CMAQ EMISSIONS CALCULATOR TOOLKIT

The purpose of the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit) is to provide users a standardized approach to estimating emission reductions from the implementation of a CMAQ-funded project. The CMAQ Toolkit uses emission rates for highway vehicles based on a national-scale run of the Motor Vehicle Emission Simulator (MOVES) as well as other data sources. For each tool in the Toolkit, the inputs and methodology are described in user guides along with some example cases. Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses. Information regarding the development of default emission rates and guidance on incorporating user-supplied emission rates can be found in the accompanying documentation of the emissions data.

Alternative Fuel Vehicles and Infrastructure

The Alternative Fuel Vehicles and Infrastructure Tool estimates the emission benefits of adopting alternative fuels in the current on-road transportation system. This tool is built on emission rates from the US Environmental Protection Agency's latest Motor Vehicle Emission Simulator (MOVES3)[1] and emission rate adjustment factors from the US Department of Energy's Alternative Fuel Lifecycle Environmental and Economic Transportation (AFLEET 2020) Tool[2] for alternative fuel vehicles not included in MOVES. This tool considers only operating emissions[3] of the vehicles and does not evaluate upstream (well-to-pump) emissions associated with production and transmission of the fuel or manufacturing of the vehicle. This Alternative Fuel Vehicles tool allows modeling of many passenger and commercial vehicle source use types in MOVES but excludes others—most notably transit buses, which are included in another tool. Note that this tool excludes electric vehicles (EV) and EV charging stations, which are included in the Electric Vehicles and EV Charging Infrastructure tool.

This tool currently contains two modules: 1) On-Road Alternative Fuel Vehicle Fleet Purchase and Restricted Access Alternative Fuel Infrastructure and 2) Unrestricted Access Alternative Fuel Infrastructure. The first module can calculate emissions from an alternative fuel vehicle fleet purchase project and a restricted access infrastructure project separately, or together. The unrestricted infrastructure module for public fueling was developed separately and should not be combined with any other module.

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[1] US Environmental Protection Agency, Office of Transportation and Air Quality, Latest Version of MOtor Vehicle Emission Simulator (MOVES) | US EPA

[2] US Department of Energy, Argonne National Laboratory, https://greet.es.anl.gov/afleet_tool

[3] Emissions from running and start exhaust as well as brake and tire wear. Extended idling and APU emissions are only considered for long-haul combination trucks. Off-network idle and evaporative emissions are included for Fleet Purchase emissions; evaporative emissions are included for specific processes and road types for restricted access infrastructure emissions.

On-Road Alternative Fuel Vehicle Fleet Purchase & Restricted Access Alternative Fuel Infrastructure Module

To reduce emissions and fuel costs, many fleet managers are interested in purchasing alternative fuel or advanced drivetrain technology vehicles to replace some or all of their existing conventional fuel vehicles. This module allows users to estimate changes in emissions from these alternative fuel replacements. Gasoline or diesel vehicles for various vehicle source use types can be replaced.

Some alternative fuel infrastructure has restricted access, such that it will only service fleet vehicles. Restricted access infrastructure is not open for public refueling. This module can also determine the emission impacts of restricted alternative fuel infrastructure siting depending on changes to the fleet miles traveled to fuel at the new infrastructure.

This document is organized into three sections for Alternative Fuel Vehicle Fleet Purchase and Restricted Access Infrastructure – User Guide, Tool Methodology, and Examples – to aid the user in understanding and interpreting results from the calculator. The User Guide gives direction for the user to properly input values into the tool and provides definitions of both user inputs and tool outputs. This tool has been updated since original publication; there is a change log tab that can be unhidden for reference. The Tool Methodology outlines the steps taken to calculate emission reductions, and includes all equations used within the tool. The Examples section aims to give some examples of how to properly input information into the tool for advanced analysis.

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USER GUIDE

This section lists the units and description for each user input and tool output. A description of emission reductions reporting and error messages as well as other assumptions inherent in the tool are provided.

User Inputs

The interface of the Alternative Fuel Fleet Vehicle Purchase and Restricted Infrastructure module functions as a wizarding tool, with questions intending to help the user input proper information for emission reductions calculations in a step-by-step process. The inputs for this tool should be specific to the conventional fuel vehicles that will be replaced by alternative fuel vehicles. The user-defined inputs are described in Table 1.

Table 1 User Inputs

User Input	Units	Description
Evaluation year	-----	Use the drop-down menu to choose a year between 2019 and 2030.
Project component: Alt Fuel Vehicle Fleet Replacement	-----	Click on the box if your project incorporates a replacement component.
Project component: Restricted Access Infrastructure	-----	Click on the box if your project incorporates new restricted access infrastructure.
FLEET PURCHASE		
Replacement vehicle type	-----	Use the drop-down menu to choose the appropriate vehicle types, including: passenger car, passenger truck, school bus, refuse truck, single unit short-haul truck, single unit long-haul truck, combination short-haul truck, and combination long-haul truck. More detailed vehicle type descriptions can be found below.
Model year of conventional fuel vehicle	-----	Input the model year of the vehicles to be replaced. If you have a range of years, you may either input the individual years and vehicles separately or input a representative replacement year for the vehicles. The model year cannot be later than the project year. Please refer to CMAQ program guidance regarding appropriate model years eligible for funding. [4]
Conventional fuel type	-----	Use the drop-down menu to select the conventional fuel type of the vehicles that will be replaced. Note that users can enter replacements for either light-duty gasoline vehicles or heavy-duty diesel vehicles.
Vehicle miles traveled to be replaced (check box)	-----	Click on the box if you know the annual vehicle miles traveled for the vehicles to be replaced. This option may be checked concurrently with the vehicle population option.

[4] US Department of Transportation, Federal Highway Administration, http://www.fhwa.dot.gov/environment/air_quality/cmaq/

User Input	Units	Description
Replacement vehicle population (check box)	-----	Click on the box if you know the number of vehicles to be replaced. This option may be checked concurrently with the vehicle miles traveled option.
Vehicle miles traveled to be replaced (input value)	miles	Input the total value of annual vehicle miles traveled for the entire fleet of vehicles to be replaced (i.e. 60,000 miles each for 10 vehicles would result in an input of 600,000 miles). The default value is zero miles.
Replacement vehicle population (input value)	vehicles	Input the number of vehicles to be replaced. The default value is one vehicle.
Model year of alternative fuel vehicle	-----	Input the model year of the vehicles to be purchased. If you have a range of years, you may either input the individual years and vehicles separately or input a representative purchase year for the vehicles. The model year cannot be later than the project year. Please refer to CMAQ program guidance regarding appropriate model years eligible for funding.
Alternative fuel type	-----	Use the drop-down menu to select the alternative fuel type of the vehicles that will be purchased. Not all vehicle type-fuel type combinations are allowable and will produce an error (see more information below).
INFRSTRUCTURE		
Vehicle type to be fueled at the facility	-----	Use the drop-down menu to choose the appropriate vehicle types, including: passenger car, passenger truck, school bus, refuse truck, single unit short-haul truck, single unit long-haul truck, combination short-haul truck, and combination long-haul truck. More detailed vehicle type descriptions can be found below. Note that this input is only available if only the infrastructure project component is selected.
Model year of vehicles to be fueled at the facility	-----	Input the model year of the vehicles to be replaced. If you have a range of years, you may either input the individual years and vehicles separately or input a representative replacement year for the vehicles. The model year cannot be later than the project year. Please refer to CMAQ program guidance regarding appropriate model years eligible for funding.[5] Note that this input is only available if only the infrastructure project component is selected.
Alternative fuel type to be fueled at the facility	-----	Use the drop-down menu to select the alternative fuel type of the vehicles that will be purchased. Not all vehicle type-fuel type combinations are allowable and will produce an error (see more information below). Note that this input is only available if only the infrastructure project component is selected.

[5] US Department of Transportation, Federal Highway Administration, http://www.fhwa.dot.gov/environment/air_quality/cmaq/

User Input	Units	Description
Increase or decrease in distance to facility	-----	In order to calculate any impact on emissions, users must select whether the restricted-access alternative fuel infrastructure will increase or decrease. Note that this tool only provides results with a change in fueling distance.
Change in total annual fleet VMT	miles	Enter in the expected change in annual vehicle miles traveled for fueling of the alternative fuel fleet after construction of the restricted-access infrastructure.

Users must provide activity data for their fleet to estimate benefits. The fleet purchase module prompts users to enter total vehicle miles traveled for the fleet, vehicle population, or both. Benefits are calculated off VMT if both activity and population are provided. If a user enters only population, the activity will be calculated by multiplying the supplied population by the default annual miles traveled per vehicle in MOVES (see equation below).

Once the parameters are input, click on the 'Calculate Output' button to calculate results. Emission results will not automatically update, so anytime changes are made to the input parameters, this button must be pushed to calculate the updated emission reductions. To return to default settings, please click on the 'Reset Inputs' button.

Vehicle Type

Table 2 lists the vehicle types provided in this tool. Any vehicles with a gross vehicle weight of 10,000 pounds or more are considered heavy-duty and any vehicles less than 10,000 pounds are considered light-duty. MOVES light-duty vehicle source types consist of passenger cars, passenger trucks, and light commercial trucks. "Long-haul" trucks are defined as trucks for which most trips are 200 miles or more.

Table 2 Vehicle Type, Source Type, and Vehicle Class in Tool

Vehicle Source Type	MOVES sourceTypeID	FHWA Vehicle Class[6]
Passenger Car	21	Class 2 vehicles
Passenger Truck	31	Class 3 vehicles weighing less than or equal to 10,000 pounds used for non-commercial purposes
Light Commercial Truck	32	Class 3 vehicles weighing less than or equal to 10,000 pounds used for commercial purposes
School Bus	43	Class 4 vehicles designed to carry students or other passengers between their residence and school
Refuse Truck	51	Vehicles in Classes 5, 6, and 7 hauling landfill waste or recycling material
Single Unit Short-haul Truck	52	Vehicles in Classes 5, 6, and 7 typically driving less than 200 miles per trip
Single Unit Long-haul Truck	53	Vehicles in Classes 5, 6, and 7 typically driving 200 miles or more per trip
Combination Short-haul Truck	61	Vehicles in Classes 8, 9, 10, 11, 12, and 13 typically driving less than 200 miles per trip
Combination Long-haul Truck	62	Vehicles in Classes 8, 9, 10, 11, 12, and 13 typically driving 200 miles or more per trip

Alternative Fuels and Advanced Engine Technologies

The AFLEET Tool has adjustment factors to conventional fuel emission rates for a variety of alternative fuels and advanced engine technologies. This CMAQ tool utilizes AFLEET adjustment factors for different hybrids, renewable fuels, natural gas, and propane. Since fuel cell vehicles have zero tailpipe emissions, their emission rates are simply copied from MOVES national defaults for brake and tire wear of gasoline light-duty and diesel heavy-duty vehicles. Some basic definitions of these alternative fuels and technologies have been included in Appendix A. Methodology on how the AFLEET adjustment factors were created can be found in documentation of the tool.[7]

Tool Outputs

The Fleet Purchase module assumes that the user is replacing conventional fuel vehicles with alternative fuel vehicles. The benefits are derived from the difference in exhaust emission rates conventionally fueled and electric vehicles. Certain pollutants, vehicle types, and model years may lead to specific disbenefits, such that the new fleet of alternative fuel vehicles are emitting more than the existing fleet

[6] FHWA, https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm
[7] DOE, https://greet.es.anl.gov/files/afleet-tool-2016-user-guide

of conventional fuel vehicles. The module assumes one-to-one replacement of vehicle miles traveled and population from the conventional fuel fleet to the alternative fuel fleet. That is, new alternative fuel vehicles are expected to be operated in the same way as the conventional fuel vehicles they are replacing. Any vehicles or activity by the alternative fuel fleet or conventional fuel fleet not directly displaced will need to be accounted for outside of the tool.

Emission reductions are calculated for five criteria pollutants – carbon monoxide (CO), particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), particulate matter less than 10 microns in diameter (PM_{10}), NOx (nitrogen oxides), and VOC (volatile organic compounds). In addition, carbon dioxide and carbon dioxide equivalent (CO_2e) in kilograms/year as well as total energy consumption (TEC) generated in MMBTU/year are also included. Each pollutant is divided by 365 for the CMAQ daily emission reductions reported in kilograms/day and energy becomes MMBTU/day. In the event that a different annualization is desired, users are recommended to multiply their daily results by 365 and then divide by their chosen number of days annually, i.e. 250 working days.

Error Messages

Table 3 below summarizes any error and warning messages associated with the Fleet Purchase module, the reasons for those errors, and possible solutions. More information to guide solutions to errors are provided below the table. Note that once the error is corrected, please press 'Calculate Output' again to estimate emissions.

Table 3 Error Messages

Error Message	Reason for Error	Solution
Please select a valid project evaluation year for analysis.	Project Evaluation Year Error	Select an evaluation year from the pull-down list
Please select a project component.	Project Component Error	Select the checkbox of the project component(s) included in the project.
Please select a valid vehicle type for analysis.	Invalid Input: Vehicle Type	Select a vehicle type from the pull-down list
Please input a valid model year for replaced vehicles.	Invalid Input: Model Year of Replaced Vehicles	Enter a model year
Please select a valid conventional fuel to be replaced.	Invalid Input: Conventional Fuel	Select a conventional fuel from the pull-down list
Please input a valid model year for purchased vehicles.	Invalid Input: Model Year of Purchased Vehicles	Enter a model year
Please select a valid alternative fuel for the purchased vehicles.	Invalid Input: Alternative Fuel	Select an alternative fuel from the pull-down list
Please select which fleet activity data you will be providing.	Invalid Input: Activity Selection	Select the checkbox of the type of activity data to input.
Please ensure that vehicle-miles traveled is greater than zero.	WARNING: Vehicle Miles Traveled	Enter a VMT that is greater than 0
Fleet purchase must be greater than zero.	WARNING: Insufficient Fleet Purchase	Enter a number that is greater than 1

Please input an indication of how distance to the primary fueling facility will change	Invalid Input: Change in Distance	Select "increase" or "decrease" from the drop-down menu.
Please input a number greater than zero for the change in annual fleet VMT.	Invalid Input: Change in Annual Fleet VMT	Enter a number that is greater than 0
Year Input Error - This tool only includes vehicle that are 30 years old or less. Please choose an appropriate year within this range.	Invalid input for model year of conventional fuel vehicle(s)	Input an appropriate model year
Year Input Error - This tool only includes vehicle that are 30 years old or less. Please choose an appropriate year within this range.	Invalid input for model year of alternative fuel vehicle(s)	Input an appropriate model year
WARNING: There is not enough test data available to estimate emissions from vehicles with this source type-alternative fuel combination. For these vehicles, the tool will report zero emission reductions.	In some cases, AFLEET factors or MOVES emission rates were zero for certain source type-alternative fuel combinations due to insufficient or unavailable emissions test data	Choose a different source type-alternative fuel combination for modeling

Source type-fuel type combinations: Not every vehicle type and -fuel type combination will produce results in this CMAQ tool. Some AFLEET alternative fuels have factors for every MOVES source type and other fuels do not. Table 4 below shows which fuels have MOVES emission rates or non-zero AFLEET factors by source type. Since MOVES contains emissions for light-duty E85-capable vehicles, those rates were pulled directly from MOVES instead of an estimate with an AFLEET factor. AFLEET provides CNG factors for some heavy-duty source types, namely school buses, short-haul single unit trucks, and long-haul single unit trucks, and these factors have been used in this CMAQ tool.

As noted above, for combinations without AFLEET data such the alternative fuel factors are zero, warnings will pop up and any subsequent emission reductions will appear as zero. For more information on the AFLEET factors, please consult the GREET documentation on analyzing heavy-duty vehicle emission rate[8] and updating GREET emission factors with MOVES data[9] accordingly.

MOVES data has some minor gaps for conventional fuel vehicles as well. Gasoline combination long-haul trucks cannot be modeled in MOVES at all. Please consult the most recent MOVES technical report on vehicle populations and activity[10] and the latest default MOVES database[11] for further identifying data gaps.

[8] DOE, https://greet.es.anl.gov/publication-heavy-duty
[9] DOE, https://greet.es.anl.gov/publication-vehicles-13
[10] EPA, *Population and Activity of On-road Vehicles in MOVES3*, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1011TF8.pdf
[11] EPA, https://www.epa.gov/moves/moves2014a-latest-version-motor-vehicle-emission-simulator-moves

Table 4 Vehicle source type-alternative fuel type combinations in tool

Vehicle Source Type	Fuel Type									
	Dual Fuel	B100	B20	CNG	E85	FCV	HEV	HHV	LNG	LPG
Passenger Car		A	A	A	M	A	A		A	A
Passenger Truck		A	A	A	M	A	A		A	A
Light Commercial Truck		A	A	A	M	A	A		A	A
School Bus		A	A	A	A	A	A	A	A	A
Refuse Truck	A	A	A	A		A	A	A	A	
Single Unit Short-haul Truck	A	A	A	A	A	A	A	A	A	A
Single Unit Long-haul Truck	A	A	A	A	A	A	A	A	A	A
Combination Short-haul Truck	A	A	A	A		A	A	A	A	
Combination Long-haul Truck	A	A	A	A		A	A	A	A	

For reference, the AFLEET factors are based on gasoline for light-duty vehicles (LDVs) and diesel for heavy-duty vehicles (HDVs). Table 5 below indicates which conventional fuel is the baseline estimate for each AFLEET factor according to source type. Since MOVES can be used for light-duty emission rates of ethanol (E85) vehicles[12] and heavy-duty compressed natural gas (CNG) vehicles, the CMAQ tool prioritizes those modal MOVES rates over AFLEET-adjusted emission rates. Only the alternative fuel vehicle types with MOVES rates, as well as FCVs of all source types, will produce CO_2, CO_2e or TEC; all of the other the alternative fuel vehicles will report "N/A" for greenhouse gases and energy. FCVs, like electric vehicles, have zero tailpipe emissions and only generate emissions for particulate matter from brakewear and tirewear. While more common scenarios will involve replacement of gasoline LDVs and diesel HDVs, users can replace diesel LDVs and gasoline HDVs if desired.

Table 5 Source type and baseline conventional fuel for AFLEET factor

sourceTypeID	Vehicle Source Type	AFLEET Baseline Fuel
21	Passenger Car	Gasoline
31	Passenger Truck	Gasoline
32	Light Commercial Truck	Gasoline
43	School Bus	Diesel
51	Refuse Truck	Diesel
52	Single Unit Short-haul Truck	Diesel
53	Single Unit Long-haul Truck	Diesel
61	Combination Short-haul Truck	Diesel
62	Combination Long-haul Truck	Diesel

[12] This CMAQ tool assumes that E85 is utilized 100 percent of the time in flexible fuel vehicles.

Evaluation years: Evaluation year and model year information: Evaluation years range from 2018 to 2040 and model years can range from the evaluation year to 30 years prior to that evaluation year. MOVES only generates results for model years in that 30-year window. The tool will push messages if a user selects a disallowed source type-fuel type combination or an erroneous year.

TOOL METHODOLOGY

Fleet Purchase

Annual emission reductions, which are divided by 365 to be reported in kilograms/day for the total number of conventional fuel vehicles being replaced by alternative fuel vehicles, are calculated for a given pollutant as followed:

$$reduced\ emissions = \frac{(e_{conv\ replace} - e_{alt}) \cdot VMT_{fleet}}{365} \quad (1)$$

where for E85 LDVs and all fuel cell vehicles,

$$e_{alt} = e_{alt\ MOVES} \quad (2)$$

and where for all other alternative fuel vehicles,

$$e_{alt} = e_{conv\ purc\ hase} \cdot A_{alt} \quad (3)$$

such that,

$e_{conv_{replace}}$ = annual conventional fuel (diesel or gasoline) emission rate for a given source type and model year of the vehicles to be replaced (kilogram/mile),

e_{alt} = annual alternative fuel emission rate for a given source type and model year of the vehicles to be purchased (kilogram/mile),

$e_{alt_{MOVES}}$ = alternative fuel emission rate pulled directly from MOVES (kilogram/mile),

VMT_{fleet} = total annual vehicle miles traveled by the fleet to be replaced (miles),

$e_{conv_{purchase}}$ = annual conventional fuel (diesel or gasoline) emission rate for a given source type and model year of the vehicles to be purchased (kilogram/mile), and

A_{alt} = AFLEET factor for a specified alternative fuel, determined by vehicle source type and pollutant.

Either vehicle miles traveled or population is required for proper calculation of emission reductions. If only a population is provided by the user, the fleet activity (VMT_{fleet}) is instead calculated leveraging national MOVES default values using the applicable equations:

$$VMT_{fleet} = POP_{user} \left(\frac{VMT_{national}}{POP_{national}}\right) \quad (4)$$

in which,

POP_{fleet} = total number of alternative fuel vehicles to be purchased,
$VMT_{national}$ = national vehicle miles traveled from MOVES defaults for vehicles to be replaced of specified a model year, fuel type, and vehicle type in the given project evaluation year, and
$POP_{national}$ = national vehicle populations from MOVES defaults for vehicles to be replaced of specified a model year, fuel type, and vehicle type in the given project evaluation year.

Restricted Access Infrastructure

Emission reductions, reported in kilograms/day for the construction of alternative fuel infrastructure with restricted access, are calculated for a given pollutant as followed:

$$reduced\ emissions = \frac{e_{alt} \cdot \Delta VMT_{fleet}}{365} \quad (1)$$

where for E85 LDVs and most CNG HDVs,

$$e_{alt} = e_{alt\ MOVES} \quad (2)$$

and where for all other alternative fuel vehicles,

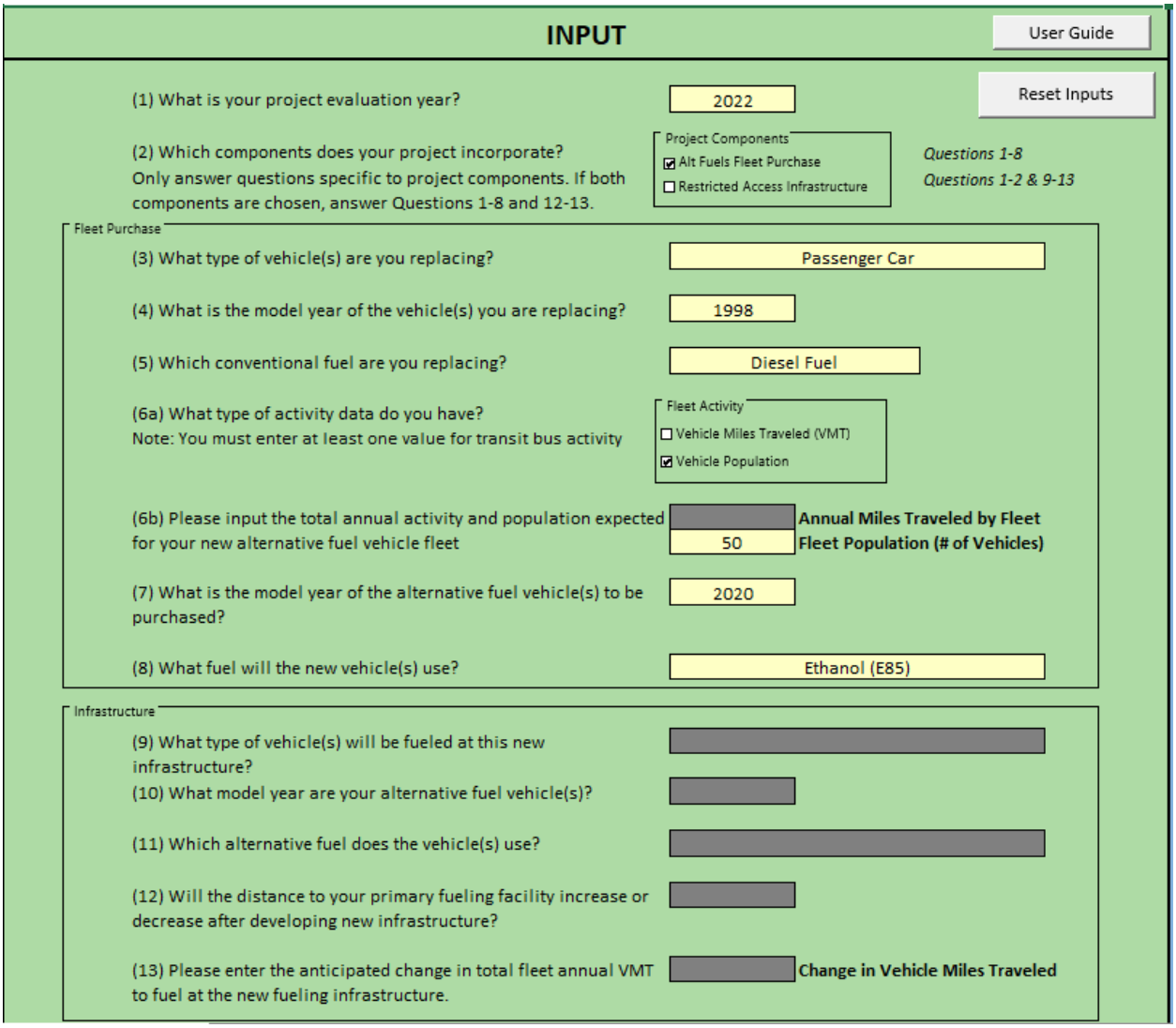
$$e_{alt} = e_{conv\ purc\ hase} \cdot A_{alt} \quad (3)$$

such that,
e_{conv} = annual conventional fuel (diesel or gasoline) emission rate for a given vehicle source type and model year of the vehicles to be purchased (kilogram/mile) in the selected evaluation year,
e_{alt} = annual alternative fuel emission rate for a given source type and model year of the vehicles to be purchased (kilogram/mile),
$e_{alt_{MOVES}}$ = alternative fuel emission rate pulled directly from MOVES (kilogram/mile),
A_{alt} = AFLEET factor for a specified alternative fuel, determined by vehicle source type and pollutant, and
ΔVMT_{fleet} = change in annual distance traveled to refuel the alternative fuel fleet after construction of restricted access infrastructure (miles).

EXAMPLES

Example 1: Purchasing a Fleet of Ethanol Passenger Cars (Population Known, VMT Unknown), No Restricted Access Infrastructure Component

Scenario: County X in State AA would like to purchase 50 E85-fueled cars for their municipal fleet. The county does not have a good measurement of activity for the conventional fuel fleet being replaced, so they will rely on national default values of annual miles traveled per vehicle. In the Vehicle Purchase tool, the following inputs would be chosen, as shown in the image below:



Project Year: 2022
Alt Fuels Fleet Replacement [check box]: Selected
Vehicle Type: Passenger Car
Model Year for Conventional Fuel Vehicles: 1998
Conventional Fuel: Diesel
Vehicle Population [check box]: Selected

Vehicle Population: 50
Model Year of Alternative Fuel Vehicles: 2020
Alternative Fuel: Ethanol (E85)

Once the inputs are entered, select the 'Calculate Output' button to estimate fleet performance and emission reductions for the project, as shown below:

OUTPUT Calculate Output

FLEET PERFORMANCE

Annual Activity for Fleet Purchase Projects

	BEFORE	AFTER
Annual Total Vehicle Miles Traveled	310,647	310,647
Annual Transit Bus Population	50	50
Annual Miles Traveled per Vehicle	6,213	6,213

EMISSION REDUCTIONS

Pollutant	Total (kg/day unless noted)
Carbon Monoxide (CO)	10.808
Nitrogen Oxide (NOx)	1.183
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.013
Particulate Matter <10 µm (PM_{10})	0.014
Volatile Organic Compounds (VOC)	0.392

Carbon Dioxide (CO_2)	143.891
Carbon Dioxide Equivalent (CO_2e)	142.755
Total Energy Consumption (MMBTU/day)	1.785

Note: emissions models have limited CO_2, CO_2e and energy estimates for alternative fuel vehicles, they only exist for E85 light-duty vehicles, CNG heavy-duty vehicles, and all FCV vehicles.

In the absence of user-supplied vehicle miles traveled data, this tool utilizes national rates to calculate emission benefits. For this example, the tool estimates that 6,213 miles are traveled by every 20 year-old car in the fleet.

The emission reductions in kg/day for all pollutants as well as the energy reduction in MMBTU/day are:

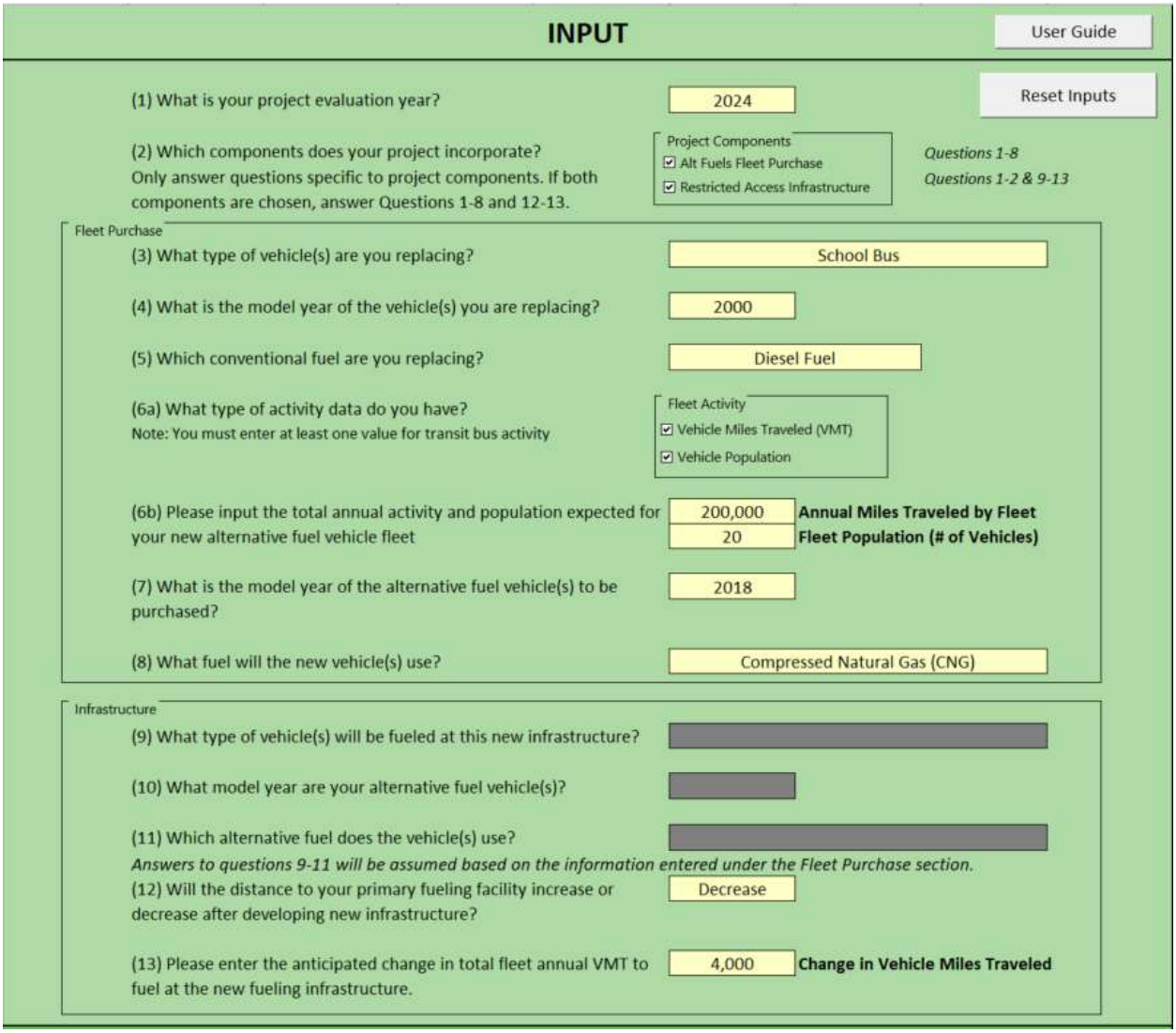
Carbon Monoxide (CO): 10.808
Nitrogen Oxide (NOx): 1.183
Particulate Matter (PM10): 0.013
Particulate Matter (PM2.5): 0.014
Volatile Organic Compounds (VOC): 0.392

Carbon Dioxide (CO_2): 143.891

Carbon Dioxide Equivalent (CO_2e): 142.755
Total Energy Consumption (TEC): 1.785

Example 2: Purchasing a Fleet of Compressed Natural Gas School Buses (Population and VMT Known), Restricted Access Infrastructure Component

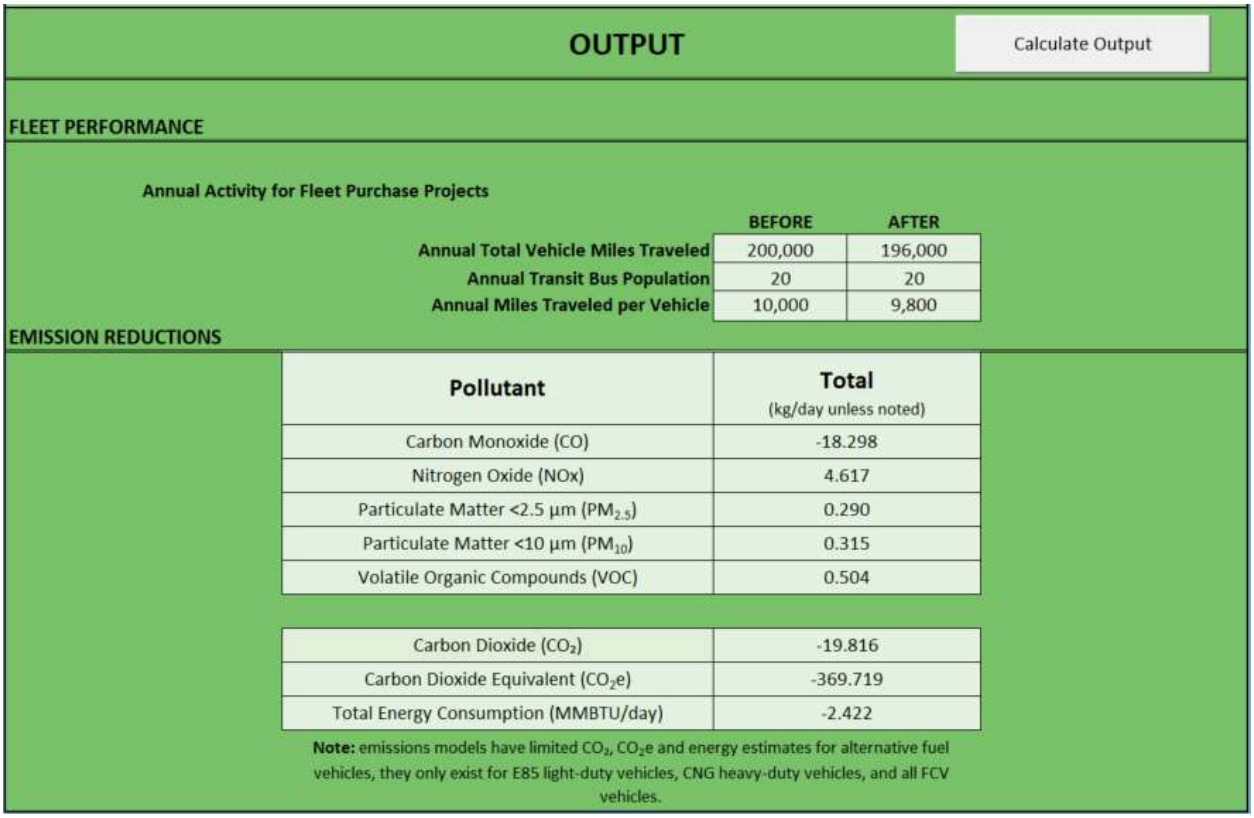
County X would like to replace 20 of their oldest diesel school buses with compressed natural gas ones, and knows activity rates of its fleet. The County will also construct a restricted access fueling facility to fuel the new buses, resulting in a 4,000 mile reduction in annual VMT. In this case, the county provides both the vehicle miles traveled and population. For this example, the following inputs have been selected:



Project Year: 2024
Alt Fuels Fleet Replacement [check box]: Selected
Vehicle Type: School Bus
Model Year for Conventional Fuel Vehicles: 2000
Conventional Fuel: Gasoline

Vehicle Miles Traveled (VMT) [check box]: Selected
Vehicle Population [check box]: Selected
Annual Miles Traveled by Fleet: 200,000
Vehicle Population: 20
Model Year of Alternative Fuel Vehicles: 2018
Alternative Fuel: Compressed Natural Gas (CNG)
Change in Distance to Facility: Decrease
Change in Annual VMT: 4,000

The Calculate Output button computes emission benefits and fleet performance of the 20 diesel school buses being replaced with CNG buses, as shown below:



OUTPUT Calculate Output

FLEET PERFORMANCE

Annual Activity for Fleet Purchase Projects

	BEFORE	AFTER
Annual Total Vehicle Miles Traveled	200,000	196,000
Annual Transit Bus Population	20	20
Annual Miles Traveled per Vehicle	10,000	9,800

EMISSION REDUCTIONS

Pollutant	Total (kg/day unless noted)
Carbon Monoxide (CO)	-18.298
Nitrogen Oxide (NOx)	4.617
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.290
Particulate Matter <10 µm (PM_{10})	0.315
Volatile Organic Compounds (VOC)	0.504

Carbon Dioxide (CO_2)	-19.816
Carbon Dioxide Equivalent (CO_2e)	-369.719
Total Energy Consumption (MMBTU/day)	-2.422

Note: emissions models have limited CO_2, CO_2e and energy estimates for alternative fuel vehicles, they only exist for E85 light-duty vehicles, CNG heavy-duty vehicles, and all FCV vehicles.

The emission reductions in kg/day for all pollutants as well as the energy reduction in MMBTU/day are:

Carbon Monoxide (CO): -18.298
Nitrogen Oxide (NOx): 4.617
Particulate Matter (PM10): 0.290
Particulate Matter (PM2.5): 0.315
Volatile Organic Compounds (VOC): 0.504

Carbon Dioxide (CO_2): -19.816

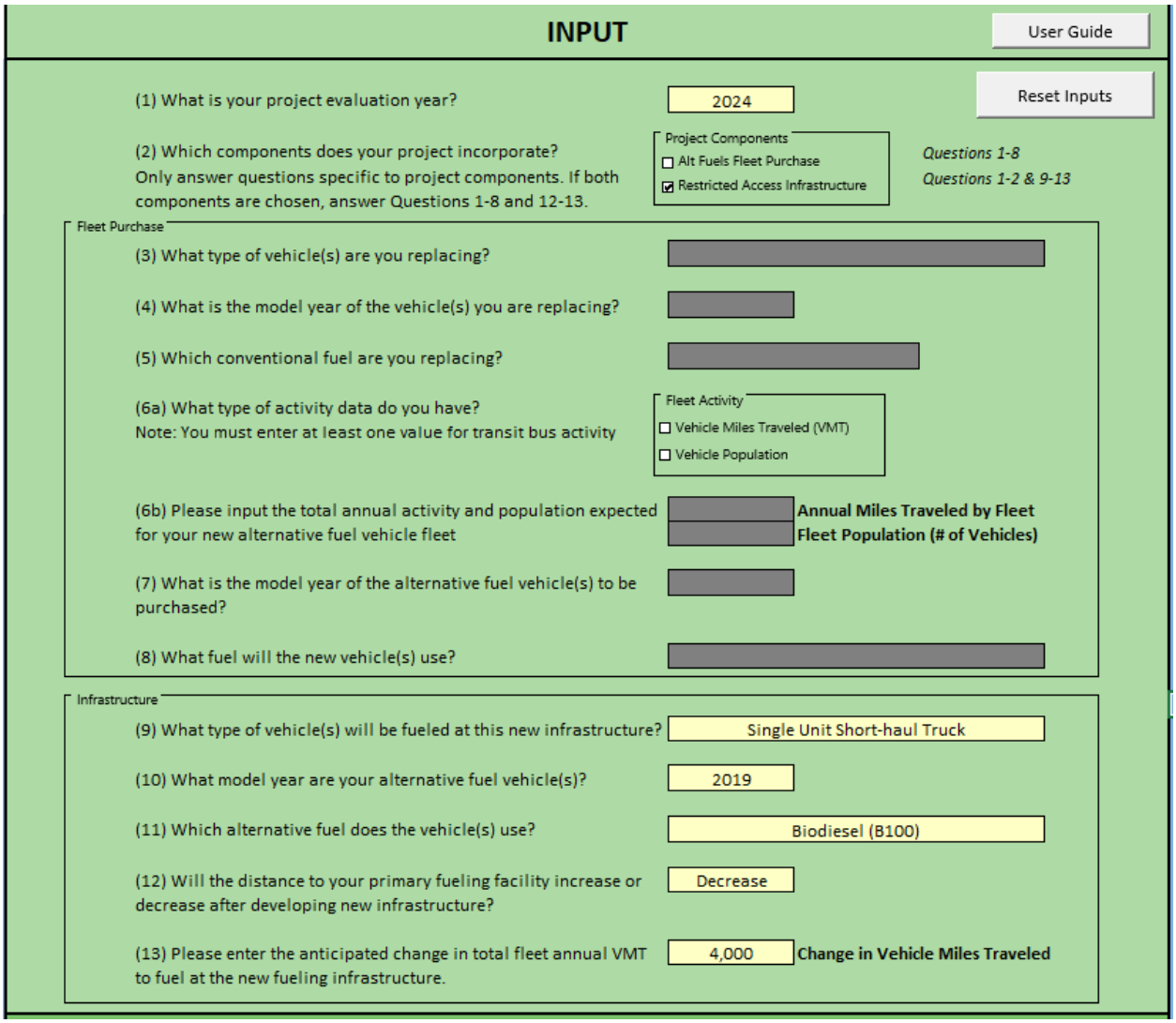
Carbon Dioxide Equivalent (CO_2e): -369.719
Total Energy Consumption (TEC): -2.422

Negative emission outputs indicate an increase in emissions for certain pollutants. In this case, the transition to a CNG fleet from a diesel fleet will cause an increase in carbon monoxide, carbon dioxide, carbon dioxide equivalent, and total energy consumption. Carbon dioxide, carbon dioxide equivalent, and total energy consumption may be calculated for this source type and fuel type combination because the data is available in MOVES and does not come from an AFLEET factor calculation.

Please note the fleet activity output will be the same as the fleet activity input when it is given, in this case each bus travels 10,000 miles per year. If not provided as an input, the fleet performance depends on MOVES national default values.

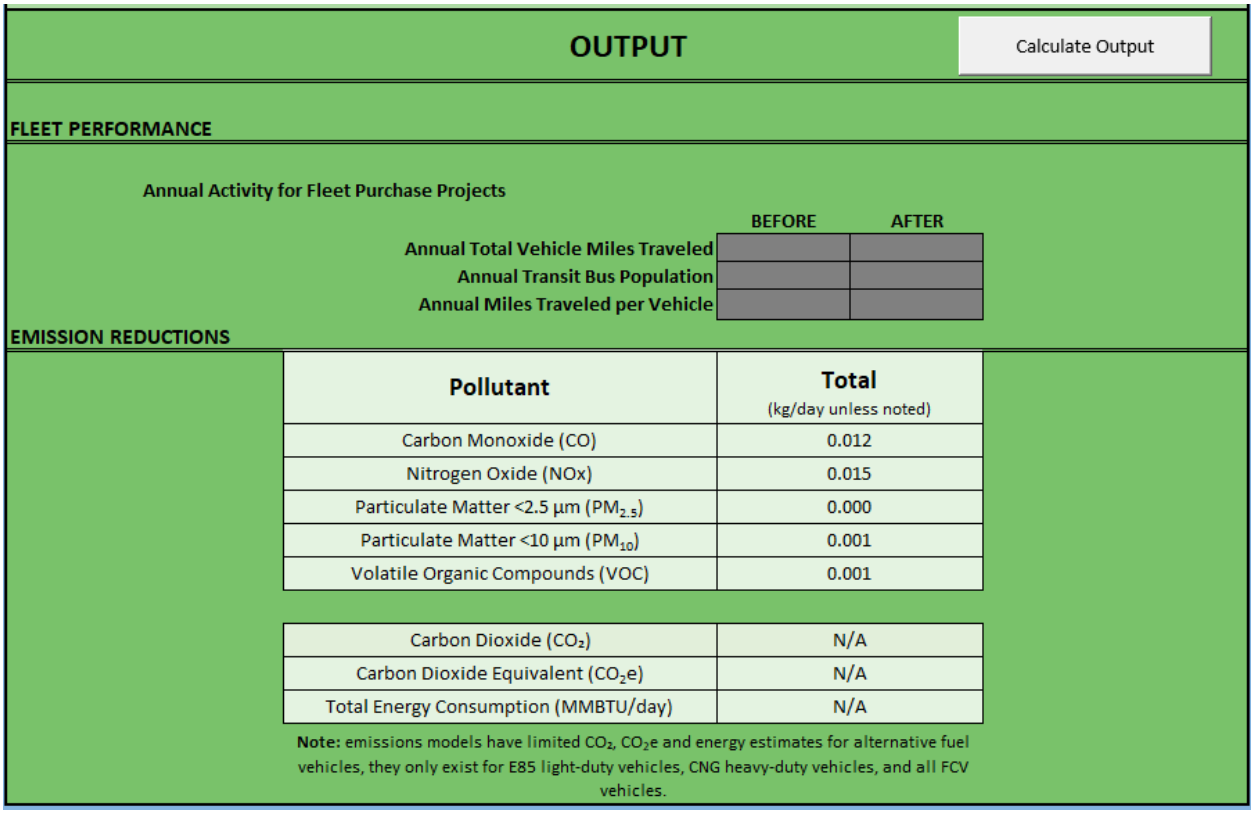
Example 3: No Fleet Purchase, Building Restricted Infrastructure for a Single-Unit Short-Haul Biodiesel (B100) Fleet

A county is planning on constructing a restricted access fueling facility for an existing fleet of biodiesel single-unit short-haul trucks, without making any new fleet purchase. The new facility will decrease the distance to the primary fueling facility, resulting in a reduction of 5,000 miles annually.



Project Year: 2024
Vehicle Type: Single Unit Short-Haul Truck
Model Year of Alternative Fuel Vehicles: 2019
Alternative Fuel: Biodiesel (B100)
Change in Distance to Facility: Decrease
Change in Annual VMT: 4,000

The Calculate Output button will produce emission impacts, whether positive or negative, from installing the restricted-access fueling infrastructure, as shown below:



OUTPUT

Calculate Output

FLEET PERFORMANCE

Annual Activity for Fleet Purchase Projects

	BEFORE	AFTER
Annual Total Vehicle Miles Traveled		
Annual Transit Bus Population		
Annual Miles Traveled per Vehicle		

EMISSION REDUCTIONS

Pollutant	Total (kg/day unless noted)
Carbon Monoxide (CO)	0.012
Nitrogen Oxide (NOx)	0.015
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.000
Particulate Matter <10 µm (PM_{10})	0.001
Volatile Organic Compounds (VOC)	0.001

Carbon Dioxide (CO_2)	N/A
Carbon Dioxide Equivalent (CO_2e)	N/A
Total Energy Consumption (MMBTU/day)	N/A

Note: emissions models have limited CO_2, CO_2e and energy estimates for alternative fuel vehicles, they only exist for E85 light-duty vehicles, CNG heavy-duty vehicles, and all FCV vehicles.

The emission reductions in kg/day for all pollutants as well as the energy reduction in MMBTU/day are:

Carbon Monoxide (CO): 0.012
Nitrogen Oxide (NOx): 0.015
Particulate Matter (PM2.5): 0.000
Particulate Matter (PM10): 0.001
Volatile Organic Compounds (VOC): 0.001

Carbon Dioxide (CO_2): N/A
Carbon Dioxide Equivalent (CO_2e): N/A
Total Energy Consumption (TEC): N/A

Appendix A: Alternative Fuels and Advanced Engine Technologies

A **hybrid electric vehicle (HEV)** uses a combination of an electric motor and an internal combustion engine to propel the vehicle. Usually hybrids have downsized engines, this coupled with power from an on-board battery system to the electric drivetrain, leads to better fuel efficiency than non-hybridized models.[13] The most common example of a gasoline HEV is a Toyota Prius, which charges its batteries through regenerative braking. At low speeds, a Prius is powered entirely by its batteries and electric motor. Specialized designs such as plug-in hybrid electric vehicles (PHEVs) and extended range electric vehicles (EREVs) are part of this broader hybrid electric category.

A **hydraulic hybrid vehicle (HHV)** utilizes a pressurized fluid system rather than batteries for chemical energy storage but operates much in the same way as a hybrid electric vehicle. Hydraulic hybrids, like HEVs, capture energy for storage through regenerative braking.[14] Hydraulic hybrids also offer better fuel economy and often lower emissions than comparable non-hybridized vehicles.

A **fuel cell vehicle (FCV)** runs on an electric motor which is powered by hydrogen fuel cells rather than electricity stored in batteries.[15] Most commonly for vehicle applications, the fuel cells efficiently convert stored hydrogen fuel into electrical energy through a polymer electrolyte membrane (PEM) design that splits the hydrogen's protons and electrons and then uses the electrons to do work across an external circuit creating electricity and some waste heat.[16] The (positive) hydrogen ions are reformed with the free electrons and oxygen, such that FCVs do not emit any harmful tailpipe exhaust—only water vapor and warm air.[17] Like for electric vehicles, many FCVs utilize regenerative braking to charge an onboard battery that provides supplemental power to the electric motor.[16]

Natural gas is increasingly being used as a transportation fuel. Most commonly natural gas is distributed as a pressurized gas or in liquid form. Some original equipment manufacturers (OEMs) produce natural gas vehicles like the now discontinued Honda Civic GX that ran on **compressed natural gas (CNG)**, but many natural gas vehicles are retrofitted conventional fuel vehicles with aftermarket conversion kits. These vehicles may be either dedicated for natural gas or use a system that runs on a conventional fuel and natural gas. A **dual fuel vehicle** uses diesel for pilot ignition and natural gas for propulsion. CNG is dispensed at 3000 or 3600 pounds per square inch (psi) and stored on the vehicle in high-pressure fuel tanks. **Liquefied natural gas (LNG)** is super-cooled and then stored at extremely cold temperatures in cryogenic fuel tanks.[18] Natural gas has a lower energy density than either gasoline or diesel, which results in less range for natural gas vehicles across equivalent fuel volumes.

Similar to natural gas, **propane** is a byproduct of petroleum refining, also called **liquefied petroleum gas (LPG)**, and is stored onboard the vehicle in pressurized tanks. Propane can be injected into the

[13] US Department of Energy, http://www.afdc.energy.gov/vehicles/electric_basics_hev.html
[14] US Environmental Protection Agency, https://archive.epa.gov/otaq/technology/web/html/research-hhvs.html
[15] DOE, http://www.afdc.energy.gov/vehicles/fuel_cell.html
[16] DOE/EPA, https://www.fueleconomy.gov/feg/fcv_PEM.shtml
[17] Smithsonian Institution, http://americanhistory.si.edu/fuelcells/basics.htm
[18] DOE, http://www.afdc.energy.gov/fuels/natural_gas_basics.html

combustion chamber as a vapor or as a liquid. Liquid injection improves engine performance over vapor injection.[19]

Renewable fuels such as corn ethanol and soy biodiesel are also included in the CMAQ tool. For this tool, **ethanol** is only available in one blend—85 percent plant-based ethanol and 15 percent gasoline, known colloquially as **E85**, although actual blends may contain less ethanol depending on location and time of year.[20] **Biodiesel** comes in two blends for this tool, either 20 percent biodiesel and 80 percent petrol-based diesel (**B20**) or 100 percent biodiesel (**B100**).[21]

Note that electric vehicles are included in the Electric Vehicles and Infrastructure Tool.

[19] DOE, http://www.afdc.energy.gov/vehicles/propane.html
[20] DOE, http://www.afdc.energy.gov/fuels/ethanol_fuel_basics.html
[21] DOE, http://www.afdc.energy.gov/fuels/biodiesel_basics.html