User Guide for AFLEET Tool 2013

by
A. Burnham
Systems Assessment Group
Energy Systems Division, Argonne National Laboratory

October 2013

CONTENTS

FIGURES

ACKNOWLEDGEMENTS

This work was supported by the Vehicle Technologies Office, U.S. Department of Energy. The author gratefully thanks Linda Bluestein and Dennis Smith of Clean Cities for their sponsorship and technical guidance. Thanks are extended to Marcy Rood Werpy, Linda Gaines, Dan Santini, Marianne Mintz, Anant Vyas, Tom Stephens, Yan Zhou, and Michael Wang of Argonne National Laboratory for their comments. In addition, the author thanks all the external reviewers of the tool. Finally, special thanks to Ashwini Bharatkumar and Dana Johnson for their help developing the tool. The author is responsible for this work and not the U.S. Department of Energy, Argonne National Laboratory, nor the reviewers.

NOTATION

Acronyms and Abbreviations

AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation
AFV	alternative fuel vehicle
Argonne	Argonne National Laboratory
B100	blend of 100% biodiesel by volume
B20	blend of 20% biodiesel and 80% diesel by volume
CD	charge depleting
CNG	compressed natural gas
CO	carbon monoxide
DEF	diesel exhaust fluid
DOE	U.S. Department of Energy
E85	blend of 85% ethanol and 15% gasoline by volume
EPA	Environmental Protection Agency
EREV	extended range electric vehicle
EV	all-electric vehicle
GHG	greenhouse gas
GREET	Greenhouse gases, Regulated Emissions, and Energy Use in Transportation
HDV	heavy-duty vehicle
HEV	hybrid electric vehicle
HHV	hydraulic hybrid vehicle
LDV	light-duty vehicle
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MOVES	Motor Vehicle Emission Simulator
NO_x	nitrogen oxides
PHEV	plug-in hybrid electric vehicle
PM_{10}	particulate matter with a diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with a diameter of 2.5 micrometers or less
PTW	pump-to-wheels
TBW	tire and brake wear
TCO	total cost of ownership

VOC	volatile organic compound
WTP	well-to-pump
WTW	well-to-wheels

Units of Measure

mpdge	mile(s) per diesel gallon equivalent
mpgge	mile(s) per gasoline gallon equivalent

User Guide for AFLEET Tool 2013

Andrew Burnham

Center for Transportation Research
Argonne National Laboratory

October 2013

1. BACKGROUND

Beginning in 1998, the Department of Energy's (DOE's) Clean Cities program enlisted expertise at Argonne National Laboratory (Argonne) to develop a U.S. Environmental Protection Agency (EPA) co-sponsored tool to assist metropolitan areas and Clean Cities coalitions in estimating criteria air pollutant reductions achieved by near-term introduction of alternative-fueled vehicles. Known as AirCRED, the tool was designed to be used by stakeholders of DOE's Clean Cities program to assist state and regional air quality officials with developing ozone precursor and carbon monoxide emission reduction strategies for use in State Implementation Plans. In 2009, DOE requested Argonne to develop a calculator to measure the petroleum displacement and greenhouse gas (GHG) emissions of medium- and heavy-duty alternative fuel vehicles and off-road equipment. Known as the GREET Fleet Footprint Calculator, this tool was developed for Clean Cities stakeholders to estimate these values using simple spreadsheet inputs.

Now in accordance with the desire to measure both the environmental and economic costs and benefits of alternative fuel and advanced vehicles (AFVs), Argonne has developed the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. Building on both AirCRED and GREET Fleet, AFLEET Tool allows Clean Cities stakeholders to estimate life-cycle petroleum use, life-cycle greenhouse gas emissions, vehicle operation air pollutant emissions, and costs of ownership for light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs). AFLEET Tool provides three calculation methods depending on the user's goals.

The first option is the Simple Payback Calculator that examines acquisition and annual operating costs to calculate a simple payback for purchasing a new AFV as compared to its conventional counterpart, as well as average annual petroleum use, GHGs, and air pollutant emissions. The second option is the Total Cost of Ownership (TCO) Calculator that evaluates the net present value of operating and fixed costs over the years of planned ownership of a new vehicle, as well as lifetime petroleum use, GHGs, and air pollutant emissions. Finally, the Fleet Energy and Emissions Footprint Calculator estimates the annual petroleum use, GHGs, and air pollutant emissions of existing and new vehicles, taking into consideration that older vehicles typically have higher air pollutant emission rates than newer ones.

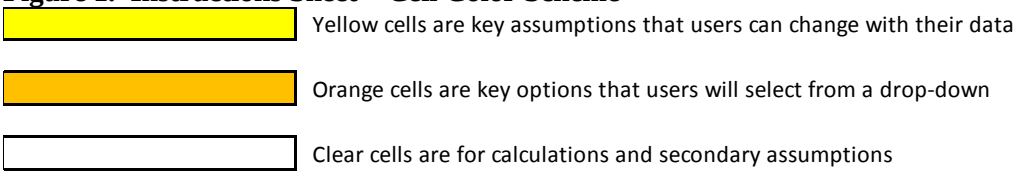
2. DESCRIPTION OF AFLEET TOOL

There are nine Microsoft® Excel sheets in the calculator, which are explained below.

2.1 Instructions Sheet

This sheet contains the software copyright notice and it presents a brief summary of cell types (Figure 1) and other worksheets in AFLEET Tool.

Figure 1. Instructions Sheet – Cell Color Scheme



2.2 Inputs Sheet

The essential user inputs (Figure 2) for both the Simple Payback and Total Cost of Ownership calculators (the Fleet Energy and Emissions Footprint Calculator also uses the specified vehicle location for its air pollutant calculations) are:

- **primary vehicle location (state)**
- **vehicle type**
- **vehicle fuel type**
- **number of vehicles**
- **annual vehicle mileage**
- **fuel economy**
- **vehicle purchase price**
- **fuel and diesel emission fluid (DEF) price**.

Argonne has provided default data for many inputs in AFLEET Tool; however, it is highly recommended that users enter their own data whenever possible. However, the user must enter the number of vehicles to be compared as the default is set to zero. When estimating a simple payback, the user must enter data for both the AFVs and their conventional counterpart (e.g. gasoline vehicle for LDVs and diesel vehicle for HDVs). When entering their own data, users need to enter the fuel economy values on a mile per gasoline gallon equivalent (mpgge) basis for both LDVs and HDVs. As a mile per diesel gallon equivalent (mpdge) fuel economy is often used for HDVs, we provide an estimated mpdge value to the right of the key inputs table to help with any conversion needed.

Figure 2. Inputs Sheet - Key Inputs

Primary Vehicle Location				
State	ILLINOIS			
Light-Duty Vehicle Information				
Vehicle Type	Passenger Car			
Light-Duty Fuel Type	**Number of Light-Duty Vehicles**	**Annual Vehicle Mileage**	**Fuel Economy (MPGGE)**	**Purchase Price ($/Vehicle)**
Gasoline	0	12,400	26.7	$20,000
Diesel	0	12,400	32.0	$22,500
Gasoline HEV	0	12,400	37.4	$28,000
Gasoline PHEV	0	12,400	41.5	$33,000
Gasoline EREV	0	12,400	31.5	$35,000
EV	0	12,400	90.8	$37,500
Biodiesel (B20)	0	12,400	32.0	$22,500
Biodiesel (B100)	0	12,400	32.0	$22,500
Ethanol (E85)	0	12,400	26.7	$20,000
Propane (LPG)	0	12,400	26.7	$26,000
Compressed Natural Gas (CNG)	0	12,400	25.4	$27,000
Heavy-Duty Vehicle Information				
Vehicle Type	Combination Long-Haul Truck			
Heavy-Duty Fuel Type	**Number of Heavy-Duty Vehicles**	**Annual Vehicle Mileage**	**Fuel Economy (MPGGE)**	**Purchase Price ($/Vehicle)**
Gasoline	0	0	4.3	$0
Diesel	0	170,000	5.2	$100,000
EV	0	0	14.7	$0
Diesel HEV	0	170,000	5.5	$140,000
Diesel Hydraulic Hybrid	0	0	5.2	$0
Biodiesel (B20)	0	170,000	5.2	$100,000
Biodiesel (B100)	0	170,000	5.2	$100,000
Ethanol (E85)	0	0	4.3	$0
Propane (LPG)	0	0	4.7	$0
Compressed Natural Gas (CNG)	0	170,000	4.7	$165,000
Liquefied Natural Gas (LNG)	0	170,000	4.7	$150,000
LNG / Diesel Pilot Ignition	0	170,000	5.2	$190,000

Fuel and DEF Price	Fuel Unit	$/Fuel Unit
Gasoline	gasoline gallon	$3.56
Diesel	diesel gallon	$4.11
Electricity	kWh	$0.11
B20	B20 gallon	$4.16
B100	B100 gallon	$4.55
E85	E85 gallon	$3.40
Propane	LPG gallon	$2.91
CNG	CNG GGE	$2.21
LNG	LNG gallon	$1.53
DEF	DEF gallon	$2.80

The vehicle types in AFLEET Tool are based on EPA's Motor Vehicle Emission Simulator (MOVES) as this allows the tool to estimate vehicle operation (e.g. tailpipe, brake and tire wear) emissions for various vehicle vocations (EPA 2013a). Each vehicle type has default vocational data that populate the cells. This information is available in lookup tables on the Background Data sheet. As discussed in Section 2.9 of this document, a user can click the blue hyperlink for "Vehicle Type" and modify the default vocation type using the dropdown boxes. The current light-duty vehicle types available in AFLEET Tool are:

- **passenger car** (four wheel, two axle vehicle whose primary function is passenger transport)

- **passenger truck** (four wheel, two axle vehicle whose primary functional design is for cargo, but are used primarily for passenger transport)
- **light commercial truck** (four wheel, two axle vehicle used primarily for cargo transport).

While the heavy-duty vehicle types are:

- **school bus** (passenger vehicle with a capacity of 15 or more persons used primarily for transport of students for school)
- **transit bus** (passenger vehicle with a capacity of 15 or more persons primarily used for transport within cities)
- **refuse truck** (truck primarily used to haul refuse to a central location)
- **single unit short-haul truck** (single unit truck with more than four tires with a range of operation of up to 200 miles)
- **single unit long-haul truck** (single unit truck with more than four tires with a range of operation of over 200 miles)
- **combination short-haul truck** (combination tractor/trailer truck with more than four tires with a range of operation of up to 200 miles)
- **combination long-haul truck** (combination tractor/trailer truck with more than four tires with a range of operation of over 200 miles).

The current light-duty vehicle fuel types available in AFLEET Tool are:

- **gasoline**
- **diesel**
- **gasoline hybrid electric vehicle (HEV)**
- **gasoline plug-in hybrid electric vehicle (PHEV)**
- **gasoline extended range electric vehicle (EREV)**
- **all-electric vehicle (EV)**
- **biodiesel 20% blend (B20)**
- **biodiesel 100% blend (B100)**
- **ethanol flex-fuel 85% blend (E85)**
- **propane / liquefied petroleum gas (LPG)**
- **compressed natural gas (CNG)**.

While the heavy-duty vehicle fuel types are:

- **gasoline**
- **diesel**
- **EV**
- **diesel HEV**
- **diesel hydraulic hybrid vehicle (HHV)**
- **B20**
- **B100**
- **E85**
- **LPG**
- **CNG**
- **liquefied natural gas (LNG)**

- **liquefied natural gas / diesel pilot ignition**.

If one wants to perform TCO calculations (Figure 3), the user can modify the:

- **planned years of ownership**
- **whether vehicle purchase is financed by a loan**
- **loan term**
- **loan interest rate**
- **discount factor**.

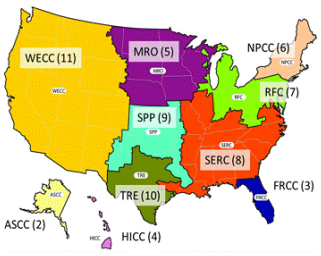
Figure 3. Inputs Sheet - Total Cost of Ownership Inputs

Light-Duty Vehicle Information		
Years of Planned Ownership	years	16
Heavy-Duty Vehicle Information		
Years of Planned Ownership	years	28
Financial Assumptions		
Loan	yes/no	No
Loan Term	years	5
Interest Rate	%	4.14%
Percent Down Payment	%	0.00%
Discount Factor	%	0.79%

The user can also modify the fuel production assumptions (Figure 4), which will impact the petroleum use and GHG calculations. For instance, a user can compare the footprint of ethanol vehicles using either a corn or cellulosic feedstock. A user who wants to enter a custom electricity generation mix will need to go to Background Data sheet. If one clicks the blue hyperlink for the "12 – User Defined" mix in the fuel production assumptions table, the user will be taken to the correct cells to enter the new values.

Figure 4. Inputs Sheet – Fuel Production Assumptions

Biodiesel Feedstock Source	1 - Soy 2 - Algae	1	
Ethanol Feedstock Source	1 - Corn 2 - Switchgrass	1	
CNG Feedstock Source	1 - North American NG 2 - Non-North American NG 3 - Landfill Gas	1	
LNG Feedstock Source	1 - North American NG 2 - Non-North American NG 3 - Landfill Gas	1	
North American NG Feedstock Source		Conventional 66%	Shale 34%
LPG Feedstock Source		NG 69%	Petroleum 31%
Source of Electricity for Plug-in Hybrid Electric Vehicles (PHEVs) and All-Electric Vehicles (EVs)			
	1 - Average U.S. Mix	1	
	2 to 11 - EIA Region Mix (see map)		
	12 - User Defined (go to 'Background Data' sheet)		



2.3 Payback Sheet

This sheet contains the Simple Payback Calculator, which examines acquisition and annual operating costs as well as average annual petroleum use, GHGs, and air pollutant emissions. The vehicle operation air pollutant emissions calculated are:

- **carbon monoxide (CO)** from tailpipe
- **nitrogen oxides (NO_x)** from tailpipe
- **particulate matter with a diameter of 10 micrometers or less (PM_{10})** from tailpipe and tire and brake wear (TBW)
- **particulate matter with a diameter of 2.5 micrometers or less ($PM_{2.5}$)** from tailpipe and TBW
- **VOCs (volatile organic compounds)** from tailpipe and evaporation.

Key assumptions for light-duty vehicles, heavy-duty vehicles, and fuel price from the Inputs sheet are fed into the first three tables in the Payback sheet (Figure 5). Additional user inputs can be modified on this sheet for the fuel consumption of charge depleting (CD) operation of PHEVs and EREVs, vehicle purchase incentive, maintenance and repair cost per mile, share of LNG fuel use in a LNG diesel pilot ignition vehicle, and DEF consumption.

Figure 5. Payback Sheet – LDVs, HDVs, and Fuel Inputs

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel Hydraulic Hybrid	Biodiesel (B20)	Biodiesel (B100)	Ethanol (E85)	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	LNG / Diesel Pilot Ignition
Light-Duty Vehicle Inputs															
Vehicle Type	Passenger Car														
Number of LDVs	10	0	10	10	10	10			0	0	10	0	10		
Annual Mileage	12,400	12,400	12,400	12,400	12,400	12,400			12,400	12,400	12,400	12,400	12,400		
Fuel Economy (MPGGE)	26.7	32.0	37.4	41.4	31.5	90.8			32.0	32.0	26.7	26.7	25.4		
Fuel Consumption (GGE/100mi)	3.7	3.1	2.7	2.4	3.2	1.1	0.0	0.0	3.1	3.1	3.7	3.7	3.9		
CD Electricity Use (kWh/100mi)				22.6	33.6	36.2									
CD Electricity Use (GGE/100mi)				0.7	1.0										
CD Gasoline Use (GGE/100mi)				1.4	0.0										
PHEV CD Range (miles)				10.9	33.1										
Charges/day				1.0	1.0										
Days driven/week				5	5										
Share of CD miles				23%	70%										
Purchase Price ($/vehicle)	$20,000	$22,500	$28,000	$33,000	$35,000	$37,500			$22,500	$22,500	$20,000	$26,000	$27,000		
Incentive ($/vehicle)	$0	$0	$0	$0	$0	$0			$0	$0	$0	$0	$0		
Maintenance & Repair ($/mile)	$0.14	$0.19	$0.14	$0.13	$0.13	$0.13			$0.19	$0.19	$0.14	$0.14	$0.14		
Heavy-Duty Vehicle Inputs															
Vehicle Type	Combination Long-Haul Truck														
Number of HDVs	0	10				0	0	0	10	0	0	0	10	10	10
Annual Mileage	0	170,000				0	170,000	0	170,000	170,000	0	0	170,000	170,000	170,000
Fuel Economy (MPGGE)	4.3	5.2				14.7	5.5	5.2	5.2	5.2	4.3	4.7	4.7	4.7	5.2
Fuel Consumption (GGE/100mi)	23.1	19.2				6.8	18.1	19.2	19.2	19.2	23.1	21.4	21.4	21.4	19.2
Fuel Consumption (DGE/100mi)	20.3	17.0				6.0	15.9	17.0	17.0	17.0	20.3	18.8	18.8	18.8	17.0
CD Electricity Use (kWh/100mi)						223.4									
Share of LNG Fuel Use (energy %)															95%
DEF Use (% of fuel consumption)	0%	2%				2%	2%	2%	2%	2%	0%	0%	0%	0%	2%
Purchase Price ($/vehicle)	$0	$100,000				$0	$140,000	$0	$100,000	$100,000	$0	$0	$165,000	$150,000	$190,000
Incentive ($/vehicle)	$0	$0				$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance & Repair ($/mile)	$0.00	$0.19				$0.17	$0.18	$0.18	$0.19	$0.19	$0.00	$0.00	$0.19	$0.19	$0.20

On the Inputs sheet, the user can enter the charge sustaining (i.e. hybrid mode) fuel economy of PHEVs and EREVs. While on the Payback sheet, users will need to examine further inputs to make sure they are properly analyzing these vehicles. These include the CD electricity and fuel consumption, CD operating range, charges per day, and days driven per week, which are all used to estimate the amount of electricity and gasoline used by these vehicles.

The electricity and fuel use inputs for CD operation of PHEVs and EREVs are on a fuel consumption basis (i.e. electricity and gasoline per 100 miles driven, instead of miles per gallon). These values will be found on FuelEconomy.gov on this basis. CD operation (i.e. EV mode)

occurs when the vehicle is dependent on the using the battery for operation and the battery's state of charge depletes. In AFLEET Tool, we allow the user to separately simulate PHEVs and EREVs. While an EREV is a type of PHEV, the key difference that we used to differentiate them for AFLEET Tool is that an EREV operates all electrically until the battery is depleted and will typically have a large battery pack than a PHEV. With current battery technology, PHEVs other than EREVs typically operate in blended CD mode, which is when the battery's energy is primarily used to drive the vehicle but the engine may turn on to assist driving the vehicle (e.g. during hard accelerations). Therefore, PHEVs may have CD gasoline use, while EREVs will not.

Default maintenance (scheduled) and repair (unscheduled) costs on a per mile basis are included for each vehicle type. Though again, it is highly recommended that users enter their own data whenever possible as this cost data will depend on the individual fleet/operator. The incremental maintenance and repair cost difference between various vehicle types is typically small as we usually assume similar costs. In some cases, we do calculate differences as hybrids and electric drive vehicles (i.e. PHEVs, EREVs, and EVs) may have reduced brake (and other) costs as compared to conventional vehicles. In addition, incremental maintenance costs for natural gas vehicles, such as CNG tank inspection and increased oil change intervals for heavy-duty natural gas vehicles are included. In this version, we do not include battery replacement costs for hybrids and electric drive vehicles as reliable data for replacement intervals and expected costs are not available at this time. Biodiesel has different cold weather operability as compared to diesel and may require additives or treatments to improve performance. In the current version of AFLEET Tool, no costs for these treatments are included as data was not available.

The share of LNG fuel use in a LNG / diesel pilot ignition vehicle is set to match the performance of the Westport™ high-pressure direct injection system, though other systems will have different performance. Some vehicles use selective catalytic reduction systems to reduce NO_x emissions. These systems require DEF, a urea-based solution, to operate correctly. DEF use is typically estimated as a percent of fuel consumption; users can adjust this value on this sheet. A vehicle purchase incentive can be entered on this sheet or can be included in the purchase price on the Inputs sheet.

The other tables (Figure 6) in this sheet include the calculation for simple payback, petroleum use, GHG emissions, and air pollutant emissions. The calculation for simple payback is based on the acquisition and annual operating costs for a new AFV as compared to its conventional counterpart. Specifically, calculating the years (and miles) needed for the operating savings to payback the higher incremental acquisition cost. In cases where the operating costs for the AFV are higher than the costs of the conventional vehicle, there will be no payback calculated. In AFLEET Tool 2013, only incremental vehicle purchase costs are included for acquisition costs. In the future, we plan to include other acquisition costs like refueling infrastructure and maintenance depot modification.

Figure 6. Payback Sheet – Calculations

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel Hydraulic Hybrid	Biodiesel (B20)	Biodiesel (B100)	Ethanol (E85)	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	LNG / Diesel Pilot Ignition
Acquisition Cost															
Light-Duty (LD) Fleet Cost	$200,000	$0	$280,000	$330,000	$350,000	$375,000	$0	$0	$0	$0	$200,000	$0	$270,000	$0	$0
Heavy-Duty (HD) Fleet Cost	$0	$1,000,000	$0	$0	$0	$0	$0	$0	$1,000,000	$0	$0	$0	$1,650,000	$1,500,000	$1,900,000
Annual Operating Cost															
LD Fuel Cost	$16,533	$0	$11,810	$10,357	$7,555	$5,109	$0	$0	$0	$0	$21,549	$0	$10,804	$0	$0
LD Maintenance Cost	$17,620	$0	$17,046	$16,727	$16,727	$15,526	$0	$0	$0	$0	$17,620	$0	$17,620	$0	$0
HD Fuel Cost	$0	$1,163,846	$0	$0	$0	$0	$0	$0	$1,196,538	$0	$0	$0	$802,778	$831,838	$769,413
HD Diesel Exhaust Fluid Cost	$0	$18,308	$0	$0	$0	$0	$0	$0	$18,308	$0	$0	$0	$0	$0	$18,308
HD Maintenance Cost	$0	$323,000	$0	$0	$0	$0	$0	$0	$323,000	$0	$0	$0	$328,289	$328,289	$333,200
Annual Operating Savings															
Compared to Gasoline LD Fleet			$5,298	$7,069	$9,872	$13,518					-$5,016		$5,729		
Compared to Diesel HD Fleet									-$32,692				$374,087	$345,027	$384,233
Simple Payback															
LD Fleet (miles)			187,254.9	228,033.4	188,417.3	160,521.3					No payback		151,497.4		
LD Fleet (years)			15.1	18.4	15.2	12.9					No payback		12.2		
HD Fleet (miles)									No payback				295,385.7	246,357.3	398,196.2
HD Fleet (years)									No payback				1.7	1.4	2.3
Life-Cycle Petroleum Use (barrels)															
LD Petroleum Use	96.9	0.0	69.2	56.6	25.7	1.2	0.0	0.0	0.0	0.0	21.2	0.0	0.5	0.0	0.0
HD Petroleum Use	0.0	7,268.1	0.0	0.0	0.0	0.0	0.0	0.0	5,905.2	0.0	0.0	0.0	38.5	88.3	416.4
Life-Cycle Greenhouse Gas (GHG) Emissions (short tons)															
LD GHG Emissions	56.0	0.0	40.0	36.8	33.2	29.1	0.0	0.0	0.0	0.0	41.5	0.0	48.1	0.0	0.0
HD GHG Emissions	0.0	4,107.9	0.0	0.0	0.0	0.0	0.0	0.0	3,484.6	0.0	0.0	0.0	3,576.3	3,555.9	3,237.2
Vehicle Operation Air Pollutant Emissions (lb)															
Light-Duty Vehicle Type	Passenger Car														
CO	752.0	0.0	563.3	508.4	171.3				0.0	0.0	468.9	0.0	544.3		
NOx	27.1	0.0	17.4	15.7	5.3				0.0	0.0	17.7	0.0	22.6		
PM10	1.8	0.0	1.8	1.6	0.5				0.0	0.0	1.8	0.0	1.8		
PM10 (TBW)	5.5	0.0	5.5	5.5	5.5	5.5			0.0	0.0	5.5	0.0	5.5		
PM2.5	1.7	0.0	1.7	1.6	0.5				0.0	0.0	1.7	0.0	1.7		
PM2.5 (TBW)	1.4	0.0	1.4	1.4	1.4	1.4			0.0	0.0	1.4	0.0	1.4		
VOC	23.9	0.0	16.2	14.6	4.9				0.0	0.0	22.5	0.0	14.0		
VOC (Evap)	8.2	0.0	8.2	7.4	2.5				0.0	0.0	7.0	0.0	4.1		
Heavy-Duty Vehicle Type	Combination Long-Haul Truck														
CO	#N/A	8,073.1					0.0	0.0	8,073.1	0.0	#N/A	#N/A	124,325.5	124,325.5	1,614.6
NOx	#N/A	24,169.4					0.0	0.0	24,169.4	0.0	#N/A	#N/A	14,501.6	14,501.6	14,501.6
PM10	#N/A	165.2					0.0	0.0	165.2	0.0	#N/A	#N/A	165.2	165.2	165.2
PM10 (TBW)	#N/A	311.1				0.0	0.0	0.0	311.1	0.0	#N/A	#N/A	311.1	311.1	311.1
PM2.5	#N/A	160.5					0.0	0.0	160.5	0.0	#N/A	#N/A	160.5	160.5	160.5
PM2.5 (TBW)	#N/A	78.7				0.0	0.0	0.0	78.7	0.0	#N/A	#N/A	78.7	78.7	78.7
VOC	#N/A	1,999.9					0.0	0.0	1,999.9	0.0	#N/A	#N/A	6,499.5	6,499.5	799.9
VOC (Evap)	#N/A	0.0					0.0	0.0	0.0	0.0	#N/A	#N/A	61.8	61.8	61.8

The petroleum use and GHG calculations are both well-to-wheels (WTW) (i.e. life-cycle) estimates and similar to those in the GREET Fleet tool. The basis of these calculations is Argonne's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) fuel-cycle model, which is used to generate necessary petroleum use and GHG emission co-efficients (Argonne 2013). A WTW analysis can be divided into two stages: well-to-pump (WTP) and pump-to-wheels (PTW). The WTP stage starts with the fuel feedstock recovery, followed by fuel production, and ends with the fuel available at the pump, while the PTW stage represents the vehicle's operation activities. It is important to examine petroleum use and GHG emissions of transportation fuels and technologies on a WTW basis in order to properly compare alternatives, as activities upstream of vehicle operation can use significant amounts of energy and subsequently produce a large amount of emissions. The location of where the petroleum is used or GHGs are emitted does not significantly alter their impacts.

However, for air pollutants the location where they are emitted does play a major role as they impact local air quality. Thus, air quality management organizations and other Clean Cities stakeholders are primarily interested in vehicle operation emissions, as WTP emissions often occur a significant distance from where the vehicle is used. For those interested in WTP air pollutant emissions, see the GREET fuel-cycle model. The calculation methodology for these emissions is based on Argonne's AirCRED tool. EPA's MOVES is used to generate emission factors by state for gasoline and diesel vehicle types. In some cases, there are no emissions data for vehicles as they are not available in the marketplace (e.g. no gasoline refuse or combination trucks) and therefore in AFLEET Tool the calculation will show the not applicable error sign "#N/A".

The state emission factors used in the emission calculations are based on a new vehicle (model year 2014 for AFLEET Tool 2013). However, for the annual calculations used in this sheet we used a deterioration rate from MOVES for a 5-year-old vehicle, as emission rates increase as a vehicle ages. Argonne's VISION model, which uses National Highway Traffic Safety Administration data, shows that on average, both LDVs and HDVs reach the midpoint of its lifetime based on VMT at this age (vehicles are driven more miles per year earlier in their life). As there is limited data for AFV emission rates, we cannot use MOVES simulations to directly calculate them. Following the AirCRED methodology, we develop "AFV multipliers" for each pollutant based on EPA light-duty vehicle (EPA 2013b) and heavy-duty engine (EPA 2013c) certification tailpipe emission data and the GREET model's evaporation data.

2.4 Payback Outputs Sheet

This sheet summarizes the outputs of the Simple Payback Calculator with tables and graphs for costs, petroleum use, GHGs, and air pollutant emissions. In the cost and energy use and emissions tables (Figures 7-8), both LDVs and HDVs are included, while LDV and HDV energy use and emissions are presented separately in the graphs (Figures 9-12). The following figures are shown as an example of the outputs generated; a user's results will vary depending on the specific inputs used.

Figure 7. Payback Outputs Sheet – Annual Costs Summary Table

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel Hydraulic Hybrid (HHV)	Biodiesel (B20)	Biodiesel (B100)	Ethanol (E85)	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	LNG / Diesel Pilot Ignition
Acquisition Cost															
Light-Duty (LD) Fleet	$200,000		$280,000	$330,000	$350,000	$375,000					$200,000		$270,000		
Heavy-Duty (HD) Fleet		$1,000,000							$1,000,000				$1,650,000	$1,500,000	$1,900,000
Annual Operating Cost															
LD Fuel Cost	$16,533		$11,810	$10,357	$7,555	$5,109					$21,549		$10,804		
LD Maintenance Cost	$17,620		$17,046	$16,727	$16,727	$15,526					$17,620		$17,620		
HD Fuel Cost		$1,163,846							$1,196,538				$802,778	$831,838	$769,413
HD Diesel Exhaust Fluid Cost		$18,308							$18,308				$0	$0	$18,308
HD Maintenance Cost		$323,000							$323,000				$328,289	$328,289	$333,200
Incremental Acquisition Cost															
Compared to Gasoline LD Fleet			$80,000	$130,000	$150,000	$175,000					$0		$70,000		
Compared to Diesel HD Fleet									$0				$650,000	$500,000	$900,000
Annual Operating Savings															
Compared to Gasoline LD Fleet			$5,298	$7,069	$9,872	$13,518					-$5,016		$5,729		
Compared to Diesel HD Fleet									-$32,692				$374,087	$345,027	$384,233
Simple Payback (years)															
Light-Duty Fleet			**15.1**	**18.4**	**15.2**	**12.9**					**No payback**		**12.2**		
Heavy-Duty Fleet									**No payback**				**1.7**	**1.4**	**2.3**

Figure 8. Payback Outputs Sheet – Annual Energy Use and Emissions Summary Table

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
Annual Life-Cycle Petroleum Use (barrels)															
LD Petroleum Use	96.9		69.2	56.6	25.7	1.2					21.2		0.5		
HD Petroleum Use		7,268.1							5,905.2				38.5	88.3	416.4
Annual Life-Cycle Greenhouse Gas Emissions (short tons)															
LD GHG Emissions	56.0		40.0	36.8	33.2	29.1					41.5		48.1		
HD GHG Emissions		4,107.9							3,484.6				3,576.3	3,555.9	3,237.2
Vehicle Operation Air Pollutant Emissions (lb)															
Light-Duty Fleet															
CO	752.0		563.3	508.4	171.3	0.0					468.9		544.3		
NOx	27.1		17.4	15.7	5.3	0.0					17.7		22.6		
PM10	7.3		7.3	7.1	6.1	5.5					7.3		7.3		
PM2.5	3.1		3.1	2.9	1.9	1.4					3.1		3.1		
VOC	32.1		24.4	22.0	7.4	0.0					29.4		18.1		
Heavy-Duty Fleet															
CO		8,073.1							8,073.1				124,325.5	124,325.5	1,614.6
NOx		24,169.4							24,169.4				14,501.6	14,501.6	14,501.6
PM10		476.3							476.3				476.3	476.3	476.3
PM2.5		239.2							239.2				239.2	239.2	239.2
VOC		1,999.9							1,999.9				6,561.4	6,561.4	861.8

Figure 9. Payback Outputs Sheet – Annual LDV Energy Use and GHGs Summary Graph

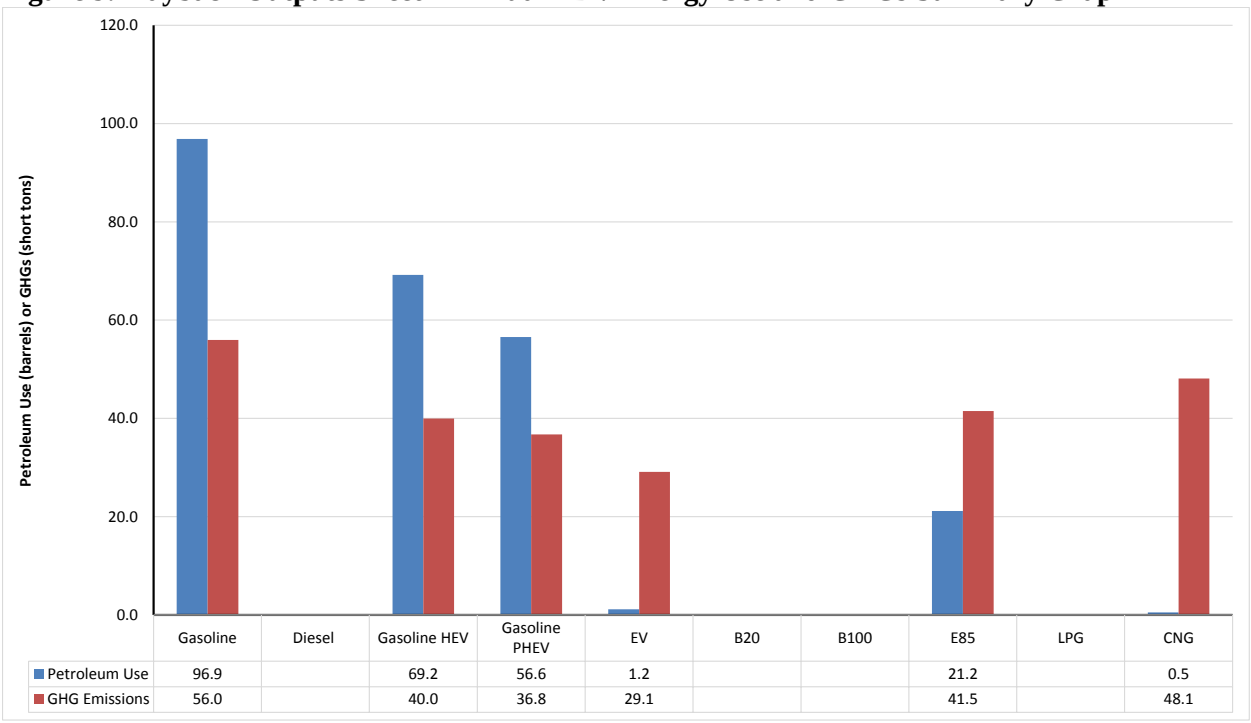
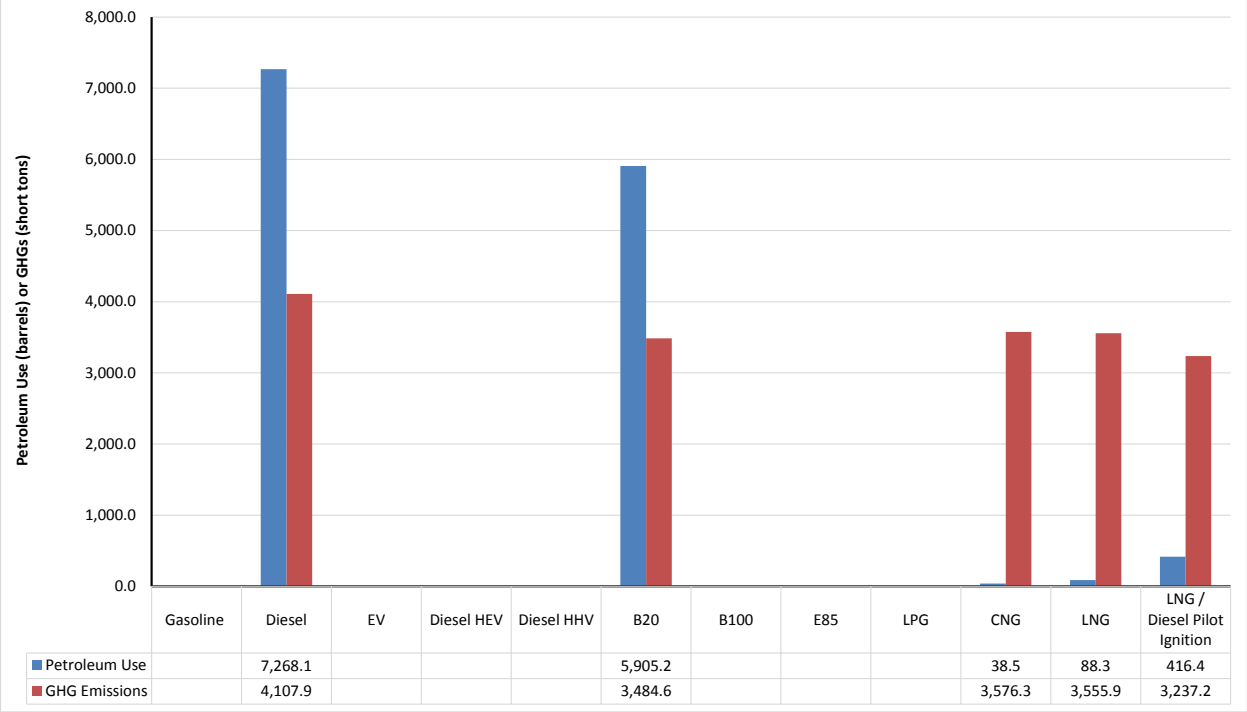
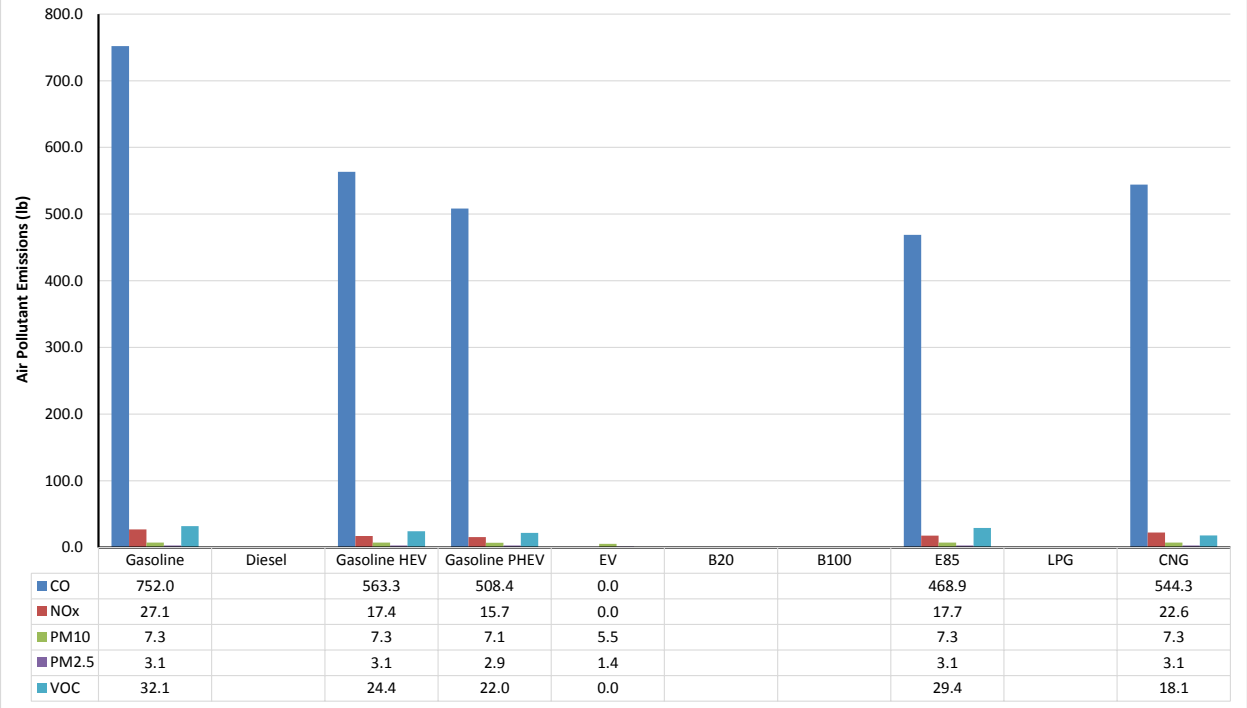


Figure 10. Payback Outputs Sheet – Annual HDV Energy Use and GHGs Summary Graph



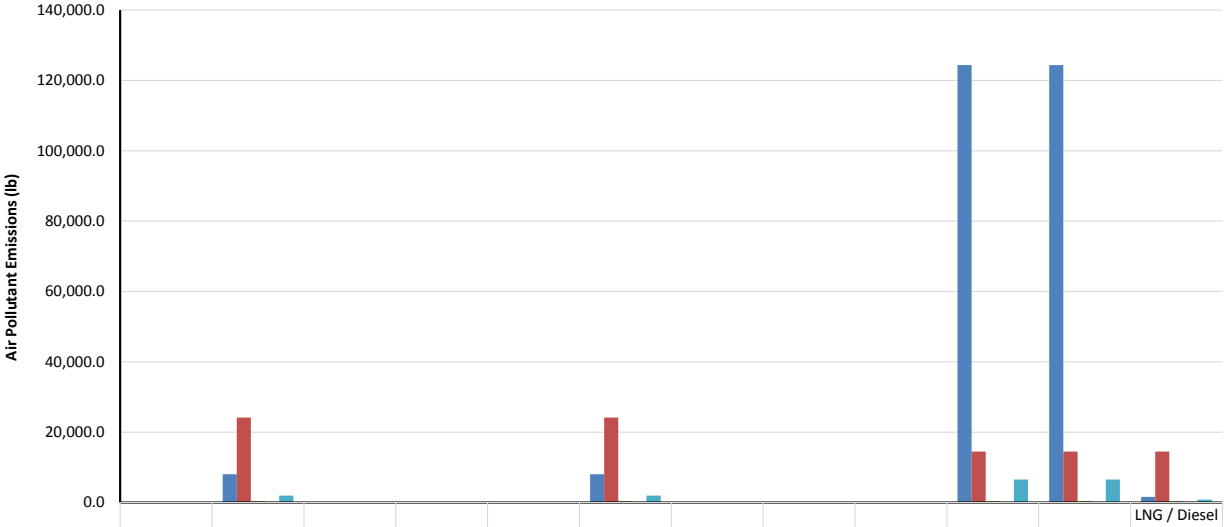
	Gasoline	Diesel	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
Petroleum Use		7,268.1				5,905.2				38.5	88.3	416.4
GHG Emissions		4,107.9				3,484.6				3,576.3	3,555.9	3,237.2

Figure 11. Payback Outputs Sheet – Annual LDV Air Pollutant Emissions Summary Graph



	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	EV	B20	B100	E85	LPG	CNG
CO	752.0		563.3	508.4	0.0			468.9		544.3
NOx	27.1		17.4	15.7	0.0			17.7		22.6
PM10	7.3		7.3	7.1	5.5			7.3		7.3
PM2.5	3.1		3.1	2.9	1.4			3.1		3.1
VOC	32.1		24.4	22.0	0.0			29.4		18.1

Figure 12. Payback Outputs Sheet – Annual HDV Air Pollutant Emissions Summary Graph



	Gasoline	Diesel	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
CO		8,073.1				8,073.1				124,325.5	124,325.5	1,614.6
NOx		24,169.4				24,169.4				14,501.6	14,501.6	14,501.6
PM10		476.3				476.3				476.3	476.3	476.3
PM2.5		239.2				239.2				239.2	239.2	239.2
VOC		1,999.9				1,999.9				6,561.4	6,561.4	861.8

2.5 TCO Sheet

This sheet contains the Total Cost of Ownership Calculator, which evaluates the net present value of operating and fixed costs over the years of planned ownership of a new vehicle, as well as lifetime petroleum use, GHGs, and air pollutant emissions. There are no key user inputs on the TCO sheet as all the data is based on user inputs from the Inputs and Payback sheets. An advanced user may want to modify the mileage per year assumptions as typically vehicles are driven more miles per year earlier in their life. The sheet includes both LDVs and HDVs; the user can use the hyperlinks at the top of the page as this sheet is very long.

The structure of the TCO calculations is to look at the operating and fixed costs on an annual basis for every year of planned ownership of a new vehicle purchase (Figures 13 and 15, several project year columns are not shown for clarity sake). This sheet has more detailed cost calculations as compared to the Simple Payback Calculator. It includes the costs of financing a loan, depreciation, insurance, license, and registration, in addition to the operating and acquisition costs. Using assumptions of inflation for various costs and a discount rate, a user can calculate the net present value of a vehicle purchase. In addition, lifetime petroleum use, GHGs, and air pollutant emissions are also calculated (Figures 14 and 16). The difference in these calculations as compared to those on the Payback sheet is that these look at the actual air pollutant deterioration rate of a vehicle as it ages instead of using a deterioration rate for an average vehicle's midpoint lifetime.

Figure 13. TCO Sheet – LDV Characteristics and Cost Calculations

		Project Year	1	2	3	4	5
Total Cost of Ownership - Light-Duty							
Gasoline Passenger Car							
Gasoline Passenger Car Characteristics							
Number of Vehicles Purchased			10				
Annual Mileage	miles/vehicle		12,400	12,400	12,400	12,400	12,400
Fuel Economy	MPGGE		26.7	26.7	26.7	26.7	26.7
Fuel Usage	GGE/vehicle		464	464	464	464	464
Gasoline Passenger Car Acquisition Cost							
Purchase Price	$/vehicle		$20,000				
Incentive	$/vehicle		$0				
Total Purchase Price of Vehicle(s)	$/fleet		$200,000				
Total Incentives	$/fleet		$0				
Total Net Price of Vehicle(s)	$/fleet		$200,000				
Down Payment	$/fleet		$0				
Loan Amount	$/fleet		$0				
Fixed Costs - Annual Gasoline Passenger Car Fleet Acquisition							
Credit	$/year		$0				
Down Payment	$/year		$200,000				
Interest Payment	$/year		$0	$0	$0	$0	$0
Principal Payment	$/year		$0	$0	$0	$0	$0
Total Loan Payment	$/year		$0	$0	$0	$0	$0
Total Acquisition Costs	**$/year**		**$200,000**	**$0**	**$0**	**$0**	**$0**
Fixed Costs - Annual Gasoline Passenger Car Fleet Depreciation							
Resale Value	$/year		$154,000	$130,900	$111,265	$94,575	$80,389
Depreciation Cost	**$/year**		**$46,000**	**$23,100**	**$19,635**	**$16,690**	**$14,186**
Fixed Costs - Annual Gasoline Passenger Car Fleet Insurance and Licensing							
Insurance	$/year		$9,930	$10,151	$10,378	$10,609	$10,846
License and Registration	$/year		$1,075	$1,099	$1,123	$1,149	$1,174
Total Insurance & Licensing Costs	**$/year**		**$11,005**	**$11,250**	**$11,501**	**$11,758**	**$12,020**
Operating Costs - Gasoline Passenger Car Fleet							
Fuel Cost	$/year		$16,533	$16,591	$16,649	$16,708	$16,766
	$/mile		$0.13	$0.13	$0.13	$0.13	$0.14
Maintenance and Repair Cost	$/year		$17,620	$18,013	$18,415	$18,825	$19,245
	$/mile		$0.14	$0.15	$0.15	$0.15	$0.16
Total Operating Costs	**$/year**		**$34,153**	**$34,604**	**$35,064**	**$35,533**	**$36,011**
Annual Net Cash Flow	**$/year**		**-$245,158**	**-$45,855**	**-$46,565**	**-$47,291**	**-$48,031**
Discounted Cash Flow	**$/year**		**-$245,158**	**-$45,495**	**-$45,838**	**-$46,187**	**-$46,543**
Net Present Value (NPV)		**-$954,597**					
Total Cost of Ownership Summary - Per Lifetime Ownership of Gasoline Passenger Car Fleet							
Financing		**$0**	$0	$0	$0	$0	$0
Depreciation		**$188,045**	$0	$0	$0	$0	$0
Fuel		**$256,046**	$16,533	$16,461	$16,389	$16,318	$16,247
Maintenance and Repair		**$314,239**	$17,620	$17,872	$18,127	$18,386	$18,649
Insurance		**$177,094**	$9,930	$10,072	$10,216	$10,362	$10,510
License and Registration		**$19,172**	$1,075	$1,090	$1,106	$1,122	$1,138
Total Cost of Ownership		**$954,597**					

Figure 14. TCO Sheet – LDV Energy Use and Emissions Calculations

Project Year	1	2	3	4	5
Total Cost of Ownership - Light-Duty					
Gasoline Passenger Car					

Annual Gasoline Passenger Car Fleet Life-Cycle Petroleum Use, Life-Cycle Greenhouse Gas Emissions, and Vehicle Operation Air Pollutant Emissions

Petroleum Use	barrels/year	96.9	96.9	96.9	96.9	96.9
GHG	short ton/year	56.0	56.0	56.0	56.0	56.0
CO	lb/year	423.9	413.4	415.3	746.8	752.0
NOx	lb/year	17.8	16.8	16.9	26.8	27.1
PM10	lb/year	1.4	1.4	1.4	1.8	1.8
PM10 (TBW)	lb/year	5.5	5.5	5.5	5.5	5.5
PM2.5	lb/year	1.3	1.4	1.4	1.7	1.7
PM2.5 (TBW)	lb/year	1.4	1.4	1.4	1.4	1.4
VOC	lb/year	14.5	14.6	14.9	23.4	23.9
VOC (Evap)	lb/year	8.2	8.2	8.2	8.2	8.2

Total Petroleum Use, GHG Emissions, and Vehicle Operation Emissions - Per Lifetime Ownership of Gasoline Passenger Car Fleet

Petroleum Use	**barrels**	**1,550**
GHG	**short tons**	**895**
CO	**pounds**	**15,705**
NOx	**pounds**	**635**
PM10	**pounds**	**132**
PM2.5	**pounds**	**65**
VOC	**pounds**	**774**

Figure 15. TCO Sheet – HDV Characteristics and Cost Calculations

	Project Year	1	2	3	4	5
Total Cost of Ownership - Heavy Duty						
Diesel Combination Long-Haul Truck						
Diesel Combination Long-Haul Truck Characteristics						
Number of Vehicles Purchased		10				
Annual Mileage	miles/vehicle	170,000	170,000	170,000	170,000	170,000
Fuel Economy	MPGGE	5.2	5.2	5.2	5.2	5.2
Fuel Usage	GGE/vehicle	32,692	32,692	32,692	32,692	32,692
Diesel Combination Long-Haul Truck Acquisition Cost						
Purchase Price	$/vehicle	$100,000				
Incentive	$/vehicle	$0				
Total Purchase Price of Vehicle(s)	$/fleet	$1,000,000				
Total Incentives	$/fleet	$0				
Total Net Price of Vehicle(s)	$/fleet	$1,000,000				
Down Payment	$/fleet	$0				
Loan Amount	$/fleet	$0				
Fixed Costs - Annual Diesel Combination Long-Haul Truck Fleet Acquisition						
Credit	$/year	$0				
Down Payment	$/year	$1,000,000				
Interest Payment	$/year	$0	$0	$0	$0	$0
Principal Payment	$/year	$0	$0	$0	$0	$0
Total Loan Payment	$/year	$0	$0	$0	$0	$0
Total Acquisition Costs	**$/year**	**$1,000,000**	**$0**	**$0**	**$0**	**$0**
Fixed Costs - Annual Diesel Combination Long-Haul Truck Fleet Depreciation						
Resale Value	$/year	$770,000	$654,500	$556,325	$472,876	$401,945
Depreciation Cost	**$/year**	**$230,000**	**$115,500**	**$98,175**	**$83,449**	**$70,931**
Fixed Costs - Annual Diesel Combination Long-Haul Truck Fleet Insurance and Licensing						
Insurance	$/year	$51,270	$52,413	$53,582	$54,777	$55,999
License and Registration	$/year	$5,400	$5,520	$5,644	$5,769	$5,898
Total Insurance & Licensing Costs	**$/year**	**$56,670**	**$57,934**	**$59,226**	**$60,546**	**$61,897**
Operating Costs - Diesel Combination Long-Haul Truck Fleet						
Fuel Cost	$/year	$1,163,846	$1,174,204	$1,184,655	$1,195,198	$1,205,835
	$/mile	$0.68	$0.69	$0.70	$0.70	$0.71
Diesel Exhaust Fluid Cost	$/year	$18,308	$18,465	$18,624	$18,784	$18,946
	$/mile	$0.01	$0.01	$0.01	$0.01	$0.01
Maintenance and Repair Cost	$/year	$323,000	$330,203	$337,566	$345,094	$352,790
	$/mile	$0.19	$0.19	$0.20	$0.20	$0.21
Total Operating Costs	**$/year**	**$1,505,154**	**$1,522,872**	**$1,540,845**	**$1,559,076**	**$1,577,571**
Annual Net Cash Flow	**$/year**	**-$2,561,824**	**-$1,580,806**	**-$1,600,071**	**-$1,619,623**	**-$1,639,467**
Discounted Cash Flow	**$/year**	**-$2,561,824**	**-$1,568,416**	**-$1,575,086**	**-$1,581,836**	**-$1,588,668**

Net Present Value (NPV)	**-$16,758,395**

Total Cost of Ownership Summary - Per Lifetime Ownership of Diesel Combination Long-Haul Truck Fleet

Financing	**$0**	$0	$0	$0	$0	$0
Depreciation	**$833,849**	$0	$0	$0	$0	$0
Fuel	**$11,690,562**	$1,163,846	$1,165,001	$1,166,157	$1,167,314	$1,168,472
Diesel Exhaust Fluid	**$183,650**	$18,308	$18,320	$18,333	$18,346	$18,359
Maintenance and Repair	**$3,445,776**	$323,000	$327,615	$332,295	$337,043	$341,858
Insurance	**$546,950**	$51,270	$52,003	$52,745	$53,499	$54,263
License and Registration	**$57,607**	$5,400	$5,477	$5,555	$5,635	$5,715
Total Cost of Ownership	**$16,758,395**					

Figure 16. TCO Sheet – HDV Energy Use and Emissions Calculations

Project Year		1	2	3	4	5
Total Cost of Ownership - Heavy Duty						
Diesel Combination Long-Haul Truck						
Annual Diesel Combination Long-Haul Truck Fleet Life-Cycle Petroleum Use, Life-Cycle Greenhouse Gas Emissions, and Vehicle Operation Air Pollutant Emissions						
Petroleum Use	barrels/year	7,268.1	7,268.1	7,268.1	7,268.1	7,268.1
GHG	short ton/year	4,107.9	4,107.9	4,107.9	4,107.9	4,107.9
CO	lb/year	7,712.9	7,723.4	7,740.4	8,044.8	8,073.1
NOx	lb/year	21,195.5	21,196.8	21,198.9	24,166.0	24,169.4
PM10	lb/year	115.8	115.8	115.8	165.2	165.2
PM10 (TBW)	lb/year	311.1	311.1	311.1	311.1	311.1
PM2.5	lb/year	112.5	112.5	112.5	160.5	160.5
PM2.5 (TBW)	lb/year	78.7	78.7	78.7	78.7	78.7
VOC	lb/year	1,970.0	1,970.2	1,970.6	1,999.2	1,999.9
VOC (Evap)	lb/year	0.0	0.0	0.0	0.0	0.0

Total Petroleum Use, GHG Emissions, and Vehicle Operation Emissions - Per Lifetime Ownership of Diesel Combination Long-Haul Truck Fleet

Petroleum Use	**barrels**	**72,681**
GHG	**short tons**	**41,079**
CO	**pounds**	**80,233**
NOx	**pounds**	**233,004**
PM10	**pounds**	**4,616**
PM2.5	**pounds**	**2,250**
VOC	**pounds**	**19,924**

2.6 TCO Outputs Sheet

This sheet summarizes the outputs of the Total Cost of Ownership Calculator with tables and graphs for costs, petroleum use, GHGs, and air pollutant emissions. In the cost and energy use and emissions tables (Figures 17-18), both LDVs and HDVs are included, while LDVs and HDVs are presented separately in the graphs (Figures 19-28). This sheet has additional cost graphs as compared to the Payback Outputs sheet. Specically, the cumulative cost of ownership compared to a conventional counterpart (Figures 19-20) show similar results to a simple payback. The payback period is equal to the year when the line for each AFV crosses the x-axis. Figures 21-22 show the cumulative cash flow for both AFVs and conventional vehicles. Finally, Figures 23-24 show the total cost of ownership broken down into the major cost categories: financing, depreciation, fuel, maintenance and repair, insurance, and license and registration. The following figures are shown as an example of the outputs generated; a user's results will vary depending on the specific inputs used.

Figure 17. TCO Outputs Sheet – Lifetime Costs Summary Table

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel Hydraulic Hybrid (HHV)	Biodiesel (B20)	Biodiesel (B100)	Ethanol (E85)	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	LNG / Diesel Pilot Ignition
Light-Duty Passenger Car Fleet															
Financing	$0		$0	$0	$0	$0					$0		$0		
Depreciation	$188,045		$263,263	$310,275	$329,079	$352,585					$188,045		$253,861		
Fuel	$256,046		$182,890	$159,959	$115,014	$76,048					$332,985		$173,765		
Maintenance and Repair	$314,239		$304,006	$298,311	$298,311	$276,889					$314,239		$314,239		
Insurance	$177,094		$177,094	$177,094	$177,094	$177,094					$177,094		$177,094		
License and Registration	$19,172		$19,172	$19,172	$19,172	$19,172					$19,172		$19,172		
Total Cost of Ownership	$954,597		$946,426	$964,811	$938,671	$901,787					$1,031,536		$938,132		
Heavy-Duty Combination Long-Haul Truck Fleet															
Financing		$0						$0					$0	$0	$0
Depreciation		$833,849						$833,849					$1,375,850	$1,250,773	$1,584,312
Fuel		$11,690,562						$12,018,948					$8,052,914	$8,052,914	$7,719,009
Diesel Exhaust Fluid		$183,650						$183,650					$0	$0	$174,468
Maintenance and Repair		$3,445,776						$3,445,776					$3,502,199	$3,502,199	$3,554,590
Insurance		$546,950						$546,950					$546,950	$546,950	$546,950
License and Registration		$57,607						$57,607					$57,607	$57,607	$57,607
Total Cost of Ownership		$16,758,395						$17,086,781					$13,535,520	$13,410,443	$13,636,937

Figure 18. TCO Outputs Sheet – Lifetime Energy Use and Emissions Summary Table

	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
Lifetime Life-Cycle Petroleum Use (barrels)															
LD Petroleum Use	1,550		1,107	905	411	18					339		8		
HD Petroleum Use		72,681							59,052				385	883	4,164
Lifetime Life-Cycle Greenhouse Gas Emissions (short tons)															
LD GHG Emissions	895		640	588	531	466					664		770		
HD GHG Emissions		41,079							34,846				35,763	35,559	32,372
Lifetime Vehicle Operation Air Pollutant Emissions (lb)															
Light-Duty Passenger Car Fleet															
CO	15,705		11,765	10,617	3,578	0					9,793		11,366		
NOx	635		409	369	124	0					415		531		
PM10	132		132	128	102	88					132		132		
PM2.5	65		65	61	35	22					65		65		
VOC	774		566	511	172	0					715		442		
Heavy-Duty Combination Long-Haul Truck Fleet															
CO		80,233							80,233				1,235,595	1,235,595	16,047
NOx		233,004							233,004				139,802	139,802	139,802
PM10		4,616							4,616				4,616	4,616	4,616
PM2.5		2,250							2,250				2,250	2,250	2,250
VOC		19,924							19,924				65,370	65,370	8,588

Figure 19. TCO Outputs Sheet – LDV Cumulative Cash Flow Compared to Gasoline Summary Graph

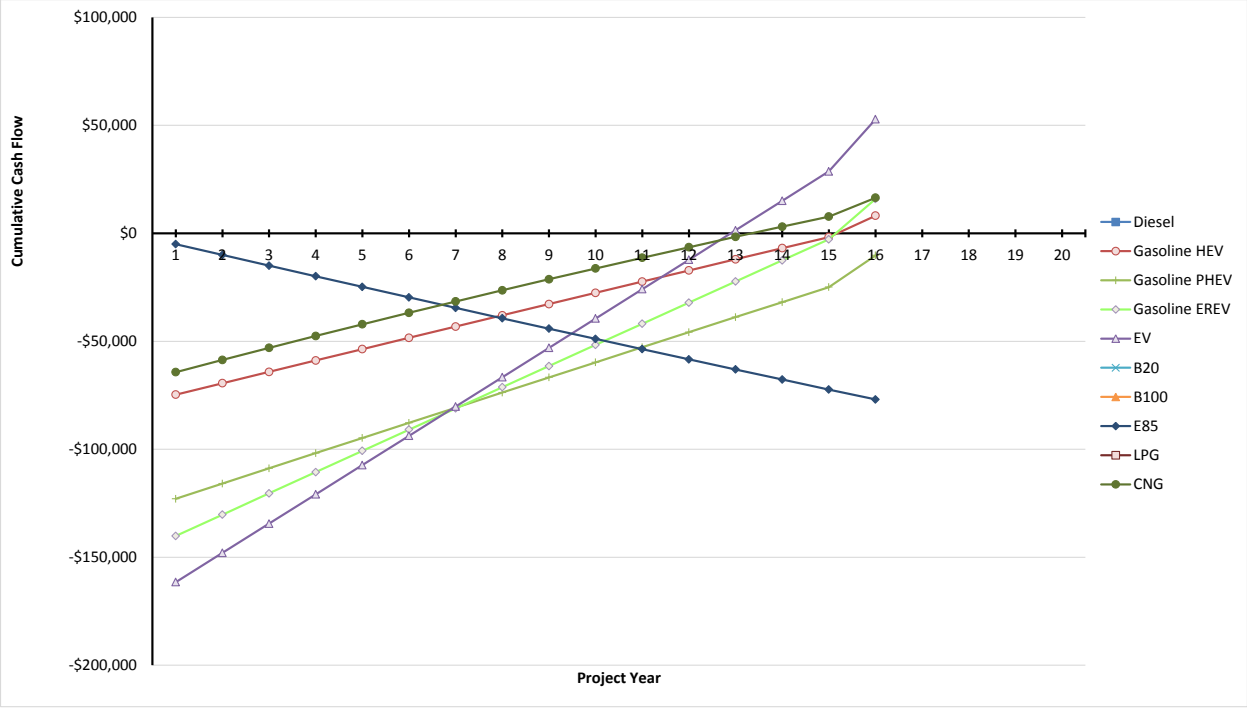


Figure 20. TCO Outputs Sheet – HDV Cumulative Cash Flow Compared to Diesel Summary Graph

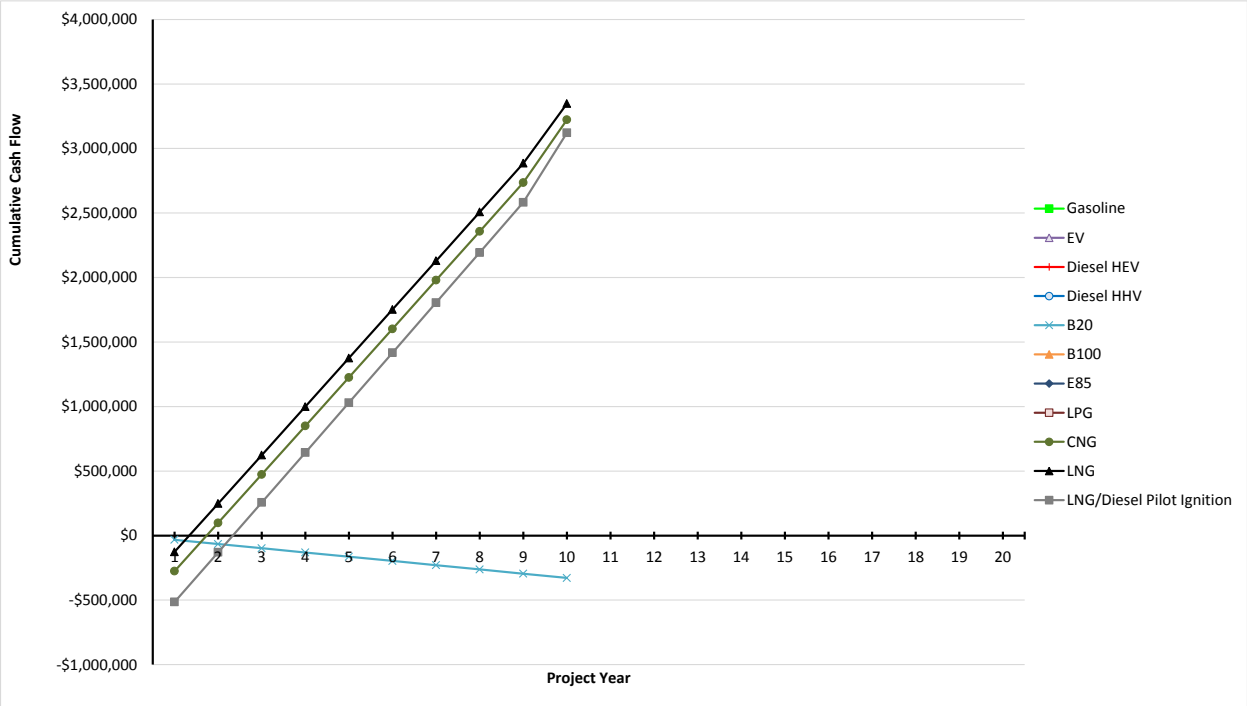


Figure 21. TCO Outputs Sheet – LDV Cumulative Cash Flow Summary Graph

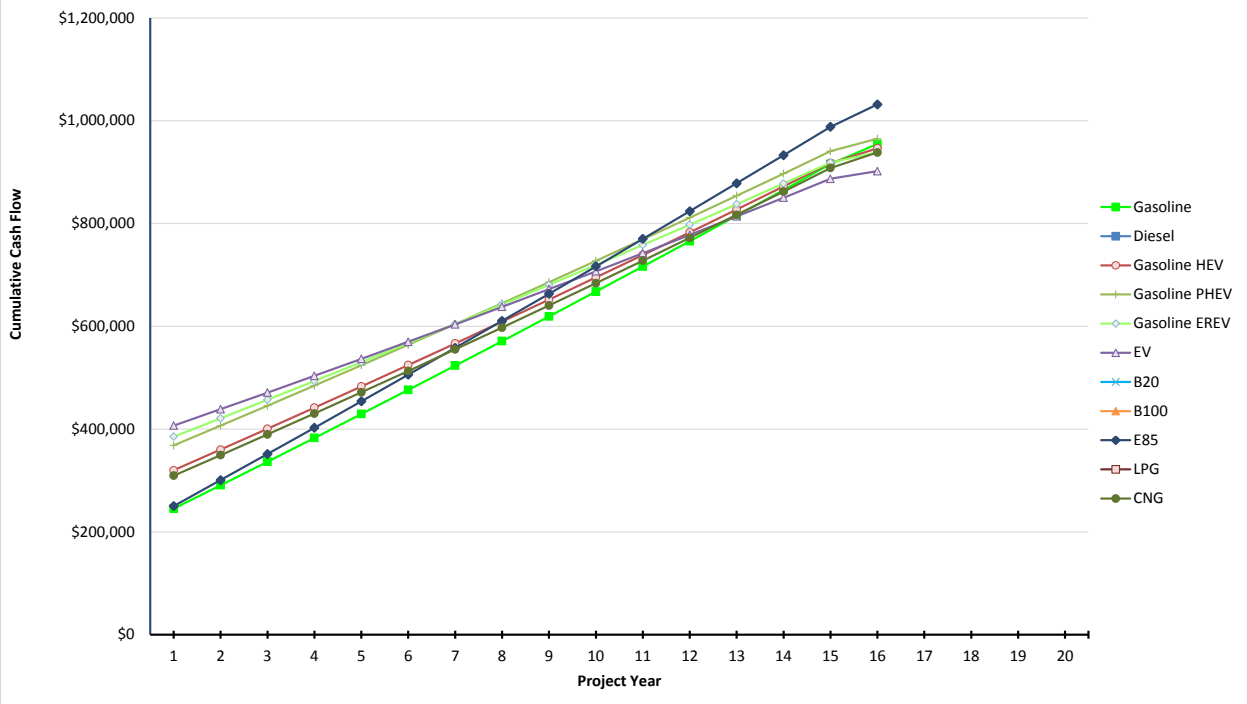


Figure 22. TCO Outputs Sheet – HDV Cumulative Cash Flow Summary Graph

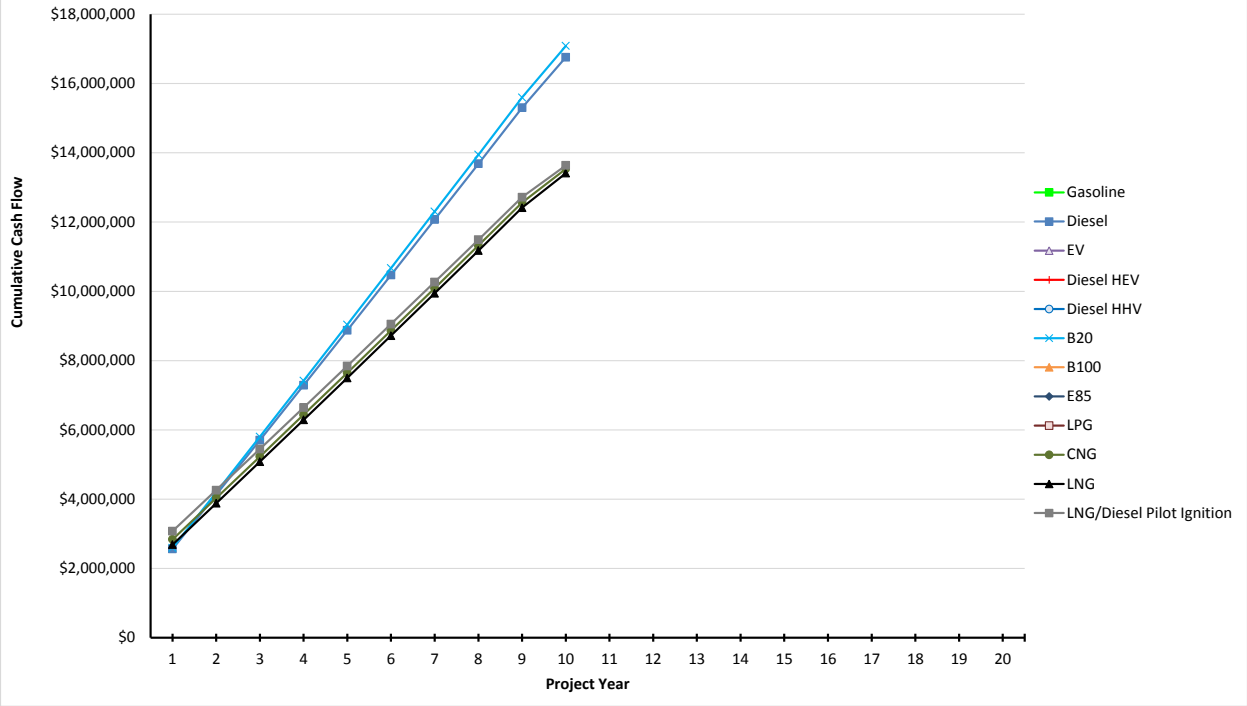
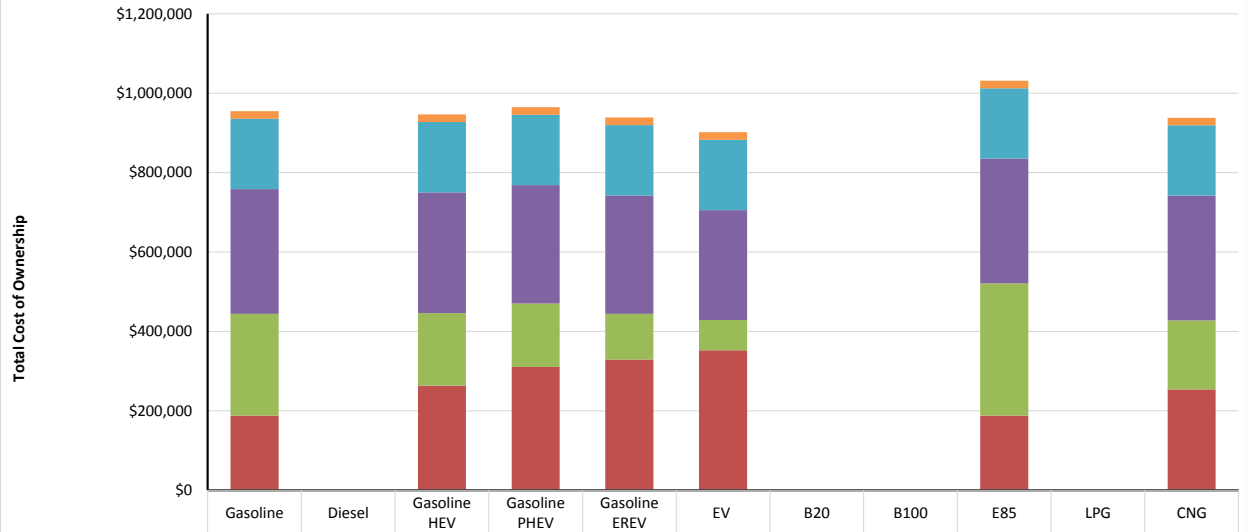
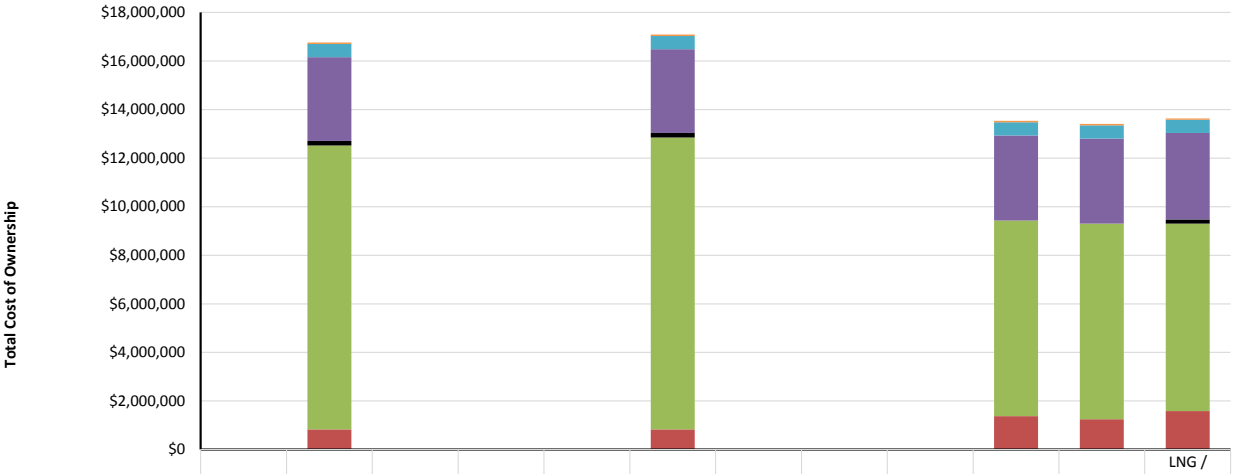


Figure 23. TCO Outputs Sheet – LDV Total Cost of Ownership Summary Graph



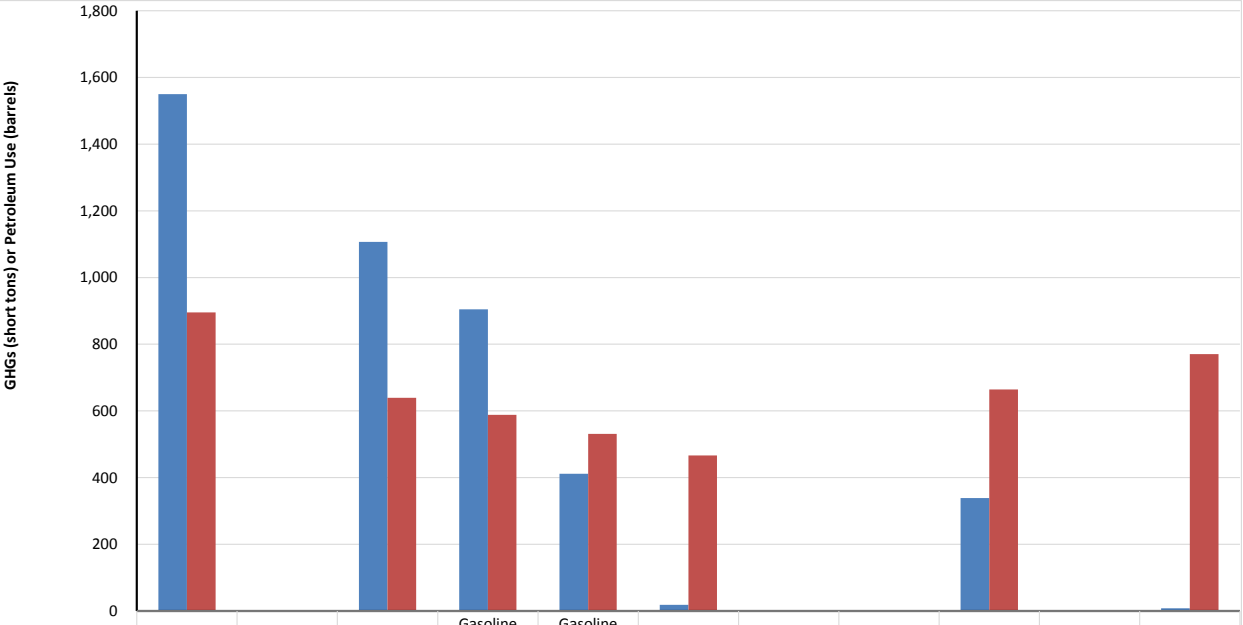
	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	B20	B100	E85	LPG	CNG
License and Registration	$19,172		$19,172	$19,172	$19,172	$19,172			$19,172		$19,172
Insurance	$177,094		$177,094	$177,094	$177,094	$177,094			$177,094		$177,094
Maintenance and Repair	$314,239		$304,006	$298,311	$298,311	$276,889			$314,239		$314,239
Fuel	$256,046		$182,890	$159,959	$115,014	$76,048			$332,985		$173,765
Depreciation	$188,045		$263,263	$310,275	$329,079	$352,585			$188,045		$253,861
Financing	$0		$0	$0	$0	$0			$0		$0

Figure 24. TCO Outputs Sheet – HDV Total Cost of Ownership Summary Graph



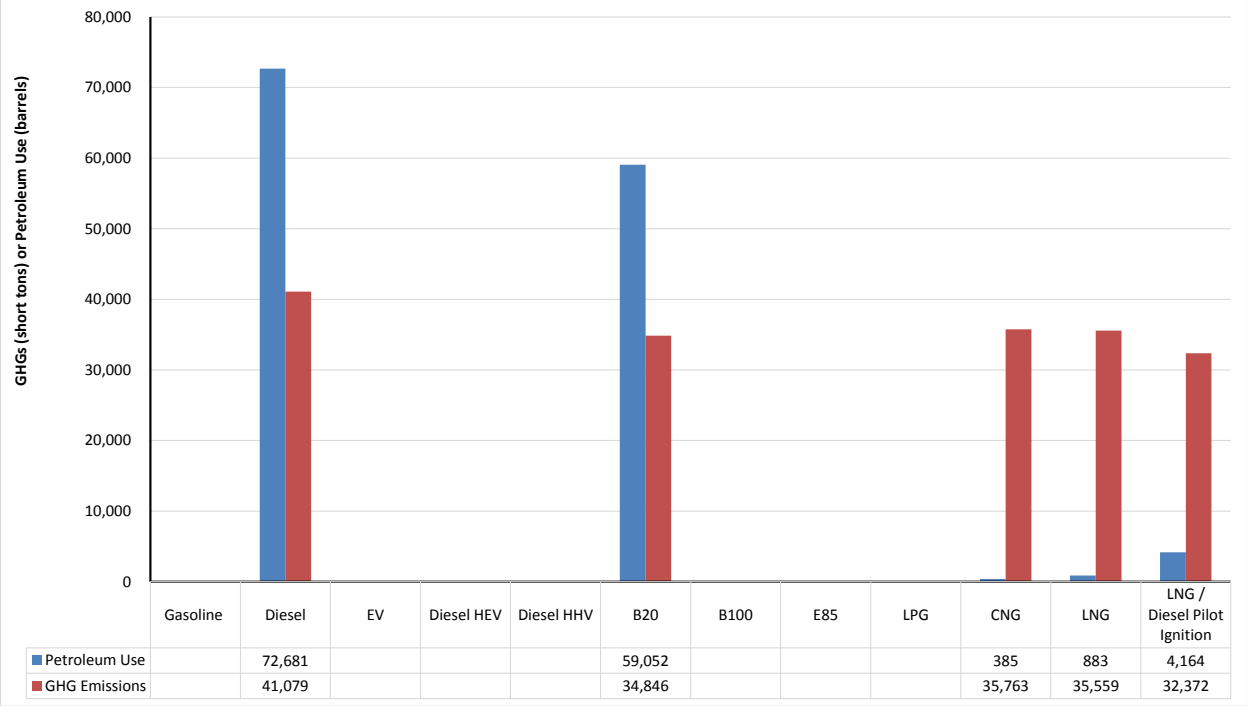
	Gasoline	Diesel	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
License and Registration		$57,607				$57,607				$57,607	$57,607	$57,607
Insurance		$546,950				$546,950				$546,950	$546,950	$546,950
Maintenance and Repair		$3,445,776				$3,445,776				$3,502,199	$3,502,199	$3,554,590
Diesel Exhaust Fluid		$183,650				$183,650				$0	$0	$174,468
Fuel		$11,690,562				$12,018,948				$8,052,914	$8,052,914	$7,719,009
Depreciation		$833,849				$833,849				$1,375,850	$1,250,773	$1,584,312
Financing		$0				$0				$0	$0	$0

Figure 25. TCO Outputs Sheet – Lifetime LDV Energy Use and GHGs Summary Graph



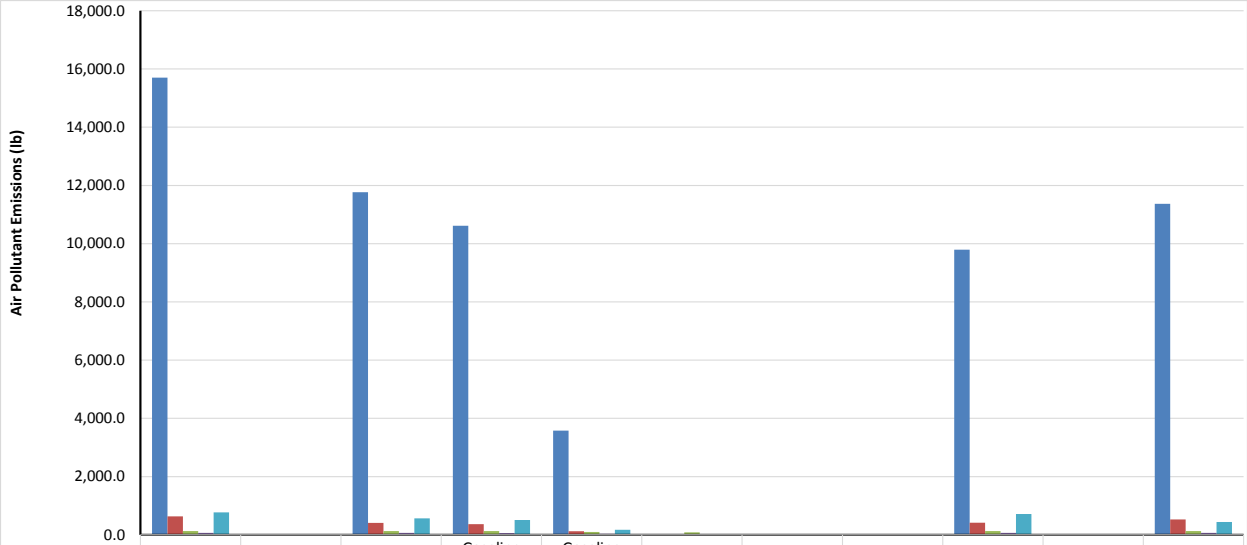
	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	B20	B100	E85	LPG	CNG
Petroleum Use	1,550		1,107	905	411	18			339		8
GHG Emissions	895		640	588	531	466			664		770

Figure 26. TCO Outputs Sheet – Lifetime HDV Energy Use and GHGs Summary Graph



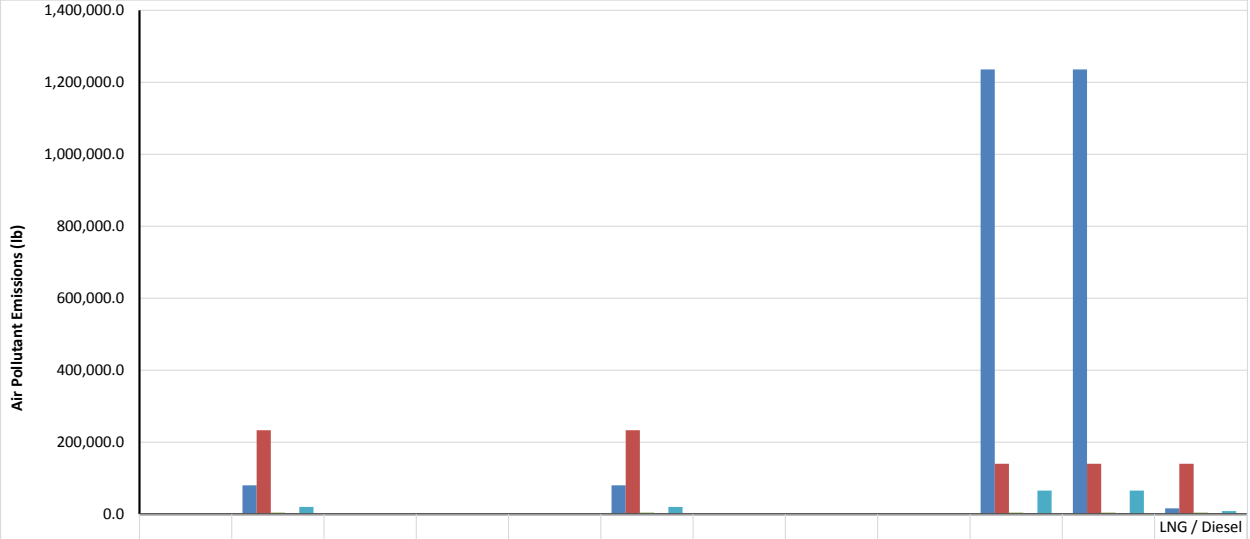
	Gasoline	Diesel	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
Petroleum Use		72,681				59,052				385	883	4,164
GHG Emissions		41,079				34,846				35,763	35,559	32,372

Figure 27. TCO Outputs Sheet – Lifetime LDV Air Pollutant Emissions Summary Graph



	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	B20	B100	E85	LPG	CNG
CO	15,705.0		11,765.1	10,616.7	3,577.8	0.0			9,793.4		11,366.5
NOx	634.7		408.8	368.9	124.3	0.0			415.3		530.6
PM10	132.1		132.1	127.8	101.6	88.3			132.1		132.1
PM2.5	64.8		64.8	60.7	35.0	22.0			64.8		64.8
VOC	773.6		566.3	511.0	172.2	0.0			715.5		442.4

Figure 28. TCO Outputs Sheet – Lifetime HDV Air Pollutant Emissions Summary Graph



	Gasoline	Diesel	EV	Diesel HEV	Diesel HHV	B20	B100	E85	LPG	CNG	LNG	LNG / Diesel Pilot Ignition
CO		80,233.5				80,233.5				1,235,595.	1,235,595.	16,046.7
NOx		233,004.1				233,004.1				139,802.4	139,802.4	139,802.4
PM10		4,616.2				4,616.2				4,616.2	4,616.2	4,616.2
PM2.5		2,249.7				2,249.7				2,249.7	2,249.7	2,249.7
VOC		19,923.6				19,923.6				65,370.2	65,370.2	8,587.9

2.7 Footprint Sheet

This sheet contains the Fleet Energy and Emissions Footprint Calculator, which estimates the annual petroleum use, GHGs, and air pollutant emissions of existing and new vehicles, taking into consideration that older vehicles typically have higher air pollutant emission rates than newer ones. The key inputs (Figure 29) for this sheet are:

- **vehicle type**
- **model year**
- **annual vehicle mileage**
- **fuel use.**

The user can change the vehicle types via dropdown box. The user then must enter a model year between 1980 and 2015, vehicle mileage, and fuel use to estimate its energy use and emissions (Figure 30) of existing fleet vehicles and vehicles planned to be purchased. If one would like to examine more vehicles, the user can copy and paste the entire row(s) with calculations (rows 6-35 in AFLEET Tool 2013) below the existing rows.

Figure 29. Footprint Sheet - Inputs

Vehicle Type	Model Year	Annual Vehicle Mileage	Fuel Use																		
			Gasoline (gal)	Diesel (gal)	Gasoline HEV (gal)	Gasoline PHEV (gal)	Gasoline PHEV (kWh)	Gasoline EREV (gal)	Gasoline EREV (kWh)	Electricity (kWh)	Diesel HEV (gal)	Diesel HHV (gal)	B20 (gal)	B100 (gal)	E85 (gal)	LPG (gal)	CNG (GGE)	LNG (gal)	LNG / Diesel (LNG gal)	LNG / Diesel (diesel gal)
Passenger Car	1998	40,000	1,600																		
Passenger Car	2013	40,000			1,100																
Passenger Car																					
Passenger Truck	1995	60,000	4,000																		
Passenger Truck	2013	60,000	3,000																		
Passenger Truck																					
Light Commercial Truck																					
Light Commercial Truck																					
Light Commercial Truck																					
School Bus	1997	100,000		12,000																	
School Bus	2013	100,000														20,000					
School Bus																					
Transit Bus																					
Transit Bus																					
Transit Bus																					
Refuse Truck																					
Refuse Truck																					
Refuse Truck																					
Single Unit Short-Haul Truck																					
Single Unit Short-Haul Truck																					
Single Unit Short-Haul Truck																					
Single Unit Long-Haul Truck																					
Single Unit Long-Haul Truck																					
Single Unit Long-Haul Truck																					
Combination Short-Haul Truck																					
Combination Short-Haul Truck																					
Combination Short-Haul Truck																					
Combination Long-Haul Truck																					
Combination Long-Haul Truck																					
Combination Long-Haul Truck																					

Figure 30. Footprint Sheet - Energy Use and Emissions Calculations

Vehicle Type	Petroleum Use (barrels)	GHG (short tons)	Vehicle Operation Air Pollutant Emissions (lb)							
			CO	NOx	PM10	PM10 (TBW)	PM2.5	PM2.5 (TBW)	VOC	VOC (Evap)
Passenger Car	33.4	19.3	725.2	123.2	1.7	1.8	1.5	0.4	63.5	10.1
Passenger Car	22.9	13.3	102.6	3.7	0.4	1.8	0.4	0.4	3.1	2.6
Passenger Car	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Passenger Truck	83.4	48.2	4,404.8	672.6	6.9	3.7	6.3	0.9	470.6	209.7
Passenger Truck	62.6	36.2	340.7	26.7	1.0	3.7	0.9	0.9	9.0	4.5
Passenger Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Commercial Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Commercial Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Light Commercial Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
School Bus	307.9	174.0	1,488.8	3,150.6	174.8	18.5	169.5	4.9	245.8	0.0
School Bus	106.7	161.8	16,703.7	499.0	3.1	11.5	2.8	2.9	314.9	12.9
School Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transit Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transit Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transit Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuse Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuse Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuse Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2.8 Footprint Outputs Sheet

This sheet summarizes the outputs of the Fleet Energy and Emissions Footprint Calculator with a table and graphs for petroleum use, GHGs, and air pollutant emissions of the entire fleet (Figures 31-33). The following figures are shown as an example of the outputs generated; a user's results will vary depending on the specific inputs used.

Figure 31. Footprint Outputs Sheet - Energy Use and Emissions Summary Table

Vehicle Type	Petroleum Use (barrels)	GHG Emissions (short tons)	CO (lb)	NOx (lb)	PM10 (lb)	PM2.5 (lb)	VOC (lb)
Passenger Car	56.3	32.5	827.8	126.9	5.6	2.8	79.3
Passenger Truck	146.0	84.4	4,745.6	699.4	15.3	9.1	693.8
Light Commercial Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0
School Bus	414.6	335.8	18,192.5	3,649.6	208.0	180.1	573.6
Transit Bus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refuse Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Unit Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Short-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combination Long-Haul Truck	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**616.9**	**452.7**	**23,765.8**	**4,475.8**	**229.0**	**192.0**	**1,346.7**

Figure 32. Footprint Outputs Sheet – Fleet Energy Use and GHGs Summary Graph

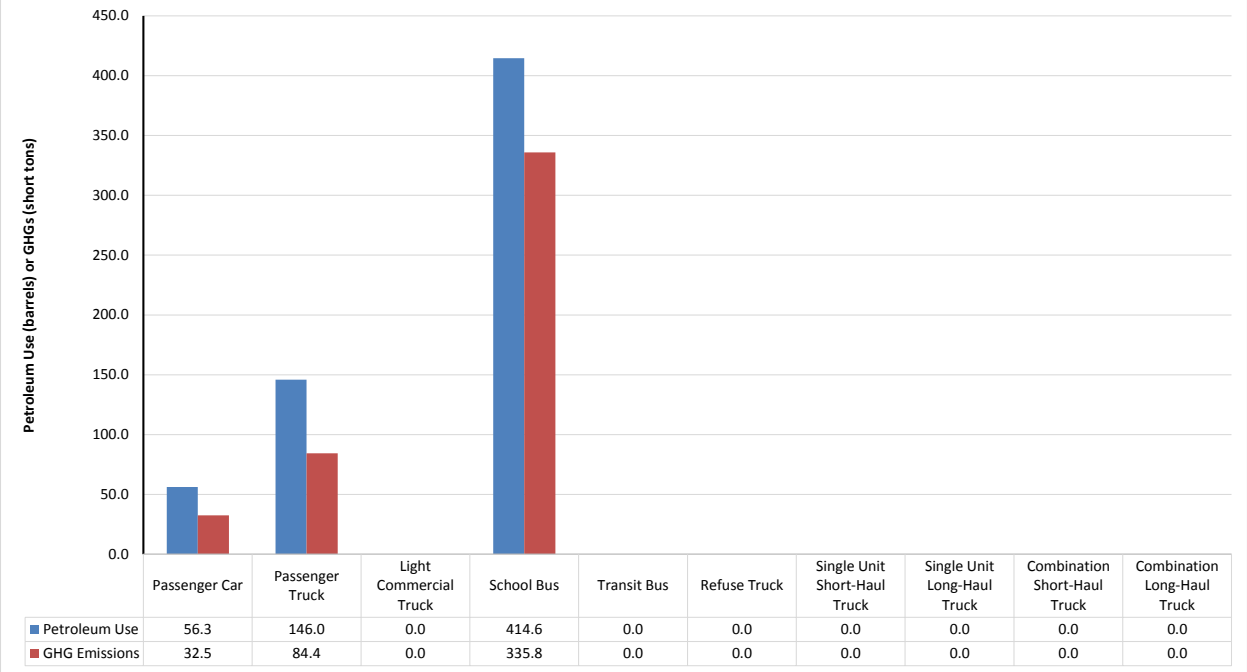
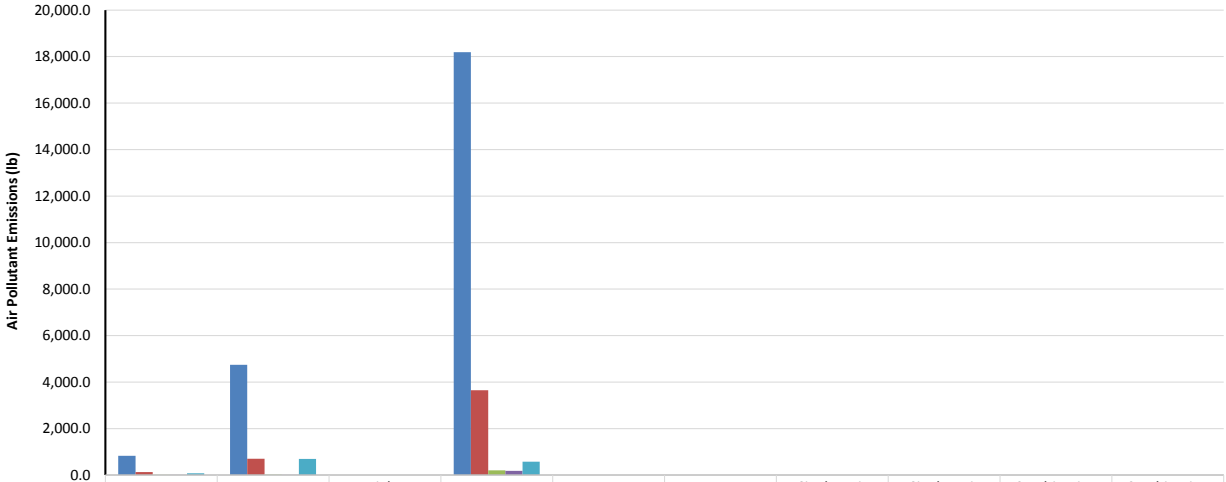


Figure 33. Footprint Outputs Sheet - Fleet Air Pollutant Emissions Summary Graph



	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
CO	827.8	4,745.6	0.0	18,192.5	0.0	0.0	0.0	0.0	0.0	0.0
NOx	126.9	699.4	0.0	3,649.6	0.0	0.0	0.0	0.0	0.0	0.0
PM10	5.6	15.3	0.0	208.0	0.0	0.0	0.0	0.0	0.0	0.0
PM2.5	2.8	9.1	0.0	180.1	0.0	0.0	0.0	0.0	0.0	0.0
VOC	79.3	693.8	0.0	573.6	0.0	0.0	0.0	0.0	0.0	0.0

2.9 Background Data Sheet

This sheet contains the background data for the Simple Payback, Total Cost of Ownership, and Fleet Energy and Emissions Footprint calculators. The user can navigate this sheet and jump to various sections by using the hyperlinks at the top of the page. As previously mentioned, a user can change the default vocation type using the dropdown boxes in this sheet (Figure 34). This will alter the lookup tables, which AFLEET Tool references for the default data of key inputs in the various sheets. Figure 35 shows an example of one look up table. Also mentioned previously, the user can input custom electricity mixes on this sheet (Figure 36). The Background Data sheet includes the source of assumptions and data for each input. Sometimes the sources are included in a comment for a specific cell. To view these comments, place the mouse cursor over a cell with a red triangle in its top left corner.

Figure 34. Background Data Sheet - AFLEET Look Up Tables - Vehicle Vocation Selection

Passenger Car	Car
Passenger Truck	Light-Duty Pickup Truck
Light Commercial Truck	Medium-Duty Pickup Truck
School Bus	School Bus
Transit Bus	Transit Bus
Refuse Truck	Refuse Truck
Single Unit Short-Haul Truck	Delivery Step Van
Single Unit Long-Haul Truck	Delivery Straight Truck
Combination Short-Haul Truck	Regional Haul Freight Truck
Combination Long-Haul Truck	Long Haul Freight Truck

Figure 35. Background Data Sheet - AFLEET Look Up Tables - New Vehicle Purchase Price

Vocation Type	MOVES Category	Gasoline	Diesel	Gasoline HEV	Gasoline PHEV	Gasoline EREV	EV	Diesel HEV	Diesel Hydraulic Hybrid	Biodiesel (B20)	Biodiesel (B100)	Ethanol (E85)	Propane (LPG)	Compressed Natural Gas (CNG)	Liquefied Natural Gas (LNG)	LNG / Diesel Pilot Ignition
Long Haul Freight Truck	Combination Long-Haul Truck		$100,000					$140,000		$100,000	$100,000			$165,000	$150,000	$190,000
Regional Haul Freight Truck	Combination Short-Haul Truck		$90,000					$137,500		$90,000	$90,000			$130,000	$120,000	$155,000
Delivery Straight Truck	Single Unit Long-Haul Truck		$75,000					$115,000		$75,000	$75,000			$140,000	$125,000	
Delivery Step Van	Single Unit Short-Haul Truck		$65,000				$150,000	$105,000		$65,000	$65,000			$105,000	$95,000	
Dump Truck			$80,000							$80,000	$80,000			$140,000	$130,000	
Bucket/Aerial Truck			$155,000				$355,000			$155,000	$155,000			$215,000	$205,000	
Snow Plow/Sander			$100,000							$100,000	$100,000			$170,000	$160,000	
Sewer Cleaner			$385,000							$385,000	$385,000			$410,000	$410,000	
Street Sweeper			$190,000							$190,000	$190,000			$265,000		
Refuse Truck	Refuse Truck		$210,000				$670,000	$260,000	$250,000	$210,000	$210,000			$260,000	$250,000	
Transit Bus	Transit Bus		$300,000					$510,000		$300,000	$300,000			$360,000	$350,000	
School Bus	School Bus		$90,000					$150,000		$90,000	$90,000		$105,000	$140,000	$130,000	
Shuttle/Paratransit Bus			$65,000					$120,000		$65,000	$65,000		$75,000	$90,000		
Medium-Duty Pickup Truck	Light Commercial Truck	$30,500	$38,000							$38,000	$38,000	$30,500	$38,500	$43,000		
Utility Cargo Van		$31,000	$43,000				$66,000			$43,000	$43,000	$31,000	$39,000	$47,000		
Shuttle/Paratransit Van		$30,000	$42,000							$42,000	$42,000	$30,000	$36,500	$40,000		
Light-Duty Pickup Truck	Passenger Truck	$24,500	$32,000	$42,000						$32,000	$32,000	$24,500	$31,000	$36,000		
SUV		$24,000	$26,500	$31,500			$55,500			$26,500	$26,500	$24,000	$30,000	$36,500		
SUV - Taxi		$24,000	$26,500	$31,500			$55,500			$26,500	$26,500	$24,000	$30,000	$36,500		
Car	Passenger Car	$20,000	$22,500	$28,000	$33,000	$35,000	$37,500			$22,500	$22,500	$20,000	$26,000	$27,000		
Car - Taxi		$20,000	$22,500	$28,000	$33,000	$35,000	$37,500			$22,500	$22,500	$20,000	$26,000	$27,000		
Car - Police		$20,000	$22,500	$28,000	$33,000	$35,000	$37,500			$22,500	$22,500	$20,000	$26,000	$27,000		
Maintenance Utility Vehicle		$14,000					$19,000			$0	$0	$14,000				
Other																

Figure 36. Background Data Sheet – GREET Fleet Specifications – Electricity Mix

	U.S. Average Mix	Alaska Systems Coordinating Council (ASCC)	Florida Reliability Coordinating Council (FRCC)	Hawaiian Islands Coordinating Council (HICC)	Midwest Reliability Organization (MRO)	Northeast Power Coordinating Council (NPCC)	Reliability First Corporation (RFC)	SERC Reliability Corporation (SERC)	Southwest Power Pool (SPP)	Texas Regional Entity (TRE)	Western Electricity Coordinating Council (WECC)	User Mix
Residual oil	0.5%	14.3%	1.0%	96.3%	0.3%	0.7%	0.3%	0.4%	0.4%	0.1%	0.2%	0.5%
Natural gas	25.4%	59.4%	60.4%	3.4%	2.0%	41.7%	13.0%	25.2%	26.2%	43.2%	25.8%	25.4%
Coal	41.4%	3.1%	20.7%	0.0%	63.5%	5.9%	54.8%	43.7%	56.5%	34.3%	30.5%	41.4%
Nuclear power	20.6%	0.0%	16.1%	0.0%	14.8%	31.9%	28.2%	26.4%	4.4%	12.9%	9.4%	20.6%
Biomass	0.4%	0.9%	0.3%	0.0%	0.3%	1.6%	0.2%	0.4%	0.0%	0.3%	0.3%	0.4%
Others (Wind, Solar, Hydro, etc)	11.8%	22.4%	1.6%	0.3%	19.1%	18.3%	3.5%	3.9%	12.6%	9.2%	33.8%	11.8%

3. REFERENCES

Argonne National Laboratory, 2013, GREET Model – GREET1_2013 version, http://greet.es.anl.gov, last accessed October.

EPA, 2013a, Motor Vehicle Emission Simulator (MOVES) – MOVES2010b version. http://www.epa.gov/otaq/models/moves, last accessed October.

EPA, 2013b, Annual Certification Test Results & Data – Model Year 2013 Light Duty Vehicle Data. http://www.epa.gov/otaq/crttst.htm, last accessed October.

EPA, 2013c, Engine Certification Data – Model Year 2013 On-Highway Heavy Duty. http://epa.gov/otaq/certdata.htm, last accessed October.