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.

Carpooling and Vanpooling Tool

Carpooling and vanpooling encourage participants to commute together. With fewer commuters driving alone[1], these programs reduce vehicle activities and subsequent emissions.

This tool contains two modules: 1) Carpooling and 2) Vanpooling. The tool can model participants driving to a centralized location or being picked up at their residences. These modules estimate emission reductions from eligible CMAQ projects, which include starting new carpool and vanpool programs, increasing ridership in existing programs[2], and purchasing vehicles for vanpool programs.

The most current version is dated March 2018. 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.

Vanpooling Module

Vanpooling is a travel demand management strategy that provides an alternative high occupancy mode of transportation for commuters who live in a common geographical area and who wish to travel to and from work together instead of driving alone. Vanpools typically carry from 7 to 15 passengers during work days. Most vanpools pick up participants at a central location such as a transit station, park and ride lot, or other common place to meet, and drop off at a common workplace.

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

[1] For simplicity, this tool does not consider other types of mode-switching.
[2] See the examples section on how to calculate benefits of increased ridership.

within the tool. The Examples section aims to give some examples of how to properly input information into the tool for different types of analysis.

Contents

USER GUIDE 3
User Inputs 3
Tool Outputs 5
Error Messages 6
TOOL METHODOLOGY 7
EXAMPLES 8
Example 1: Purchasing a Fleet of Vans to Start a New Vanpool Program 8
Example 2: Calculating Benefits of Increased Ridership 10
Example 3: Calculating Benefits Without Drivers for Hire 12

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 Vanpooling 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 vehicles that will participate in the vanpool. The user-defined inputs for this type of project 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 between 2016 and 2021.
(2)	Average vanpool commute distance (daily roundtrip)	miles	Input the average roundtrip commute distance that a vanpool vehicle will drive from the pickup location to the end destination each day. For non-centralized pickups, the distance driven to each home should be incorporated into the total distance.
(3)	Centralized pick-up/drop-off locations (check box)	-----	Click on the box if there will be a centralized location where vanpool participants gather. This option is checked by default. Unchecking this check box will grey out the *Average distance participants drive to the centralized location* field. If the cell does not grey out, minimize and maximize the program.
(3a)	Average distance participants drive to the centralized locations (daily roundtrip)	miles	Input the average roundtrip commute distance that the participants will drive to the centralized location each day, assumed to shorten the commute distance.
(4)	Number of vehicles in the vanpool fleet	vehicle number	Input the number of vehicles in the fleet that are participating in the vanpool program.
(5)	Passengers per van (not including driver)	people	Input the average number of passengers per vehicle, not including the driver. This value can include decimals as it is an average of people. Additional information is provided below this table.
(6)	Vehicle type in the vanpool	-----	Select the vehicle type that will be used in the vanpool program. Additional information is provided below this table.
(7)	Fuel type used by the vanpool vehicle(s)	-----	Select the fuel type of the vehicles that will be used in the vanpool program. Additional information is provided below this table.
(8)	Model year of the vanpool vehicle(s)	-----	Select the model year (or a representative year) of the vehicle type that will be used in the vanpool program.

There is one field that has a default value that is based on a national average, average roundtrip commute distance (25.2 miles)[3]. For specific localities, a Brookings study determined the typical one-way commute distance in 96 metropolitan areas across the country.[4] Users are encouraged to enter their own estimates where possible rather than relying on national default values.

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.

Evaluation year and model year information: Evaluation years can range from 2016 to 2021 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.

Passengers per vehicle: The passengers per vehicle field assumes that the driver of the van would otherwise not be on the road if not for the vanpool program, i.e., the driver is hired to drive the van. This extra VMT from the van is accounted for during the net benefit calculation. If a specific vanpool program does not use drivers for hire but instead uses employees going to that destination already to drive the van, then an extra passenger should be added to the van so that emission reductions from the driver's personal vehicle taken off the road can be accounted for properly. Please see Example 3 for further explanation of this scenario.

Vehicle type: Table 2 lists the vehicle types provided in this tool. Their emission rates are based on the source type-regulatory class combination.

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

Vehicle Type	MOVES Source Type ID	MOVES Regulatory Class ID	FHWA Vehicle Class[5]	Maximum number of passengers (driver not included)
Mini Van	31	30	Class 3 vehicles weighing less than or equal to 8,500 pounds	7
Van (8,500 < GVW ≤ 10,000 lbs.)	32	40	Class 3 vehicles weighing greater than 8,500 pounds and less than or equal to 10,000 pounds used to transport passengers	14
Van (10,000 < GVW ≤ 14,000 lbs.)	43	41	Class 3 vehicles weighing greater than 10,000 and less than or equal to 14,000 pounds used for transporting passengers	17

[3] US DOT, FHWA, https://www.fhwa.dot.gov/policy/2010cpr/execsum.cfm#c1
[4] Elizabeth Kneebone and Natalie Holmes (2015), Brookings Institution, "The growing distance between people and jobs in metropolitan America," https://www.brookings.edu/wp-content/uploads/2016/07/Srvy_JobsProximity.pdf
[5] FHWA, https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm

Passenger capacities used in the module for Mini Van[6], Van (8,500 < GVW ≤ 10,000 lbs.)[7], and Van (10,000 < GVW ≤ 14,000 lbs.)[8] were taken from example manufacturer's sites.

Fuel type: This module gives users the ability to model vans fueled by gasoline (MOVES fuelTypeID 1), diesel (fuelTypeID 2), or compressed natural gas (CNG, fuelTypeID 3). Lacking MOVES emission rates, CNG van rates are derived from *gasoline* rates for mini vans and vans (8,500 < GVW ≤ 10,000 lbs.) multiplied by the appropriate AFLEET factor for vehicle type and pollutant. Similarly, CNG emission rates for larger vans (10,000 < GVW ≤ 14,000 lbs.) are derived from *diesel* emission rates multiplied by the appropriate AFLEET factor. Methodology on how the AFLEET adjustment factors were created can be found in documentation of the AFLEET tool.[9] The AFLEET factors and baseline fuels by vehicle type and pollutant are summarized in Table 3 below.

Table 3 Vehicle type and baseline conventional fuel for AFLEET CNG factors by pollutant

CMAQ Vanpool Vehicle Type	Baseline Fuel	MOVES pollutantID	Pollutant Name	CNG AFLEET Factor
Mini Van	Gasoline	2	CO	0.7
Van (8,500 < GVW ≤ 10,000 lbs.)	Gasoline	2	CO	1.3
Van (10,000 < GVW ≤ 14,000 lbs.)	Diesel	2	CO	26.7
Mini Van	Gasoline	3	NOx	0.8
Van (8,500 < GVW ≤ 10,000 lbs.)	Gasoline	3	NOx	0.9
Van (10,000 < GVW ≤ 14,000 lbs.)	Diesel	3	NOx	0.7
Mini Van	Gasoline	110	PM2.5	1
Van (8,500 < GVW ≤ 10,000 lbs.)	Gasoline	110	PM2.5	1.2
Van (10,000 < GVW ≤ 14,000 lbs.)	Diesel	110	PM2.5	1
Mini Van	Gasoline	100	PM10	1
Van (8,500 < GVW ≤ 10,000 lbs.)	Gasoline	100	PM10	1.2
Van (10,000 < GVW ≤ 14,000 lbs.)	Diesel	100	PM10	1
Mini Van	Gasoline	87	VOC	0.6
Van (8,500 < GVW ≤ 10,000 lbs.)	Gasoline	87	VOC	0.5
Van (10,000 < GVW ≤ 14,000 lbs.)	Diesel	87	VOC	10

The tool will push messages if a user selects a disallowed source type-fuel type combination or an erroneous year (see Table 4).

Tool Outputs

The vanpooling module assumes that for each passenger in the vanpool (not including the driver), one vehicle is being taken off the road. The benefits are derived from the amount of daily emissions reduced

[6] Honda, Odyssey Mini Van http://automobiles.honda.com/odyssey/
[7] GMC, Savana Passenger Van http://www.gmc.com/vans/savana-passenger-van.html
[8] Mercedes Benz, Sprinter Mini Bus http://www.mbvans.com/sprinter/commercial-vans/minibus
[9] https://greet.es.anl.gov/afleet_tool

by vehicle miles travelled (VMT) taken off the road, while also accounting for the vanpool fleet being added to the road. For example, low ridership could yield a disbenefit as a whole.

Emission reductions are calculated for five pollutants – CO, $PM_{2.5}$, PM_{10}, NOx, and VOC. Results are reported in kilograms/day based on 250 working days per year. In the event that a different annualized reporting rate is desired, users are recommended to multiply their daily results by 250 and then divide by their chosen number of working days in a year.

Error Messages

The error messages that the user may encounter in this tool, the reason for these error messages and their solution is listed in Table 4 below:

Table 4 Error Messages

Error Message	Reason for Error	Solution
Please enter the model year of the vehicle.	Invalid input for model year	Input an appropriate model year, within 30 years prior to the project evaluation year.
Please select a vehicle and fuel type.	Either vehicle and/or fuel type have not been selected	Select both a vehicle and fuel type.
WARNING: The number of passengers entered exceeds the tool's recommended capacity for a [$vehicleType][10].	Input is greater than the referenced passenger capacities	Input an appropriate value less than or equal to the maximum number of passengers for the specific vehicle type in Table 2.

Once you correct any errors, please follow the instructions and press 'Calculate Output' to clear any errors and recalculate the results.

[10] [$vehicleType] is a wildcard variable for the three vanpool vehicle types in this tool. Note that each vehicle type will have a different capacity, as specified in Table 2.

TOOL METHODOLOGY

Emission reductions, reported in kilograms per day of the vanpool program, are calculated for a given pollutant as follows:

$$daily\ reduced\ emissions = \begin{matrix}\left(e_{running\ _{car}} \cdot VMT\ reduced + e_{starts\ _{car}} \cdot starts\ reduced\right) \\ -\left(e_{running\ _{van}} \cdot VMT\ added + e_{starts\ _{van}} \cdot starts\ added\right)\end{matrix} \quad (1)$$

where the starts and VMT reduced from the passenger vehicles displaced by the vanpool,

$$VMT\ reduced_{non\ central} = displaced\ vehicle\ pop \cdot commute\ distance \quad (2)$$

$$VMT\ reduced_{central} = displaced\ vehicle\ pop \cdot (commute\ distance - distance\ to\ central\ location) \quad (3)$$

$$starts\ reduced_{non\ central} = displaced\ vehicle\ pop \cdot starts \quad (4)$$

and where the starts and VMT added for the vans in the vanpool,

$$VMT\ added = van\ fleet\ size \cdot commute\ distance \quad (5)$$

$$starts\ added = van\ fleet\ size \cdot starts_{van} \quad (6)$$

such that the centralized and non-centralized cases are calculated somewhat differently. For the non-centralized case, the reduced emissions will look just like Equation 1. For the centralized case, the reduced emissions would not include the starts reduced the variable $e_{starts_{car}}$ in Equation 1 should be zero due to there being no starts reduced.

The variables for the equations are defined below:
$e_{running}$ = running emission rate[11] for a pollutant based on the given evaluation year,
e_{starts} = starting emission rate[12] for a pollutant based on the given evaluation year,
$van\ fleet\ size$ = the number of vehicles included in the van fleet,
$commute\ distance$ = average roundtrip distance the active vanpool vehicle will travel to and from the common workplace,

[11] In this tool, the running emission process includes crankcase running emissions for all pollutants as well as brakewear and tirewear for both PM2.5 and PM10.
[12] The tool's start emission process includes crankcase start emissions.

$displaced\ vehicle\ pop$ = the number of cars taken off the road due to the program, which equals the van fleet size times the number of passengers per van (the driver is not counted since he/she is assumed to be hired to drive the van and therefore his/her vehicle will not be taken off the road). The following equation is used:

$$displaced\ vehicle\ pop = van\ fleet\ size\ \cdot passengers\ per\ van \quad (7)$$

$distance\ to\ central\ location$ = average roundtrip distance to and from the centralized pick-up/drop-off location, which is assumed to shorten the commute distance,
$passenger\ per\ van$ = the number of passengers in each van, not including the driver, and
$starts$ = number of starts from vehicles taken off the road due to the program, where two starts will be reduced for each passenger vehicle in the non-centralized case and no starts will be reduced in centralized case; starts added is assumed to be two for each van.

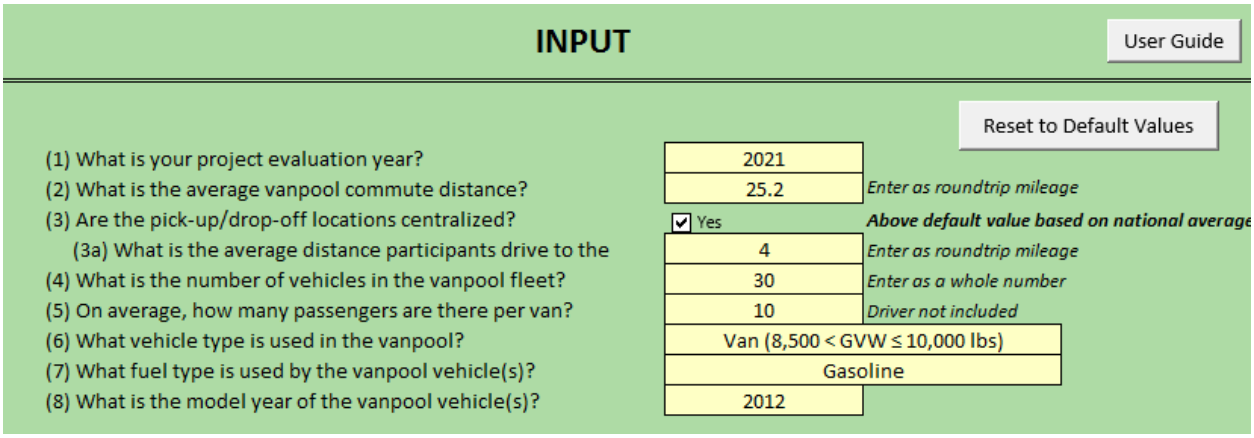
NOTE: To annualize emission reductions, multiply the daily emissions reduced by the number of days per year that the vanpool program is active.

EXAMPLES

Example 1: Purchasing a Fleet of Vans to Start a New Vanpool Program

County X in State AA would like to purchase 30 gasoline-fueled vans to start a vanpool program. The national default value for commute distance is used. The proposed vanpool program will use centralized drop-off/pick up locations and it is estimated that on average, people will drive 2 miles from their house to that location (4 miles roundtrip each day). County X estimated a total participation of 300 people, with an average of 10 passengers per van. Therefore, the vanpool program is planning to purchase 30 full-sized passenger vans. These vans all run on gasoline and are all model year 2012. The program is planned to start in 2021.

In the Vanpooling module, the following inputs would be chosen, as shown in the image below:



Project Year: 2021
Commute Distance: 25.2
Centralized Location [check box]: Selected
Average Distance to Centralized Location: 4
Vanpool Fleet: 30
Passengers per Vehicle: 10
Vehicle Type: Van (8,500 < GVW =< 10,000 lbs.)
Fuel Type: Gasoline
Model Year: 2012

Once the inputs are entered, the 'Calculate Output' button can be selected to estimate emission reductions for the project, as shown below:

OUTPUT Calculate Output

EMISSION REDUCTIONS

Pollutant	Total kg/day
Carbon Monoxide (CO)	6.125
Nitrogen Oxide (NOx)	0.577
Particulate Matter <10 µm (PM_{10})	0.001
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.018
Volatile Organic Compounds (VOC)	0.081

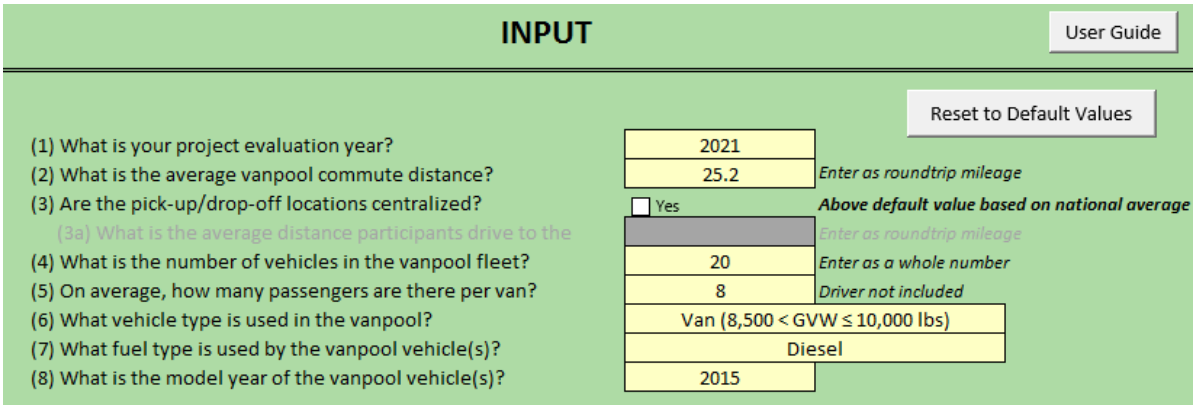
The emission reductions in kg/day for all five pollutants are:

Carbon Monoxide (CO): 6.125
Nitrogen Oxide (NOx): 0.577
Particulate Matter (PM2.5): 0.001
Particulate Matter (PM10): 0.018
Volatile Organic Compounds (VOC): 0.081

Example 2: Calculating Benefits of Increased Ridership

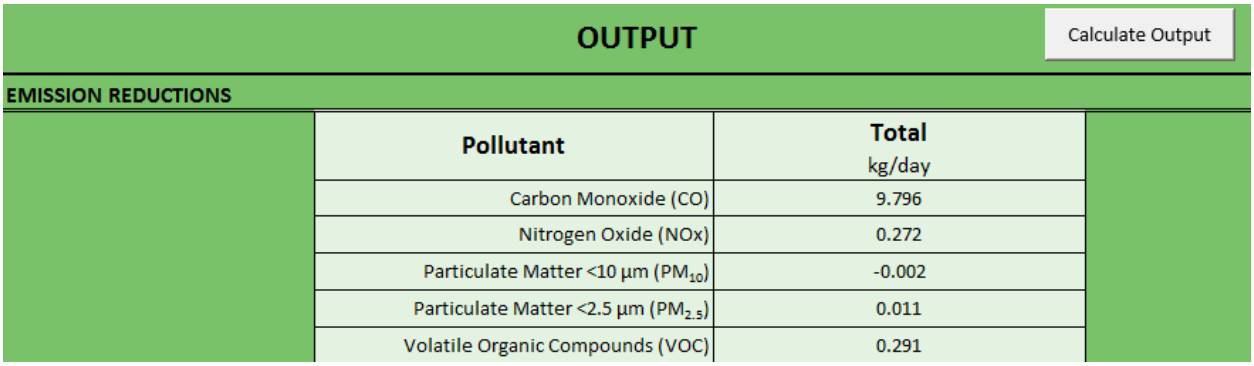
Step 1: Estimate the Baseline

Scenario: County X in State AA would like to see the benefits of increased ridership in a vanpool program without centralized pickup locations. They estimate there is a baseline of 8 passengers per vehicle. In the Vanpooling module, the following inputs would be chosen, as shown in the image below:



Project Year: 2021
Commute Distance: 25.2
Centralized Location [check box]: Unselected
Vanpool Fleet: 20
Passengers per Vehicle: 8
Vehicle Type: Van (8,500 < GVW =< 10,000 lbs.)
Fuel Type: Diesel
Model Year: 2015

Once the inputs are entered, the 'Calculate Output' button can be selected to estimate *baseline* emission reductions for the project, as shown below:



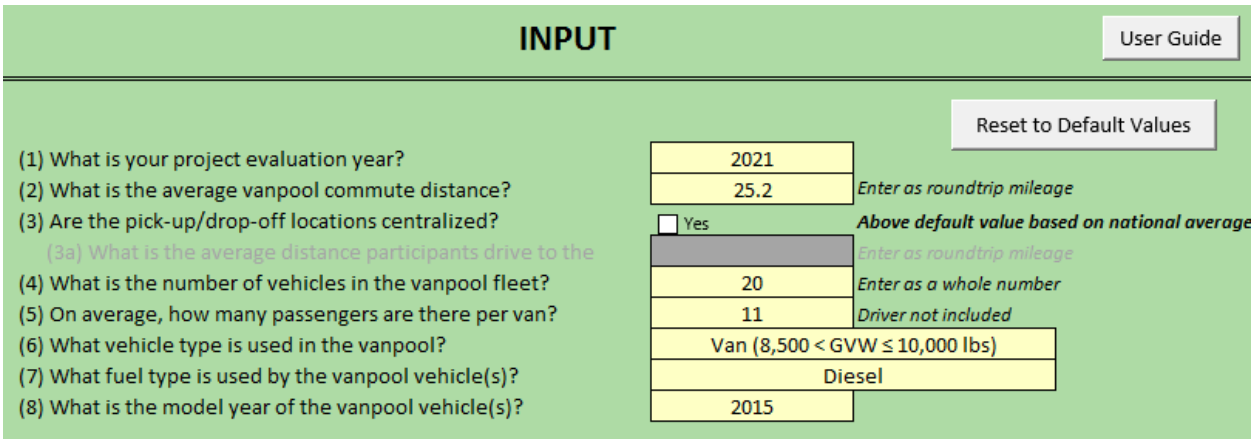
Pollutant	Total kg/day
Carbon Monoxide (CO)	9.796
Nitrogen Oxide (NOx)	0.272
Particulate Matter <10 µm (PM_{10})	-0.002
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.011
Volatile Organic Compounds (VOC)	0.291

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

Carbon Monoxide (CO): 9.796
Nitrogen Oxide (NOx): 0.272
Particulate Matter (PM2.5): -0.002
Particulate Matter (PM10): 0.011
Volatile Organic Compounds (VOC): 0.291

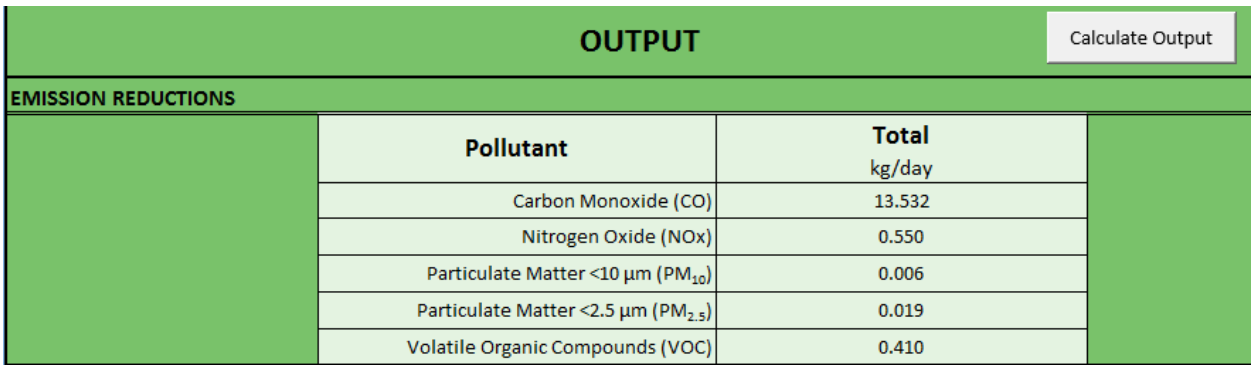
Step 2: Estimate the Emission Reductions with Increased Ridership

The county then estimates an increase in the ridership of the program to 11 passengers per vehicle with all other inputs the same, as shown in the image below:



Project Year: 2021
Commute Distance: 25.2
Centralized Location [check box]: Unselected
Vanpool Fleet: 20
Passengers per Vehicle: 11
Vehicle Type: Van (8,500 < GVW =< 10,000 lbs.)
Fuel Type: Diesel
Model Year: 2015

Once the inputs are entered, the 'Calculate Output' button can be selected to estimate the new total emission reductions for the project, as shown below:



Pollutant	Total kg/day
Carbon Monoxide (CO)	13.532
Nitrogen Oxide (NOx)	0.550
Particulate Matter <10 µm (PM_{10})	0.006
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.019
Volatile Organic Compounds (VOC)	0.410

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

Carbon Monoxide (CO): 13.532
Nitrogen Oxide (NOx): 0.550
Particulate Matter (PM2.5): 0.006
Particulate Matter (PM10): 0.019
Volatile Organic Compounds (VOC): 0.410

Step 3: Calculate the Net Benefits

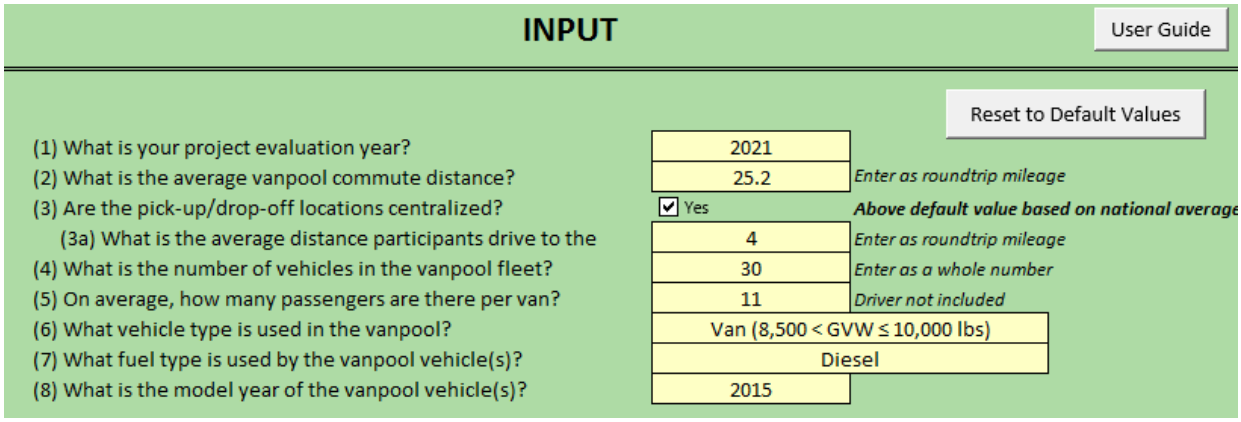
We can determine the change in emission benefits of increasing the ridership of the program by subtracting the benefits from the emission reductions of the high ridership case from the baseline reductions from the low ridership case. The net benefits are calculated in the table below.

Table 5 Net Benefits in kg/day

Pollutant	Low Ridership	High Ridership	Net Benefits
Carbon Monoxide (CO)	9.796	13.532	23.328
Nitrogen Oxide (NOx)	0.272	0.550	0.822
Particulate Matter (PM10)	-0.002	0.006	0.004
Particulate Matter (PM2.5)	0.011	0.019	0.030
Volatile Organic Compounds (VOC)	0.291	0.410	0.701

Example 3: Calculating Benefits without Drivers for Hire

This example uses the same scenario as Example 1 with a slight modification. County Y in State AA would like to start a similar vanpool program as County X but does not want to hire drivers for the program. Instead, the drivers will also be participants of the vanpool. The vanpooling module assumes that emission benefits come from removing the passengers' vehicles from the road during a commute. In this example, there is also an added benefit of removing the driver's personal vehicle from the road. The 'driver not included' note in Question 5 should be ignored, and the average passengers per van should be set to 11 rather than 10. All other inputs are identical to those in Example 1, as shown below:



Project Year: 2021
Commute Distance: 25.2
Centralized Location [check box]: Selected
Vanpool Fleet: 30
Passengers per Vehicle: 11
Vehicle Type: Van (8,500 < GVW =< 10,000 lbs.)
Fuel Type: Gasoline
Model Year: 2015

Once the inputs are entered, the 'Calculate Output' button can be selected to estimate the total emissions reduction from the proposed program.

OUTPUT Calculate Output

EMISSION REDUCTIONS

Pollutant	Total kg/day
Carbon Monoxide (CO)	13.486
Nitrogen Oxide (NOx)	0.364
Particulate Matter <10 µm (PM_{10})	0.002
Particulate Matter <2.5 µm ($PM_{2.5}$)	0.019
Volatile Organic Compounds (VOC)	0.134

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

Carbon Monoxide (CO): 13.486
Nitrogen Oxide (NOx): 0.364
Particulate Matter (PM2.5): 0.002
Particulate Matter (PM10): 0.019
Volatile Organic Compounds (VOC): 0.134