CMAQ EMISSIONS CALCULATOR TOOLKIT

The purpose of the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit) is to help a user with limited modeling experience estimate emission reductions associated with implementation of a CMAQ-funded project. The CMAQ Toolkit uses emission rates and activity data based on national-scale runs of the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator (MOVES). This document explains the use and methodology of the Bicycle and Pedestrian Improvements Tool.

Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses. For further information regarding the specific setup of MOVES used to generate the emission rates provided in this tool, please refer to the Emissions Data Documentation associated with this emissions calculator.

On-Road Diesel Repower or Replacement

The diesel repower/replacement project emission reductions calculator estimates emission reductions for repowering/replacing heavy-duty diesel vehicles (excluding transit vehicles) of a given model year with a newer diesel vehicle of a more recent model year.[1] Emission reductions are estimated by calculating the reduction in both running and starts emissions, as well as, if applicable, extended idling emissions (referred hereafter as hotelling hours) and comparing it to the emissions from the replacement engines or vehicles.[2]

This document is organized into three sections – 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 by the tool to calculate emission reductions, as well as any assumptions that are made by the tool. This Tool Methodology includes all equations used within the tool. The Examples section aims to give some examples of how to properly input information into the tool, including some examples for use with the optional Activity Calculator, for advanced analysis.

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[1] CMAQ projects must benefit air quality through demonstrated emission reductions. See the CMAQ guidance at www.fhwa.dot.gov/environment/air_quality/cmaq/ for a full list of projects that may be eligible for CMAQ funds.

[2] The most current version is dated December 2021. 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.

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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 tool's input section functions like 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 only the vehicles that will be repowered/replaced. The user-defined inputs for this type of project are described below:

Table 1. User Inputs

User Input	Units	Description
Evaluation year	-----	Use the drop-down menu to choose a year between 2018 and 2040.
Vehicle miles traveled (check box)	-----	Click on the box if you have annual vehicle miles traveled for the vehicles to be repowered/replaced. This option may be checked concurrently with the vehicle population and/or vehicle hotelling hours options.
Vehicle population (check box)	-----	Click on the box if you have the number of vehicles to be repowered/replaced. This option may be checked concurrently with the vehicle miles traveled and/or vehicle hotelling hours options. The default value is 'checked'.
Vehicle hotelling hours (check box)	-----	Click on the box if you have annual vehicle hotelling hours for the vehicles to be repowered/replaced. This option is only available for combination long-haul trucks and may be checked concurrently with the vehicle miles traveled and/or vehicle population options.
Total vehicles miles traveled	miles	Input the total value of annual vehicle miles traveled for all the vehicles to be repowered/replaced (i.e. 60,000 miles each for 10 vehicles would result in an input of 600,000 miles).
Repower/ replacement vehicle population	vehicles	Input the number of vehicles to be repowered/replaced. The default value is 1 vehicle.
Total vehicle hotelling hours	hours	Input the total value of hotelling hours for all the vehicles to be repowered/replaced. This option is only available for combination long-haul trucks.
Repower/ replacement vehicle type	-----	Use the drop-down menu to choose the appropriate vehicle type among heavy-duty diesel (non-transit vehicle) vehicles. Vehicle types included: school bus, refuse truck, single unit short-haul truck, single unit long-haul truck, combination short-haul truck, and combination long-haul truck.
Add APU	-----	Only applicable for combination long-haul trucks. If the repower/replacement vehicles will result in the addition of an auxiliary power unit, use the drop-down menu to select 'Yes'; otherwise select 'No'. If the vehicle to be replaced and the vehicle that is replacing that vehicle both have auxiliary power units, select 'No'.

User Input	Units	Description
Model year of vehicles to be repowered/ replaced	-----	Input the model year of the vehicles to be repowered/replaced. If you have a range of years, you may either input the individual years and vehicles separately or input a representative year for the vehicles to be retrofit. The model year cannot be later than the project year. Please refer to CMAQ policy for guidance regarding appropriate model years eligible for funding.
Repower/ replacement vehicle model year	-----	Input the model year of the repower/replacement vehicles. If you have a range of years, you may either input the individual years and vehicles separately or input a representative year for the vehicles to be retrofit. The model year cannot be later than the project evaluation year or precede 1986.

Once the parameters are input, click on the 'Calculate Output' to calculate results. Emission reductions results will not automatically update, so any time 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.

Tool Outputs

Fleet Performance

The tool-produced outputs for this type of project are detailed below:

Table 2. Fleet Performance Outputs

Output	Units	Description
Total vehicle miles traveled, annual activity for vehicles to be repowered/replaced	miles	The total vehicle miles traveled annually by the repower/replacement vehicles, either input by the user or calculated from vehicle population or total hotelling hours (if applicable) using national activity rates.
Total vehicle population, annual activity for vehicles to be repowered/replaced	vehicles	The number of vehicles to be repowered/replaced, either input by the user or calculated from total vehicle miles traveled or total hotelling hours (if applicable) using national activity rates
Total hotelling hours, annual activity for vehicles to be repowered/replaced	hours	The number of vehicles to be repowered/replaced, either input by the user or calculated from total vehicle miles traveled or vehicle population using national activity rates.

Emission Reductions

Emission reductions are calculated for five pollutants – carbon monoxide (CO), particulate matter with diameters of 2.5 microns or less ($PM_{2.5}$), particulate matter with diameters of 10 microns or less (PM_{10}), nitrogen oxides (NOx), volatile organic compounds (VOC), as well as greenhouse gases in terms of carbon dioxide equivalent (CO_2e) and carbon dioxide (CO_2) – in kilograms per day, and total energy consumed (TEC) in million BTU.

To get annual emission reductions, multiply these values by 365. 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 working days in a year, e.g. 250 working days.

Error Messages

The error messages that the user may encounter in this tool, the reason for these error messages and their remedy is listed in the table below: (Note: Once you correct the error, please press 'Calculate Output' to clear errors).

Table 3. Error Messages

Error Message	**Reason for Error**	**Solution**
Error! Choose at least one activity type	No activity type was chosen	Please choose an activity type to use the tool
Error! Model years cannot be later than project year Year Input Error: This tool includes model years between 1989 and 2030. Please choose appropriate years within this range.	Invalid input for model year	Input a model year that is no earlier than 1989 and no later than the project year. This is applicable to both model year of vehicles to be repowered/replaced as well as the repower/replacement vehicles
Error! Please completely fill out inputs before calculating output	All of the inputs required for emission reductions calculations have not been chosen	Please choose an appropriate project year, vehicle type, and/or model year
Warning: less than one vehicle is represented by the input activity values	The result is representative of a partial vehicle, based on national ratios of VMT to vehicle population	Just a warning, this is acceptable to get results.

Other Assumptions

While only one piece of activity information is required to use this tool, activity for vehicle miles traveled and vehicle population, as well as hotelling hours, where applicable, are, in fact, required for proper calculation of emission reductions. In the case where one piece of activity information is provided, the tool utilizes national activity rates obtained from a MOVES3 run for the activity not provided to calculate emission reductions. Providing all relevant activity information for this tool may provide the best estimation of emission reductions from a diesel repower/replacement project.

TOOL METHODOLOGY

Emission reductions (ER), reported in kilograms/day for the total number of vehicles to be repowered/replaced, are calculated for a given pollutant as shown in the following equation:

$$ER = \frac{[(e_o - e_n)_r \cdot VMT + (e_o - e_n)_s \cdot (e_o - e_n)_h \cdot HH]}{365} \quad (1)$$

in which
e_o emission rates of the vehicles that will be repowered/replaced,
e_n emission rates of the repower/replacement vehicles,
$(e_o - e_n)_r$ = annual running and crankcase running diesel emission reductions for a given vehicle type and model year in the given project year (kilogram/mile),
$(e_o - e_n)_s$ = annual start and crankcase start diesel emission reductions for a given vehicle type and model year in the given project year (kilogram/vehicle),
$(e_o - e_n)_h$ = annual extended idle and crankcase extended idle diesel emission reductions (or auxiliary power emissions) for a given vehicle type and model year in the given project year (kilogram/hour),
VMT = total annual vehicle miles traveled for the vehicles to be repowered/replaced (miles),
POP = total number of vehicles to be repowered/replaced, and
HH = total hotelling hours for the vehicles to be repowered/replaced (hours).

Both vehicle miles traveled and vehicle population (as well as hotelling hours, for combination long-haul trucks) are required for proper calculation of emission reductions. These activity values may be provided by the user. If not all the activity is provided by the user, the other activity is calculated leveraging national values using the applicable equations:

$$VMT = POP_{user} \left(\frac{VMT_{national}}{POP_{national}}\right) \quad (2)$$

$$VMT = HH_{user} \left(\frac{VMT_{national}}{HH_{national}}\right) \quad (3)$$

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

$$POP = HH_{user} \left(\frac{POP_{national}}{HH_{national}}\right) \quad (5)$$

$$HH = VMT_{user} \left(\frac{HH_{national}}{VMT_{national}}\right) \quad (6)$$

$$HH = POP_{user} \left(\frac{HH_{national}}{POP_{national}}\right) \quad (7)$$

in which

POP_{user} = number of vehicles to be repowered/replaced, provided by the user,

VMT_{user} = vehicle miles traveled for vehicles to be repowered/replaced, provided by the user (miles),

HH_{user} = hotelling hours for vehicles to be repowered/replaced, provided by the user (hours),

$POP_{national}$ = national population for diesel vehicles of the specified model year and vehicle type in the given project year,

$VMT_{national}$ = national vehicle miles traveled for diesel vehicles of specified model year and vehicle type in the given project year, and

$HH_{national}$ = national hotelling hours for diesel vehicles of specified model year and vehicle type in the given project year.

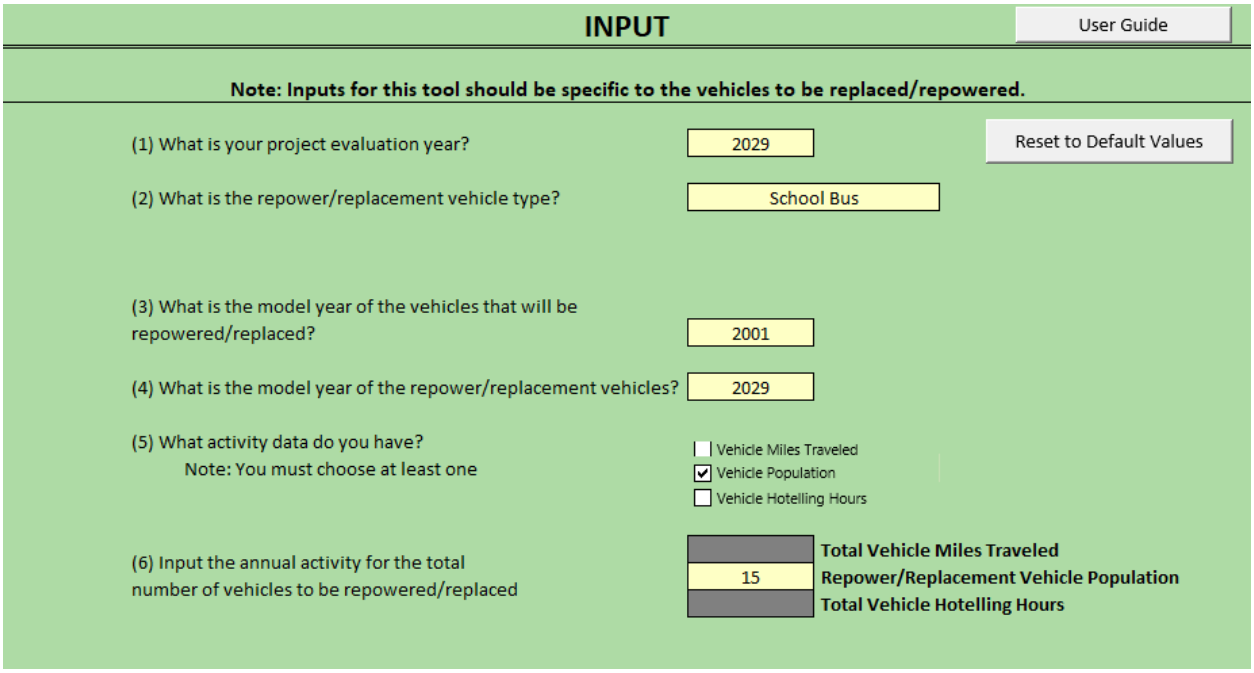
The activity, emission rates and savings are calculated using annual values. This is divided by 365 to get daily values, which are reported in kilograms/day in the tool. In the event that a different annualization is desired, users are recommended to multiply their daily results by 365 and then divided by their chosen number of working days in a year.

EXAMPLES

Example 1a: Replacement for School Buses (Population known)

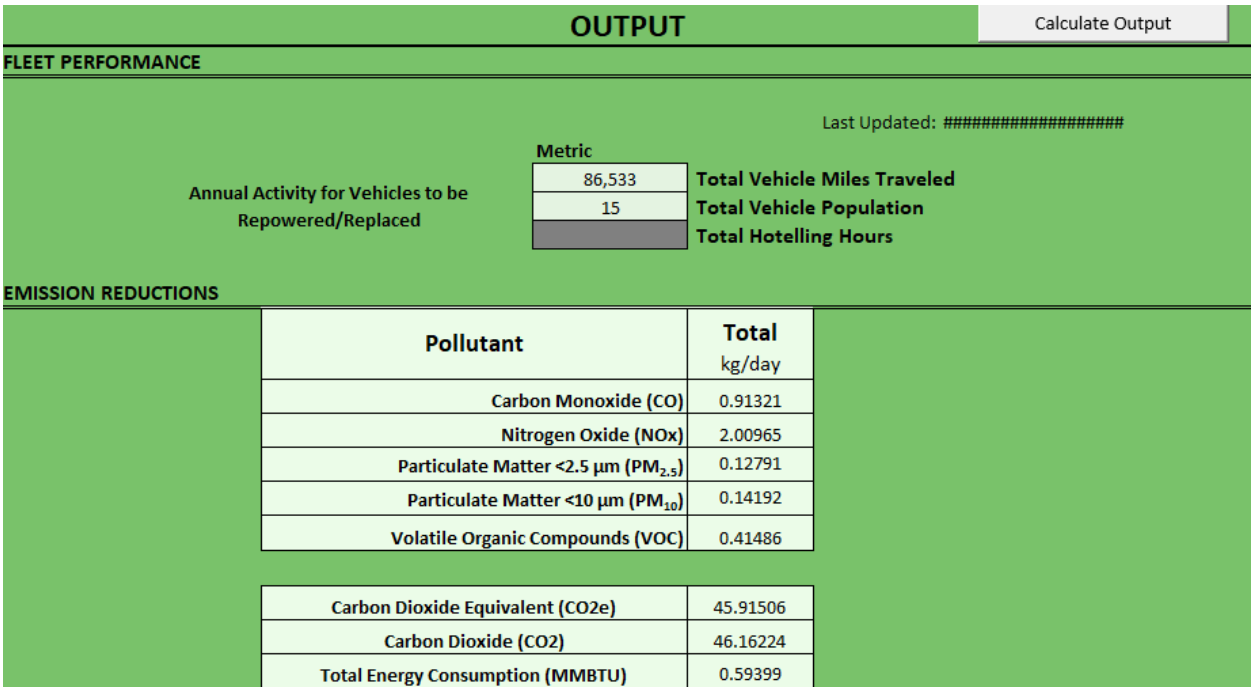
County X in State Y would like to replace their 15 model year 2001 school buses with model year 2029 buses.

In the repower/replacement tool, the following inputs would be chosen as shown:



Project Evaluation Year: 2029
Vehicle Population [check box]: selected
Repower/Replacement Vehicle Population: 15
Repower/Replacement Vehicle Type: School Bus
Model year of vehicles to be replaced: 2001
Model year of replacement vehicles: 2029

These are all of the inputs required to calculate the emission savings created by the replacement, which are given in the image below:



OUTPUT | Calculate Output

FLEET PERFORMANCE

Last Updated: ##################

	Metric	
Annual Activity for Vehicles to be Repowered/Replaced	86,533	Total Vehicle Miles Traveled
	15	Total Vehicle Population
		Total Hotelling Hours

EMISSION REDUCTIONS

Pollutant	Total kg/day
Carbon Monoxide (CO)	0.91321
Nitrogen Oxide (NOx)	2.00965
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.12791
Particulate Matter <10 µm (PM_{10})	0.14192
Volatile Organic Compounds (VOC)	0.41486

Carbon Dioxide Equivalent (CO2e)	45.91506
Carbon Dioxide (CO2)	46.16224
Total Energy Consumption (MMBTU)	0.59399

In the absence of replacement-specific vehicle miles traveled data, this tool utilizes national rates to calculate emission benefits. For school buses, this tool estimates that the fifteen model year 2001 vehicles travel 86,533 miles annually, which may be an appropriate value for the repower/replacement project.

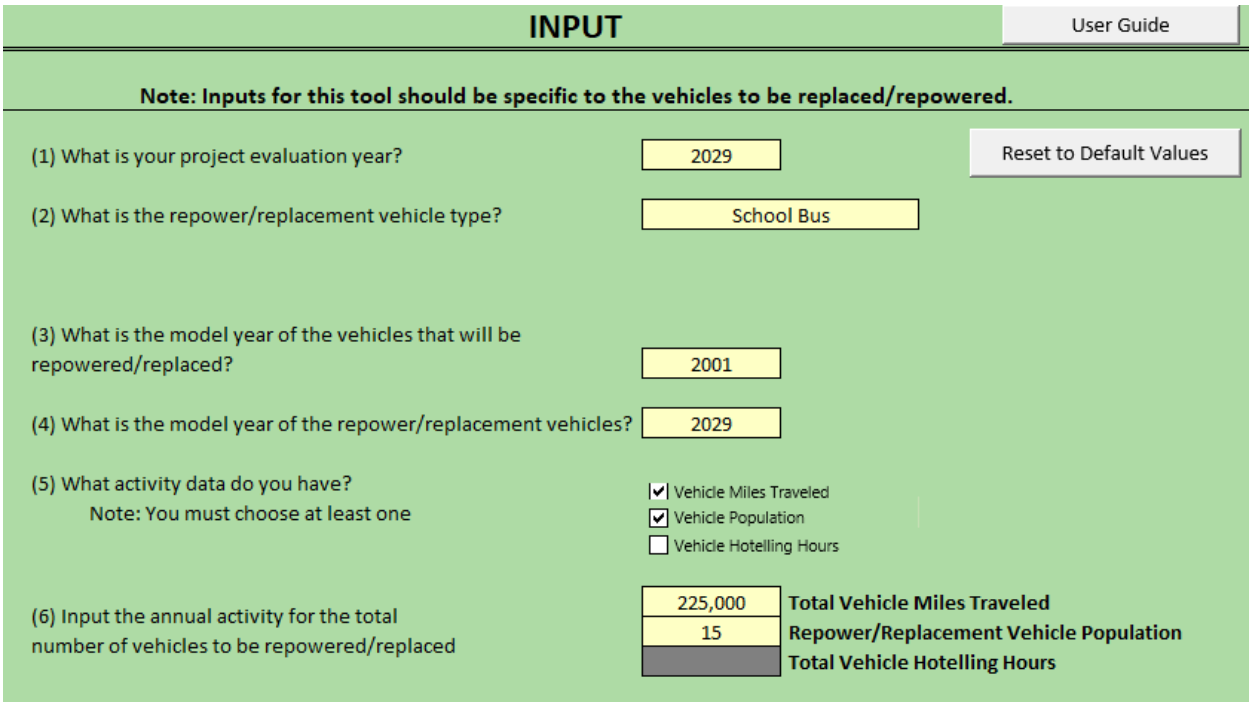
The emission reductions in kg/day and TEC reductions in millions of British Thermal Units (MMBTU) are:

Carbon Monoxide (CO): 0.91321
Nitrogen Oxide (NOx): 2.00965
Particulate Matter (PM2.5): 0.12791
Particulate Matter (PM10): 0.14192
Volatile Organic Compounds (VOC): 0.41486

Carbon Dioxide Equivalent (CO_2e): 45.91506
Carbon Dioxide (CO_2): 46.16224
Total Energy Consumption (TEC): 0.59399

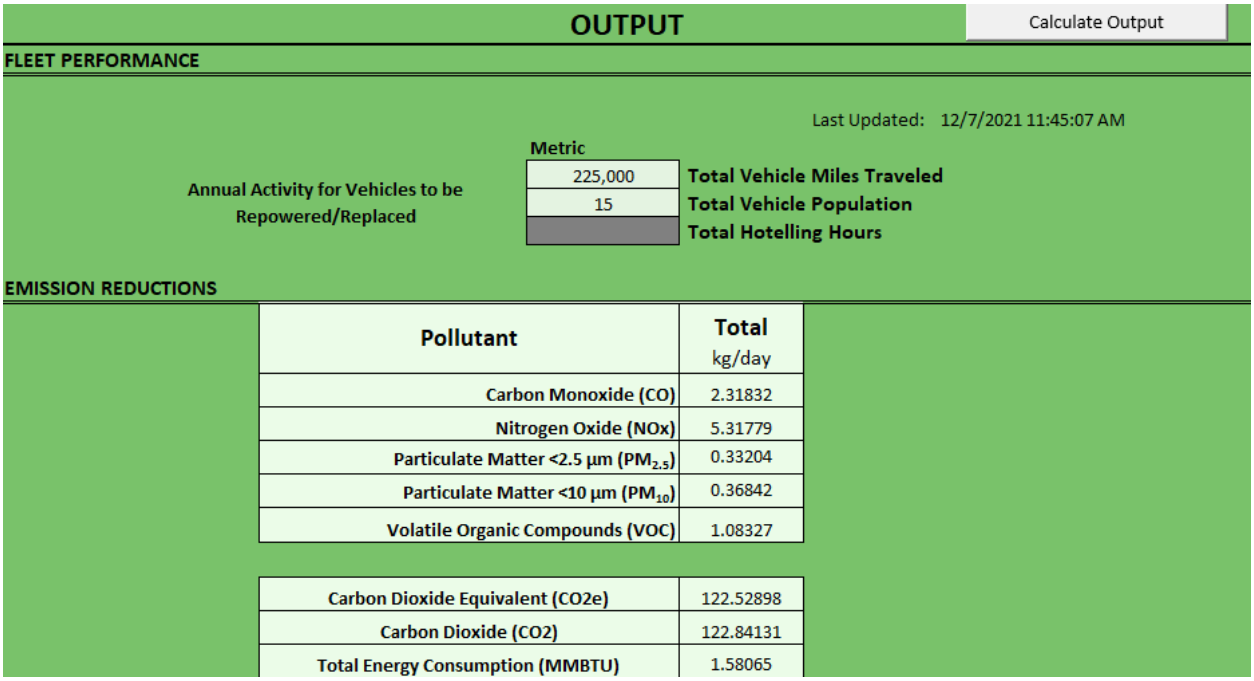
Example 1b: Replacement of School Buses (Population and VMT known)

County X knows that the 15 model year 2001 school buses that they want to replace are actually driven an average of 15,000 miles annually. In this case, input the following as shown below:



Project Evaluation Year: 2029
Vehicle Miles Traveled [check box]: selected
Vehicle Population [check box]: selected
Total Vehicle Miles Traveled: 225,000 (to account for 15 vehicles traveling an average 15,000 miles each)
Repower/Replacement Vehicle Population: 15
Repower/Replacement Vehicle Type: School Bus
Model year of vehicles to be replaced: 2001
Model year of replacement vehicles: 2029

The emission savings can then be calculated, as shown below:



OUTPUT — Calculate Output

FLEET PERFORMANCE

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	Metric	
Annual Activity for Vehicles to be Repowered/Replaced	225,000	Total Vehicle Miles Traveled
	15	Total Vehicle Population
		Total Hotelling Hours

EMISSION REDUCTIONS

Pollutant	Total kg/day
Carbon Monoxide (CO)	2.31832
Nitrogen Oxide (NOx)	5.31779
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.33204
Particulate Matter <10 µm (PM_{10})	0.36842
Volatile Organic Compounds (VOC)	1.08327

Carbon Dioxide Equivalent (CO2e)	122.52898
Carbon Dioxide (CO2)	122.84131
Total Energy Consumption (MMBTU)	1.58065

Please note in this example that the annual activity reported in the tool matches the inputs into the tool.

The emission reductions in kg/day and TEC reductions in millions of British Thermal Units (MMBTU) are:

Carbon Monoxide (CO): 2.31832
Nitrogen Oxide (NOx): 5.31779
Particulate Matter (PM2.5): 0.33204
Particulate Matter (PM10): 0.36842
Volatile Organic Compounds (VOC): 1.08327

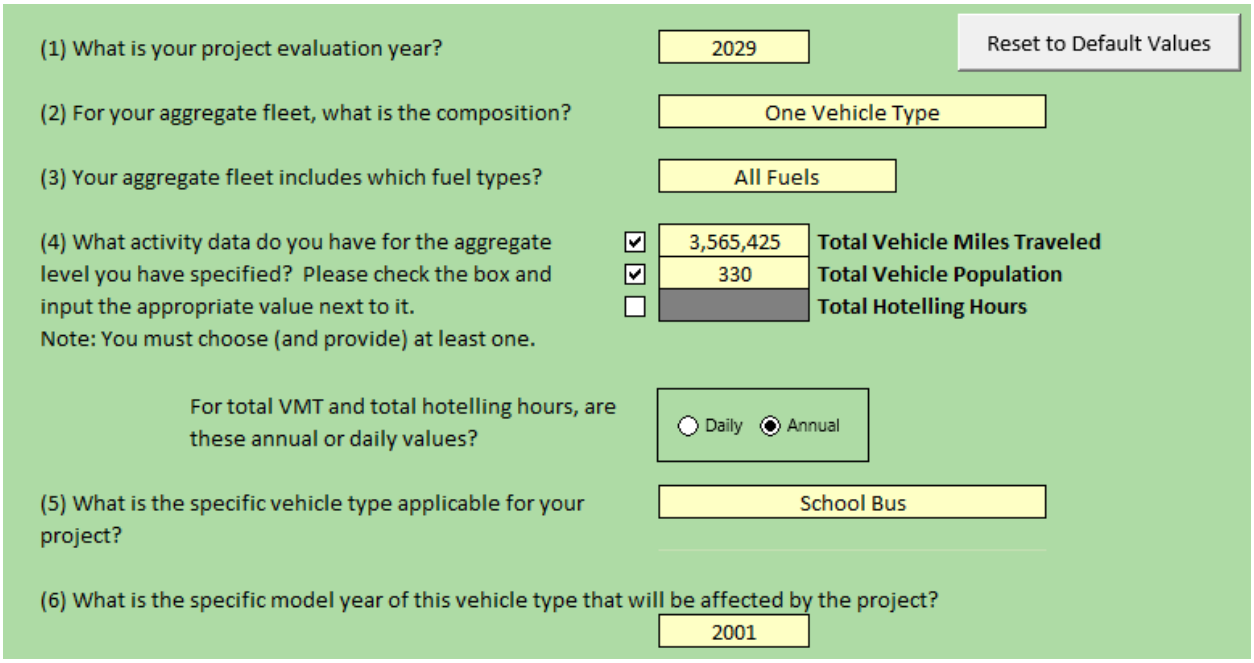
Carbon Dioxide Equivalent (CO_2e): 122.52898
Carbon Dioxide (CO_2): 122.84131
Total Energy Consumption (TEC): 1.58065

Example 2: Replacement of School Buses (Advanced Example with Activity Calculator)

Let's suppose that County X knows that their school bus fleet travels less than the national averages but they do not have specific information for the model year 2001 vehicles they are replacing. However, County X does know the total vehicle miles traveled for the 330 vehicles in their county's fleet is 3,565,425 miles. In this case, the activity calculator can be used to leverage the data inherent in MOVES to get a better estimate for vehicle miles traveled activity.

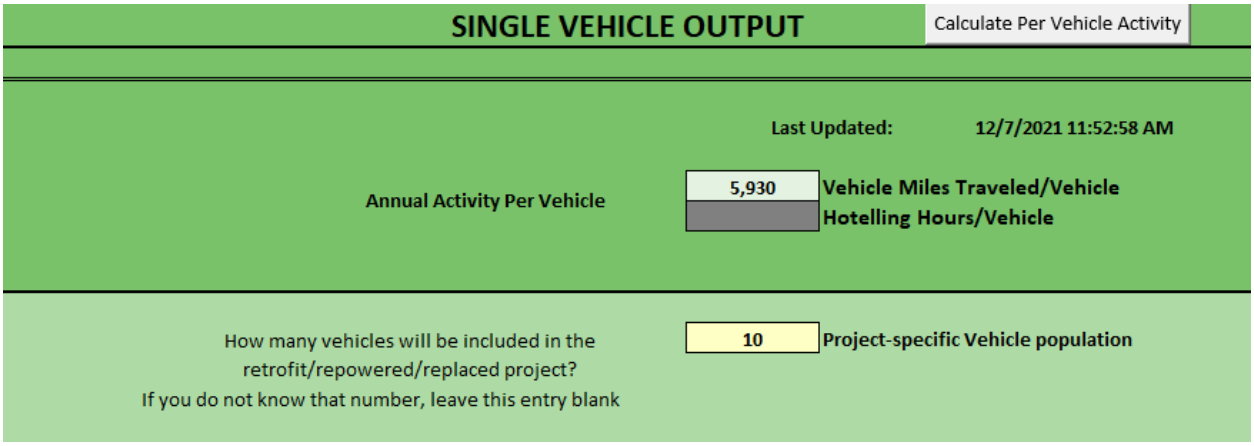
In this case, the activity calculator can first be used to determine the information that is specific for the model year 2001 vehicles that are being replaced.

Going to the activity calculator tab, input the following as shown in the image below:



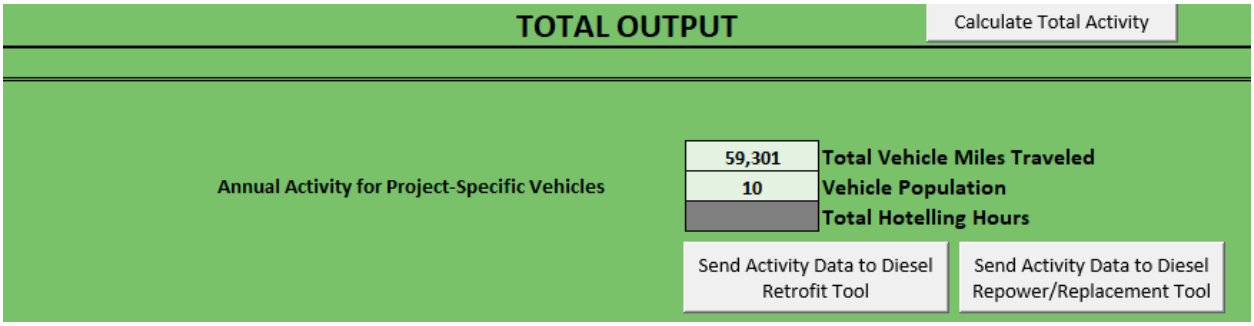
Project Evaluation Year: 2029
Fleet composition: One Vehicle Type
Aggregate Fleet: All Fuels
Total Vehicle Miles Traveled [check box]: selected
Total Vehicle Miles Traveled: 3,565,425
Total Vehicle Population [check box]: selected
Total Vehicle Population: 330
Annual/daily values: Annual
Specific vehicle type: School Bus
Model year of affected vehicles: 2001

Pressing Calculate gives an intermediate step of the calculated annual activity for the 2001 vehicles that will be replaced, as in the image below:

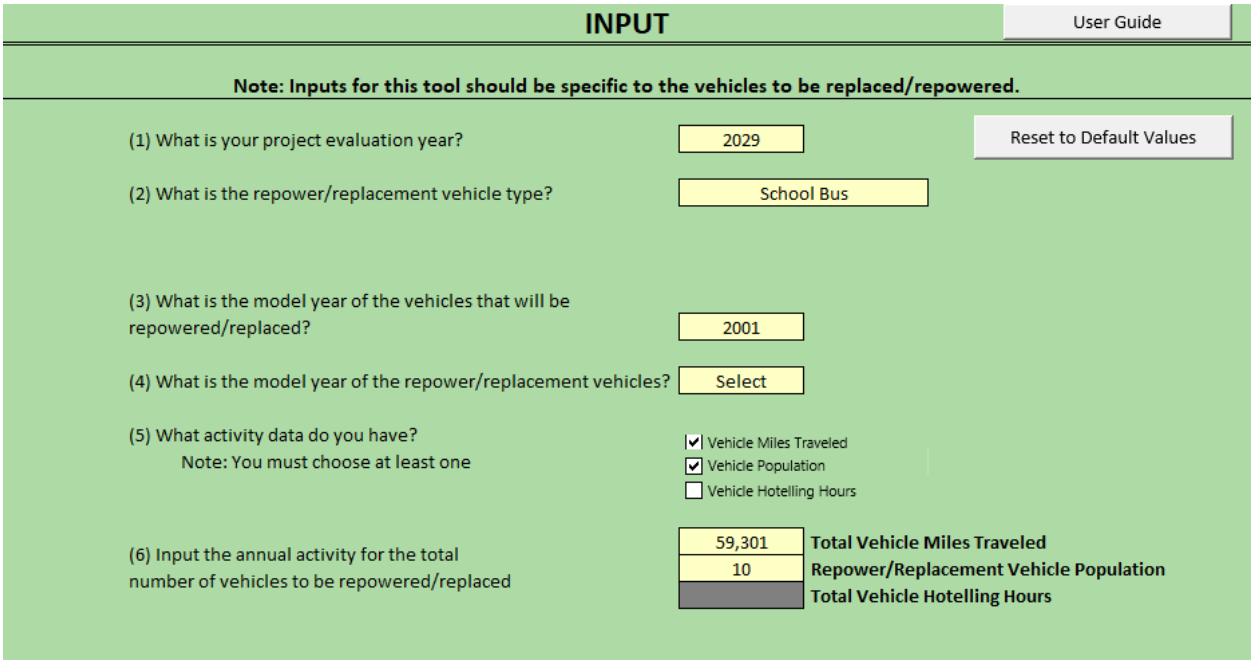


The annual activity for this fleet is 5,930 miles per vehicle, which is less than the national average. Next, the project-specific vehicle population can be input. By leaving this blank, the tool uses the distribution for vehicles by model year that occurs at the national level.

A second calculate button is then pushed to give specific activity values for the 2001 school buses to be replaced, as shown below. These values are sent to the repower/replacement tool by pressing the button labeled, “Send Activity Data to Diesel Repower/Replacement Tool”.

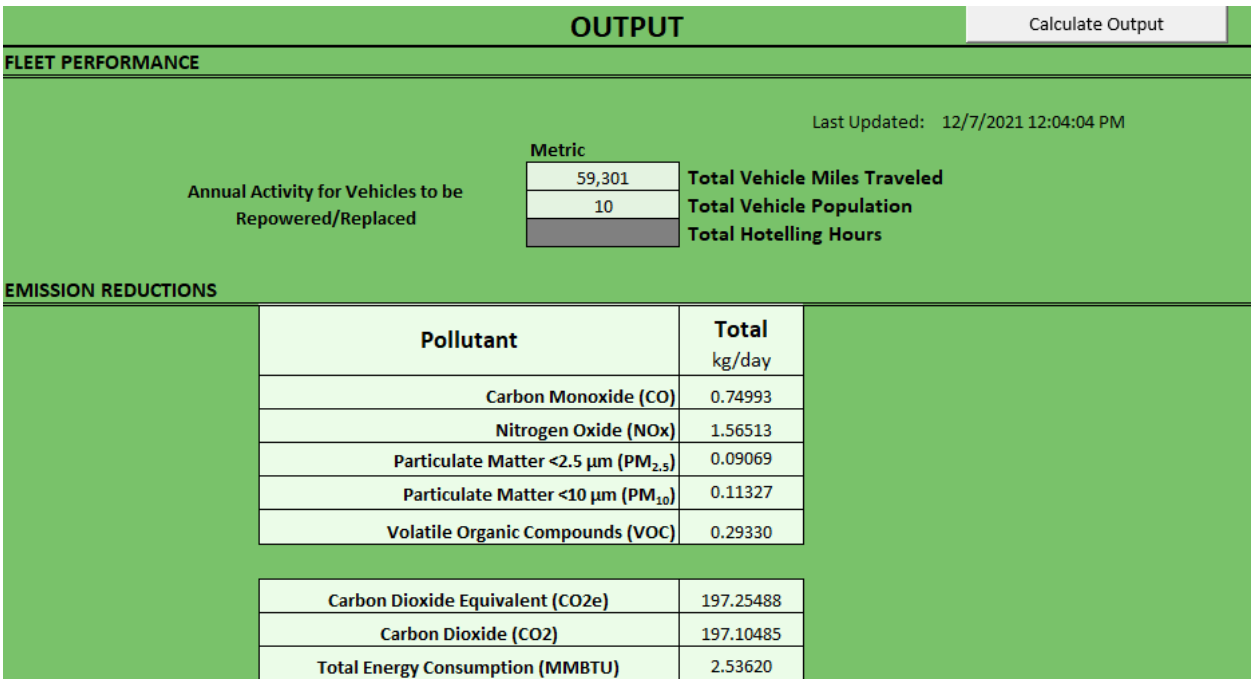


In the repower/replacement tool, the inputs should now look like this:



The only additional input that needs to be provided for proper calculation of the emissions is the model year of the vehicles that will replace the model year 2001 school buses (2029).

Emission benefits then are calculated and reported as follows:



The emission reductions in kg/day and TEC reductions in millions of British Thermal Units (MMBTU) are:

Carbon Monoxide (CO): 0.74993
Nitrogen Oxide (NOx): 1.56513
Particulate Matter (PM2.5): 0.09069
Particulate Matter (PM10): 0.11327
Volatile Organic Compounds (VOC): 0.29330

Carbon Dioxide Equivalent (CO_2e): 197.25488
Carbon Dioxide (CO_2): 197.10485
Total Energy Consumption (TEC): 2.53620