004	0.002	0.005	0.052	0.034
15	MY 2005	17.30	0.117	0.130	4.042	0.232	0.003	0.031	0.003	0.004	0.001	0.002	0.024	0.007
16	MY 2010	20.06	0.075	0.120	3.027	0.107	0.004	0.031	0.003	0.004	0.001	0.002	0.016	0.007
17	MY 2015	20.06	0.074	0.116	2.882	0.103	0.006	0.031	0.005	0.004	0.003	0.002	0.016	0.005
18	MY 2020	26.54	0.044	0.085	1.530	0.050	0.006	0.031	0.005	0.004	0.003	0.001	0.009	0.005
19	MY 2025	26.86	0.031	0.076	0.984	0.025	0.004	0.031	0.004	0.004	0.003	0.001	0.006	0.005
20	MY 2030	29.69	0.031	0.075	0.982	0.025	0.004	0.031	0.004	0.004	0.003	0.001	0.006	0.005
21	MY 2035	32.33	0.075	0.075	0.982	0.025	0.004	0.031	0.004	0.004	0.003	0.001	0.006	0.005
22	MY 2050	37.67	0.073	0.073	0.971	0.024	0.004	0.031	0.004	0.004	0.003	0.001	0.005	0.005

Default values from times series or user input

Distribution Functions of Fuel Economy and Em

	Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)
MY	1990	20.80	1.114	0.545
MY	1995	20.80	0.668	0.426
MY	2000	20.80	0.203	0.112
MY	2005	20.80	0.144	0.069
MY	2010	20.80	0.115	0.067
MY	2015	21.30	0.115	0.067
MY	2020	21.70	0.112	0.067
MY	2025	21.70	0.112	0.067
MY	2030	21.70	0.112	0.067
MY	2035	21.70	0.112	0.067
MY	2050	21.70	0.112	0.067

Diesel LDT1: stochastic simulation distribut

Press F9

Model year is 5 years earlier than simulated technology year

		31.04	0.141	0.006	2.545	0.035	0.003	0.031	0.003	0.004	0.002	0.000	0.091	0.001
		31.04	0.141	0.006	2.545	0.035	0.003	0.031	0.003	0.004	0.002	0.000	0.091	0.001
	Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)	CO	NOx	PM10 (Exhaust)	PM10 (TBW)	PM2.5 (Exhaust)	PM2.5 (TBW)	BC	OC	CH4	N2O

Default values from times series or user input

Distribution Functions of Fuel Economy and Em

	Model Year	MPGGE	VOC (Exhaust)	VOC (Evap.)
--	------------	-------	---------------	-------------

EF_TS

AgMining_EF_TS

EF

WCF

Fuel_Specs

Car_TS

LDT1_TS

LDT2_TS

Vehicles

Urban_Shares

Compressio

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R&D GREET 2

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More Functions

Name Manager

Define Name

Use in Formula

Create from Selection

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Trace Precedents

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Calculation Options

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	A	B	C	D	E	F	G	H
1	Scenario Control Variables and Input Assumptions Related to Vehicle Materials							
2	1. Material Composition for Vehicle Components							
3	1.1) Material Composition for Each Component, % by wt							
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Mat_Inputs

Car

SUV

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Steel

C.Iron

W.AI

C.AI

Lead

Nickel

Cobalt

Copper

Zinc

Magnesium

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Default Share of Virgin Steel



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R&D GREET 2

Function

Recently Used

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More Functions

Name Manager

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Create from Selection

Defined Names

Trace Precedents

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Error Checking

Evaluate Formula

Formula Auditing

Watch Window

Calculation Options

Calculation

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✓

fx

A	B	C	D	E	F	G	H
218	4. Key Input Parameters for Material Use						
219	4.1.a) Share of Virgin and Recycled Materials Used in Vehicle, % by wt						
220			Virgin Material	Recycled Material	Scrap Material		
221							
222	Steel		73.6%	26.4%	0.0%		
223	Aluminum Extrusion (Non-Automotive)		39.0%	29.9%	31.1%		
224	Aluminum Sheet (Non-Automotive)		20.3%	23.2%	56.5%		
225	Aluminum Foil (Non-Automotive)		20.3%	23.2%	56.5%		
226	Aluminum Extrusion (Automotive)		26.8%	16.2%	57.0%		
227	Aluminum Sheet (Automotive)		50.4%	0.0%	49.6%		
228	Cast Aluminum		20.0%	80.0%	0.0%		
229	Lead		0.0%	100.0%	0.0%		
230	Nickel		56.0%	44.0%	0.0%		
231	Magnesium		47.9%	52.1%	0.0%		
232							
233	4.1.b) Recycling Rate for End of Life Recycling LCA Method						
234		Recycling Rate at End of Life					
235	Steel		96.0%				
236	Aluminum Extrusion (Non-Automotive)		91.0%				
237	Aluminum Sheet (Non-Automotive)		91.0%				
238	Aluminum Foil (Non-Automotive)		91.0%				
239	Aluminum Extrusion (Automotive)		91.0%				
240	Aluminum Sheet (Automotive)		91.0%				
241	Cast Aluminum		91.0%				
242	Lead		99.0%				
243	Nickel		80.0%				
244	Magnesium		70.0%				
245							
246	4.1.c) Recycling Allocation Method Selection						

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Vehi_Inputs

Mat_Inputs

Car

SUV

PUT

Steel

C.Iron

W.AI

C.AI

Lead

Nickel

Cobalt

Copper

Zinc

Magnesium

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Calculation Options

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F238

Type 0

1

4. Key Input Parameters for Material Use

4.1.a) Share of Virgin and Recycled Materials Used in Vehicle, % by wt

	Virgin Material	Recycled Material	Scrap Material
Steel	73.6%	26.4%	0.0%
Aluminum Extrusion (Non-Automotive)	39.0%	29.9%	31.1%
Aluminum Sheet (Non-Automotive)	20.3%	23.2%	56.5%
Aluminum Foil (Non-Automotive)	20.3%	23.2%	56.5%
Aluminum Extrusion (Automotive)	26.8%	16.2%	57.0%
Aluminum Sheet (Automotive)	50.4%	0.0%	49.6%
Cast Aluminum	20.0%	80.0%	0.0%
Lead	0.0%	100.0%	0.0%
Nickel	56.0%	44.0%	0.0%
Magnesium	47.9%	52.1%	0.0%

4.1.b) Recycling Rate for End of Life Recycling LCA Method

	Recycling Rate at End of Life
Steel	96.0%
Aluminum Extrusion (Non-Automotive)	91.0%
Aluminum Sheet (Non-Automotive)	91.0%
Aluminum Foil (Non-Automotive)	91.0%
Aluminum Extrusion (Automotive)	91.0%
Aluminum Sheet (Automotive)	91.0%
Cast Aluminum	91.0%
Lead	99.0%
Nickel	80.0%
Magnesium	70.0%

4.1.c) Recycling Allocation Method Selection

2

Press F9

< > ... Vehi_Inputs Mat_Inputs Car SUV PUT Steel C.Iron W.AI C.AI Lead Nickel Cobalt Copper Zinc Magnesium ... + :



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Calculation

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A	B	C	D	E	F	G	H
218							
219	4. Key Input Parameters for Material Use						
220	4.1.a) Share of Virgin and Recycled Materials Used in Vehicle, % by wt						
221			Virgin Material	Recycled Material	Scrap Material		
222	Steel		0.0%	100.0%	0.0%		
223	Aluminum Extrusion (Non-Automotive)		39.0%	29.9%	31.1%		
224	Aluminum Sheet (Non-Automotive)		20.3%	23.2%	56.5%		
225	Aluminum Foil (Non-Automotive)		20.3%	23.2%	56.5%		
226	Aluminum Extrusion (Automotive)		26.8%	16.2%	57.0%		
227	Aluminum Sheet (Automotive)		50.4%	0.0%	49.6%		
228	Cast Aluminum		20.0%	80.0%	0.0%		
229	Lead		0.0%	100.0%	0.0%		
230	Nickel		56.0%	44.0%	0.0%		
231	Magnesium		47.9%	52.1%	0.0%		
232							
233	4.1.b) Recycling Rate for End of Life Recycling LCA Method						
234		Recycling Rate at End of Life					
235	Steel		96.0%				
236	Aluminum Extrusion (Non-Automotive)		91.0%				
237	Aluminum Sheet (Non-Automotive)		91.0%				
238	Aluminum Foil (Non-Automotive)		91.0%				
239	Aluminum Extrusion (Automotive)		91.0%				
240	Aluminum Sheet (Automotive)		91.0%				
241	Cast Aluminum		91.0%				
242	Lead		99.0%				
243	Nickel		80.0%				
244	Magnesium		70.0%				
245							
246	4.1.c) Recycling Allocation Method Selection						

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Vehi_Inputs

Mat_Inputs

Car

SUV

PUT

Steel

C.Iron

W.AI

C.AI

Lead

Nickel

Cobalt

Copper

Zinc

Magnesium

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Calculation Options

Calculation

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2

4.10.b) Selection of Cast Aluminum Electric Generation Mix for Aluminum Reduction: Hall-Heroult Process (Aluminum Smelting)

2

1 -- US national grid mix

2 -- NA smelter mix

3 -- US smelter mix

4 -- US market-weighted mix

5 -- User-defined mix

Process (Aluminum Smelting)

Wrought Aluminum

	US Mix	NA smelter mix	US smelter mix	US market-weighted mix	European smelter mix	Chinese smelter mix
Petroleum	0.3%	0.0%	0.0%	0.4%	1.4%	0.0%
NG	38.5%	2.7%	10.4%	11.2%	1.8%	0.0%
Coal	20.6%	16.9%	35.9%	19.5%	6.0%	90.0%
Biomass	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Nuclear	18.9%	0.4%	1.4%	1.3%	9.5%	0.0%
Hydro	21.5%	78.4%	52.3%	67.6%	61.7%	10.0%
Others	0.0%	1.6%	0.0%	0.0%	19.6%	0.0%

4.11) Selection of Method for Estimating Material and Energy Use for Cobalt

1

1 -- Weight based allocation

2 -- Market value based allocation

5. GREET Default Key Assumptions for Material

5.1) Energy Use of Steel: mmBtu per ton of material product

0.117	Iron Ore Extraction and Processing (per ton of Iron Ore)
16.003	Coke Production (per ton of Steel)
0.450	Sintering (per ton of Steel)

Mat_Inputs

Car

SUV

PUT

Steel

C.Iron

W.AI

C.AI

Lead

Nickel

Cobalt

Copper

Zinc

Magnesium

Glass

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4.10.c) Electric Generation Mixes for Alumina Reduction: Hall-Heroult										
	Japan aluminum mix	Korea aluminum mix	100% renewable mix	100% hydro mix	User defined Mix	Cast Aluminum				
						US Mix	NA smelter mix	US smelter mix	US market- weighted mix	User defined Mix
Petroleum	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.4%	0.0%
NG	0.0%	9.5%	0.0%	0.0%	4.1%	38.5%	4.1%	10.4%	11.2%	0.0%
Coal	91.7%	61.9%	0.0%	0.0%	14.3%	20.6%	14.3%	35.9%	19.5%	0.0%
Biomass	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
Nuclear	0.0%	0.1%	0.0%	0.0%	0.5%	20.3%	0.5%	1.4%	1.3%	0.0%
Hydro	8.2%	25.3%	0.0%	100.0%	81.1%	20.0%	81.1%	52.3%	67.6%	100.0%
Others	0.0%	3.1%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

4.11) Selection of Method for Estimating Material and Energy Use for										
	1									

5. GREET Default Key Assumptions for Material										
5.1) Energy Use of Steel: mmBtu per ton of material product										
	0.117									
	16.003									
	0.153									
	3.576									
	0.444									
	0.141									
	1.940									
	2.551									
	11.238									

Fill out the user-defined mix as shown



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Analyze Data

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fx

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
185	EV, Conventional Material																	
186		Btu/mile or g/mile					Percentage of each stage											
187	Item				Total	Vehicle Cycle Credits		WTP	Vehicle Cycle	Vehicle Operation	Total		Vehicle Cycle Credits					
188	Total energy	4,661			0		41.7%	17.7%	40.6%	100.0%		0.0%						
189	Fossil fuels	3,737			0		41.3%	19.6%	39.1%	100.0%		0.0%						
190	Coal	1,326			0		43.3%	10.3%	46.4%	100.0%		0.0%						
191	Natural gas	2,256			0		41.6%	21.2%	37.2%	100.0%		0.0%						
192	Petroleum	154			0		18.6%	76.0%	5.4%	100.0%		0.0%						
193	Water consumption	0.412			0		78.4%	21.6%	0.0%	100.0%		0.0%						
194	CO2 (VOC, CO, CO2)	277			0		82.3%	17.7%	0.0%	100.0%		0.0%						
195	CH4	0.678			0		70.7%	29.3%	0.0%	100.0%		0.0%						
196	N2O	0.005			0		70.3%	29.7%	0.0%	100.0%		0.0%						
197	GHGs	244			0		81.4%	18.6%	0.0%	100.0%		0.0%						
198	VOC: Total	0.028			0		7.8%	92.2%	0.0%	100.0%		0.0%						
199	CO: Total	0.098			0		57.9%	42.1%	0.0%	100.0%		0.0%						
200	NOx: Total	0.174			0		74.9%	25.1%	0.0%	100.0%		0.0%						
201	PM10: Total	0.025			0		31.6%	29.0%	39.4%	100.0%		0.0%						
202	PM2.5: Total	0.014			0		52.4%	32.4%	15.2%	100.0%		0.0%						
203	SOx: Total	0.145			0		45.8%	54.2%	0.0%	100.0%		0.0%						
204	BC: Total	0.001			0		46.3%	26.3%	27.4%	100.0%		0.0%						
205	OC: Total	0.004			0		70.4%	18.0%	11.6%	100.0%		0.0%						
206	VOC: Urban	0.002			0		0.9%	99.1%	0.0%	100.0%		0.0%						
207	CO: Urban	0.021			0		88.5%	11.5%	0.0%	100.0%		0.0%						
208	NOx: Urban	0.044			0		89.8%	10.2%	0.0%	100.0%		0.0%						
209	PM10: Urban	0.005			0		18.3%	1.7%	80.0%	100.0%		0.0%						
210	PM2.5: Urban	0.004			0		56.0%	5.3%	38.6%	100.0%		0.0%						
211	SOx: Urban	0.044			0		91.9%	8.1%	0.0%	100.0%		0.0%						

Vehicle cycle GHG emissions

56 g CO₂e/mile

SUV BEV built and used in 2022 and made with recycled aluminum

Battery Materials

Anode

LiMn2O4

Li Chemicals

Other Cathodes

Battery Recycling

Vehi Comp Sum

Vehi Sum

TEC_Results

Vehicle cycle GHG emissions
56 g CO₂e/mile

SUV BEV built and used in 2022 and made with recycled aluminum

ICEV Recycled Steel

Model a 2022 Sport Utility Vehicle (SUV) Internal Combustion Engine (ICEV) Using Gasoline Made with 100% Recycled Steel and Virgin Aluminum Produced with 100% Hydropower Electricity



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Vehicle Cycle GHG Emissions



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2022 SUV BEV

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A B C D E F G H I									
185	EV, Conventional Material								
186									
187	Item	Total	Vehicle Cycle Credits	WTP	Vehicle Cycle	Vehicle Operation	Percentage of each		
188	Total energy	61	0	41.7%	17.7%	40.6%			
189	Fossil fuels	37	0	41.3%	19.6%	39.1%			
190	Coal	26	0	43.3%	10.3%	46.4%			
191	Natural gas	56	0	41.6%	21.2%	37.2%			
192	Petroleum	54	0	18.6%	76.0%	5.4%			
193	Water consumption	412	0	78.4%	21.6%	0.0%			
194	CO2 (VOC, CO, CO2)	277	0	82.3%	17.7%	0.0%			
195	CH4	0.479	0.199	0.000	0.678	0.0%			
196	N2O	0.005	0.002	0.000	0.006	0.0%			
197	GHGs	244	56	0	299	0			
198	VOC: Total	0.028	0.325	0.000	0.353	0			
199	CO: Total	0.098	0.071	0.000	0.169	0			
200	NOx: Total	0.174	0.058	0.000	0.232	0			
201	PM10: Total	0.025	0.023	0.031	0.079	0			
202	PM2.5: Total	0.014	0.009	0.004	0.027	0			
203	SOx: Total	0.145	0.172	0.000	0.317	0			
204	BC: Total	0.001	0.000	0.000	0.002	0			
205	OC: Total	0.004	0.001	0.001	0.006	0			
206	VOC: Urban	0.002	0.210	0.000	0.212	0			
207	CO: Urban	0.021	0.003	0.000	0.024	0			
208	NOx: Urban	0.044	0.005	0.000	0.049	0			
209	PM10: Urban	0.005	0.000	0.022	0.027	0			
210	PM2.5: Urban	0.004	0.000	0.003	0.007	0			
211	SOx: Urban	0.044	0.004	0.000	0.048	0			

Vehicle cycle GHG emissions
56 g CO₂e/mile

2022 SUV ICEV

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A B C D E F G H I									
1	Energy Use and Emissions of Well-to-Pump, Vehicle Cycle and Vehicle Operation								
2	1) Well-to-Pump, Vehicle Cycle and Vehicle Operation Energy Use and Emissions: Btu or g per mile								
3	Energy Unit: Btu Emission Unit: g								
4	Service Functional Unit: mile								
5	Gasoline Vehicle: CG and RFG, Conventional Material								
6	Btu/mile or g/mile								
7	Item	Total	Vehicle Cycle Credits	WTP	Vehicle Cycle	Vehicle Operation	Percentage of each		
8	Total energy	7,524	0	19.9%	6.6%	73.5%			
9	Fossil fuels	6,947	0	19.3%	6.4%	74.3%			
10	Coal	118	0	53.5%	46.5%	0.0%			
11	Natural gas	1,145	0	77.2%	22.8%	0.0%			
12	Petroleum	5,685	0	6.9%	2.3%	90.8%			
13	Water consumption	0.336	0	86.8%	13.2%	0.0%			
14	CO2 (VOC, CO, CO2)	528	0	14.4%	5.2%	80.4%			
15	CH4	0.719	0	87.6%	10.2%	2.2%			
16	N2O	0.016	0.001	0.005	0.022	0			
17	GHGs	99	30	0	556	0			
18	VOC: Total	0.163	0.322	0.190	0.676	0			
19	CO: Total	0.089	0.038	2.882	3.009	0			
20	NOx: Total	0.142	0.032	0.103	0.277	0			
21	PM10: Total	0.016	0.010	0.037	0.062	0			
22	PM2.5: Total	0.010	0.005	0.009	0.025	0			
23	SOx: Total	0.038	0.047	0.003	0.087	0			
24	BC: Total	0.001	0.000	0.003	0.005	0			
25	OC: Total	0.002	0.000	0.002	0.005	0			
26	VOC: Urban	0.088	0.210	0.133	0.431	0			
27	CO: Urban	0.016	0.002	2.018	2.035	0			
28	NOx: Urban	0.024	0.005	0.072	0.101	0			

Vehicle cycle GHG emissions
30 g CO₂e/mile



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