CMAQ Emissions Calculator Toolkit

Documentation of Emissions Data for the Carpooling and Vanpooling Tool

This document serves as a supplement to the documentation for the Carpooling and Vanpooling Tool in the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit). It discusses the primary data sources and how the emissions datasets for these calculators were derived.

The document highlights the emissions data predominantly used from the US Environmental Protection Agency Motor Vehicle Emissions Simulator (MOVES)[1]. The MOVES Methodology cites specific inputs/outputs and post-processing that were used to generate the national-scale emission rates used within the tool. The tool also utilizes emissions data from the Argonne National Laboratory Alternative Fuel Lifecycle Environmental and Economic Transportation (AFLEET) Tool[2]. The AFLEET Methodology describes how alternative fuel adjustment factors were used in the tool to estimate emissions.

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MOVES METHODOLOGY

The emission reductions calculators for the Carpooling and Vanpooling tool rely on running, start, evaporative, and crankcase exhaust emission rates as well as national-scale activity rates within MOVES. The rates were obtained with a set of MOVES runs in which all evaluation years were combined together into a single MOVES run, and were generated on the national scale. MOVES3 (version from January 2022)[3] was used to obtain the emission rates used in the tool.

The MOVES emission rates for diesel and gasoline are viewable in the tool by unhiding the worksheets. The emission rates worksheets can be viewed by right-clicking on one of the worksheet tabs, selecting *Unhide*, and then selecting the worksheet.

[1] US Environmental Protection Agency, Office of Transportation and Air Quality, https://www.epa.gov/moves
[2] US Department of Energy, Argonne National Laboratory, https://greet.es.anl.gov/afleet_tool
[3] EPA, https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

National-Scale Runs

The national-scale model runs used to obtain emission rates were set up with the following parameters:

Carpool Run Parameters

Categories	Variable	Input
Description	-----	<blank>
Scale	Model	Onroad
	Domain/Scale	Default
	Calculation Type	Inventory
Time Spans	Time Aggregation Level	Year
	Years	[2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040]
	Months	All Selected
	Days	All Selected
	Hours	All Selected
Geographic Bounds	-----	No Selection Needed
Onroad Vehicles	Fuels	All Selected
	Source Use Types	Passenger Car, Passenger Truck
Road Type	Road Types	All Selected
Pollutants and Processes (selected)	Total Gaseous Hydrocarbons	All Selected
	Non-methane Hydrocarbons	All Selected
	Volatile Organic Compounds	All Selected
	Methane (CH_4)	All Selected
	Carbon Monoxide (CO)	All Selected
	Oxides of Nitrogen (NOx)	All Selected
	Primary Exhaust PM2.5 – Total	All Selected
	[+] Primary Exhaust PM2.5 - Species	Running Exhaust, Start Exhaust, Extended Idle Exhaust, Auxiliary Power Exhaust
	Primary PM2.5 – Brakewear Particulate	All Selected
	Primary PM2.5 – Tirewear Particulate	All Selected
	Primary Exhaust PM10 – Total	All Selected
	Primary PM10 – Brakewear Particulate	All Selected
	Primary PM10 – Tirewear Particulate	All Selected
	Total Energy Consumption	All Selected
	Atmospheric CO_2	All Selected
	CO_2 Equivalents	All Selected

Categories	Variable	Input
General Output	Units	Mass: kilograms, Energy: Million BTU, Distance: miles
	Activity	All Selected
Output Emissions Detail	Output Aggregation	Time: Year, Geographic: Nation
	For All Vehicle/Equipment Categories	Model Year, Fuel Type, Emission Process
	Onroad	Road Type, Source Use Type, Regulatory Class
Create Input Database	Domain Input Database	<blank>
Advanced Features	Time Aggregation	Hour
	Region Aggregation	Nation

Vanpool Run Parameters

Categories	Variable	Input
Description	-----	<blank>
Scale	Model	Onroad
	Domain/Scale	Default
	Calculation Type	Inventory
Time Spans	Time Aggregation Level	Year
	Years	[2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040]
	Months	All Selected
	Days	All Selected
	Hours	All Selected
Geographic Bounds	-----	No Selection Needed
Onroad Vehicles	Fuels	All Selected
	Source Use Types	Passenger Truck, Light Commercial Truck
Road Type	Road Types	All Selected
Pollutants and Processes (selected)	Total Gaseous Hydrocarbons	All Selected
	Non-methane Hydrocarbons	All Selected
	Volatile Organic Compounds	All Selected
	Methane (CH_4)	All Selected
	Carbon Monoxide (CO)	All Selected
	Oxides of Nitrogen (NOx)	All Selected
	Primary Exhaust PM2.5 – Total	All Selected
	[+] Primary Exhaust PM2.5 - Species	Running Exhaust, Start Exhaust, Extended Idle Exhaust, Auxiliary Power Exhaust
	Primary PM2.5 – Brakewear Particulate	All Selected

Categories	Variable	Input
	Primary PM2.5 – Tirewear Particulate	All Selected
	Primary Exhaust PM10 – Total	All Selected
	Primary PM10 – Brakewear Particulate	All Selected
	Primary PM10 – Tirewear Particulate	All Selected
	Total Energy Consumption	All Selected
	Atmospheric CO_2	All Selected
	CO_2 Equivalents	All Selected
General Output	Units	Mass: kilograms, Energy: Million BTU, Distance: miles
	Activity	All Selected
Output Emissions Detail	Output Aggregation	Time: Year, Geographic: Nation
	For All Vehicle/Equipment Categories	Model Year, Fuel Type, Emission Process
	Onroad	Road Type, Source Use Type, Regulatory Class
Create Input Database	Domain Input Database	<blank>
Advanced Features	Time Aggregation	Hour
	Region Aggregation	Nation

Post-MOVES Run Data Processing:

Results from the national-scale MOVES run were utilized to obtain different categories of data for use in this Carpooling and Vanpooling tool. The following descriptions are of the MOVES activity and emissions inventory data used in the tool:

1. **Activity rates –** To obtain national-scale activity rates, vehicle population and miles traveled were extracted from the results for all light-duty and heavy-duty vehicles. Populations were used to compute MOVES default estimates of miles traveled per vehicle.
2. **Emissions associated with Vehicle Miles Traveled –** Emission rates were generated on a per-mile basis. This involved joining emission inventories from the movesoutput table and activity from the movesactivityoutput table.

For vanpools, emission rates are based on evaluation year, pollutant, process, model year, source type, regulatory class, and fuel type.

For carpools, emission rates for passenger vehicles are the aggregate of rates for gasoline and diesel passenger car and passenger trucks across all model years. Thus, passenger vehicle emission rates in a carpool program are defined by evaluation year, pollutant, and emissions process. These composite passenger vehicle emission rates use default MOVES distributions for source type, fuel type, and model year.

Carpooling and vanpooling projects are expected to reduce the overall VMT in the affected area. Off-network idling activity and emissions from evaporative processes from vehicles on-network are projected to decrease as a result of the reduced VMT. The most recent version of this tool includes emissions from off-network idling activity and evaporative emissions from certain MOVES process types on certain road types. The included evaporative processes are:

1) Processes 11, 12, and 13 on road types 2, 3, 4, and 5.
2) Processes 1, 2, 9, 10, 15, 16, 18, 19 on all road types.

AFLEET METHODOLOGY

Compressed natural gas (CNG) factors[4] from AFLEET 2020[5] were applied to default conventional fuel emission rates depending on vehicle source, use type, and pollutant in the Vanpooling module. A more detailed description of applying AFLEET factors for CNG vans can be found in the "Fuel Type" discussion in the Vanpooling module documentation.

The CNG AFLEET emission rates can be determined by multiplying the MOVES emission rates in the MOVES Methodology section by the appropriate AFLEET factor listed in Table 3 of the Vanpooling User Guide.

USER-SUPPLIED EMISSION RATES

Some users may be interested in incorporating local data into the tool, which is based on national-scale MOVES runs. For those unfamiliar with developing local MOVES runs, please refer to EPA's mobile-source emissions modeling guidance and documentation for highway vehicles.[6] This section provides basic instructions on how to import local emission rates into the Carpooling and Vanpooling Tool.

Import Local Emissions Rates for Carpooling Module

Users may take the following steps to replace emission rates in the Carpooling module:

1. Using the national carpool run parameters listed in the table above, develop local emission rates. The CMAQ Toolkit is not prescriptive about which MOVES inputs are derived from local data. Users only must specify the same output parameters and details as the national-scale run. Complete any local MOVES runs for the selected calendar years and any other parameters listed above.

2. The MOVES output needs to be reformatted so that it can be used in the tool:
    - Unhide the 'carpoolEmissionRates' tab in Excel and ensure that the new user-supplied, local emissions output has the same fields: yearID, pollutantID, and processID.

[4] Alternative Fuel Emission Factor Multipliers for CNG vehicles can be found in AFLEET 2020's Background Data tab.
[5] DOE, https://greet.es.anl.gov/index.php?content=registration&from=afleet
[6] EPA, https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs

- To post-process the new emission rates output from MOVES, join the movesoutput and movesactivityoutput tables using yearID, pollutantID, and processID and then should create columns for vehicle miles traveled (VMT), population, miles per vehicle, starts, and starts per vehicle. Define units as appropriate. To include emissions from off-network idling activity and evaporative emissions, the following processes should be included in the movesoutput table:
    - processID 11, 12, and 13 on roadTypeID 2, 3, 4, and 5.
    - processID 1, 2, 9, 10, 15, 16, 18, and 19 on roadTypeID 1, 2, 3, 4, and 5.
- Include PM from brakewear and tirewear in the total particulate matter emissions. For PM10, change pollutantID 106 and 107 to 100. For PM2.5, change pollutantID 116 and 117 to 110. Also, the brakewear and tirewear processes should be labeled as a running exhaust process. Therefore, change processIDs 9 and 10 to 1.
- Similarly, set crankcase running exhaust processes to running exhaust and crankcase start exhaust processes to start exhaust. For crankcase running exhaust, processID 15 is changed to 1, and for crankcase start exhaust, processID 16 is changed to 2.
- Sum emissions inventory for light-duty passenger vehicles (sourceTypeID 21 and 31) where processID, pollutantID, and yearID are the same. This will create a set of composite rates for processIDs 1 and 2 for each pollutant in the table above, and for each calendar year selected during the MOVES runs. Include a column in the final output table for these inventories.
- Similarly, sum the distance traveled by, the population of, and the number of starts for the entire fleet of light duty passenger vehicles in each year run in MOVES. This will create a value for total distance traveled, total population, and a total number of starts in each year by the fleet.
- Emission rates are calculated for the running exhaust (processID 1) by dividing the emissions inventory by the VMT for each combination of yearID, processID, and pollutantID. Emission rates are calculated for the start exhaust (processID 2) by dividing the emissions inventory by the number of starts made by the fleet of vehicles.
- Miles per vehicle are calculated by dividing vehicle miles traveled by the population. Starts per vehicle are calculated by dividing the number of starts in a year by the population in that year.

The local MOVES data should now be structured and labelled in exactly the same way as the national default data initially used in the tool. Export the local emission rates in .csv or .xlsx file format.

3. Delete any data in the 'carpoolEmissionRates' tab and then copy and paste the local emission rates into the existing worksheet. Save the Carpool and Vanpool Tool under a different name and verify that the Carpool module yields new, expected results with the local data.

Import Local Emissions Rates for Vanpooling Module

Similar to the Carpooling module, users may take the following steps to replace emission rates in the Vanpooling module:

1. Using the national vanpool run parameters listed in the table above, develop local emission rates. The CMAQ Emissions Calculator Toolkit is not prescriptive about which MOVES inputs are derived from local data. Users only must specify the same output parameters and details as the national-scale run. Complete any local MOVES runs for the selected calendar years and any other parameters listed above.

2. The MOVES output needs to be reformatted so that it can be used in the tool:

    - Unhide the 'vanpoolEmissionRates' tab in Excel and ensure that the new user-supplied, local emissions output has the following fields in the lookup table of national emission rates: yearID, sourceTypeID, regClassID, fuelTypeID, modelYearID, pollutantID, and processID.
    - To post process the new emission rates output from MOVES, join the movesoutput and movesactivityoutput tables using yearID, sourceTypeID, regClassID, fuelTypeID, modelYearID, pollutantID, and processID and then create columns for vehicle miles traveled (VMT), population, miles per vehicle, starts, and starts per vehicle. Define units as appropriate. To include emissions from off-network idling activity and evaporative emissions, the following processes should be included in the movesoutput table:
        - processID 11, 12, and 13 on roadTypeID 2, 3, 4, and 5.
        - processID 1, 2, 9, 10, 15, 16, 18, 19 on roadTypeID 1, 2, 3, 4, and 5.
    - Include PM from brakewear and tirewear in the total particulate matter emissions. For PM10, change pollutantID 106 and 107 to 100. For PM2.5, change pollutantID 116 and 117 to 110. Also, the brakewear and tirewear processes should be labeled as a running exhaust process. Therefore, change processIDs 9 and 10 to 1.
    - Include emissions from crankcase running exhaust and crankcase start exhaust in running and start exhaust. For crankcase running exhaust, processID 15 is changed to 1. For crankcase start exhaust, processID 16 is changed to 2.
    - Sum emissions inventory for passenger vehicles (sourceTypeID 31, 32) where processID, pollutantID, modelyearID, fueltypeID, regclassID, sourcetypeID, and yearID are the same. This will create a set of composite rates for each combination of values in the fields listed above. Include a column in the final output table for these inventories.
    - Extract vehicle miles traveled (activitytypeID 1) for entries with sourceTypeIDs 31 and 32 from the movesActivityOutput table. Include these values in the post-processed data under vehicle miles traveled by each source type.
    - Extract population (activitytypeID 6) for entries with sourceTypeIDs 31 and 32 from the movesActivityOutput table. Include these values in the post-processed data under population of each source type.
    - Extract the number of starts (activitytypeID 7) for entries with sourceTypeIDs 31 and 32 from the movesActivityOutput table. Include these values in the post-processed data under starts made by each vehicle type.
    - Emission rates are calculated for the running exhaust (processID 1) by dividing the emissions inventory by the VMT for each entry. Emission rates are calculated for the start exhaust (processID 2) by dividing the emissions inventory by the number of starts in each entry.

- Miles per vehicle are calculated by dividing vehicle miles traveled by the population. Starts per vehicle are calculated by dividing the number of starts in a year by the population in that year.
- The vanpool module only uses certain combinations of MOVES sourcetypeID and MOVES regclassID to represent FHWA vehicle classes. These combinations are shown in the table below. Ensure that your post-processed MOVES output data contains these combinations, as the vanpool module will not produce output if none of these combinations exist. The regulatory class is often defined by gross vehicle weight (GVW) and number of axels in a vehicle.

Vehicle Type	**MOVES Source Type ID**	**MOVES Regulatory Class ID**	**FHWA Vehicle Class[7]**
Mini Van	31	30	Class 3 vehicles weighing less than or equal to 8,500 pounds
Van	32	41	Class 3 vehicles weighing greater than 8,500 pounds and less than or equal to 14,000 pounds used to transport passengers

The local MOVES data should now be structured and labelled in exactly the same way as the national default data initially used in the tool. Export the local emission rates in .csv or .xlsx file format.

3. Delete any data in the 'vanpoolEmissionRates' tab and then copy and paste the local emission rates into the existing worksheet. Save the Carpool and Vanpool Tool under a different name and verify that the Vanpool module yields new, expected results with the local data.

[7] US Federal Highway Administration, Traffic Monitoring Guide 2013, https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm