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.

Electric Vehicles and Charging Infrastructure

The Electric Vehicles (EV) and EV Charging Infrastructure Tool estimates the emission benefits of adopting electric vehicles 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] 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 Electric Vehicles tool allows modeling of many passenger and commercial vehicles (including zero emission medium- and heavy-duty vehicle) source types in MOVES but excludes transit buses, which are included in the Transit Bus Upgrades and System Improvements tool. Note that this tool excludes all other alternative fuels (e.g., hybrid-electric, fuel cell, ethanol, etc.), which are included in the Alternative Fuel Vehicles and Infrastructure tool.

This tool currently contains two modules: 1) On-Road Electric Vehicle Fleet Purchase and Restricted Access EV Charging Infrastructure and 2) Unrestricted Access EV Charging Infrastructure. The first module can calculate emissions from an electric vehicle fleet purchase project and a restricted access infrastructure project separately, or together. The unrestricted infrastructure module for public charging 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 Electric Vehicle Fleet Purchase & Restricted Access EV Charging Infrastructure Module

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

Some charging infrastructure has restricted access, such that it will only service vehicles publicly-owned fleets. Restricted access infrastructure is not open for public charging. This module can also determine the emission impacts of restricted charging infrastructure depending on changes to the fleet miles traveled to charge at the new infrastructure.

This document is organized into three sections for Electric Vehicle Fleet Purchase and Restricted Access EV Charging 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 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 Electric Vehicle Fleet Purchase and Restricted Access EV Charging 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 electric 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 2040.
Project component: Electric 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 electric vehicle population	-----	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.
INFRASTRUCTURE		
Vehicle type to be charged 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.
Increase or decrease in distance to facility	-----	In order to calculate associated emissions reductions, users must select whether the distance to restricted-access charging infrastructure will increase or decrease. Note that this tool only provides results if there is a change in distance.
Change in total annual fleet VMT	miles	Enter in the expected change in annual vehicle miles traveled for fueling of the electric 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

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

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

Tool Outputs

The fleet purchase module assumes that the user is replacing conventional fuel vehicles with electric vehicles. The benefits are derived from the difference in exhaust emission rates between conventionally fueled and electric vehicles. The module assumes one-to-one replacement of vehicle miles traveled and population from the conventional fuel fleet to the electric fleet. That is, new electric vehicles are expected to be operated in the same way as the conventional fuel vehicles they are replacing. Any

[6] FHWA, https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm

vehicles or activity by the electric 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 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 electric vehicle(s)	Input an appropriate model year

Source type-fuel type combinations: 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[7] and the latest default MOVES database[8] for further identifying data gaps.

Electric vehicle emissions are derived from the MOVES particulate matter (PM2.5 and PM10) emissions for the source type and baseline fuel combinations shown in Table 4 below, consistent with the AFLEET fuel factor baseline conventional fuel types. While more common scenarios will involve replacement of gasoline LDVs and diesel HDVs, users can replace diesel LDVs and gasoline HDVs if desired.

Table 4 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

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.

[7] EPA, *Population and Activity of On-road Vehicles in MOVES3*, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1011TF8.pdf

[8] EPA, https://www.epa.gov/moves/moves2014a-latest-version-motor-vehicle-emission-simulator-moves

TOOL METHODOLOGY

EV 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 electric 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 electric vehicles:

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

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 electric vehicle emission rate for a given source type and model year of the vehicles to be purchased (kilogram/mile),

$e_{alt_{MOVES}}$ = electric vehicle emission rate pulled directly from MOVES for brakewear and tirewear particulate matter emissions only (all the rest are zero) (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

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:

$$VMT_{fleet} = POP_{user} \left(\frac{VMT_{national}}{POP_{national}}\right) \quad (3)$$

in which,

POP_{fleet} = total number of electric 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 EV Charging Infrastructure

Emission reductions, reported in kilograms/day for the construction of electric vehicle charging 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 electric vehicles,

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

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 electric vehicle emission rate for a given source type and model year of the vehicles to be purchased (kilogram/mile),

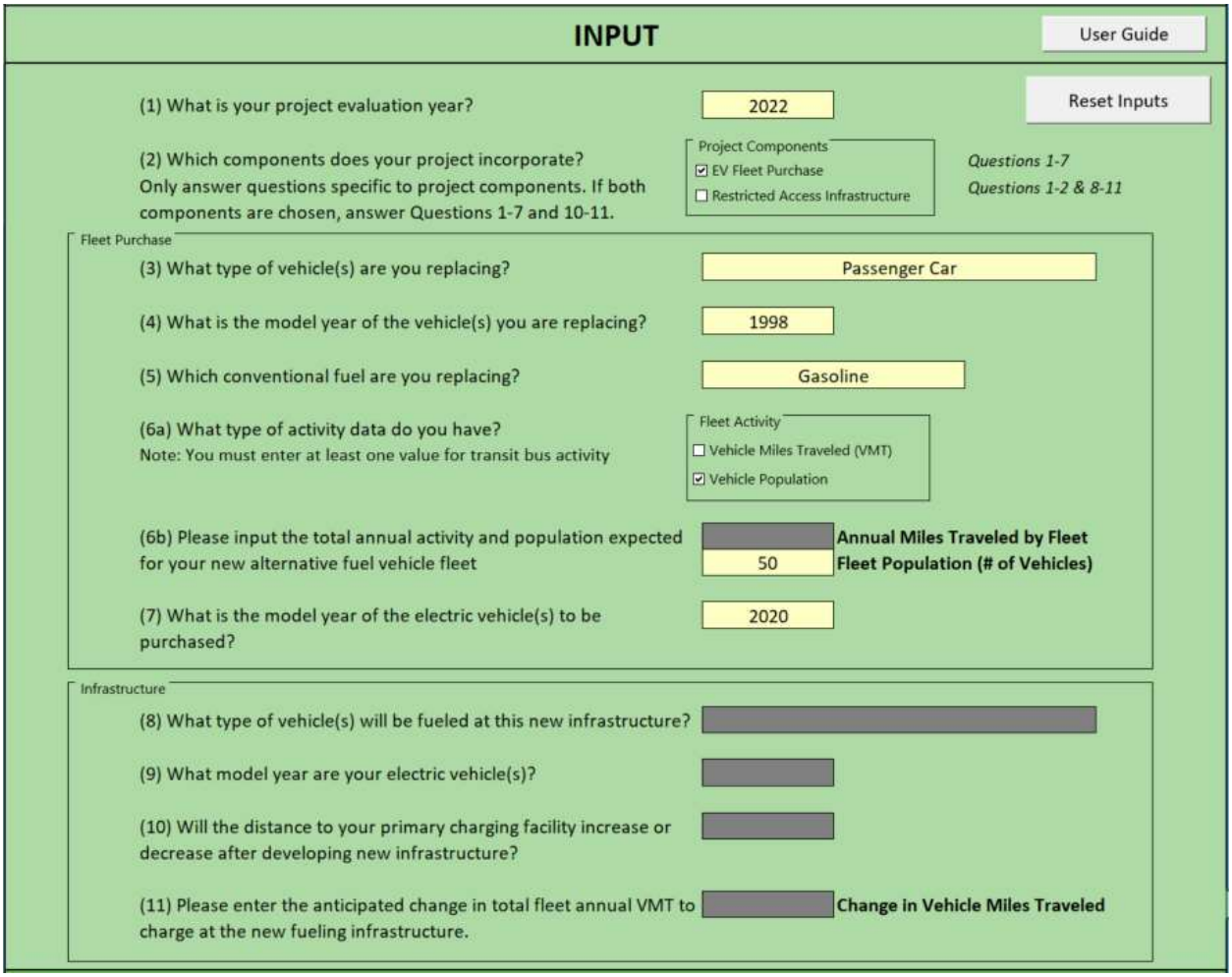
$e_{alt_{MOVES}}$ = electric vehicle emission rate pulled directly from MOVES for particulate matter brakewear and tirewear emissions (kilogram/mile), and

ΔVMT_{fleet} = change in annual distance traveled to charge the electric vehicle fleet after construction of restricted access charging infrastructure (miles).

EXAMPLES

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

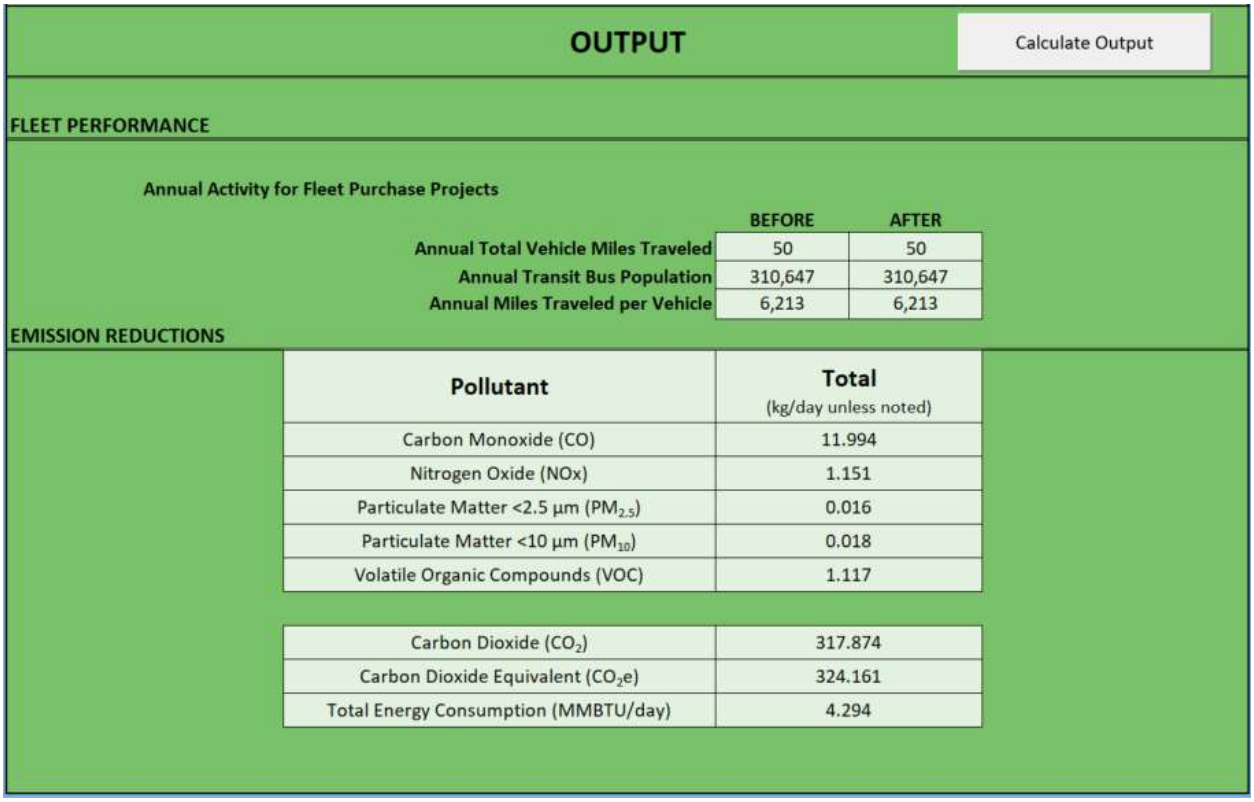
Scenario: County X in State AA would like to purchase 50 electric cars for their municipal fleet. The county does not have a good measurement of activity for the conventional fuel fleet being replaced, so they will rely on national default values of annual miles traveled per vehicle. In the Vehicle Purchase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



Project Year: 2022
Electric Vehicle Fleet Replacement [check box]: Selected
Vehicle Type: Passenger Car
Model Year for Conventional Fuel Vehicles: 1998
Conventional Fuel: Gasoline
Vehicle Population [check box]: Selected
Vehicle Population: 50

Model Year of Electric Vehicles: 2020

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

EMISSION REDUCTIONS

Pollutant	Total (kg/day unless noted)
Carbon Monoxide (CO)	11.994
Nitrogen Oxide (NOx)	1.151
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.016
Particulate Matter <10 µm (PM_{10})	0.018
Volatile Organic Compounds (VOC)	1.117

Carbon Dioxide (CO_2)	317.874
Carbon Dioxide Equivalent (CO_2e)	324.161
Total Energy Consumption (MMBTU/day)	4.294

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.

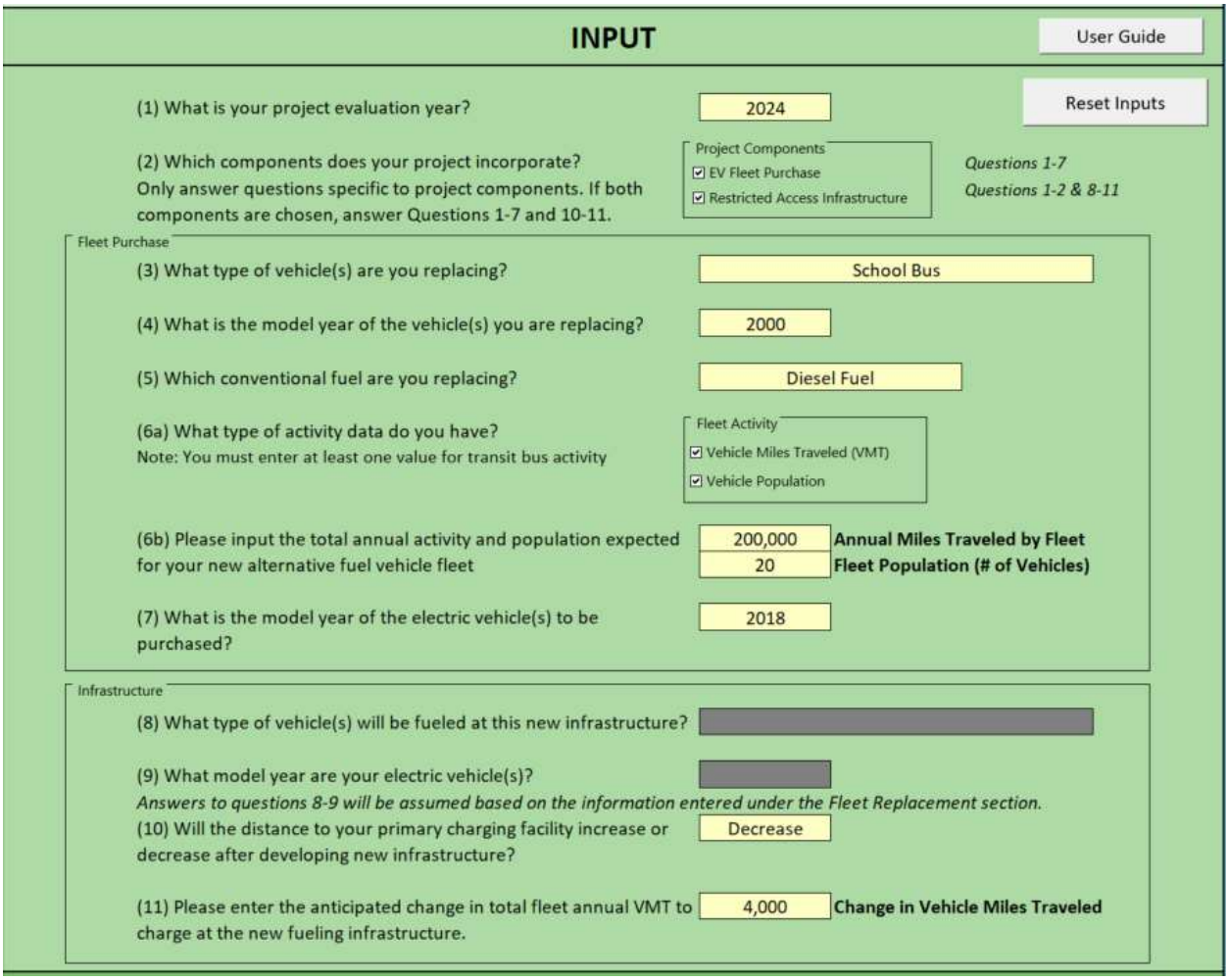
The emission reductions in kg/day for all pollutants as well as the energy reduction in MMBTU/day are:

Carbon Monoxide (CO): 11.994
Nitrogen Oxide (NOx): 1.151
Particulate Matter (PM10): 0.016
Particulate Matter (PM2.5): 0.022
Volatile Organic Compounds (VOC): 1.117

Carbon Dioxide Equivalent (CO_2): 317.874
Carbon Dioxide Equivalent (CO_2e): 324.161
Total Energy Consumption (TEC): 4.294

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

County X would like to replace 20 of their oldest diesel school buses with electric ones, and knows activity rates of its fleet. The County will also construct a restricted access facility to charge 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: Diesel
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 Electric Vehicles: 2018
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 electric buses, as shown below:

OUTPUT Calculate Output

FLEET PERFORMANCE

Annual Activity for Fleet Purchase Projects

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

EMISSION REDUCTIONS

Pollutant	Total (kg/day unless noted)
Carbon Monoxide (CO)	2.508
Nitrogen Oxide (NOx)	5.080
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.296
Particulate Matter <10 µm (PM_{10})	0.328
Volatile Organic Compounds (VOC)	1.039

Carbon Dioxide (CO_2)	660.060
Carbon Dioxide Equivalent (CO_2e)	660.567
Total Energy Consumption (MMBTU/day)	8.505

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

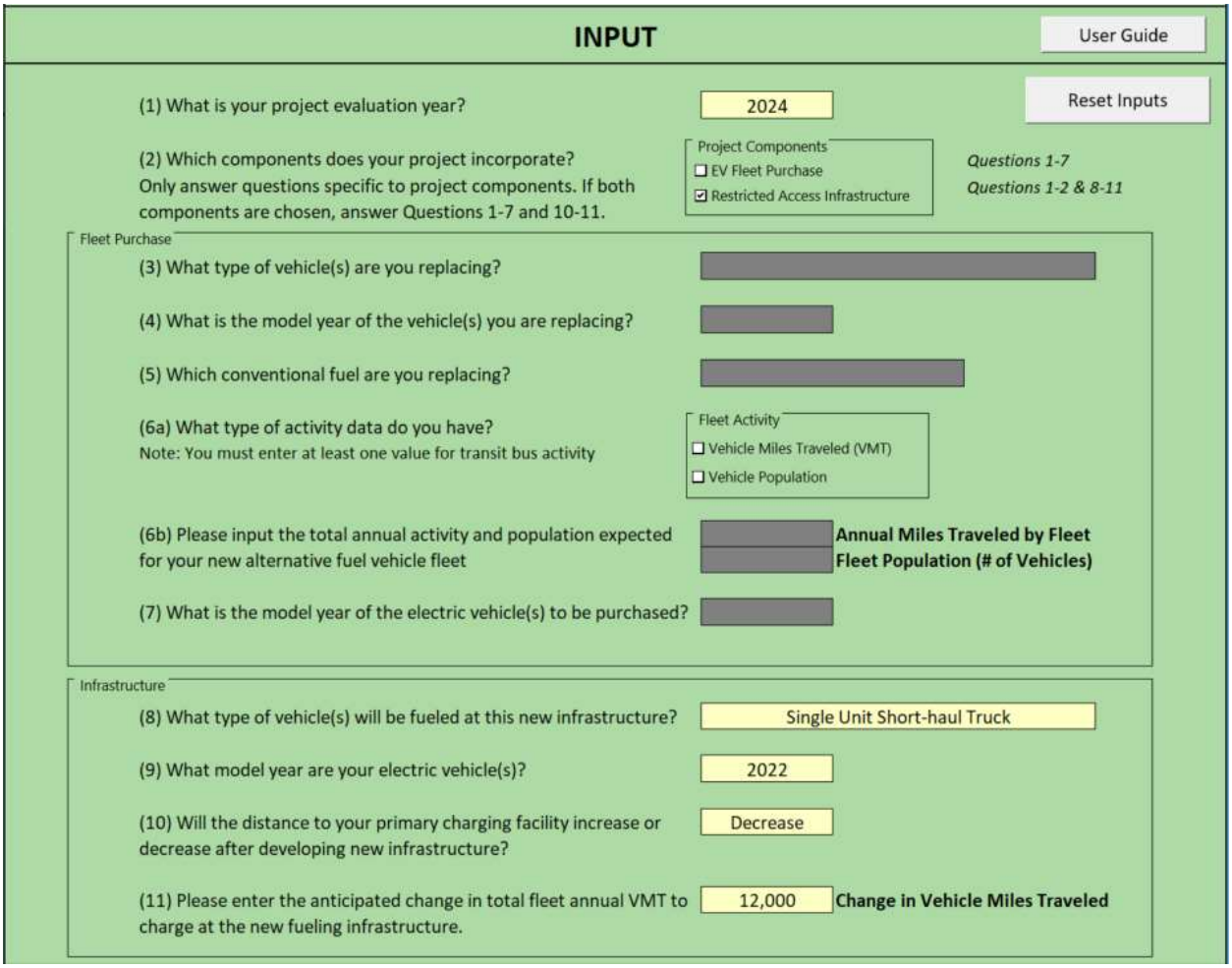
Carbon Monoxide (CO): 2.508
Nitrogen Oxide (NOx): 5.080
Particulate Matter (PM10): 0.296
Particulate Matter (PM2.5): 0.328
Volatile Organic Compounds (VOC): 1.309

Carbon Dioxide (CO_2): 660.060
Carbon Dioxide Equivalent (CO_2e): 660.567
Total Energy Consumption (TEC): 8.505

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.

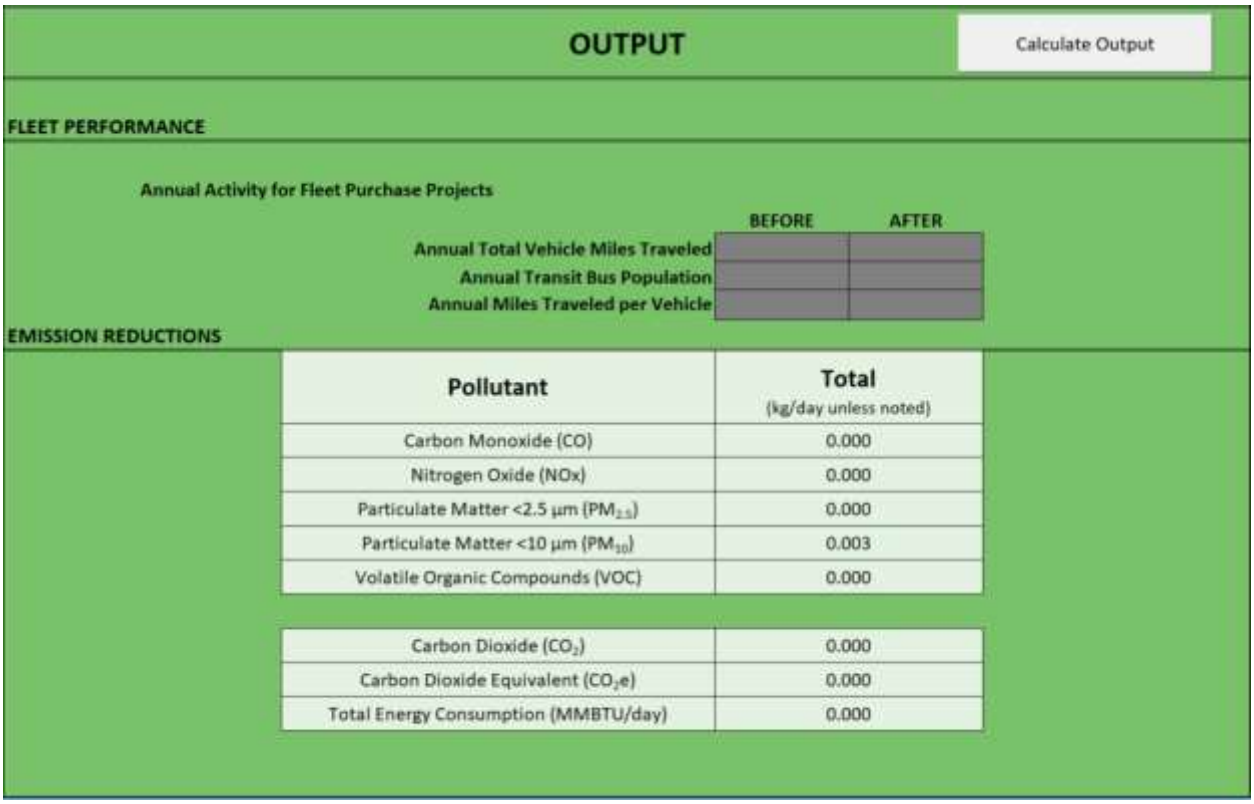
Example 3: No Fleet Purchase, Building Restricted Access EV Charging Infrastructure for a Single-Unit Short-Haul Electric Fleet

A county is planning on constructing a restricted access charging facility for an existing fleet of electric 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 12,000 miles annually.



Project Year: 2024
Vehicle Type: Single Unit Short-Haul Truck
Model Year of Electric Vehicles: 2022
Change in Distance to Facility: Decrease
Change in Annual VMT: 12,000

The Calculate Output button will produce emission impacts, whether positive or negative, from installing the restricted-access charging 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)	0.000
Nitrogen Oxide (NOx)	0.000
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.000
Particulate Matter <10 µm (PM_{10})	0.003
Volatile Organic Compounds (VOC)	0.000

Carbon Dioxide (CO_2)	0.000
Carbon Dioxide Equivalent (CO_2e)	0.000
Total Energy Consumption (MMBTU/day)	0.000

The emission reductions in kg/day for all pollutants are:

Carbon Monoxide (CO): 0.000
Nitrogen Oxide (NOx): 0.000
Particulate Matter (PM2.5): 0.000
Particulate Matter (PM10): 0.003
Volatile Organic Compounds (VOC): 0.000

Carbon Dioxide (CO_2): 0.000
Carbon Dioxide Equivalent (CO_2e): 0.000
Total Energy Consumption (TEC): 0.000

This project only produces emissions benefits for particulate matter because charging infrastructure benefits are calculated solely based on the change in annual VMT resulting from the change in location to the new infrastructure, and electric vehicles only produce particulate matter emissions resulting from brakewear and tirewear.

Appendix A: Battery Electric Vehicle Definition

A **battery electric vehicle (BEV)** is similar to the hybrid designs discussed but does not have an internal combustion engine. A BEV is instead powered solely by the electrical energy stored in its rechargeable battery system. The most popular BEVs on the market today are Tesla's Model S, Model X, and the Nissan Leaf.[9] All-electric vehicles do not produce any direct exhaust or tailpipe emissions.[10] However, the electricity used to power the vehicles does produce upstream emissions that are not accounted for in this tool. Lifecycle emission comparisons from a well-to-wheels (WTW) analysis between electric and conventional fuel vehicles will invariably yield different results than this CMAQ tool.

All other alternative fuel vehicles, including hybrid diesel-electric and hydrogen fuel cell (FCV) vehicles, can be found in the documentation for the Alternative Fuel Vehicles and Infrastructure Tool.

[9] InsideEVs, Monthly Plug-In Sales Scorecard, http://insideevs.com/monthly-plug-in-sales-scorecard/
[10] DOE, http://www.afdc.energy.gov/vehicles/electric_basics_ev.html