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Demonstration of GREET1.7 Simulations

I. Simulations through GREET GUI Program

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GREET User Workshop
June 25-26, 2007 at Argonne, IL

U.S. Department of Energy

UChicago Argonne LLC

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Outline

Three Simulations for Demonstration:

- Biofuels WTW Simulations (w/ GREET Defaults)
- Hydrogen WTW Simulations (w/ GREET Defaults)
- Biofuels and Hydrogen WTW Simulations (w/ Modified Inputs)

Outline

Three Simulations for Demonstration:

- Biofuels WTW Simulations (w/ GREET Defaults)
- Hydrogen WTW Simulations (w/ GREET Defaults)
- Biofuels and Hydrogen WTW Simulations (w/ Modified Inputs)

Biofuels WTW Simulations (w/ GREET Defaults)

Scenario and Fuel Pathway Selections:

- Fuels: Ethanol (all blending levels) vs. Baseline Gasoline
- Simulation Years: 2005 and 2020
- Vehicle Type: Passenger Cars
- Stochastic Simulation: No

Biofuels WTW Simulations (w/ GREET Defaults)

I. Fuel Production and Feedstock Market Shares:

- Conventional (CG) and Reformulated Gasoline (RFG) Production Shares

  (35% and 100% RFG in 2005 and 2020)

- Ethanol Feedstock Shares (100% from Corn)

Biofuels WTW Simulations (w/ GREET Defaults)

II. Technology Options:

- Gasoline:
  - Oxygenate type and level (Ethanol at 2.3% for RFG)
  - Sulfur Level (25.5 ppm)
  - Vehicle Type (SI Engine)
- Ethanol:
  - Plant Type and Share (Dry Milling- 68%)
  - Process Fuel (80% NG for DMP ; 60%NG for WMP)
  - Co-product Credit Calculation Method (Displacement)
  - Vehicle Technology (SI, CIDI, FCV)

Biofuels WTW Simulations (w/ GREET Defaults)

II. Technology Options:

- Electricity:
  - Marginal Generation (US mix)
  - Average Generation (US mix)
  - Advanced Plant Technology Shares (GREET Defaults)

Biofuels WTW Simulations (w/ GREET Defaults)

II. Technology Options:

- Blending Options:
  - 10% for Low-Level Blend of Ethanol with Gasoline
  - 85% for High-Level Blend of Ethanol with Gasoline
  - 10% for Low-Level Blend of Ethanol with Diesel
  - Share of CG in Gasoline for Low-Level Blend (100%)

Biofuels WTW Simulations (w/ GREET Defaults)

III. Key Production Assumptions:

- Petroleum:
  - Crude Recovery Efficiency (98%)
  - CG Refining Efficiency (86%)
  - RFG Refining Efficiency (85.5%)

- Ethanol:
  - CO2 Emissions from Landuse Change by Corn Farming (195 g/bushel)
  - Corn Farming Energy Use (23,000 Btu/bushel)
  - Ethanol Production Energy Use in DMP (36,500 Btu/gallon)
  - Ethanol Production Energy Use in WMP (46,000 Btu/gallon)

Biofuels WTW Simulations (w/ GREET Defaults)

III. Key Vehicle Operation Assumptions:

- Baseline Vehicles: Gasoline (23.1 MPG)

- Alternative-Fueled Vehicles Equivalent MPG (Relative to Baseline):
  - CIDI Vehicles w/ Diesel (124%)
  - SI Vehicle w/ Low-Level Blend with Ethanol (100%)
  - SI Vehicle w/ High-Level Blend with Ethanol (100%)
  - FCV w/ with pure Ethanol (158% for 2020)

Biofuels WTW Simulations (w/ GREET Defaults)

1. WTP Results:

Year: 2005	Baseline CG and RFG	Gasoline Vehicle: Low-Level EtOH Blend with Gasoline	EtOH FFV: E85, Corn	EtOH FCVs: Corn	CIDI Vehicle: E-Diesel
Total Energy	247,706	307,295	1,156,670	1,483,867	290,999
WTP Efficiency	80.1%	76.5%	46.4%	40.3%	77.5%
Fossil Fuels	233,161	257,456	628,332	770,589	243,329
Coal	43,755	52,221	174,657	221,777	49,735
Natural Gas	81,529	99,644	359,367	459,380	96,162
Petroleum	107,877	105,591	94,309	89,432	97,432
CO2	17,600	15,738	-5,389	-13,763	14,890
CH4	108.365	107.350	115.009	117.408	105.768
N2O	1.052	3.615	38.372	51.805	3.446
GHGs	20,404	19,277	8,615	4,272	18,343
VOC: Total	27.060	27.684	37.105	40.721	9.987
CO: Total	18.925	21.286	56.441	69.946	20.555
NOx: Total	56.359	62.146	150.269	184.076	60.084
PM10: Total	12.462	15.315	56.081	71.782	14.520
PM2.5: Total	4.940	5.898	19.713	25.030	5.586
SOx: Total	31.394	35.539	96.601	120.074	34.139
VOC: Urban	15.600	15.496	14.284	13.811	3.709
CO: Urban	5.135	4.895	2.449	1.483	4.606
NOx: Urban	13.507	13.026	8.755	7.046	12.227
PM10: Urban	2.411	2.278	0.913	0.373	2.102
PM2.5: Urban	1.391	1.316	0.539	0.233	1.215
SOx: Urban	10.478	10.233	8.433	7.697	9.680

Year: 2020	Baseline CG and RFG	Gasoline Vehicle: Low-Level EtOH Blend with Gasoline	EtOH FFV: E85, Corn	EtOH FCVs: Corn	CIDI Vehicle: E-Diesel
Total Energy	294,177	312,927	1,157,611	1,463,952	289,622
WTP Efficiency	77.3%	76.2%	46.3%	40.6%	77.5%
Fossil Fuels	260,674	263,587	622,373	750,701	242,532
Coal	48,316	50,187	155,507	193,537	46,541
Natural Gas	98,878	104,517	371,810	468,645	98,732
Petroleum	113,479	108,884	95,056	88,520	97,259
CO2	17,547	15,976	-7,515	-16,703	14,626
CH4	112.165	107.907	114.675	115.565	105.748
N2O	2.125	3.083	32.582	43.388	2.932
GHGs	20,756	19,370	4,767	-1,202	17,926
VOC: Total	27.530	27.756	40.511	45.116	10.006
CO: Total	15.518	15.730	37.012	44.638	14.986
NOx: Total	46.277	46.516	100.413	119.620	44.590
PM10: Total	12.526	13.179	44.919	56.411	12.215
PM2.5: Total	4.598	4.764	14.264	17.694	4.413
SOx: Total	22.906	23.246	53.500	64.354	22.182
VOC: Urban	15.543	15.464	14.267	13.814	3.664
CO: Urban	4.347	4.157	2.385	1.688	3.814
NOx: Urban	10.326	9.897	6.888	5.669	9.065
PM10: Urban	1.818	1.721	0.710	0.317	1.539
PM2.5: Urban	1.081	1.024	0.433	0.204	0.916
SOx: Urban	6.425	6.250	5.491	5.160	5.881

Biofuels WTW Simulations (w/ GREET Defaults)

2. WTW Results (2020):

Gasoline Vehicle: CG and RFG

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	171	1,149	4,490
Fossil Fuels	166	1,005	4,301
Coal	30	187	0
Natural Gas	81	363	0
Petroleum	54	455	4,301
CO2	3	76	345
CH4	0.409	0.094	0.010
N2O	0.000	0.009	0.012
GHGs	12	81	348
VOC: Total	0.015	0.109	0.151
CO: Total	0.027	0.042	3.482
NOx: Total	0.097	0.111	0.069
PM10: Total	0.008	0.049	0.029
PM2.5: Total	0.003	0.017	0.015
SOx: Total	0.035	0.068	0.006
VOC: Urban	0.003	0.067	0.094
CO: Urban	0.001	0.018	2.166
NOx: Urban	0.004	0.042	0.043
PM10: Urban	0.000	0.008	0.018
PM2.5: Urban	0.000	0.005	0.009
SOx: Urban	0.003	0.026	0.004

EtOH FFV: E85, Corn

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	608	4,590	4,490
Fossil Fuels	591	2,204	1,176
Coal	90	608	0
Natural Gas	272	1,398	0
Petroleum	229	198	1,176
CO2	-200	166	339
CH4	0.177	0.338	0.010
N2O	0.142	0.005	0.012
GHGs	-154	175	342
VOC: Total	-0.027	0.208	0.142
CO: Total	0.078	0.088	3.482
NOx: Total	0.243	0.207	0.069
PM10: Total	0.024	0.178	0.029
PM2.5: Total	0.011	0.053	0.015
SOx: Total	0.108	0.132	0.002
VOC: Urban	0.002	0.062	0.089
CO: Urban	0.002	0.009	2.166
NOx: Urban	0.007	0.024	0.043
PM10: Urban	0.000	0.003	0.018
PM2.5: Urban	0.000	0.002	0.009
SOx: Urban	0.006	0.019	0.001

EtOH FCVs: Corn

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	482	3,678	2,842
Fossil Fuels	469	1,664	0
Coal	70	480	0
Natural Gas	215	1,117	0
Petroleum	184	67	0
CO2	-173	125	213
CH4	0.060	0.268	0.002
N2O	0.121	0.002	0.002
GHGs	-135	132	214
VOC: Total	-0.026	0.154	0.042
CO: Total	0.061	0.066	0.696
NOx: Total	0.187	0.153	0.014
PM10: Total	0.018	0.142	0.021
PM2.5: Total	0.008	0.042	0.007
SOx: Total	0.085	0.098	0.000
VOC: Urban	0.001	0.038	0.026
CO: Urban	0.002	0.004	0.433
NOx: Urban	0.005	0.014	0.009
PM10: Urban	0.000	0.001	0.013
PM2.5: Urban	0.000	0.000	0.005
SOx: Urban	0.005	0.012	0.000

Biofuels WTW Simulations (w/ GREET Defaults)

3. WTW Results (Relative to Baseline Vehicles):

Year: 2020	GV: Low-Level EtOH Blend with Gasoline	EtOH FFV: E85, Corn	CIDI Vehicle: E-Diesel	EtOH FCVs: Corn
Total Energy	1.4%	66.7%	-19.6%	20.5%
Fossil Fuels	-1.6%	-27.4%	-21.8%	-61.0%
Coal	3.9%	221.9%	-22.3%	153.5%
Natural Gas	5.7%	276.0%	-19.5%	200.0%
Petroleum	-2.5%	-66.7%	-22.0%	-94.8%
CO2	-1.7%	-28.0%	-20.3%	-60.9%
CH4	-3.7%	2.2%	-25.0%	-35.7%
N2O	20.0%	634.8%	5.0%	483.5%
GHGs	-1.5%	-17.6%	-20.0%	-52.4%
VOC: Total	0.4%	18.1%	-65.0%	-38.2%
CO: Total	0.0%	2.7%	-83.4%	-76.8%
NOx: Total	0.4%	87.8%	-12.8%	27.8%
PM10: Total	3.5%	171.4%	-13.1%	113.1%
PM2.5: Total	2.1%	122.5%	-10.6%	62.5%
SOx: Total	1.0%	122.8%	-24.3%	68.5%
VOC: Urban	-0.2%	-6.7%	-69.1%	-60.2%
CO: Urban	0.0%	-0.4%	-84.2%	-79.9%
NOx: Urban	-2.2%	-17.3%	-7.5%	-69.2%
PM10: Urban	-1.7%	-19.2%	-7.8%	-46.8%
PM2.5: Urban	-1.8%	-20.7%	-7.0%	-62.9%
SOx: Urban	-3.4%	-20.8%	-30.7%	-46.9%

Outline

Three Simulations for Demonstration:

- Biofuels WTW Simulations (w/ GREET Defaults)
- Hydrogen WTW Simulations (w/ GREET Defaults)
- Biofuels and Hydrogen WTW Simulations (w/ Modified Inputs)

Hydrogen WTW Simulations (w/ GREET Defaults)

Scenario and Fuel Pathway Selections:

- Fuels: Gaseous and Liquid Hydrogen vs. Baseline Gasoline
- Simulation Years: 2005 and 2020
- Vehicle Type: Passenger Cars
- Stochastic Simulation: No

Hydrogen WTW Simulations (w/ GREET Defaults)

I. Fuel Production and Feedstock Market Shares:

- Conventional and Reformulated Gasoline Production Shares (35% RFG in 2005 and 100% RFG in 2020)
- Hydrogen Production Shares (100% Station Production)
- Hydrogen Feedstock Shares (100% from NG)

Hydrogen WTW Simulations (w/ GREET Defaults)

II. Technology Options:

- Gasoline:
  - Oxygenate type and level (Ethanol at 2.3% for RFG)
  - Sulfur Level (25.5 ppm)
  - Vehicle Type (SI Engine)
- Hydrogen:
  - NG Source (North America)
  - Vehicle Technology (SI,FCV)

Hydrogen WTW Simulations (w/ GREET Defaults)

II. Technology Options:

- Electricity:
  - Marginal Generation (US mix)
  - Average Generation (US mix)
  - Advanced Plant Technology Shares (GREET Defaults)

Hydrogen WTW Simulations (w/ GREET Defaults)

III. Key Production Assumptions:

- Petroleum:
  - Crude Recovery Efficiency (98%)
  - CG Refining Efficiency (86%)
  - RFG Refining Efficiency (85.5%)

- Hydrogen:
  - Refueling Station Production Efficiency (70%)
  - Liquefaction Efficiency (67%)

Hydrogen WTW Simulations (w/ GREET Defaults)

III. Key Transportation Assumptions:

- NG:
  - Transportation and Distribution Mode (Pipeline)
  - Distance from Production to Refueling Station (750 mi)

- Hydrogen:
  - Boiloff Losses per day (0.3%)
  - Boiloff Recovery Rate (80%)
  - Storage Duration at Refueling Station (3 days)

Hydrogen WTW Simulations (w/ GREET Defaults)

III. Key Vehicle Operation Assumptions:

- Baseline Vehicles:
  - Gasoline (23.1 MPG)

- Alternative-Fueled Vehicles Equivalent MPG (Relative to Baseline):
  - Hydrogen SI Vehicle (125% for 2020)
  - Hydrogen FCV (248% for 2020)

Hydrogen WTW Simulations (w/ GREET Defaults)

WTP Results:

Year: 2005	Baseline CG and RFG	FCV: G.H2	FCV: L.H2
Total Energy	247,706	737,552	1,919,377
WTP Efficiency	80.1%	57.6%	34.3%
Fossil Fuels	233,161	706,783	1,731,942
Coal	43,755	145,347	884,927
Natural Gas	81,529	544,837	775,337
Petroleum	107,877	16,599	71,677
CO2	17,600	109,916	205,248
CH4	108.365	360.070	487.005
N2O	1.052	0.504	1.799
GHGs	20,404	118,347	216,981
VOC: Total	27.060	12.432	21.144
CO: Total	18.925	35.508	58.208
NOx: Total	56.359	87.996	236.246
PM10: Total	12.462	39.076	167.988
PM2.5: Total	4.940	19.833	54.273
SOx: Total	31.394	81.590	408.680
VOC: Urban	15.600	1.850	2.508
CO: Urban	5.135	10.570	14.844
NOx: Urban	13.507	19.527	44.600
PM10: Urban	2.411	8.830	10.255
PM2.5: Urban	1.391	8.708	9.555
SOx: Urban	10.478	11.669	68.245

Year: 2020	Baseline CG and RFG	FCV: G.H2	FCV: L.H2
Total Energy	294,177	701,427	1,702,202
WTP Efficiency	77.3%	58.8%	37.0%
Fossil Fuels	260,674	675,826	1,563,641
Coal	48,316	131,096	709,116
Natural Gas	98,878	529,566	797,514
Petroleum	113,479	15,164	57,011
CO2	17,547	107,330	186,762
CH4	112.165	354.027	467.500
N2O	2.125	0.523	1.743
GHGs	20,756	115,627	198,030
VOC: Total	27.530	11.858	18.970
CO: Total	15.518	28.333	50.350
NOx: Total	46.277	62.365	136.831
PM10: Total	12.526	35.968	135.469
PM2.5: Total	4.598	18.775	45.119
SOx: Total	22.906	49.988	199.788
VOC: Urban	15.543	1.820	2.359
CO: Urban	4.347	10.215	14.986
NOx: Urban	10.326	16.456	30.151
PM10: Urban	1.818	8.729	9.724
PM2.5: Urban	1.081	8.644	9.289
SOx: Urban	6.425	6.494	33.468

Hydrogen WTW Simulations (w/ GREET Defaults)

2. WTW Results (2020):

Gasoline Vehicle: CG and RFG

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	171	1,149	4,490
Fossil Fuels	166	1,005	4,301
Coal	30	187	0
Natural Gas	81	363	0
Petroleum	54	455	4,301
CO2	3	76	345
CH4	0.409	0.094	0.010
N2O	0.000	0.009	0.012
GHGs	12	81	348
VOC: Total	0.015	0.109	0.151
CO: Total	0.027	0.042	3.482
NOx: Total	0.097	0.111	0.069
PM10: Total	0.008	0.049	0.029
PM2.5: Total	0.003	0.017	0.015
SOx: Total	0.035	0.068	0.006
VOC: Urban	0.003	0.067	0.094
CO: Urban	0.001	0.018	2.166
NOx: Urban	0.004	0.042	0.043
PM10: Urban	0.000	0.008	0.018
PM2.5: Urban	0.000	0.005	0.009
SOx: Urban	0.003	0.026	0.004

FCV: G.H2

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	138	1,132	1,811
Fossil Fuels	137	1,086	1,811
Coal	4	233	0
Natural Gas	125	834	1,811
Petroleum	8	20	0
CO2	10	185	0
CH4	0.432	0.209	0.000
N2O	0.000	0.001	0.000
GHGs	20	190	0
VOC: Total	0.011	0.011	0.000
CO: Total	0.014	0.037	0.000
NOx: Total	0.037	0.076	0.000
PM10: Total	0.001	0.064	0.021
PM2.5: Total	0.001	0.033	0.007
SOx: Total	0.021	0.070	0.000
VOC: Urban	0.000	0.003	0.000
CO: Urban	0.000	0.018	0.000
NOx: Urban	0.001	0.029	0.000
PM10: Urban	0.000	0.016	0.013
PM2.5: Urban	0.000	0.016	0.005
SOx: Urban	0.000	0.011	0.000

FCV: L.H2

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	139	2,942	1,811
Fossil Fuels	139	2,692	1,811
Coal	5	1,279	0
Natural Gas	126	1,318	1,811
Petroleum	8	95	0
CO2	10	328	0
CH4	0.436	0.411	0.000
N2O	0.000	0.003	0.000
GHGs	20	339	0
VOC: Total	0.011	0.024	0.000
CO: Total	0.014	0.077	0.000
NOx: Total	0.037	0.211	0.000
PM10: Total	0.002	0.244	0.021
PM2.5: Total	0.001	0.081	0.007
SOx: Total	0.021	0.341	0.000
VOC: Urban	0.000	0.004	0.000
CO: Urban	0.000	0.027	0.000
NOx: Urban	0.001	0.053	0.000
PM10: Urban	0.000	0.018	0.013
PM2.5: Urban	0.000	0.017	0.005
SOx: Urban	0.000	0.060	0.000

Hydrogen WTW Simulations (w/ GREET Defaults)

3. WTW Results (Relative to Baseline Vehicles):

Year: 2020	G.H2 ICE Vehicle	L.H2 ICE Vehicle	FCV: G.H2	FCV: L.H2
Total Energy	5.2%	67.0%	-47.0%	-15.8%
Fossil Fuels	10.0%	68.3%	-44.5%	-15.2%
Coal	117.1%	1074.1%	9.4%	491.8%
Natural Gas	1137.5%	1354.3%	523.8%	633.0%
Petroleum	-98.9%	-95.7%	-99.4%	-97.9%
CO2	-8.9%	58.4%	-54.1%	-20.1%
CH4	147.6%	226.9%	24.7%	64.7%
N2O	-35.6%	-15.2%	-95.6%	-85.4%
GHGs	-5.1%	61.9%	-52.6%	-18.8%
VOC: Total	-77.6%	-68.3%	-92.2%	-87.5%
CO: Total	-77.5%	-75.3%	-98.6%	-97.4%
NOx: Total	5.9%	102.5%	-59.2%	-10.5%
PM10: Total	77.4%	498.7%	0.9%	213.3%
PM2.5: Total	113.0%	380.0%	16.5%	151.1%
SOx: Total	65.4%	561.1%	-16.6%	233.2%
VOC: Urban	-88.9%	-87.7%	-98.0%	-97.4%
CO: Urban	-78.5%	-77.7%	-99.2%	-98.8%
NOx: Urban	14.3%	69.4%	-66.6%	-38.9%
PM10: Urban	71.9%	85.7%	10.0%	17.0%
PM2.5: Urban	156.5%	172.9%	43.6%	51.9%
SOx: Urban	-28.0%	271.1%	-63.7%	87.0%

Outline

Three Simulations for Demonstration:

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- Biofuels and Hydrogen WTW Simulations (w/ Modified Inputs)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

Scenario and Fuel Pathway Selections:

- Fuels: Ethanol, Gaseous Hydrogen, and Gasoline
- Simulation Years: 2020
- Vehicle Type: Passenger Cars
- Stochastic Simulation: No

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

I. Fuel Production and Feedstock Market Shares:

- Conventional and Reformulated Gasoline Production Shares (100% RFG in 2020)
- Ethanol Feedstock Shares (100% from Herbaceous Biomass)
- Hydrogen Production Shares (100% Central Production)
- Hydrogen Feedstock Shares (100% from Nuclear TCWC)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

II. Technology Options:

- Gasoline:
  - Oxygenate type and level (Ethanol at 2.3% for RFG)
  - Sulfur Level (25.5 ppm)
  - Vehicle Type (SI Engine, GIHEV, GCHEV, FCV)
- Ethanol:
  - Herbaceous Biomass Plant Type (Fermentation)
  - Vehicle Technology (FCV)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

II. Technology Options:

- Electricity:
  - Marginal Generation (US mix)
  - Average Generation (US mix)
  - Advanced Plant Technology Shares (GREET Defaults)

- Hydrogen:
  - Nuclear HTGR Technology Shares for TCWC (10% Gas Diffusion)
  - Vehicle Technology (SI, FCV)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

III. Key Production Assumptions:

- Petroleum:
  - Crude Recovery Efficiency (98%)
  - RFG Refining Efficiency (85%)

- Ethanol:
  - CO2 Emissions from Landuse Change by Herbaceous Biomass Farming (-48,500 g/dry ton)
  - Herbaceous Biomass Farming Energy Use (217,230 Btu/dry ton)
  - Ethanol Yield (105 gallon/dry ton)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

III. Key Production Assumptions:

- Hydrogen:
  - Electricity Use for Uranium Enrichment
    - Gas Diffusion Plants (2400 kWh/SWU)
    - Centrifuge Plants (50 kWh/SWU)
  - Refueling Station Compression Efficiency
    - NG Compressors (85%)
    - Electric Compressors (92.5%)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

III. Key Vehicle Operation Assumptions:

- Baseline Vehicles:
  - Gasoline (25.3 MPG)

- Alternative-Fueled Vehicles Equivalent MPG (Relative to Baseline):
  - Gasoline GIHEV (160%)
  - Gasoline GCHEV (300% grid mode)
  - Ethanol FCV (158%)
  - Hydrogen SI Vehicle (125%)
  - Hydrogen FCV (248%)

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

WTP Results:

Year: 2020	Baseline CG and RFG	EtOH FCVs: H. Biomass	Grid-Connected SI HEV: Gasoline and Electricity	FCV: G.H2
Total Energy	271,192	678,231	548,891	280,324
WTP Efficiency	78.7%	59.6%	64.6%	78.1%
Fossil Fuels	232,309	150,189	506,782	243,947
Coal	39,017	5,748	248,505	152,823
Natural Gas	81,006	51,707	151,738	70,976
Petroleum	112,286	92,734	106,538	20,149
CO2	15,017	-63,728	56,683	22,544
CH4	107.560	19.028	148.174	32.627
N2O	2.051	3.571	2.318	0.356
GHGs	18,097	-62,233	60,777	23,400
VOC: Total	27.668	25.255	25.914	2.266
CO: Total	16.653	37.765	25.620	8.422
NOx: Total	46.675	79.356	79.184	34.922
PM10: Total	10.888	6.738	65.281	27.362
PM2.5: Total	4.138	3.769	18.230	7.331
SOx: Total	20.219	6.167	101.335	42.806
VOC: Urban	15.530	13.646	12.598	0.186
CO: Urban	4.298	1.008	6.076	1.494
NOx: Urban	10.180	3.565	15.801	5.406
PM10: Urban	1.808	0.181	1.955	0.274
PM2.5: Urban	1.075	0.119	1.175	0.172
SOx: Urban	6.172	0.853	20.265	7.649

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

2. WTW Results:

Gasoline Vehicle: CG and RFG

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	171	1,046	4,490
Fossil Fuels	166	877	4,301
Coal	30	145	0
Natural Gas	81	283	0
Petroleum	54	450	4,301
CO2	3	64	345
CH4	0.409	0.074	0.010
N2O	0.000	0.009	0.012
GHGs	12	69	348
VOC: Total	0.015	0.109	0.151
CO: Total	0.027	0.047	3.482
NOx: Total	0.097	0.113	0.069
PM10: Total	0.008	0.041	0.029
PM2.5: Total	0.003	0.015	0.015
SOx: Total	0.035	0.056	0.006
VOC: Urban	0.003	0.067	0.094
CO: Urban	0.001	0.018	2.166
NOx: Urban	0.004	0.041	0.043
PM10: Urban	0.000	0.008	0.018
PM2.5: Urban	0.000	0.005	0.009
SOx: Urban	0.003	0.025	0.004

Grid-Independent SI HEV: CG and RFG

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	107	654	2,806
Fossil Fuels	104	548	2,688
Coal	19	91	0
Natural Gas	51	177	0
Petroleum	34	281	2,688
CO2	2	40	215
CH4	0.256	0.046	0.005
N2O	0.000	0.006	0.012
GHGs	8	43	219
VOC: Total	0.009	0.068	0.108
CO: Total	0.017	0.030	3.482
NOx: Total	0.061	0.070	0.058
PM10: Total	0.005	0.026	0.029
PM2.5: Total	0.002	0.010	0.015
SOx: Total	0.022	0.035	0.004
VOC: Urban	0.002	0.042	0.067
CO: Urban	0.001	0.011	2.166
NOx: Urban	0.003	0.026	0.036
PM10: Urban	0.000	0.005	0.018
PM2.5: Urban	0.000	0.003	0.009
SOx: Urban	0.002	0.016	0.002

FCV: G.H2

Item	Btu/mile or grams/mile		
	Feedstock	Fuel	Vehicle Operation
Total Energy	56	451	1,811
Fossil Fuels	51	390	0
Coal	26	251	0
Natural Gas	19	109	0
Petroleum	6	30	0
CO2	4	36	0
CH4	0.008	0.051	0.000
N2O	0.000	0.001	0.000
GHGs	5	38	0
VOC: Total	0.001	0.003	0.000
CO: Total	0.003	0.012	0.000
NOx: Total	0.008	0.055	0.000
PM10: Total	0.005	0.045	0.021
PM2.5: Total	0.001	0.012	0.007
SOx: Total	0.007	0.070	0.000
VOC: Urban	0.000	0.000	0.000
CO: Urban	0.000	0.002	0.000
NOx: Urban	0.001	0.009	0.000
PM10: Urban	0.000	0.000	0.013
PM2.5: Urban	0.000	0.000	0.005
SOx: Urban	0.001	0.013	0.000

Biofuels and Hydrogen WTW Simulations (Modified Inputs)

3. WTW Results (Relative to Baseline Vehicles):

Year: 2020	G.H2 ICE Vehicle	Grid-Independent SI HEV: CG and RFG	Grid-Connected SI HEV: CG and RFG	FCV: G.H2	FCV: LS Gasoline	EtOH FCVs: H. Biomass
Total Energy	-19.4%	-37.5%	-35.6%	-59.4%	-36.7%	-16.4%
Fossil Fuels	-83.6%	-37.5%	-36.8%	-91.7%	-36.7%	-92.0%
Coal	213.3%	-37.5%	373.8%	57.9%	-36.7%	-90.7%
Natural Gas	-29.9%	-37.5%	32.0%	-64.7%	-36.7%	-59.6%
Petroleum	-98.5%	-37.5%	-57.0%	-99.2%	-36.7%	-94.5%
CO2	-80.3%	-37.5%	-32.3%	-90.1%	-38.0%	-92.3%
CH4	-76.0%	-37.8%	-28.0%	-88.0%	-37.6%	-88.6%
N2O	-37.4%	-16.3%	-36.1%	-97.0%	-61.2%	-40.8%
GHGs	-79.6%	-37.2%	-32.3%	-90.1%	-38.4%	-91.4%
VOC: Total	-90.2%	-32.6%	-51.4%	-98.5%	-50.1%	-58.8%
CO: Total	-79.6%	-0.8%	-32.7%	-99.6%	-79.1%	-77.4%
NOx: Total	-30.2%	-32.2%	-18.6%	-77.3%	-47.4%	-14.1%
PM10: Total	54.3%	-23.7%	133.5%	-9.6%	-33.6%	-48.8%
PM2.5: Total	3.0%	-20.9%	66.6%	-38.4%	-42.9%	-46.0%
SOx: Total	59.4%	-37.5%	151.8%	-19.7%	-40.5%	-81.8%
VOC: Urban	-92.4%	-32.4%	-54.3%	-99.8%	-50.7%	-60.5%
CO: Urban	-79.9%	-0.3%	-32.9%	-99.9%	-79.6%	-80.0%
NOx: Urban	-29.7%	-27.1%	-30.4%	-89.0%	-57.7%	-76.9%
PM10: Urban	-45.0%	-11.8%	-19.8%	-48.9%	-30.9%	-48.4%
PM2.5: Urban	-59.9%	-12.9%	-25.5%	-65.4%	-45.9%	-64.8%
SOx: Urban	-12.1%	-37.5%	58.6%	-55.7%	-43.9%	-90.9%

THANK YOU!