CMAQ Emissions Calculator Toolkit

Documentation of Emissions Data for the Transit Bus Upgrades & System Improvements Tool

This document serves as a supplement to the documentation for the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit) Transit Bus Upgrades and System Improvements Tool. It discusses the primary data sources and how the emissions datasets for these calculators were derived. Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses.

This document highlights the emissions data used from the US Environmental Protection Agency (EPA) Motor Vehicle Emissions Simulator (MOVES)[1] and the Argonne National Laboratory Alternative Fuel Lifecycle Environmental and Economic Transportation (AFLEET) Tool.[2] 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 AFLEET Methodology describes how alternative fuel adjustment factors were accessed to estimate emissions for alternative fuel vehicle data not included in MOVES.

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MOVES METHODOLOGY

The emission reductions calculators for the Transit Bus Upgrades and System Improvements Tool rely primarily on running, start, and crankcase exhaust emissions rates[3] as well as national-scale activity rates within MOVES. Data for evaporative emissions during retrofitting and refueling events of alternative fuel buses were not readily available, so evaporative processes were not included in these MOVES runs. The rates were obtained with a set of MOVES runs in which all evaluation years were combined into a single MOVES run, and were generated on the national scale. MOVES3 (version from September 2021)[4] was used to obtain the emission rates for this tool.

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[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] As a simplification, brakewear and tirewear have been included in the running particulate matter (PM) emissions.

[4] EPA, Latest Version of MOtor Vehicle Emission Simulator (MOVES) | US EPA

National-Scale Run

The national-scale run used to obtain emission rates was set up with the following parameters:

Table 1 National-scale run parameters

Category	Variable	Input
Description	-----	<blank>
Scale	Model	Onroad
	Domain/Scale	National
	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	-----	Nation
Vehicles/Equipment	On-Road Vehicle Equipment	Diesel and CNG Transit Buses
Road Type	Road Types	All Selected
Pollutants and Processes (selected)	Total Gaseous Hydrocarbons	Running Exhaust, Start Exhaust
	Non-methane Hydrocarbons	Running Exhaust, Start Exhaust
	Volatile Organic Compounds	Running Exhaust, Start Exhaust, Crankcase Running Exhaust, Crankcase Start Exhaust
	Carbon Monoxide (CO)	Running Exhaust, Start Exhaust, Crankcase Running Exhaust, Crankcase Start Exhaust
	Oxides of Nitrogen (NOx)	Running Exhaust, Start Exhaust, Crankcase Running Exhaust, Crankcase Start Exhaust
	Primary Exhaust PM2.5 – Total	Running Exhaust, Start Exhaust, Crankcase Running Exhaust, Crankcase Start Exhaust
	Primary PM2.5 – Brakewear Particulate	Brakewear
	Primary PM2.5 – Tirewear Particulate	Tirewear
	Primary Exhaust PM10 – Total	Running Exhaust, Start Exhaust, Crankcase Running Exhaust, Crankcase Start Exhaust
	Primary PM10 – Brakewear Particulate	Brakewear
	Primary PM10 – Tirewear Particulate	Tirewear

Category	Variable	Input
	Carbon Dioxide Equivalent (CO_2e)	Running Exhaust, Start Exhaust
	Total Energy Consumption (TEC)	Running Exhaust, Start Exhaust
Manage Input Data Series	-----	<blank>
Strategies	Rate of Progress	<blank>
General Output	Units	Mass: kilograms, Energy: Million BTU, Distance: miles
	Activity	Distance Traveled, Population, Starts
Output Emissions Detail	Always	Year, Nation
	On Road/Off Road	Road Type, Source Use Type
	For All Vehicle/Equipment Combinations	Model Year, Fuel Type, Emission Process
Advanced Performance Features	-----	<blank>

Post-MOVES Run Data Processing

Results from the national-scale MOVES run were used to obtain different categories of data for use in this Transit Bus Upgrades & System Improvements 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 for transit buses (sourceTypeID 42). This meant joining emission inventories from the movesoutput table and activity from the movesactivityoutput table. The emission rates of transit buses adopting retrofit technology were developed separately for start and running processes while the emission rates associated with the replacement of transit buses were developed over all vehicle operations.

Emission rates are based on evaluation year, pollutant, emission process, model year, source type, and fuel type. The retrofits module only allows retrofits on diesel transit buses. The Non-EV and EV replacement modules allow replacement of diesel or compressed natural gas (CNG) buses with diesel, CNG, alternative fuel, or electric buses as well as emissions from changes in VMT to and from new restricted access infrastructure.

AFLEET METHODOLOGY

To allow replacement with alternative fuel buses to be modeled in this tool, the Alternative Fuel Emission Factor Multipliers from AFLEET 2020's Background Data tab were used directly in the tool's emissions calculations. Where alternative fuel emission rates were not available in MOVES, alternative

fuel factors from AFLEET 2020[5] were applied to default conventional fuel emission rates depending on the fuel type and pollutant. As included in the tool's other documentation, Table 2 below presents a list of data sources of replacement fuel types (diesel, CNG, or alternative fuels) and indicates whether the emissions data for each replacement fuel has come from MOVES directly or from AFLEET-adjusted conventional fuel emission rates. Combinations without emissions data are left out from the table but included on the footnote of the table title.

Table 2 Alternative fuels available in this tool for transit bus replacement[6]

Replacement Fuel	Data Source	Module
Diesel Fuel	M	Non-EV
Compressed Natural Gas (CNG)	M	Non-EV
Biodiesel (B100)	A	Non-EV
Biodiesel (B20)	A	Non-EV
Hybrid Electric (HEV)	A	Non-EV
Hydraulic Hybrid (HHV)	A	Non-EV
Liquefied Natural Gas (LNG)	A	Non-EV
Dual Fuel (Natural Gas/Diesel, LNG/D)	A	Non-EV
Hydrogen Fuel Cell (FCV)	A	Non-EV
Battery Electric (BEV)	A	EV
M = MOVES emission rates, **A = A**FLEET factors combined with conventional fuel emission rates		

It is also important to denote AFLEET's baseline conventional fuels to appropriately estimate alternative fuel vehicle emissions. In this tool, AFLEET alternative fuel factors for transit buses are applied to MOVES diesel transit bus rates for emission estimates.

USER-SUPPLIED EMISSION RATES

The tool's emissions rates are based on national-scale MOVES runs. Some users may be interested in incorporating local data into the tool, and this section provides instructions on how to import local emission rates into the Transit Bus Upgrades and System Improvements Tool. For those unfamiliar with developing local MOVES runs, please refer to EPA's mobile-source emissions modeling guidance and documentation for transit buses.[7]

Using Local Emissions Data in the Transit Bus Modules

Users are recommended to take the following steps to replace emissions rates in the Transit Bus Retrofit module:

1. Using the national-scale MOVES 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.

[5] DOE, https://greet.es.anl.gov/index.php?content=registration&from=afleet

[6] There is not sufficient test data to estimate emissions of propane (LPG) or ethanol (E85) transit buses, so these fuel types were not included in this tool.

[7] EPA, https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs

Complete any local MOVES runs for the selected calendar years and any other parameters listed in the table above.

2. The MOVES output data needs to be reformatted so that it can be used in the tool. The details on post processing this output are described below:

    - Unhide the 'EmissionRates' tab in Excel and ensure that MOVES output has the six parameters yearID, sourcetypeID, fueltypeID, modelyearID, pollutantID, and processID.
    - For running emission rates, extract emissions by aggregating the "movesoutput" table by the above six output parameters. Include only transit bus source types (sourcetypeID 42) in the post-processed data.
        - Extract vehicle miles traveled (VMT) from the movesactivityoutput table (activitytypeID 1), differentiating only by unique combinations of yearID, sourceTypeID, fuelTypeID, and modelYearID.
        - Create a running emission rate table with emissions results from running exhaust, brakewear, tirewear, and crankcase running exhaust processes (processID 1, 9, 10, 15, respectively) and VMT results.
    - Similar to running rates, for start emission rates, extract emissions by aggregating the "movesoutput" table by the same six output parameters: yearID, sourcetypeID, fueltypeID, modelyearID, pollutantID, and processID.
        - Extract population from the movesactivityoutput table (activitytypeID 6), differentiating only by unique combinations of yearID, sourceTypeID, fuelTypeID, and modelYearID. There should be no repeated combinations of population outputs.
        - Create a start emission rate table with emissions results from start exhaust and crankcase start emissions (processID 2 and 16, respectively) and vehicle population results.
    - Combine the running and start emissions results by simply appending the running rate and start rate tables to create one table of local post-processed data.

    The local MOVES output data should now be formatted in exactly the same way as the national default output data initially used in the tool. Export the final table of local emissions rates in .csv or .xlsx file format.

3. Delete any data (keep the title of the columns the same) in the 'EmissionRates' tab in the Transit Bus tool and then copy and paste your exported local emission rates data into the existing worksheet with the same table format. Save a new version of the Transit Bus Retrofit and Replacement Tool under a different name and verify that the Transit Bus Retrofit module produces expected results with local emissions rates.