

AFLEET TOOL TO EXAMINE EMISSIONS AND COSTS OF ALTERNATIVE FUEL VEHICLES



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ARGONNE HAS SUPPORTED DOE'S CLEAN CITIES WITH TOOL DEVELOPMENT FOR 15+ YEARS

- **AirCRED**
 - O₃ precursor & CO emission credits from AFVs for SIPs
- **Clean Cities AOI 4 Emissions Benefit Tool**
 - GHG & air pollutant benefits of ARRA grant proposals
- **GREET Fleet Footprint Calculator**
 - Petroleum use & GHG footprints of HDVs & off-road equipment



“AFLEET TOOL” TO ANALYZE AFV COSTS & BENEFITS

- **Examines light-duty & heavy-duty vehicle:**
 - Petroleum use
 - GHG emissions
 - Air pollutant emissions
 - Cost of ownership
- **Contains 16 fuel/vehicle technologies**
 - Conventional
 - Hybrids
 - Plug-in electrics
 - Alternative fuels: CNG, LNG, LPG, H₂, ethanol, biodiesel
- **Includes 7 Major Vehicle Types**
 - Cost, MPG, & VMT data on 23 vocations
- **AFLEET Tool 2016 & its user manual available at:**
<http://greet.es.anl.gov/afleet>



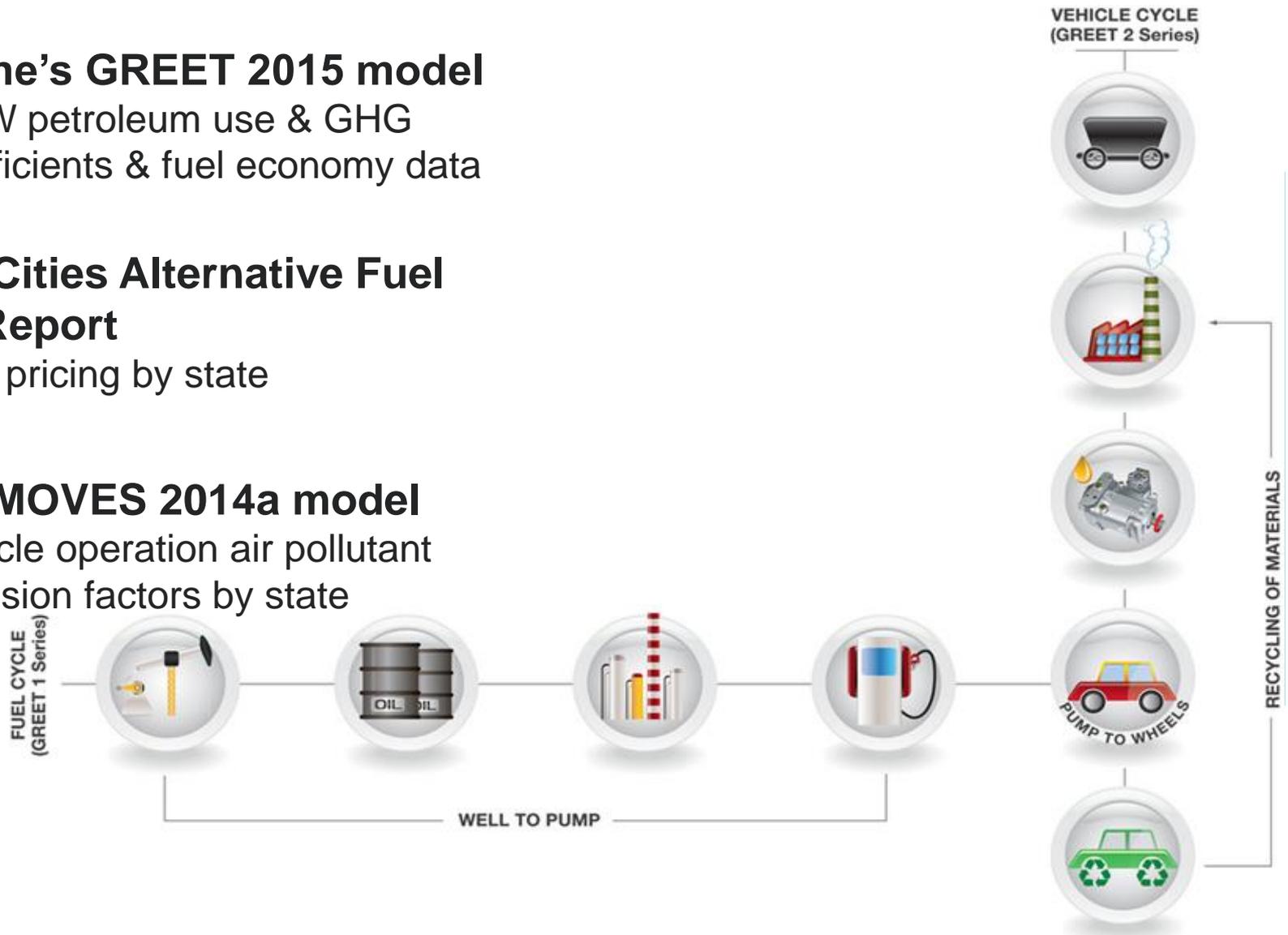
AFLEET TOOL'S CALCULATION METHODS

- **Tool has 3 calculation methods & which to use depends on your goals**
- **Simple Payback Calculator**
 - Annual emissions & simple payback of purchasing new AFV vs. conventional counterpart
- **Total Cost of Ownership Calculator**
 - Lifetime emissions & NPV of costs over the years of planned ownership of a new vehicle
- **Fleet Energy and Emissions Footprint Calculator**
 - Annual petroleum use, GHGs & air pollutant emissions of existing & new vehicles



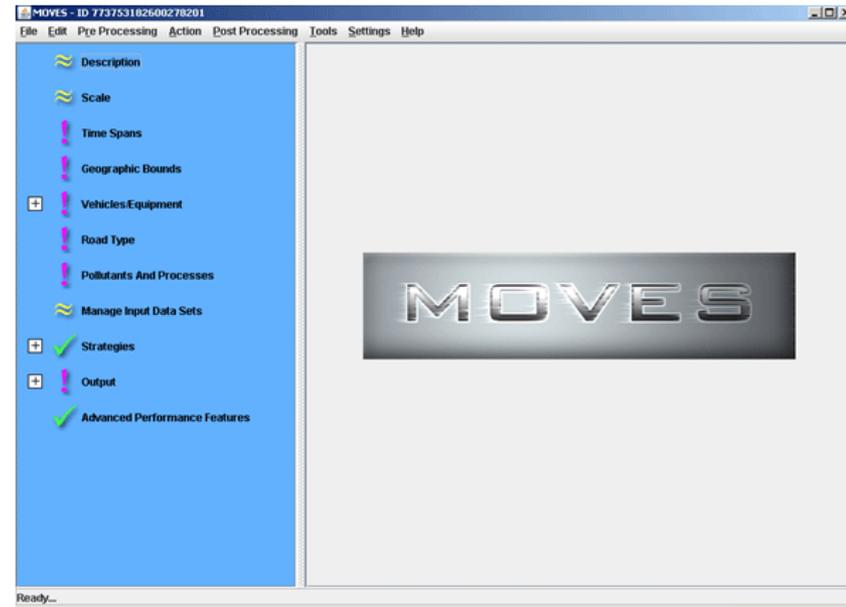
AFLEET TOOL'S MAJOR DATA SOURCES

- **Argonne's GREET 2015 model**
 - WTW petroleum use & GHG coefficients & fuel economy data
- **Clean Cities Alternative Fuel Price Report**
 - Fuel pricing by state
- **EPA's MOVES 2014a model**
 - Vehicle operation air pollutant emission factors by state



AFLEET VEHICLE AIR POLLUTANT EMISSIONS

- **Generate MOVES emission factors for gasoline & diesel vehicles**
 - NO_x, PM₁₀, PM_{2.5}, VOCs, CO
 - LDV = passenger car & truck; light commercial truck
 - HDV = school & transit bus; refuse; single unit & combination trucks
- **Emissions for both old & new vehicles in current year**
 - Can develop footprint & examine benefit of removing old vehicles
- **Deterioration rates for new vehicles**
 - Can examine future emissions of new vehicles



AFLEET VEHICLE AIR POLLUTANT EMISSIONS

- **Use relative AFV emission estimates from GREET**
 - Recently developed GREET HDV module examined in-use emissions
- **AFLEET multiplies MOVES emission factors and GREET AFV relative emission rates**
 - AFV compared to appropriate counterpart engine, e.g.
 - Propane compared w/ gasoline
 - Biodiesel compared w/ diesel
- **AFLEET does not include upstream or electricity generation emissions**



AFLEET TOOL 2017 PLANNED UPDATES

- **Option to examine HDVs with low-NOx engines**
- **Idling emissions and idle reduction technologies**
- **Upstream & vehicle production emissions**
- **Renewable diesel**
- **Online user interface**



AFLEET SUMMARY

- **Argonne developed AFLEET for DOE Clean Cities to assist stakeholders & fleet operators nationwide**
- **AFLEET can help estimate the economic and environmental costs and benefits of AFVs**
 - Inform new vehicle purchases
 - Examine energy and emissions footprint of existing vehicles
- **Default data provided for key inputs**
 - Using your own data makes your analysis more meaningful
- **AFV in-use air pollutant emissions based on EPA's MOVES and Argonne's GREET models**

THANK YOU!!!

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BACKUP SLIDES

AFLEET TUTORIAL – DEMO #1

Using the Fleet Energy & Emissions Footprint Calculator to Examine Existing Fleet



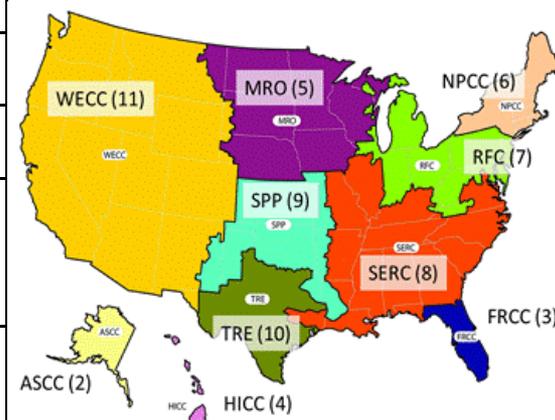
AFLEET TUTORIAL – FLEET ENERGY & EMISSIONS FOOTPRINT CALCULATOR

- 1st step: enter location on “Inputs” sheet

Primary Vehicle Location	
State	CALIFORNIA
County	LOS ANGELES

- 2nd step: if necessary, adjust fuel production assumptions on “Inputs” sheet

Biodiesel Feedstock Source	1 - Soy	1
	2 - Algae	
Ethanol Feedstock Source	1 - Corn	1
	2 - Switchgrass	
CNG Feedstock Source	1 - North American NG	1
	2 - Renewable NG - Wastewater Treatment	
	3 - Landfill Gas	
LNG Feedstock Source	1 - North American NG	1
	2 - Renewable NG - Wastewater Treatment	
	3 - Landfill Gas	
North American NG Feedstock Source	Conventional	66%
	Shale	34%
LPG Feedstock Source	NG	69%
	Petroleum	31%
Source of Electricity for PHEVs, EVs, and FCVs (Electrolysis)	1 - Average U.S. Mix	1
	2 to 11 - EIA Region Mix (see map)	
	12 - User Defined (go to 'Background Data' sheet)	
G.H2 Production Process	1 - Refueling Station SMR (On-site)	1
	2 - Central Plant SMR (Off-site)	
	3 - Refueling Station Electrolysis (On-site)	



AFLEET TUTORIAL – FLEET ENERGY & EMISSIONS FOOTPRINT CALCULATOR

- 4th step: copy and paste fleet data into “Footprint” sheet
 - Model year
 - Annual mileage
 - Fuel use

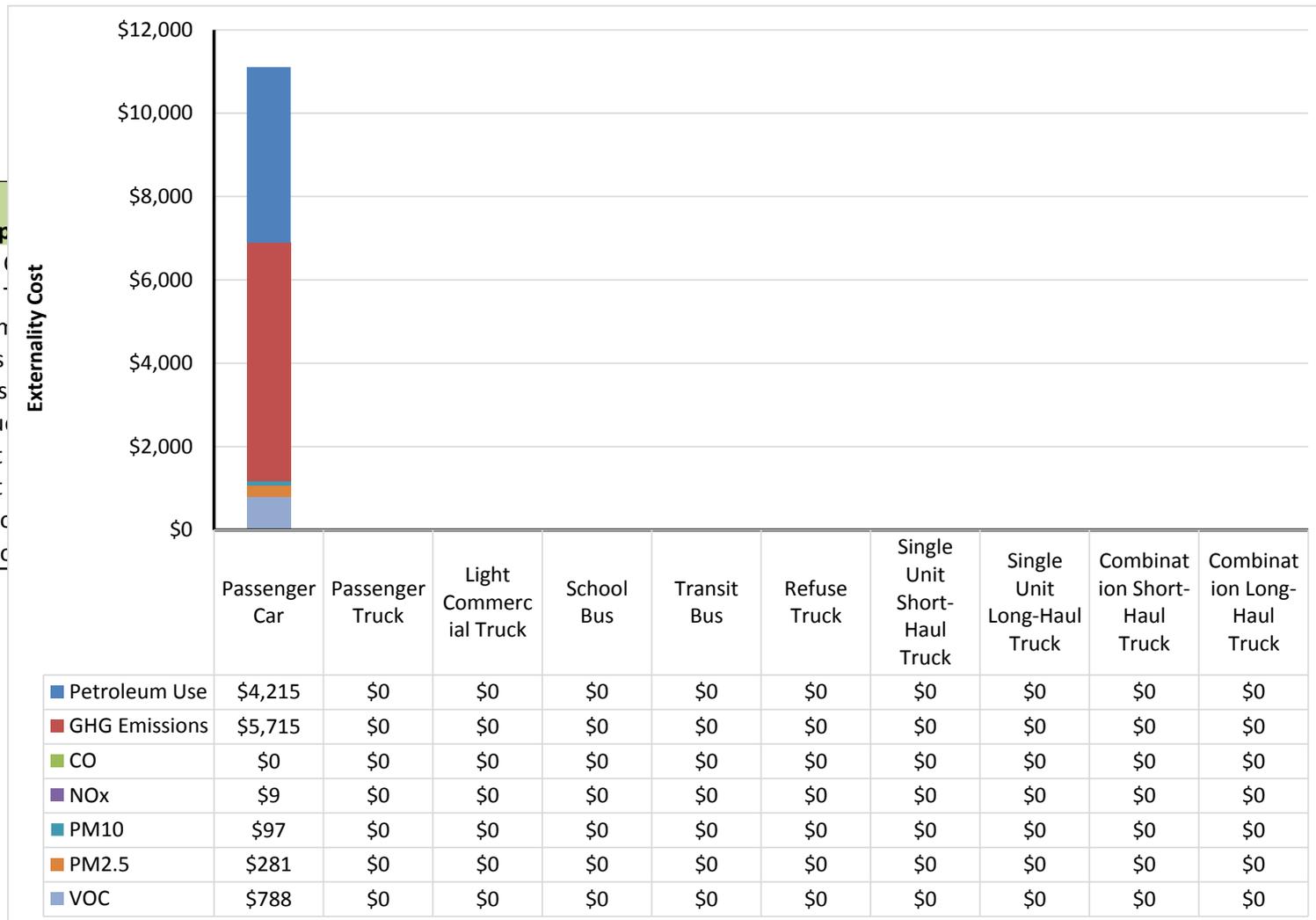
- 5th step: adjust vehicle type via drop-down

Vehicle Type	Model Year	Annual Vehicle Mileage	Fuel Use			Petroleum Use (barrels)	GHG (short tons)	Vehicle Operation Air Pollutant Emissions (lb)							
			Gasoline (gal)	Diesel (gal)	Gasoline HEV (gal)			CO	NOx	PM10	PM10 (TBW)	PM2.5	PM2.5 (TBW)	VOC	VOC (Evap)
Passenger Car	2005	10,255	513			10.7	6.0	92.4	7.0	0.1	0.7	0.1	0.1	3.9	2.6
Passenger Car	2005	10,312	516			10.8	6.1	92.9	7.0	0.1	0.7	0.1	0.1	3.9	2.7
Passenger Car	2005	10,369	518			10.8	6.1	93.4	7.0	0.1	0.7	0.1	0.1	3.9	2.7
Passenger Car	2005	10,426	521			10.9	6.1	93.9	7.1	0.1	0.7	0.1	0.1	4.0	2.7
Passenger Car	2005	10,483	524			10.9	6.2	94.4	7.1	0.1	0.7	0.1	0.1	4.0	2.7
Passenger Car	2005	10,540	527			11.0	6.2	94.9	7.2	0.1	0.7	0.1	0.1	4.0	2.7
Passenger Car	2005	10,597	530			11.1	6.2	95.5	7.2	0.1	0.7	0.1	0.1	4.0	2.7
Passenger Car	2005	10,654	533			11.1	6.3	96.0	7.2	0.1	0.7	0.1	0.1	4.0	2.7
Passenger Car	2005	10,711	536			11.2	6.3	96.5	7.3	0.1	0.7	0.1	0.1	4.1	2.8
Passenger Car	2005	10,768	538			11.2	6.3	97.0	7.3	0.1	0.7	0.1	0.1	4.1	2.8
Passenger Car	2005	10,825	541			11.3	6.4	97.5	7.4	0.1	0.7	0.1	0.1	4.1	2.8
Passenger Car	2005	10,882	544			11.4	6.4	98.0	7.4	0.1	0.7	0.1	0.1	4.1	2.8
Passenger Car	2007	10,939	497			10.4	5.9	67.6	3.9	0.1	0.7	0.1	0.1	2.7	1.8
Passenger Car	2007	10,996	500			10.4	5.9	68.0	3.9	0.1	0.7	0.1	0.1	2.7	1.8
Passenger Car	2007	11,053	502			10.5	5.9	68.3	3.9	0.1	0.7	0.1	0.1	2.7	1.8
Passenger Car	2007	11,110	505			10.5	5.9	68.7	4.0	0.1	0.7	0.1	0.1	2.7	1.8
Passenger Car	2007	11,167	508			10.6	6.0	69.0	4.0	0.1	0.7	0.1	0.1	2.8	1.8
Passenger Car	2007	11,224	510			10.7	6.0	69.4	4.0	0.1	0.7	0.1	0.1	2.8	1.9
Passenger Car	2007	11,281	513			10.7	6.0	69.7	4.0	0.1	0.7	0.1	0.1	2.8	1.9
Passenger Car	2007	11,338	515			10.8	6.1	70.1	4.0	0.1	0.7	0.1	0.1	2.8	1.9
Passenger Car	2007	11,395	518			10.8	6.1	70.4	4.1	0.1	0.8	0.1	0.1	2.8	1.9
Passenger Car	2007	11,452	521			10.9	6.1	70.8	4.1	0.1	0.8	0.1	0.1	2.8	1.9
Passenger Car	2007	11,509	523			10.9	6.2	71.1	4.1	0.1	0.8	0.1	0.1	2.8	1.9
Passenger Car	2007	11,566	526			11.0	6.2	71.5	4.1	0.1	0.8	0.1	0.1	2.9	1.9
Passenger Car	2007	11,623	528			11.0	6.2	71.8	4.2	0.1	0.8	0.1	0.1	2.9	1.9

Note: Several fuels are not shown for clarity in this presentation

AFLEET TUTORIAL – FLEET ENERGY & EMISSIONS FOOTPRINT CALCULATOR

- View existing fleet results on “Footprint Outputs” sheet



Vehicle Type
Passenger Car
Passenger Truck
Light Commercial Truck
School Bus
Transit Bus
Refuse Truck
Single Unit Short-Haul Truck
Single Unit Long-Haul Truck
Combination Short-Haul Truck
Combination Long-Haul Truck

Total

CO2e (lb)	VOC (lb)
5	141
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0

5 **141**

AFLEET TUTORIAL – DEMO #2

Using Simple Payback and TCO Calculators to Compare Potential Acquisitions



AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

▪ 1st step: enter key inputs on “Inputs” sheet

- State, County (for externalities) & vehicle type (via drop-down)
- # of vehicles, VMT, MPGGE, and purchase price
 - Default and MPDGE reference values available (to the side of below tables)
- Can simulate both an LDV and HDV

Primary Vehicle Location				
State	CALIFORNIA			
County	LOS ANGELES			
Heavy-Duty Vehicle Information				
Vehicle Type	Transit Bus			
Heavy-Duty Fuel Type	Number of Heavy-Duty Vehicles	Annual Vehicle Mileage	Fuel Economy (MPDGE)	Purchase Price (\$/Vehicle)
Gasoline	0	0	3.4	\$0
Diesel	0	35,000	4.1	\$300,000
All-Electric Vehicle (EV)	0	35,000	11.3	\$750,000
Gaseous Hydrogen (G.H2) Fuel Cell Vehicle (FCV)	0	35,000	6.8	\$1,800,000
Diesel Hybrid Electric Vehicle (HEV)	0	35,000	5.7	\$510,000
Diesel Hydraulic Hybrid (HHV)	0	0	5.3	\$0
Biodiesel (B20)	0	35,000	4.1	\$300,000
Biodiesel (B100)	0	35,000	4.1	\$300,000
Ethanol (E85)	0	0	3.4	\$0
Propane (LPG)	0	0	3.4	\$0
Compressed Natural Gas (CNG)	0	35,000	3.5	\$360,000
Liquefied Natural Gas (LNG)	0	35,000	3.5	\$350,000
LNG / Diesel Pilot Ignition	0	0	3.9	\$0

Note: Red cells show values changed for demo, cell color doesn't change in AFLEET

AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

- **2nd step: enter key fuel price inputs on “Inputs” sheet**
 - Choose either public or private station fuel pricing (via drop-down)
 - Results based on state level AFPR data
 - Choose if you want to look at fuel price sensitivity for simple payback (via drop-down)
 - Enter fuel price data (in respective fuel unit)

Refueling Information			
Fueling Type	Private Station	For infrastructure costs, go to 'Payback' sheet	
Fuel Price Sensitivity	No	To enter fuel price range, go to 'Payback' sheet	
<u>Fuel and DEF Price</u>			
		Public Station	Private Station
	Fuel Unit	(\$/Fuel Unit)	
Gasoline	gasoline gallon	\$3.01	\$2.84
Diesel	diesel gallon	\$3.04	\$3.03
Electricity	kWh	\$0.16	\$0.16
G.H2	hydrogen kg	\$20.29	\$6.99
B20	B20 gallon	\$2.92	\$2.70
B100	B100 gallon	\$3.94	\$4.41
E85	E85 gallon	\$2.59	\$2.56
Propane	LPG gallon	\$3.01	\$2.63
CNG	CNG GGE	\$2.43	\$1.96
LNG	LNG gallon	\$2.86	\$2.11
Diesel Exhaust Fluid (DEF)	DEF gallon	\$2.80	\$2.80

AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

- 3rd step: enter TCO inputs on “Inputs” sheet

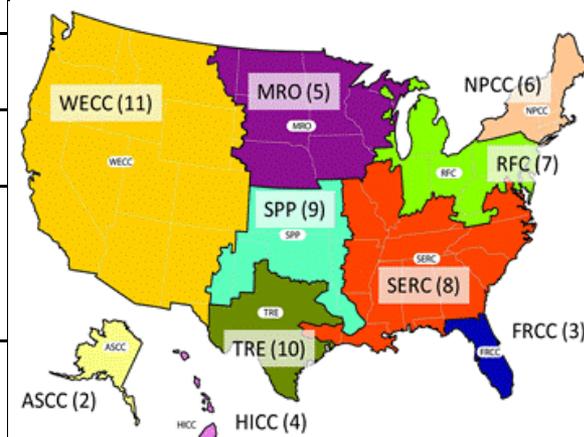
Total Cost of Ownership Inputs

Light-Duty Vehicle Information			
Years of Planned Ownership	years	15	
Heavy-Duty Vehicle Information			
Years of Planned Ownership	years	15	
Infrastructure Information			
Years of Planned Ownership	years	15	
Financial Assumptions			
		Vehicles	Infrastructure
Loan	yes/no	No	No
Loan Term	years	5	5
Interest Rate	%	3.37%	3.37%
Percent Down Payment	%	0.00%	0.00%
Discount Factor	%	0.83%	

AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

- 4th step: adjust fuel production assumptions on “Inputs” sheet

Biodiesel Feedstock Source	1 - Soy 2 - Algae	1	
Ethanol Feedstock Source	1 - Corn 2 - Switchgrass	1	
CNG Feedstock Source	1 - North American NG 2 - Renewable NG - Wastewater Treatment 3 - Landfill Gas	1	
LNG Feedstock Source	1 - North American NG 2 - Renewable NG - Wastewater Treatment 3 - Landfill Gas	1	
North American NG Feedstock Source		Conventional 66%	Shale 34%
LPG Feedstock Source		NG 69%	Petroleum 31%
Source of Electricity for PHEVs, EVs, and FCVs (Electrolysis)	1 - Average U.S. Mix 2 to 11 - EIA Region Mix (see map) 12 - User Defined (go to 'Background Data' sheet)	11	
G.H2 Production Process	1 - Refueling Station SMR (On-site) 2 - Central Plant SMR (Off-site) 3 - Refueling Station Electrolysis (On-site)	1	



AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

▪ 5th step: if examining PHEV or EREV, enter additional data on “Payback” sheet

- CD “EV mode” fuel consumption & range
- Charges per day & days driven per week
- Other secondary assumptions are on this sheet as well

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	G.H2 FCV
<u>Light-Duty Vehicle Inputs</u>							
Vehicle Type	<u>Passenger Car</u>						
Number of LDVs	25	25	25	25	25	25	25
Annual Mileage	11,000	11,000	11,000	11,000	11,000	11,000	11,000
Fuel Economy (MPGGE)	28.8	34.6	40.3	42.9	41.2	95.0	57.3
CD Electricity Use (kWh/100mi)				23.0	31.4	34.6	
CD Electricity Use (GGE/100mi)				0.7	1.0		
CD Gasoline Use (GGE/100mi)				0.7	0.0		
PHEV CD Range (miles)				19.6	34.0		
Charges/day				1.0	1.0		
Days driven/week				5	5		
Share of CD miles				46%	81%		
Share of Alternative Fuel Use in Dual-Fuel or PHEV (Energy %)				17%	62%		
DEF Use (% of fuel consumption)	0%	2%	0%	0%	0%	0%	0%
Purchase Price (\$/vehicle)	\$20,000	\$22,500	\$23,000	\$32,500	\$34,000	\$30,000	\$58,500
Incentive (\$/vehicle)	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance & Repair (\$/mile)	\$0.142	\$0.192	\$0.137	\$0.135	\$0.135	\$0.125	\$0.125

Note: Several fuels are not shown for clarity in this presentation

AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

▪ 6th step: if examining fuel price sensitivity, enter additional data on “Payback” sheet

- Enter high and low fuel prices for either public or private station
 - Can either enter values or % relative to default price
 - Do not have to enter multiple times for vehicles using same fuel

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	G.H2 FCV
Fuel Price Sensitivity							
Public Fuel Price Sensitivity Case							
	No						
High Fuel Price (% increase vs default)	17%	19%	17%	17%	17%	0%	0%
High Primary Fuel Price (\$/GGE)	\$3.51	\$3.13	\$3.51	\$3.51	\$3.51	\$5.34	\$20.29
High Secondary Fuel Price (\$/GGE)				\$5.34	\$5.34		
Low Primary Fuel Price (% decrease vs default)	17%	19%	17%	17%	17%	0%	0%
Low Primary Fuel Price (\$/GGE)	\$2.51	\$2.13	\$2.51	\$2.51	\$2.51	\$5.34	\$20.29
Low Secondary Fuel Price (\$/GGE)				\$5.34	\$5.34		
Private Fuel Price Sensitivity Case							
	No						
High Fuel Price (% increase vs default)	18%	19%	17%	17%	17%	0%	0%
High Primary Fuel Price (\$/GGE)	\$3.34	\$3.13	\$3.31	\$3.31	\$3.31	\$5.34	\$6.99
High Secondary Fuel Price (\$/GGE)				\$5.34	\$5.34		
Low Primary Fuel Price (% decrease vs default)	18%	19%	17%	17%	17%	0%	0%
Low Primary Fuel Price (\$/GGE)	\$2.34	\$2.13	\$2.37	\$2.37	\$2.37	\$5.34	\$6.99
Low Secondary Fuel Price (\$/GGE)				\$5.34	\$5.34		

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AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

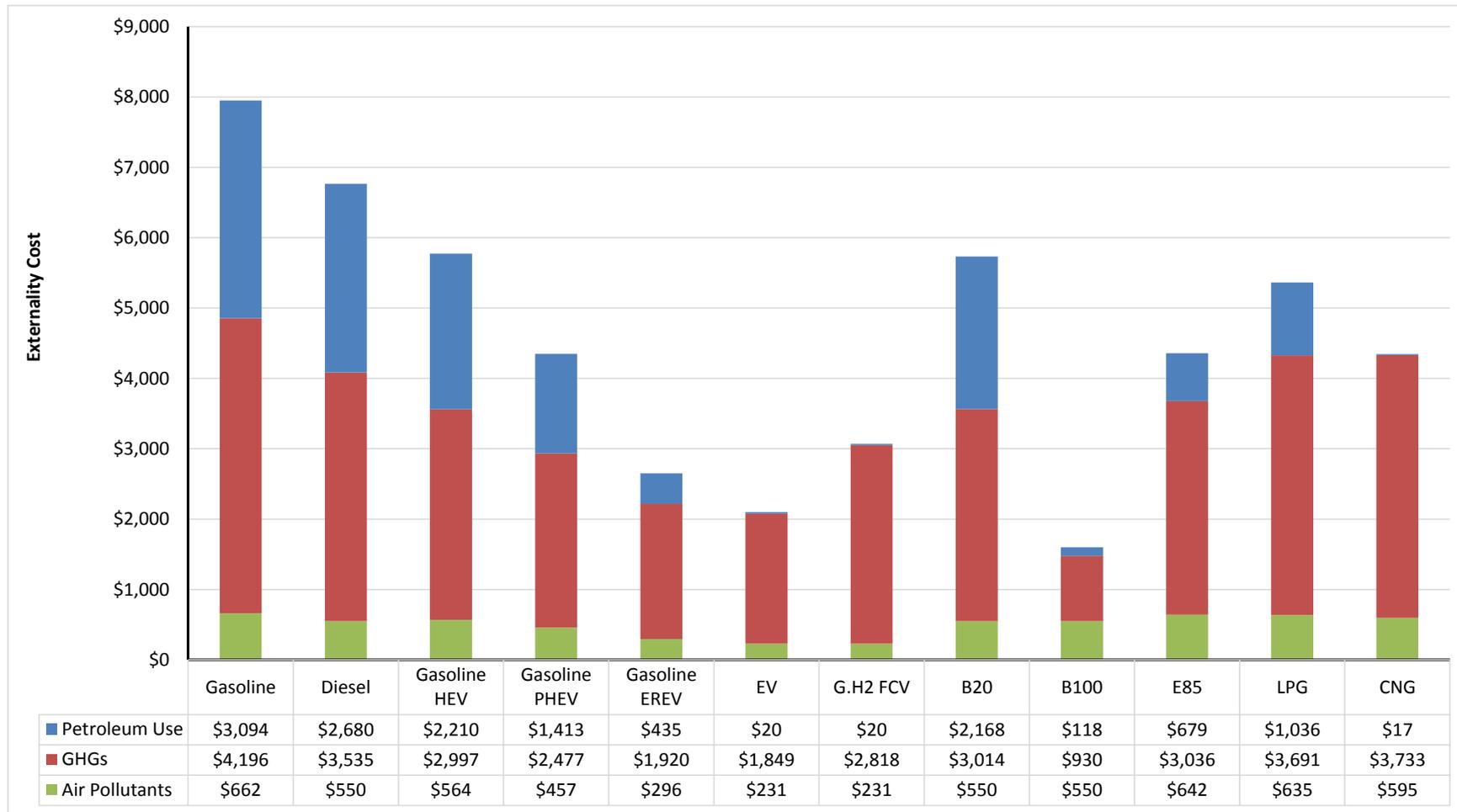
- 7th step: if examining infrastructure costs, enter additional data on “Payback” sheet
 - Enter station type (via drop down), number of stations, and station & O&M costs

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV
Infrastructure Inputs						
Station/EVSE Type	New Private	New Private	New Private	Level 2 - Parking Garage	Level 2 - Parking Garage	Level 2 - Parking Garage
Number of stations/EVSEs	0	0	0	13	13	13
Total Refueling Station/EVSE Cost	\$0	\$0	\$0	\$40,556	\$40,556	\$40,556
Total Incentive	\$0	\$0	\$0	\$0	\$0	\$0
Maintenance Depot Cost	\$0	\$0	\$0	\$0	\$0	\$0
Annual Private Station/EVSE Operation & Maintenance	\$0	\$0	\$0	\$9,100	\$9,100	\$9,100
Default Refueling Station/EVSE Cost	\$0	\$0	\$0	\$40,556	\$40,556	\$40,556
Default Annual Private Station/EVSE O&M Costs (\$/yr)	\$0	\$0	\$0	\$9,100	\$9,100	\$9,100
Annual Private Fueling Labor & Misc. Costs (\$/yr)	\$0	\$0	\$0	\$0	\$0	\$0

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AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

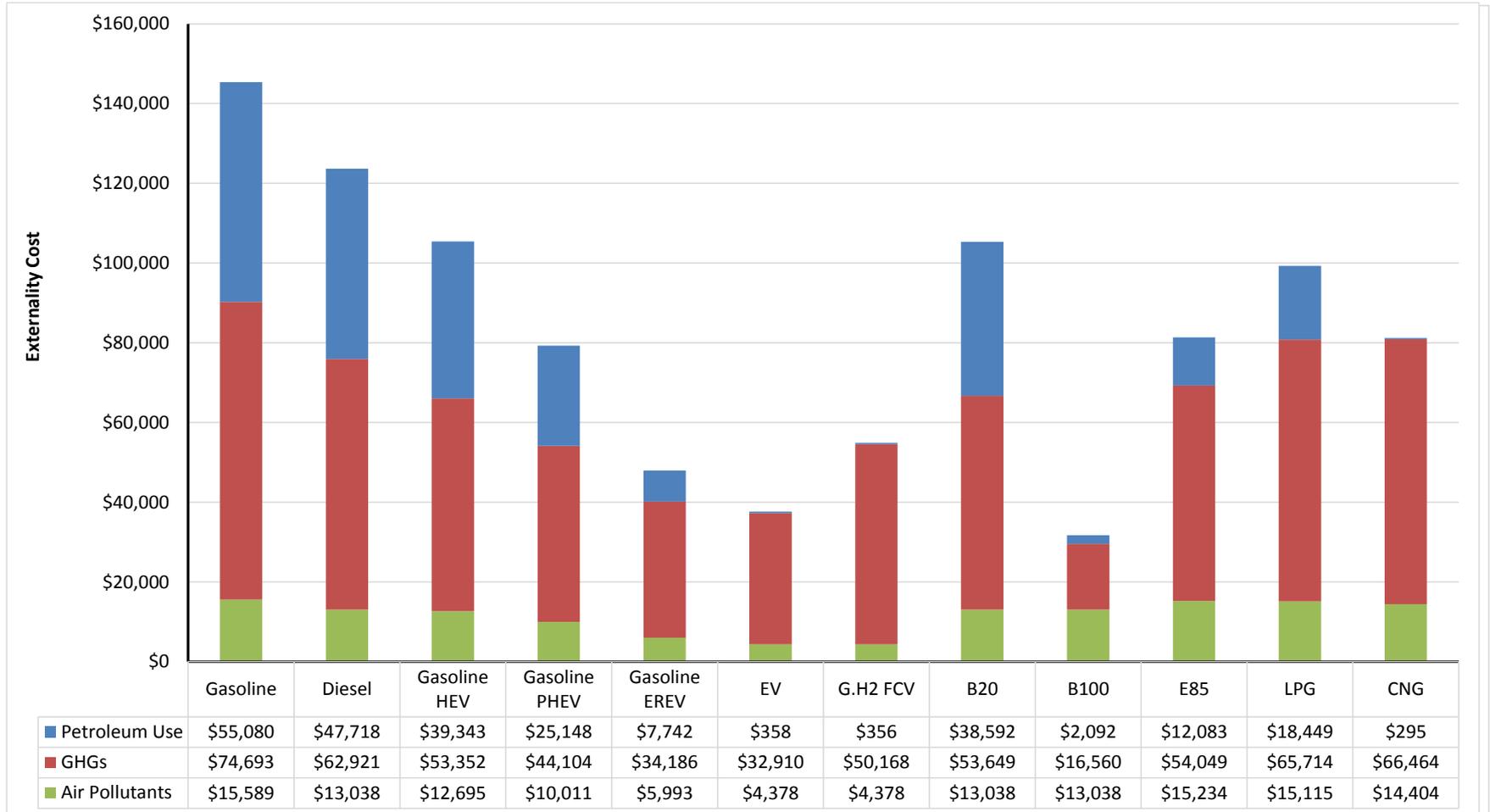
- View results on “Payback Outputs” sheet



Note: Several fuels are not shown for clarity in this presentation

AFLEET TUTORIAL – SIMPLE PAYBACK AND TCO CALCULATORS

- View results on “TCO Outputs” sheet



Note: Several fuels are not shown for clarity in this presentation