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.

Transit Bus Upgrades & System Improvements Tool

The Transit Bus Upgrades and System Improvements Tool contains three modules: 1) retrofits of diesel transit buses with new emission reduction technologies, 2) replacements of diesel and compressed natural gas (CNG) transit buses (or engines) with either newer diesel, CNG, or alternative fuel (non-electric) buses, and 3) replacements of diesel and compressed natural gas (CNG) transit buses (or engines) with electric transit buses. Both of the replacement modules (2 & 3) allow for a restricted access infrastructure component, which may be selected in conjunction with or separate from a bus replacement project component.

This tool allows modeling of transit buses only. Emission benefits of other vehicle source types may be modeled using other CMAQ calculators for Diesel Retrofits, Diesel Repower/Replacements, Alternative Fuel Vehicle Fleet Purchase, or Electric Vehicle Fleet Purchase modules.[1]

The most current version is dated April 2022. To verify the version, check the date on the Introduction page of the tool. Release notes are included in the Change Log tab, which can be viewed by right-clicking on any tab in the tool, selecting “Unhide”, and revealing the tab.

This tool uses emission rates from the US Environmental Protection Agency’s (EPA) latest Motor Vehicle Emission Simulator (MOVES3)[2] and emission rate adjustment factors from the US Department of Energy’s Alternative Fuel Lifecycle Environmental and Economic Transportation (AFLEET 2020) Tool[3] for alternative fuel transit buses not included in MOVES. This tool considers only operating emissions[4] of transit buses and does not evaluate upstream (well-to-pump) emissions associated with production and transmission of fuel or manufacturing of transit buses. The specific setup of MOVES for generating the

[1] Other CMAQ tools can be found on the CMAQ website: https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/

[2] US Environmental Protection Agency, Office of Transportation and Air Quality, https://www.epa.gov/moves

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

[4] Emissions from running and start exhaust as well as brake and tire wear. This tool assumes the MOVES national average annual number of starts per bus. Analysis does not include evaporative emissions.

tool's national emission rates and instructions on importing local emission rates have been detailed in the Documentation of Emissions Data for the Transit Bus Upgrades and System Improvements Tool.[5]

Electric (EV) Transit Bus Replacement Module

This module estimates changes in emissions from replacing diesel or CNG transit buses with electric (EV) buses with or without the change in emissions resulting in changes in vehicle miles traveled to and from new electric bus charging, restricted access infrastructure.

This document is organized into three sections for EV Transit Bus Replacement – 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. The Tool Methodology outlines the steps taken to calculate emission reductions, and includes all equations used within the tool. The Examples section provides some examples of how to properly input information into the tool for different types of analysis.

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[5] The Documentation of Emissions Data is available on the CMAQ website: https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/

USER GUIDE

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

User Inputs

The interface of the EV Transit Bus Replacement module functions as a wizarding tool, with questions intending to help the user input proper information for emission reduction calculations in a step-by-step process. The inputs for this tool should be specific to the conventional fuel transit buses that will be replaced by alternative fuel transit buses. The user-defined inputs are described in Table 1.

Table 1 User Inputs

Item	User Input	Units	Description
(1)	Project evaluation year	-----	Use the drop-down menu to choose a year from 2018 to 2040.
(2)	Project component: EV Transit Bus Replacement	-----	Click on the box if your project incorporates a replacement component.
(2)	Project component: Restricted Access Infrastructure		Click on the box if your project incorporates new restricted access infrastructure.
REPLACEMENT			
(3)	Model year of current transit buses (buses to be replaced)	-----	Input the model year of the buses to be replaced. If you have a range of years, you may either input the individual years of transit buses separately or input a representative[6] year for all buses to be replaced. The model year cannot be later than the project year or more than 30 years prior to it. Please refer to CMAQ program guidance regarding appropriate model years eligible for funding. [7]
(4)	Fuel type of transit buses to be replaced	-----	Use the drop-down menu to select either diesel or CNG for the fuel type of the buses that will be replaced.
(5a)	Activity data: 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 transit bus population option.
(5a)	Activity data: transit bus population to be replaced (check box)	-----	Click on the box if you know the number of buses to be replaced. This option may be checked concurrently with the vehicle miles traveled option.

[6] "A representative year" indicates the model year of the majority of the transit buses to be replaced. A more accurate representative year can be estimated by taking a weighted average of the model years and number of buses of each model year, then round the result to an integer. For example, the weighted average model year for five 2010 buses and ten 2014 buses can be calculated by: (5*2010+10*2014) / (5+10) = 2012.7, users can take 2013 as the representative year in this case.

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

Item	User Input	Units	Description
(5b)	Annual total vehicle miles traveled to be replaced (input value)	miles	Input the total value of annual vehicle miles traveled for the entire fleet of transit buses to be replaced (i.e., 60,000 miles each for 10 buses would result in an input of 600,000 miles).
(5b)	Transit bus population to be replaced (input value)	vehicles	Input the number of buses to be replaced. The default value is one bus.
(6)	Model year of replacement transit buses	-----	Input the model year of the replacement transit buses. If you have a range of years, you may either input the individual years of buses separately or input a representative year for all replacement (i.e., newer) buses. The model year cannot be later than the project year or more than 30 years prior to it. Please refer to CMAQ program guidance regarding appropriate model years eligible for funding.
INFRASTRUCTURE			
(7)	Model year of current transit buses (transit buses to be replaced)	-----	Input the model year of the buses to be replaced. If you have a range of years, you may either input the individual years of transit buses separately or input a representative[8] year for all buses to be replaced. The model year cannot be later than the project year or more than 30 years prior to it. Please refer to CMAQ program guidance regarding appropriate model years eligible for funding. [9]
(8)	Change in fueling distance	-----	In order to calculate any impact on emissions, users must select whether the restricted-access alternative fuel infrastructure will increase, decrease. Note that this tool only provides results with a change in fueling distance.
(9)	Distance changed for fueling	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.

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. If you would like to return to default settings, please click on the 'Reset to Default Values' button.

[8] "A representative year" indicates the model year of the majority of the transit buses to be replaced. A more accurate representative year can be estimated by taking a weighted average of the model years and number of buses of each model year, then round the result to an integer. For example, the weighted average model year for five 2010 buses and ten 2014 buses can be calculated by: (5*2010+10*2014) / (5+10) = 2012.7, users can take 2013 as the representative year in this case.

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

Activity Information

Users must provide some information on their fleet activity to estimate benefits. The EV Transit Bus Replacement module prompts users to enter the total vehicle miles traveled for the fleet, the bus population, or both. If a user enters only one piece of activity information, the tool utilizes MOVES3 national activity rates to obtain the other piece of activity information. Providing both activities for this tool will likely provide the best estimation of emission reductions from a transit bus replacement project.

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 electric vehicles are expected to be operated in the same way as the conventional fuel vehicles they are replacing. Any vehicles or activity by the electric fleet or conventional fuel fleet not directly displaced will need to be accounted for outside of the tool.

Vehicle Type

This module applies to one vehicle type: Transit Bus. MOVES uses the National Transit Database's motor bus (MB) definition[10], a transit mode comprised of rubber-tired passenger vehicles operating on fixed routes and schedules over roadways. This tool pertains to standard 40-foot low floor transit buses, as described in procurement guidelines from the American Public Transportation Association (APTA).[11] Transit buses are regulated under separate emission standards.[12] The emission rates, activity, and population assumptions are all based on MOVES sourceTypeID 42. Information on the default transit bus weights can be found in the MOVES3 technical report on fleet composition.[13] Other transit vehicles, such as shuttles and smaller buses, may be modeled through other tools in the CMAQ Toolkit.[1]

Fuel Type

Transit buses in this module can be powered by diesel or CNG for buses to be replaced and electricity for replacement buses. Diesel and CNG emission rates are from MOVES. The AFLEET Tool provides adjustment factors to adjust MOVES emission rates for a variety of alternative fuels and advanced engine technologies. This tool uses AFLEET adjustment factors, which provides emission estimates for electricity. Note that this module assumes replacement with electric transit buses and all other alternative fuel replacements, including hybrid-electric (HEV) and hydrogen fuel cell (FCV), are available in the Non-EV Transit Bus Replacement module. For a full list of the alternative fuels available in the Non-EV Transit Bus Replacement module, please see the Non-EV Transit Bus Replacement User Guide. Some basic definitions of these alternative fuels and technologies have been included in Appendix A.

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[10] US Federal Transit Administration, National Transit Database (NTD) glossary, https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary

[11] American Public Transportation Association, "Standard Bus Procurement Guidelines – Low Floor Diesel," http://www.apta.com/resources/reportsandpublications/Documents/lfdiesel.pdf.

[12] See 40 CFR 86.091-2, Legal Information Institute, Cornell University Law School, https://www.law.cornell.edu/cfr/text/40/86.091-2

[13] Population and Activity of On-road Vehicles in MOVES3 https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=541815

The methodology for creating the AFLEET adjustment factors can be found in documentation of the AFLEET tool.[14]

Tool Outputs

Fleet Performance

The fleet performance (non-emission) outputs for this type of project are detailed below in Table 2. These outputs are particularly useful when relying on national default estimates for annual miles traveled per bus.

Table 2 Transit Bus Performance Output

Output	Units	Description
Annual Total Vehicle Miles Traveled	miles	The total vehicle miles traveled annually by the replaced transit buses, either input by the user or calculated based on transit bus population using national activity rates from MOVES.
Annual Transit Bus Population	vehicles	The number of transit buses to be replaced, either input by the user or calculated based on annual total replaced vehicle miles traveled using national activity rates from MOVES.
Annual Miles Traveled per Vehicle	miles	The average annual vehicle miles traveled by each replaced transit bus. It is calculated by the annual total vehicles miles traveled divided by the bus population. Note, if population is not provided as an input, this output is based on MOVES national estimates, assumes a minimum population of one bus, and calculates VMT based on non-integer population values.

Emission Reductions

The EV Transit Bus Replacement module assumes that the user is replacing diesel or CNG fueled buses with electric buses. The benefits are derived from the difference in exhaust, brake- and tirewear for emission rates between the two fuels and/or vehicle model years. Certain scenarios may lead to specific dis-benefits, such as the case where a new restricted access facility increases the total annual VMT such that the new fleet of vehicles are emitting more than the existing fleet of vehicles. In the case where the project only includes new restricted access infrastructure that results in an increase in annual VMT, dis-benefits would appear in particulate matter ($PM_{2.5}$ and PM_{10}), as these pollutants are the only emissions associated with electric buses. Dis-benefits are displayed as negative values in tool outputs.

Emission reductions are calculated for five pollutants – Carbon Monoxide (CO), Particulate Matter 2.5 micrometers or smaller ($PM_{2.5}$), Particulate Matter 10 micrometers or smaller (PM_{10}), Nitrogen Oxides (NOx), and Volatile Organic Compounds (VOC) – in kilograms/year, and then are divided by 365 for the CMAQ daily emission reductions reporting in kilograms/day. In the event a different annualized reporting rate is desired, users can multiply their daily results by 365 and then divide by their chosen number of days annually (e.g., 250 working days). Reductions in greenhouse gasses are also calculated in

[14] DOE, https://greet.es.anl.gov/files/afleet-tool-2016-user-guide

terms of carbon dioxide (CO_2) and carbon dioxide equivalent (CO_2e) – in kilograms per day, and total energy consumed (TEC) in million BTU.

Error Messages

Table 3 below summarizes any error and warning messages associated with this 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
ERROR: Please enter an appropriate project evaluation year.	Invalid input for project evaluation year.	Input a year between 2018 and 2040.
Project Component Error: Choose at least one project component.	No project component in question (1) is selected.	Select either the Non-EV Transit Bus Replacement option, the Restricted Access Infrastructure option, or both.
ERROR: This tool includes model years going back to a maximum of 30 years for the given evaluation year. Please choose an appropriate model year within this range.	Invalid input for model year of the transit buses in questions (3) and/or (6) for replacement project selection (checkbox in question (2)) or question (7) for restricted access infrastructure project selection.	Input an appropriate model year between the evaluation year and 30 years prior to that evaluation year.
Activity Data Error: Choose at least one activity type.	No activity type in question (5a) is selected.	Select at least one activity type.
Activity Data Error: Vehicle activity cannot be less than one.	Invalid input for vehicle activity in question (5b).	Input a number for annual transit bus population that is greater than one.
Activity Data Error: Vehicle population cannot be less than one.	Invalid input for vehicle population in question (5b).	Input a number for annual total vehicle miles traveled that is greater than one.
Please completely fill out inputs before calculating output.	Replacement project selection in question (2): No input for any of the following questions (1), (3) - (6) or no activity type in question (5a) is selected.	Either make selections or input values. Note that you need to select at least one activity type.

Please completely fill out inputs before calculating output.	Restricted access infrastructure selection only in question (2): No input for any of the following questions (1), (7), (8), or (9).	Either make selections or input values.
Change in Distance Error: Change in distance must be greater than zero.	Invalid input for change in vehicle miles traveled in question (9).	Input a number for change in vehicle miles traveled that is greater than zero.
WARNING: There is no test data available to estimate the emissions or the national default activity from buses with these model years and fuel types. The tool will report zero emission reductions and/or activity.	Invalid input for model year or fuel type of transit buses.	Input an appropriate model year between the evaluation year and 30 years prior to that evaluation year, or change the fuel type.

Data Insufficiency: Not every model year or fuel type will produce results in this CMAQ tool. Some AFLEET alternative fuels have factors for every MOVES source type and other fuels do not. Diesel and compressed natural gas (CNG) use MOVES emission rates while electricity uses non-zero AFLEET factors. For more information on the AFLEET factors, please consult the Greenhouse Gases, Regulated Emissions, and Energy use in Transportation Model (GREET) documentation on analyzing heavy-duty vehicle emission rates[15] and updating GREET emission factors with MOVES data[16] accordingly.

MOVES data have some minor gaps in transit bus emission rates, namely for CNG buses before their phase-in period, where results will appear as zero.[17] Please consult the most recent MOVES technical report on vehicle populations and activity[18] and the latest default MOVES database[19] for identifying data gaps. As noted above, for combinations without data, warnings will pop up and any subsequent emission reductions will appear as zero.

For reference, the AFLEET factors are based on diesel for heavy-duty vehicles (HDVs). By default, transit buses are considered as HDVs, therefore, this tool uses diesel-based AFLEET factors and MOVES rates for transit buses to calculate the alternative fuel rates.

Lack of AFLEET Factors for CO_2, CO_2e and TEC: Another source of data insufficiency is AFLEET's lack of alternative fuel factors for carbon dioxide (CO_2), carbon dioxide equivalent emissions (CO_2e) or total energy consumption (TEC). Because AFLEET does not contain factors for these pollutant metrics, the Replacement module of this tool will not output emissions reduction results for electric (EV) buses.

[15] DOE, https://greet.es.anl.gov/publication-heavy-duty
[16] DOE, https://greet.es.anl.gov/publication-vehicles-13
[17] For example, there are no CNG fueled transit buses before model year 1990 in MOVES2014a.
[18] EPA, *Population and Activity of On-road Vehicles in MOVES2014*, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100O7VJ.pdf
[19] EPA, https://www.epa.gov/moves/moves2014a-latest-version-motor-vehicle-emission-simulator-moves

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 generate error messages if a user selects a disallowed fuel type or an erroneous year.

TOOL METHODOLOGY

Replacement Project Methodology

This tool allows the users to calculate emission reductions of replacing a diesel or CNG fuel transit bus with electric (EV) buses. The equation below describes the tool's calculation for emission reductions when transit buses are replaced by diesel, CNG, or alternative fuel buses. The emissions of a given pollutant reduced by replacing a diesel or CNG transit bus are reported in kilograms/day for the total number of buses replaced as followed:

$$\begin{aligned} reduced\ emissions \\ &= \left[\left(e_{running\ \ to\ be\ replaced} - e_{running\ \ replacement}\right) \cdot VMT_{fleet}\right. \\ &\left. + \left(e_{starts\ \ to\ be\ replaced} - e_{starts\ \ replacement}\right) \cdot POP_{fleet}\right]/365 \end{aligned} \quad (1)$$

where for diesel bus replacement,

$$e_{(running\ \ or\ starts)\ replacement} = e_{MOVES_{diesel}} \quad (2)$$

where for CNG bus replacement,

$$e_{(running\ \ or\ starts)\ replacement} = e_{MOVES_{CNG}} \quad (3)$$

where:

$e_{running\ to\ be\ replaced}$ = running emission rate for to be replaced transit bus of a specified fuel type (diesel or CNG) and model year of the transit bus to be replaced (kilogram/mile),

$e_{starts\ to\ be\ replaced}$ = start emission rate for to be replaced transit bus of a specified fuel type (diesel or CNG) and model year of the transit bus to be replaced (kilogram/vehicle),

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

POP_{fleet} = total number of alternative fuel transit buses to be replaced,

$e_{running\ replacement}$ = emission rate for replacement transit bus of specified fuel type and model year (kilogram/mile),

$e_{starts\ replacement}$ = emission rate for replacement transit bus of specified fuel type and model year (kilogram/mile),

A_{alt} = AFLEET factor for a specified alternative fuel, determined by pollutant,

$e_{MOVES_{diesel}}$ = MOVES diesel transit bus emission rate for a given model year (kilogram/mile), and

$e_{MOVES_{CNG}}$ = MOVES CNG transit bus emission rate for a given model year (kilogram/mile).

Either vehicle miles traveled or population is required for proper calculation of emission reductions. If only one of these inputs is provided by the user, the other parameter is calculated using the relationship below, such that the parameter not defined by the user is reliant on the national default ratio of VMT to Bus Population:

$$VMT_{fleet} = POP_{fleet}\left(\frac{VMT_{national}}{POP_{national}}\right) \quad (5)$$

where:

$VMT_{national}$ = national vehicle miles traveled from MOVES defaults for transit buses to be replaced by the specified model year and fuel type in the given project year, and

$POP_{national}$ = national vehicle populations from MOVES defaults for transit buses to be replaced by the specified model year and fuel type in the given project year.

Restricted Access Infrastructure Methodology

Emission reductions, reported in kilograms/day for the construction of electric bus 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 transit bus fleet

$$e_{alt} = e_{conv} \cdot A_{alt} \quad (2)$$

such that,

e_{conv} = annual conventional fuel (diesel or gasoline) emission rate for the model year of the transit buses to be purchased (kilogram/mile) in the selected evaluation year,

e_{alt} = annual electric transit bus emission rate for a given model year of the transit buses to be purchased (kilogram/mile),

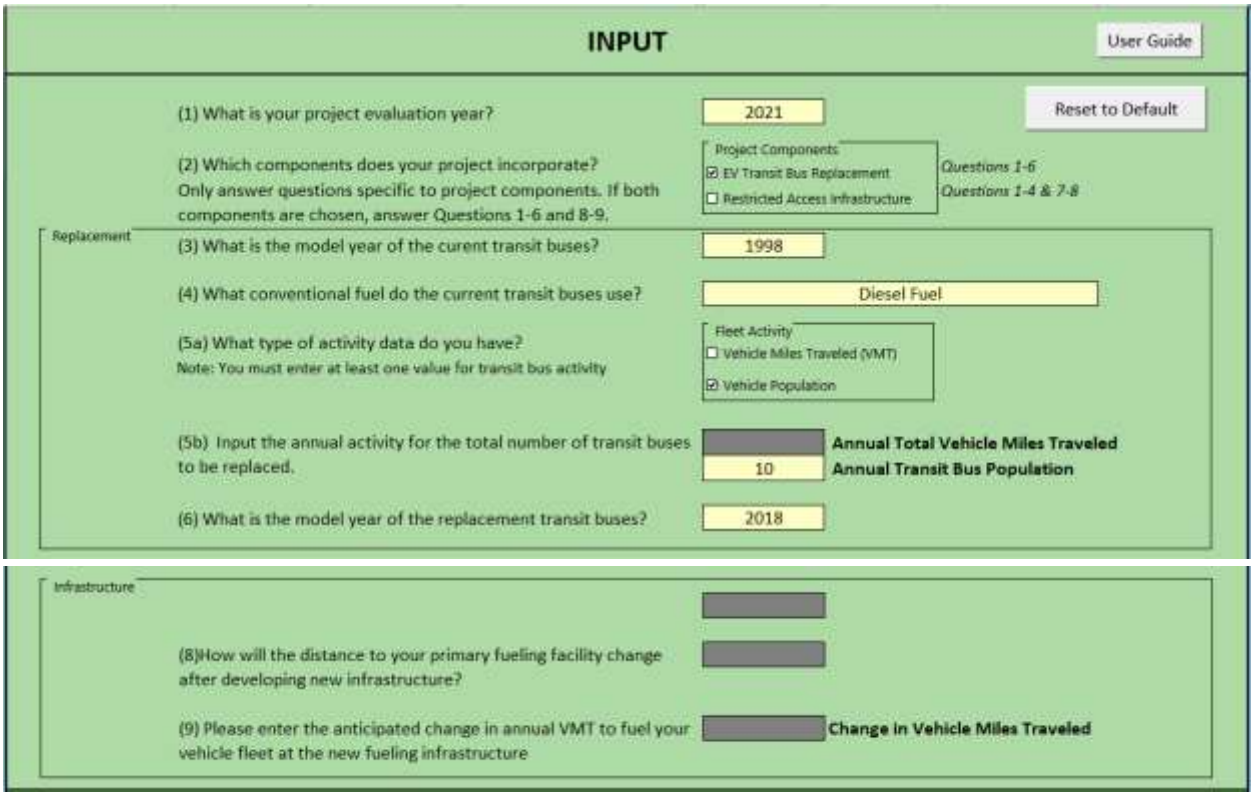
A_{alt} = AFLEET factor for electric transit buses, and

ΔVMT_{fleet} = change in annual distance traveled to refuel the alternative fuel fleet after construction of restricted access infrastructure (miles).

EXAMPLES

Example 1: Replacing diesel-fueled transit buses with electric buses (Population Known, VMT Unknown), No restricted access infrastructure component

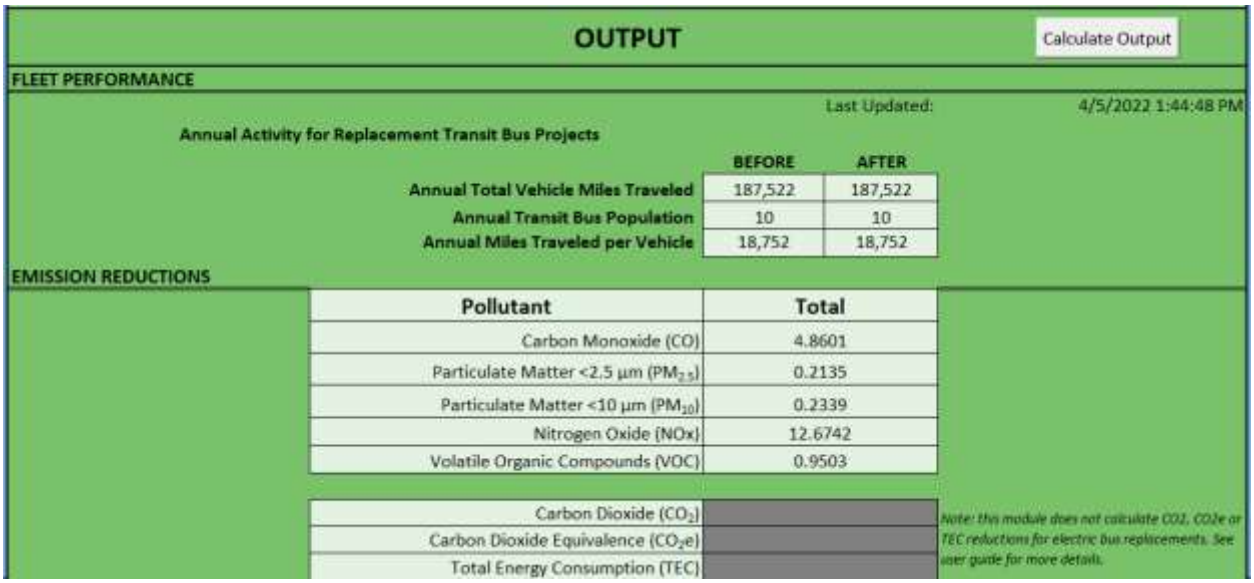
A county transportation provider would like to replace 10 diesel-fueled buses with 10 electric buses for their transit fleet. The county does not have activity data for the conventional fuel fleet being replaced, so they will rely on national default values of annual miles traveled per vehicle. The project will not include the addition of any restricted access charging infrastructure. The following inputs would be chosen, as shown in the screen shot below:



Project Year: 2021
EV Transit Bus Replacement [check box]: Selected
Restricted Access Infrastructure [check box]: Unselected
Model Year for Conventional Fuel Buses: 1998
Conventional Fuel: Diesel
Vehicle Miles Traveled [check box]: Unselected
Transit Bus Population [check box]: Selected
Transit Bus Population: 10
Model Year of Alternative Fuel Buses: 2018

Because the project does not include a restricted access infrastructure component (as indicated in question 2), question 7 (hidden) and questions 8-9 are grayed out and may be skipped.

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



OUTPUT — Calculate Output

FLEET PERFORMANCE

Last Updated: 4/5/2022 1:44:48 PM

Annual Activity for Replacement Transit Bus Projects

	BEFORE	AFTER
Annual Total Vehicle Miles Traveled	187,522	187,522
Annual Transit Bus Population	10	10
Annual Miles Traveled per Vehicle	18,752	18,752

EMISSION REDUCTIONS

Pollutant	Total
Carbon Monoxide (CO)	4.8601
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.2135
Particulate Matter <10 µm (PM_{10})	0.2339
Nitrogen Oxide (NOx)	12.6742
Volatile Organic Compounds (VOC)	0.9503
Carbon Dioxide (CO_2)	
Carbon Dioxide Equivalence (CO_2e)	
Total Energy Consumption (TEC)	

Note: this module does not calculate CO2, CO2e or TEC reductions for electric bus replacements. See user guide for more details.

In the absence of user-supplied vehicle miles traveled data, this tool uses national rates to calculate VMT. For this example, the tool estimates that a total of 187,522 miles are traveled by ten, 20 year-old buses in the fleet.

The emission reductions for all five pollutants are:

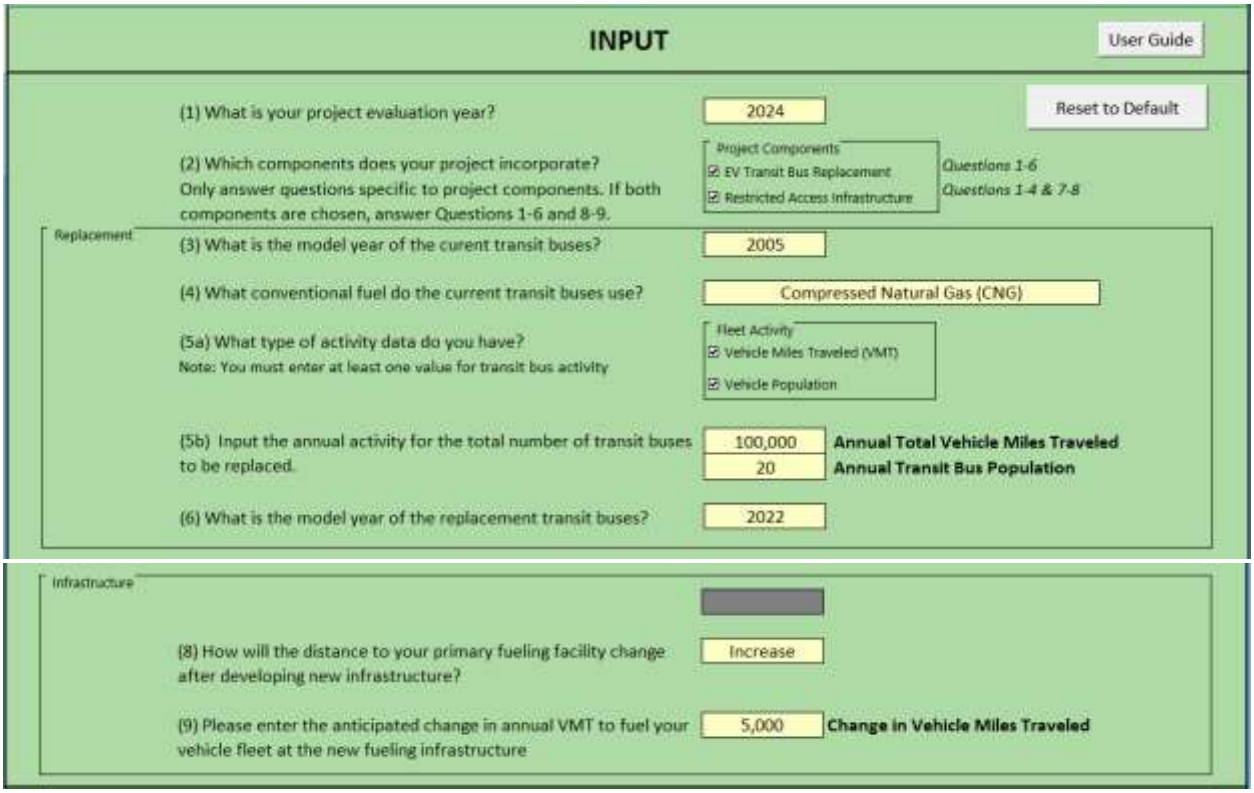
Carbon Monoxide (CO): 4.8601
Particulate Matter ($PM_{2.5}$): 0.2135
Particulate Matter (PM_{10}): 0.2339
Nitrogen Oxide (NOx): 12.6742
Volatile Organic Compounds (VOC): 0.9503

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

This tool does not calculate results for CO_2, CO_2eq, or TEC for electric buses, as in this example.

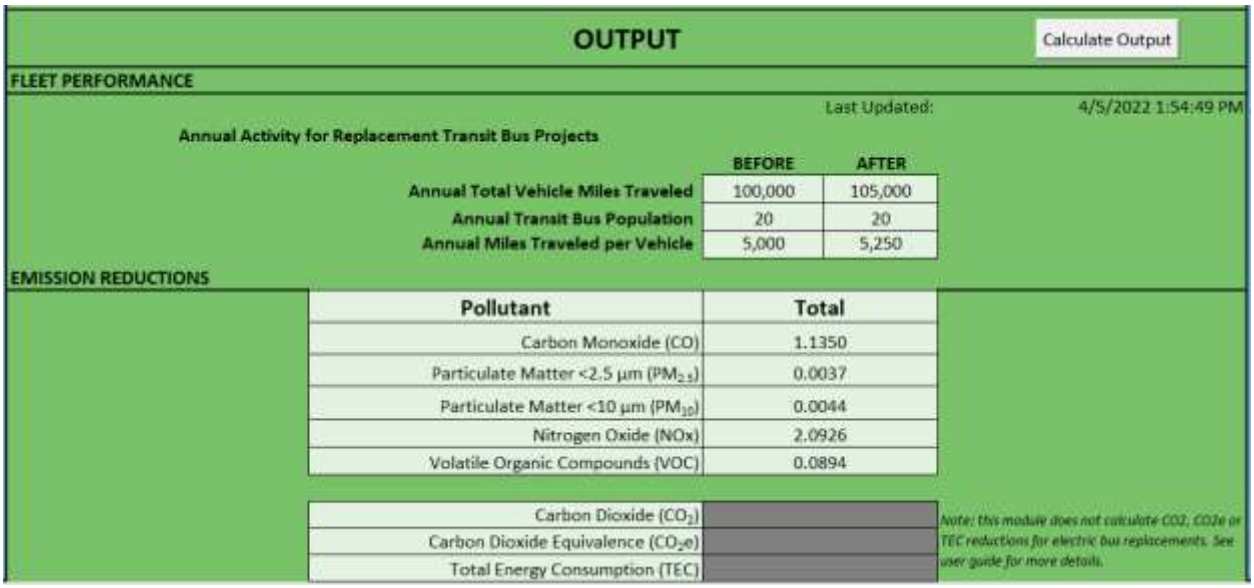
Example 2: Replacing CNG-fueled transit buses with electric buses (Population and VMT Known) with the addition of new restricted access charging infrastructure

A county transit provider is interested in replacing 20 CNG-fueled buses with 20 electric buses for their transit fleet, and knows its activity rates of the fleet. The county will also construct a new restricted access charging facility that will add 5,000 miles to the total annual VMT of the fleet. The following inputs would be chosen, as shown in the screen shot below:



Project Year: 2024
EV Transit Bus Replacement [check box]: Selected
Restricted Access Infrastructure [check box]: Selected
Model Year for Conventional Fuel Buses: 2005
Conventional Fuel: CNG
Vehicle Miles Traveled [check box]: Selected
Transit Bus Population [check box]: Selected
Total Vehicle Miles Traveled: 100,000
Transit Bus Population: 20
Model Year of Alternative Fuel Buses: 2022
Type of Change in Distance: Increase
Change in VMT: 5,000

Pressing the Calculate Output button computes fleet performance and emission reductions of the 20 CNG transit buses being replaced with electric buses combined with the change in emissions from the new charging infrastructure, as shown below:



OUTPUT — Calculate Output

FLEET PERFORMANCE

Last Updated: 4/5/2022 1:54:49 PM

Annual Activity for Replacement Transit Bus Projects

	BEFORE	AFTER
Annual Total Vehicle Miles Traveled	100,000	105,000
Annual Transit Bus Population	20	20
Annual Miles Traveled per Vehicle	5,000	5,250

EMISSION REDUCTIONS

Pollutant	Total
Carbon Monoxide (CO)	1.1350
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.0037
Particulate Matter <10 µm (PM_{10})	0.0044
Nitrogen Oxide (NOx)	2.0926
Volatile Organic Compounds (VOC)	0.0894
Carbon Dioxide (CO_2)	
Carbon Dioxide Equivalence (CO_2e)	
Total Energy Consumption (TEC)	

Note: this module does not calculate CO2, CO2e or TEC reductions for electric bus replacements. See user guide for more details.

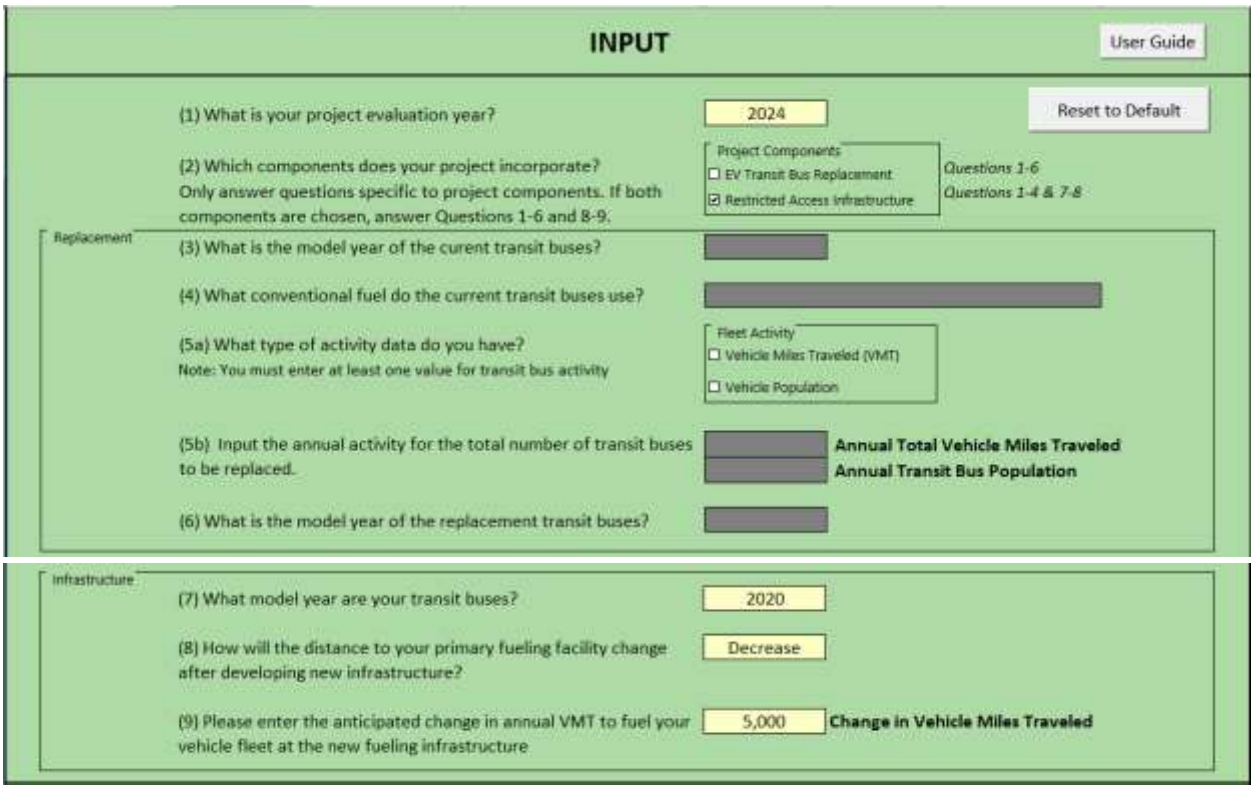
The emission reductions for all five pollutants are:

Carbon Monoxide (CO): 1.1350
Particulate Matter ($PM_{2.5}$): 0.0037
Particulate Matter (PM_{10}): 0.0044
Nitrogen Oxide (NOx): 2.0926
Volatile Organic Compounds (VOC): 0.0894

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

Example 3: Building Restricted Infrastructure for an Electric Bus Fleet

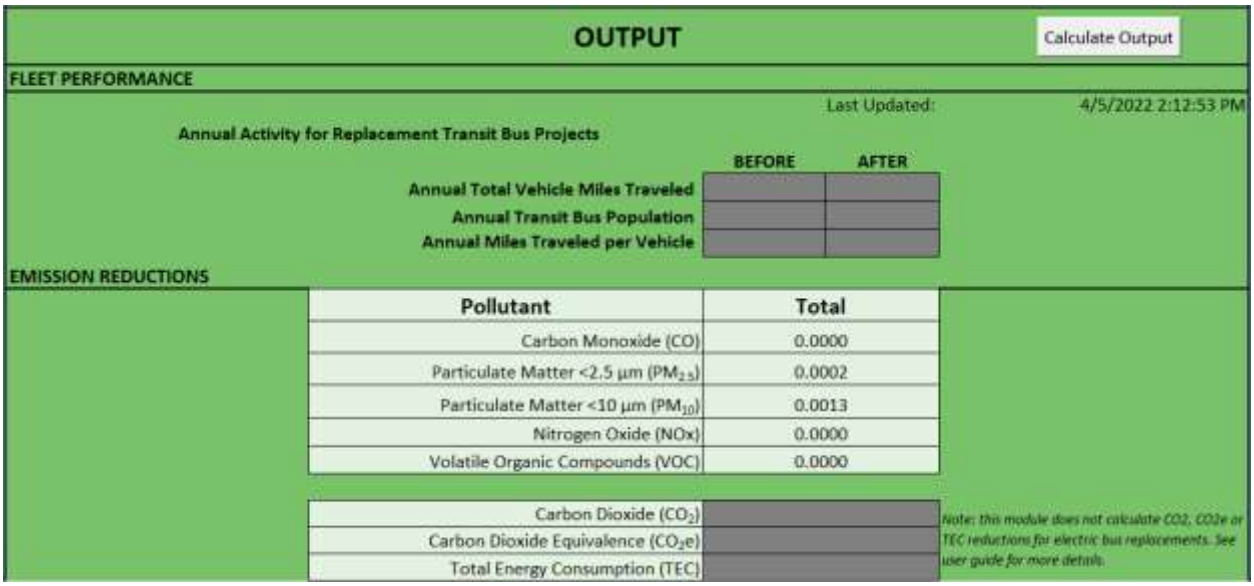
A county transit provider recently bought model year 2020 electric transit buses and would like to build new restricted access infrastructure to charge the buses in 2024. The transit provider estimates that the new hydrogen fuel cell infrastructure will allow the fleet to avoid 5,000 miles per year to fuel elsewhere. For this example, the following inputs have been selected:



Project Year: 2024
EV Transit Bus Replacement [check box]: Unselected
Restricted Access Infrastructure [check box]: Selected
Model Year of Alternative Fuel Transit Buses: 2020
Type of Change in Distance: Decrease
Change in VMT: 5,000

Since the project in this example builds infrastructure for an existing fleet and does not replace conventionally-fueled buses with electric buses, questions 3 through 6 may be skipped.

Pressing the Calculate Output button computes fleet performance and emission reductions of reducing annual VMT by 5,000 for a fleet of electric buses:



OUTPUT — Calculate Output

FLEET PERFORMANCE

Last Updated: 4/5/2022 2:12:53 PM

Annual Activity for Replacement Transit Bus Projects

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

EMISSION REDUCTIONS

Pollutant	Total
Carbon Monoxide (CO)	0.0000
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.0002
Particulate Matter <10 µm (PM_{10})	0.0013
Nitrogen Oxide (NOx)	0.0000
Volatile Organic Compounds (VOC)	0.0000

Carbon Dioxide (CO_2)	
Carbon Dioxide Equivalence (CO_2e)	
Total Energy Consumption (TEC)	

Note: this module does not calculate CO2, CO2e or TEC reductions for electric bus replacements. See user guide for more details.

The emission reductions for all five pollutants are:

Carbon Monoxide (CO): 0.0000
Particulate Matter ($PM_{2.5}$): 0.0002
Particulate Matter (PM_{10}): 0.0013
Nitrogen Oxide (NOx): 0.0000
Volatile Organic Compounds (VOC): 0.000

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

Since electric bus emissions only include particulate matter emissions from brake- and tirewear, there are only emissions reductions in $PM_{2.5}$ and PM_{10} for this example, where emissions are derived only from changes in total VMT.

Appendix A: Battery Electric Vehicle Definition

A **battery electric vehicle (BEV)**, or an all-electric vehicle, uses a battery pack to store electrical energy that powers the motor entirely. EVs are charged through plugging the vehicle into an electric power source, and even though electricity production may contribute to air pollution based on the power source makeup of the electrical grid, the EPA classifies EVs as zero-emission vehicles due to their lack of direct exhaust and tailpipe emissions.[20] Any emissions associated with EVs come from brakewear and tirewear particulate matter emissions.

[20] US Department of Energy, Alternative Fuels Data Center: All-Electric Vehicles (energy.gov)