CMAQ Emissions Calculator Toolkit

Documentation of Emissions Data for the Dust Mitigation Tool

This document supplements the User Guide for the Dust Mitigation Tool in the Congestion Mitigation and Air Quality Improvement Program Emissions Calculator Toolkit (CMAQ Toolkit). It discusses the primary data sources and how the emission datasets for this tool were derived. Emission estimates from the CMAQ Toolkit are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses.

The document highlights the emissions data obtained from the US Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES).[1] The MOVES Methodology section describes the specific inputs and outputs, pre-processing, and post-processing that were used to generate the national-scale emission rates used within the tool. The tool also utilizes fugitive dust emissions methodology from the EPA's AP-42 Compilation of Air Emission Factors[2] and emission factors from the EPA's Emission Standards for Heavy-Duty Highway Engines and Vehicles.[3]

Contents

EMISSION RATE DATA SUMMARY 2
MOVES METHODOLOGY 2
MOVES Parameters 3
Post-MOVES Run Data Processing 6
EMISSIONS METHODOLOGY 7
Paved Roads 7
Unpaved Roads 9
Unpaved to Paved 10
STREET SWEEPER EMISSIONS 11
Heavy-Duty Vehicle Emission Standards 11
Zero-Emissions Street Sweepers 13
USER-SUPPLIED EMISSION RATES 13
Paved Roads 13
Unpaved Roads 14
Unpaved to Paved 14
APPENDIX 16

[1] US Environmental Protection Agency, Office of Transportation and Air Quality, https://www.epa.gov/moves
[2] AP-42: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors
[3] Heavy-Duty Standards: https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-heavy-duty-highway-engines-and-vehicles

EMISSION RATE DATA SUMMARY

Emission rates for the Dust Mitigation tool were derived from three different sources. Below is a summary of how each data source was used in the three different tool modules (Paved Roads, Unpaved Roads, and Unpaved to Paved).

1. EPA's MOVES
    - Paved Roads: national-scale runs to obtain brakewear and tirewear emission rates ($PM_{2.5}$ and PM_{10}) for street sweepers.
    - Unpaved to Paved: project-level runs to obtain exhaust emission rates (all pollutants) for speeds 0 to 75 mph to account for a speed change after paving.
2. EPA's AP-42 Compilation of Air Emission Factors[4]
    - Paved Roads: fugitive dust emission rates and control efficiency[5] for street sweeping.
    - Unpaved Roads: fugitive dust emission rates for unpaved roads and control efficiencies for chemical treatment and wet suppression.
    - Unpaved to Paved: fugitive dust emission rates for unpaved roads and control efficiency for paving.
3. EPA's Emission Standards for Heavy-Duty Highway Engines and Vehicles[6]
    - Paved Roads: exhaust emission rates for gasoline, diesel, and clean/alternative fuel street sweepers. Note users may also enter their own street sweeper emission rates if available.

MOVES METHODOLOGY

All fugitive dust emissions in the Dust Mitigation Tool were estimated using AP-42 methodology, described in more detail below. MOVES3.0.3 (version from January 2022)[7] was used to determine select emission rates for the Paved Roads and Unpaved to Paved modules. No MOVES data was used in the Unpaved Roads module.

National-scale MOVES runs were used to obtain brake and tire wear emission rates for street sweepers in the Paved Roads module. Project-level MOVES runs were used to determine running and evaporative emission rates at different speeds for the Unpaved to Paved module. These emission rates were used to determine the change in emissions due to a potential speed change after paving an unpaved road.

[4] AP-42: Compilation of Air Emissions Factors. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

[5] Control efficiency refers to the efficiency of the dust control measure in reducing fugitive dust emissions. For example, a control efficiency of 0.95 would reduce fugitive dust by 95% compared with no dust control.

[6] EPA Emission Standards for Heavy-Duty Highway Engines and Vehicles. https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-heavy-duty-highway-engines-and-vehicles

[7] EPA, https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

MOVES Parameters

Table 1 summarizes parameters used for the Paved Roads module and Table 2 summarize parameters for the Unpaved to Paved module, including inputs to the Project Data Manager

Table 1. MOVES Parameters for Paved Roads Module

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
Vehicles/Equipment	On-Road Vehicle Equipment	Combination Long-haul Truck Combination Short-haul Truck Single Unit Long-haul Truck Single Unit Short-haul Truck Transit Bus Other Buses School Bus Refuse Truck
Road Type	Road Type	All Road Types
Pollutants and Processes	Primary PM2.5 – Brakewear Particulate	All Selected
	Primary PM2.5 – Tirewear Particulate	All Selected
	Primary PM10 – Brakewear Particulate	All Selected
	Primary PM10 – Tirewear Particulate	All Selected
General Output	Units	Mass: kilograms, Energy: million BTU, Distance: miles
	Activity	Source Hours Operating
Output Emissions Detail	Output Aggregation	Time: Year, Geographic: Nation
	For All Vehicle/Equipment Categories	Model Year
	Onroad	Road Type
Create Input Database	Domain Input Database	<blank>
Advanced Features	Time Aggregation	Hour
	Region Aggregation	Nation

Table 2a. MOVES Parameters for Unpaved to Paved Module (Project-Level Run Parameters)

Category	Variable	Input
Description	-----	<blank>
Scale	Model	Onroad
	Domain/Scale	Project
	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	January
	Days	Weekday
	Hours	00:00 – 00:59
Geographic Bounds	Counties	Custom Domain
Vehicles/Equipment	On-Road Vehicle Equipment	All Fuel/Type Combinations Selected
Road Type	Road Types	Rural Restricted Access, Rural Unrestricted Access, Urban Restricted Access, Urban Unrestricted Access
Pollutants and Processes (selected)	Total Gaseous Hydrocarbons	Running Exhaust, Crankcase Running Exhaust, Evap Permeation, Evap Fuel Vapor, Evap Fuel Leaks
	Non-methane Hydrocarbons	Running Exhaust, Crankcase Running Exhaust, Evap Permeation, Evap Fuel Vapor, Evap Fuel Leaks
	Volatile Organic Compounds	Running Exhaust, Crankcase Running Exhaust, Evap Permeation, Evap Fuel Vapor, Evap Fuel Leaks
	Methane (CH_4)	Running Exhaust, Crankcase Running Exhaust
	Carbon Monoxide (CO)	Running Exhaust, Crankcase Running Exhaust
	Oxides of Nitrogen (NOx)	Running Exhaust, Crankcase Running Exhaust
	Nitrous Oxide (N_2O)	Running Exhaust, Crankcase Running Exhaust
	Primary Exhaust PM2.5 – Total	Running Exhaust, Crankcase Running Exhaust

Category	Variable	Input
	Primary PM2.5 – Brakewear Particulate	Brakewear
	Primary PM2.5 – Tirewear Particulate	Tirewear
	Primary Exhaust PM10 – Total	Running Exhaust, Crankcase Running Exhaust
	Primary PM10 – Brakewear Particulate	Brakewear
	Primary PM10 – Tirewear Particulate	Tirewear
	Total Energy Consumption	Running Exhaust
	Atmospheric Carbon Dioxide	Running Exhaust
	Carbon Dioxide Equivalent	Running Exhaust
General Output	Units	Mass: kilograms, Energy: million BTU, Distance: miles
	Activity	Distance Traveled, Source Hours, Source Hours Operating
Output Emissions Detail	For All Vehicle/Equipment Categories	Model Year, Fuel Type, Emission Process
	Onroad	Road Type
Create Input Database	Domain Input Database	<blank>
Advanced Performance Features	Time Aggregation	Hour
	Region Aggregation	County

Table 2b. MOVES Parameters for Unpaved to Paved Module (Project Data Manager – Inputs by Tab)

Data	Source
Age Distribution	Adopted MOVES3 age distributions for all evaluation years from 2018 through 2040 (taken from sourcetypeagedistribution table in movesdb20210726 database)
AVFT [8]	Used default tables for each run
Fuel Formulation	Used default tables for each run
Fuel Supply	Used default tables for each run
Fuel Usage Fraction	Used default tables for each run
Generic	---
Hotelling	---
I/M Programs[9]	Used imcoverage table from movesexecution database in national-scale inventory run for all evaluation years (2018 through 2040)

[8] Alternative Vehicle Fuel Technology. Note that national-scale MOVES runs were used to populate the AVFT table, as it is not populated in the MOVES default database. If needed, please follow the parameters laid out above for the Paved Roads Module's national-scale runs.

[9] Inspection and Maintenance Programs. Note that national-scale MOVES runs were used to populate the I/M Program table, as it is not populated in the MOVES default database. If needed, please follow the parameters laid out above for the Paved Roads Module's national-scale runs.

Links	Customized input with the following data: • linkID: roadTypeID concatenated with linkAvgSpeed (i.e., 200, 201, 202… 275) • countyID: 25017 • zoneID: 1 • roadTypeID: 2, 3, 4, 5 • linkLength: equal to linkAvgSpeed (except when 0 mph, then equal to 1 mile) • linkVolume: 100 • linkAvgSpeed: 0 through 75 mph (repeated for all four road types) • linkDescription: --- • linkAvgGrade: 0
Link Source Type	Customized input with the following data: • linkID: 200-275, 300-375, 400-475, 500-575 • sourceTypeID: all 13 types • sourceTypeHourFraction: normalized values from movesactivityoutput table in default-scale inventory run for all years 2018-2040 of vehicle miles traveled by source type over the total vehicle miles traveled on a given road type (source type fractions sum to 1 by road type)
Meteorological Data[10]	Used default tables for each run
Off-Network	For all source types: • Vehicle Population: 4 • Start Fraction: 0.5 • Extended Idle Fraction: 0 • Parked Vehicle Fraction: 0.5
Operating Mode Distribution	Data from default-scale inventory run described previously
Retrofit Data	---
Tools	---

Post-MOVES Run Data Processing

Results from the MOVES runs were utilized to obtain different categories of data for use in the Dust Mitigation tool. The following section describes MOVES activity and emissions inventory data used in the tool.

Paved Roads Module

1. **Activity rates –** To obtain national-scale activity rates (Table 1), the number of source hours operated (activityTypeID 4) was extracted from the results for all vehicles.

[10] Note that national-scale MOVES runs were used to populate the meteorological data table, as it is not populated in the MOVES default database. If needed, please follow the parameters laid out above for the Paved Roads Module's national-scale runs.

2. **Hourly emissions –** Emission rates were generated on a per-hour basis. This involved joining emission inventories from the movesoutput table and activity from the movesactivityoutput table. To determine brake and tire wear emission rates, brakewear and tirewear emissions (processID 9 and 10) were divided by source hours operated.

Emission rates are based on project evaluation year, pollutant, model year, and road type.

Unpaved to Paved Module

Project-level MOVES runs (Table 2) were used to generate inputs for the Project Data Manager.

1. **Activity rates –** To obtain project-level activity rates, the distance travelled (activityType1) was extracted from the results for all vehicles.
2. **Hourly emissions –** Emission rates were generated on a per-mile basis. This involved joining emission inventories from the movesoutput table and activity from the movesactivityoutput. To determine emission rates, emissions (aggregated across all processes) were divided by distance travelled.

Emission rates are based on project evaluation year, speed, pollutant, and road type.

The most recent version of the Unpaved to Paved module includes evaporative emissions from certain MOVES process types on certain road types. The processes included in this module are:

- Processes 1, 9, 10, 11, 12, 13, and 15 on road types 2, 3, 4, and 5.

EMISSIONS METHODOLOGY

The following sections provide a detailed description of emission rate equations and default input parameters for each of the three modules. All fugitive dust emission rates used in the Dust Mitigation Tool are derived from EPA's AP-42 Compilation of Emission Factors.

Paved Roads

Fugitive dust emissions on paved roads are determined by Equation 1 (AP-42, Chapter 13.2.1). Default values for silt loading as a function of roadway type are provided in Table 3.

$$E = k \times sL^{0.91} \times W^{1.02} \quad (1)$$

where:

E = paved road dust emission factor (g/VMT),
k = particle size multiplier (g/VMT),
sL = road surface silt loading (g/m2) (dimensionless in equation), and
W = average weight (tons) of all vehicles traveling the road (dimensionless in equation).

Table 3. Default values for silt content (s) as a function of surface material (from EPA's AP-42)

Roadway Type	Silt Loading (g/m^2)
Rural Restricted Access	1
Rural Unrestricted Access	2.5
Urban Restricted Access	0.02

Urban Unrestricted Access	0.08

The average weight (W)[11] is calculated based on the fractions of light-duty versus heavy-duty vehicles travelling on the road, using vehicle mass values from Table 4. These same data are also used in MOVES. Average weight impacts the amount of fugitive dust uplifted by vehicle traffic.

The average light-duty vehicle weight was assumed to be 1.4 tons and the average heavy-duty vehicle weight was assumed to be 16.4 tons. Light-duty vehicles were assumed to include motorcycles, passenger cars and trucks, and light commercial trucks, while heavy-duty vehicles include buses, refuse trucks, and short- and long-haul trucks.

Example: For light-duty and heavy-duty activity percentages of 75% and 25%, respectively, the average weight is calculated using a weighted average: (0.75 × 1.4 tons) + (0.25 × 16.4 tons) or 5.15 tons.

Table 4. Source Mass of Different Vehicle Types in MOVES (from EPA's AP-42)

MOVES Vehicle Type	Source Mass, W (tons)
Motorcycle	0.285
Passenger Car	1.479
Passenger Truck	1.867
Light Commercial Truck	2.0598
Intercity Bus	19.594
Transit Bus	16.556
School Bus	9.07
Refuse Truck	23.114
Single Unit Short-haul Truck	8.539
Single Unit Long-haul Truck	6.984
Motor Home	7.526
Combination Short-haul Truck	22.975
Combination Long-haul Truck	24.601

The reduction in fugitive dust emissions are determined by applying a control efficiency (fraction of dust removed) to the fugitive $PM_{2.5}$ and PM_{10} emissions determined from Equation 1. In the tool, users may either input their own control efficiency or use a national default.[12] The national default efficiency from AP-42 is 0.79 and assumes vacuum sweeping[13] of paved roads twice per month.

The Paved Roads module also considers running exhaust and brake and tire wear emissions from street sweeping activity. Street sweeper exhaust emissions were determined using the EPA's emissions rates for heavy-duty vehicles, including gasoline, diesel, clean, and alternative fuel engines. Brake and tire

[11] Average weight of all vehicles (entire fleet) traveling on the paved road.
[12] The control efficiency for street sweeping is based on national averages from EPA's AP-42 Paved Roads (Ch. 13.2.1).
[13] Conservative estimate of PM10 sweeping efficiency, based on vacuum technology.

wear emissions rates were obtained from MOVES3. The street sweeper methodology is described in detail below.

The total emission reductions on paved roads are determined as:

$$Emission\ Reduction\ (g) = Fugitive\ Dust\ Emissions\ \left(\frac{g}{VMT}\right) \times Activity\ (VMT\ of\ Fleet) \times (1 - CE) + Street\ Sweeper\ Emissions\ (g) + Brake\ and\ Tire\ Wear\ Emissions\ (g) \quad (2)$$

where CE is the control efficiency of street sweeping.

The output of Equation 2 (g) is then convert to kg/d for the tool output (see Annualization below).

Unpaved Roads

Fugitive dust emissions on unpaved roads are determined by Equation 3 (AP-42, Ch. 13.2.2) for publicly accessible roads and Equation 4 for industrial sites. Values for all constants and parameters in Equations 3 and 4 are given in Tables 5 through 8 below. All default values were obtained from EPA's AP-42.

Publicly Access Roads (primarily light-duty vehicles):

$$E = \frac{k \times (s/12) \times (SPD/30)^{0.5}}{(M/0.5)^{0.2}} - C \quad (3)$$

E = unpaved road dust emission factor (lb/VMT)
k = particle size multiplier (lb/VMT)
s = surface material silt content (%)
SPD = mean vehicle speed (mph)
M = surface material moisture content (%)
C = emission factor for vehicle fleet exhaust, brake wear, and tire wear (lb/VMT)

Industrial Sites (significant heavy-duty traffic):

$$E = k \times (s/12)^a \times (W/3)^b \quad (4)$$

where *a* and *b* are empirically-determined constants equal to 0.9 and 0.45, respectively. See the Paved Roads section and Table 4 above for details of the average weight (W) calculation.
Table 5 provides the values of constants (k and C) used in Equations 3 and 4. Tables 6 through 8 give default values for mean vehicle speed, silt content, and moisture content, respectively. The user may input a default value based on roadway characteristics, or enter their own value.

Table 5. Constants (k and C) for unpaved roads Equations 3 and 4 (from EPA's AP-42)

Constant	PM10	PM2.5
k (lb/VMT) – Public Access	1.8	0.18
k (lb/VMT) – Industrial	1.5	0.15
C – Public Access	0.00047	0.00036

Table 6. Default values for mean vehicle speed (SPD) as a function of roadway type (from EPA's AP-42)

Roadway Type	Default Speed (mph)
Rural Minor Arterial	39
Rural Major Collector	34
Rural Minor Collector	30
Rural Local	30
Urban	20

Table 7. Default values for silt content (s) as a function of surface material (from EPA's AP-42)

Surface Material	Default Silt %
Gravel	6.4
Dirt	11

Table 8. Default values for moisture content (M)

Moisture Conditions	Default Moisture %
Dry	0.2
Typical	1.1

The reductions in fugitive dust emissions are determined by applying a control efficiency for the particular treatment (wet suppression or chemical treatment) to the PM_{10} and $PM_{2.5}$ emissions determined from Equations 3 and 4. In the tool, users may either input their own control efficiency or use a national default from AP-42.[14] The default efficiencies for wet suppression and chemical dust treatment are 0.75 and 0.8, respectively, and assume a common application interval of 2 weeks to 1 month.

The total emission reductions on unpaved roads are determined as:

$$Emission\ Reduction\ (lb) = Fugitive\ Dust\ Emissions\left(\frac{lb}{VMT}\right) \times\ Activity\ (VMT) \times (1 - CE) \quad (5)$$

The output of Equation 5 is converted from lb to kg/d for the tool output (see Annualization below).

Unpaved to Paved

Fugitive dust emissions associated with paving an unpaved road are calculated by applying a control efficiency to the unpaved road emissions (Equation 3) and considering vehicle running emissions associated with a potential change in speed after paving. In the tool, users may either input their own

[14] Control efficiencies for wet suppression and chemical treatment are based on national averages from EPA's AP-42 Paved Roads (Ch. 13.2.1).

control efficiency or use a national default.[15] The default control efficiency from AP-42 for paving projects is 0.96. Emissions due to the speed change were determined by running MOVES for each potential road type and speed combination (see Table 2).

The total emission reductions associated with paving are determined as:

$$\begin{aligned} &Emission\ Reduction\ (g) \\ &\quad = Fugitive\ Dust\ Emissions\ \left(\frac{g}{VMT}\right) \times\ Activity\ (VMT) \times (1 - CE) \\ &\quad + Speed\ Change\ Emissions\ (g) \end{aligned} \tag{6}$$

The output of Equation 6 is converted from g to kg/d for the tool output (see Annualization below).

STREET SWEEPER EMISSIONS

Heavy-Duty Vehicle Emission Standards

Several states have recognized that regular street sweeping may have emissions impacts and moved towards upgrading fleets to low or zero-emissions street sweepers. For example, the South Coast Air Quality Management District (SCAQMD) in California requires local governments to purchase or upgrade to sweepers which meet strict PM10 certification requirements.[16]

There has been limited research on street sweeper exhaust emission rates and the few published studies have focused on specific manufacturers and models. In order to provide a conservative estimate of exhaust emissions, the Paved Roads module uses the EPA's Emission Standards for Heavy-Duty (HD) Highway Engines and Vehicles.[17] These standards cover compression-ignition (diesel) and spark-ignition (gasoline) engines for vehicles with gross weights of 8,500 up to 60,000 lbs. Beginning in 2005, alternative and clean fuel vehicles (e.g., CNG, LNG, methanol, LEV, ULEV) are also required to comply with the HD compression-ignition standards.[18] The compression-ignition standards encompass all vehicle weights, while the spark-ignition standards are delineated based on gross vehicle weights of less than or equal to 14,000 lbs or greater than 14,000 lbs.

Users have the option to input their own street sweeper emission rates (for example, manufacturer-specific rates for a CNG street sweeper). If these data are not available, the Paved Roads module uses EPA's HD standards as default values. See the Appendix for a summary of default gasoline and diesel/alternative/clean street sweeper emission rates with all conversions and adjustments applied.

[15] The control efficiency for paving an unpaved road is based on national averages from EPA's AP-42 Unpaved Roads (Ch. 13.2.2).

[16] SCAQMD Rule 1186 requires testing of sweepers' ability to remove more than 80% of the typical urban street dust loadings and limits the amount of PM10 entrained during the sweeping process to less than 200 mg/m of roadway. Rule1186 Certified Street Sweepers as of June 2018: http://www.aqmd.gov/docs/default-source/rule-book/support-documents/rule-1186/certified-street-sweepers-equipment-list.pdf.

[17] EPA Heavy-Duty Emission Standards: https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-heavy-duty-highway-engines-and-vehicles

[18] See 40 Code of Federal Regulations Part 86. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-86

Brake Horse Power Conversion

The diesel standards are reported in terms of g/bhp-hr where 'bhp' represents the brake horse power of the engine. BHP is a measure of an engine's horsepower before the loss in power caused by the gearbox and drive train. It is measured at the crankshaft just outside of the engine and is a function of engine torque and rotational speed. The following conversion factors[19] (Table 9) were used to convert g/bhp-hr to g/mi, to determine street sweeper exhaust emissions based on miles of road swept.

Table 9. Truck conversion factors for 1997 and later model years (bhp-hr/mi)

Fuel Type	Gross Vehicle Weight (lbs)	Conversion Factor (bhp-hr/mi)
Diesel	Less than 14,000	1.25
Diesel	14,000 and above	1.60
Gasoline	Less than 14,000	1.15
Gasoline	14,000 and above	1.30

$$Sweeper\ Emissions\ (g) = HD\ standard\left(\frac{g}{bhp-hr}\right) \times Conv.Factor\left(\frac{bhp-hr}{mi}\right) \times Sweeper\ Activity\ (mi) \quad (7)$$

HC to VOC Conversion

EPA's HD hydrocarbon emission standards for some model years were reported in terms of total hydrocarbons (THC) or non-methane hydrocarbons (NMHC). THC and NMHC were converted to VOC for consistency with tool output and CMAQ reporting requirements, using the following factors.[20]

Diesel:

$$\frac{NMHC}{THC} = 0.984$$

$$\frac{VOC}{THC} = 1.053$$

Gasoline (4-stroke):

$$\frac{NMHC}{THC} = 0.900$$

[19] EPA (2002). Update Heavy-Duty Engine Emission Conversion Factors for MOBILE6: Analysis of BSFCs and Calculation of Heavy-Duty Engine Emission Conversion Factors. Publication No. EPA420-R-02-005. https://nepis.epa.gov/Exe/ZyPDF.cgi/P10022L1.PDF?Dockey=P10022L1.PDF

[20] EPA (2005). Conversion Factors for Hydrocarbon Components. Publication No. EPA420-R-05-015. https://19january2017snapshot.epa.gov/www3/otaq/models/nonrdmdl/nonrdmdl2005/420r05015.pdf

$$\frac{VOC}{THC} = 0.933$$

Note: EPA HD standards for gasoline-fueled vehicles for select pollutants are given in g/mi rather than g/bhp-hr for model years 2005+ or 2008+. These standards were used directly as emission rates defaults in the tool, instead of applying the conversion factors. See the Appendix for more detail.

Zero-Emissions Street Sweepers

Several manufacturers have developed electric and fuel cell-powered street sweepers designed to have zero exhaust emissions.[21] This tool assumes zero running exhaust emissions for these sweepers, but includes brake and tire wear emissions. Brake and tire wear emissions are determined by multiplying the operating hours (user input) by the MOVES-derived emission rates for PM_{10} and $PM_{2.5}$ (see

Table *1*).

USER-SUPPLIED EMISSION RATES

Fugitive dust emissions in all three modules (Paved Roads, Unpaved Roads, and Unpaved to Paved) are based on methodology from EPA's AP-42 as described above. Fugitive dust emission rates are calculated based on activity, roadway characteristics, and control efficiency. The methodology and equations for fugitive dust are built into the tool and cannot be modified. However, users have the option of entering their own values for various roadway properties (e.g., silt loading) and efficiency of the dust control method.

The Paved Roads module also allows users the option of inputting their own emission rates for street sweepers. These rates are entered directly into the interface, as shown in Example 1 of the User Guide.

The sections below provide basic instructions on how to import select local emission rates from MOVES into the Dust Mitigation Tool. For those unfamiliar with developing local MOVES runs, please refer to EPA's mobile-source emissions modeling guidance and documentation for highway vehicles.[22]

Paved Roads

Users may take the following steps to replace emission rates in the Paved Roads module of the Dust Mitigation tool. These emission rates are specific to brakewear and tirewear for zero-emission street sweepers.

1. Using the national Dust Mitigation run parameters listed in MOVES Methodology (
2. Table *1*), develop local emission rates. The CMAQ Emissions Calculator Toolkit does not prescribe 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.

[21] For example, Global Environmental Products will be providing Caltrans with sweepers powered by hydrogen fuel cells: https://www.sciencedirect.com/science/article/pii/S1464285917302146
[22] EPA, https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs

3. Reformat the MOVES output so that it can be used in the tool, as described below:
    - Unhide the 'BrakewearTirewear' tab in Excel and ensure that the new user-supplied, local MOVES output is structured and labelled exactly as the national default data initially used in the tool.
        i. Columns in emissions table: yearID, pollutantID, processID, modelYearID, roadTypeID, emissionsQuant
        ii. Columns in activity table: yearID, modelyearID, roadTypeID, activityTypeID, activity

4. Export the local emission rates in .csv or .xlsx file format. Delete any data in the 'BrakewearTirewear' tab and then copy and paste the local emission rates into the existing worksheet. Save the Dust Mitigation Tool under a different name and verify that the calculator yields new, expected results with the local data.
    - Emission rates are calculated automatically by tool by dividing the emissions inventory by activity for each combination of yearID, pollutantID, processID, modelYearID, and roadTypeID. Refer to Post-MOVES Run Data Processing for further detail.

Unpaved Roads

The Unpaved Roads module does not use any emissions or activity data from MOVES, as the module only estimates reductions in fugitive dust emissions (fugitive dust is not included in MOVES).

Unpaved to Paved

Users may take the following steps to replace emission rates in the Unpaved to Paved module of the Dust Mitigation tool. These emission rates are specific to emissions associated with a speed change after paving.

1. Using the project-level Dust Mitigation run parameters listed in MOVES Methodology (Table 2), develop local emission rates. The CMAQ Emissions Calculator Toolkit does not prescribe which MOVES inputs are derived from local data. Users only must specify the same output parameters and details as the project-level run. Complete any local MOVES runs for the selected calendar years and any other parameters listed above.

2. Reformat the MOVES output so that it can be used in the tool, as described below:
    - Unhide the 'SpeedChangeER' tab in Excel and ensure that the new user-supplied, local MOVES output is structured and labelled exactly as the project-level default data initially used in the tool.
        i. Columns in table: yearID, pollutantID, linkID, speed, roadTypeID, emissionRate
    - To post process the new emission rates output from MOVES, join the movesoutput and movesactivity output tables using yearID, pollutantID, and roadTypeID. To include emissions from evaporative processes, the following processes should be included in the movesoutput table:

        processID 1, 9, 10, 11, 12, 13, and 15 on roadTypeID 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.
- Sum the emissions inventory where yearID, pollutantID, linkID, and roadTypeID are the same. This will create a set of composite rates for each pollutant for each year.
- Similarly, sum the distance traveled by the entire fleet where yearID, linkID, and roadTypeID are the same. This will create a value for the total distance traveled in each year by the fleet.
- Emission rates are calculated by dividing the emissions inventory by the VMT for each combination of yearID, pollutantID, and linkID.

3. Export the local emission rates in .csv or .xlsx file format. Delete any data in the 'SpeedChangeER' tab and then copy and paste the local emission rates into the existing worksheet. Save the Dust Mitigation Tool under a different name and verify that the calculator yields new, expected results with the local data.
    - Emission rates are calculated automatically by tool by dividing the emissions inventory by activity for each combination of yearID, pollutantID, processID, modelYearID, and roadTypeID. Refer to Post-MOVES Run Data Processing for further detail.

APPENDIX

Table A1. Street Sweeper Emission Rates by Model Year Group for Diesel, Alternative, Clean, and Gasoline Fueled Vehicles

Fuel	Year	Pollutant	Vehicle Weight	Standard (g/bhp-hr)	Standard (g/mi)	Notes / Assumptions
Diesel/Alternative/Clean	1994-1997	VOC	14,000 and above	1.3689	2.1902	VOC from HC
Diesel/Alternative/Clean	1994-1997	NOx	14,000 and above	5	8	
Diesel/Alternative/Clean	1994-1997	PM	14,000 and above	0.1	0.16	
Diesel/Alternative/Clean	1994-1997	CO	14,000 and above	15.5	24.8	
Diesel/Alternative/Clean	1991-1993	VOC	14,000 and above	1.3689	2.1902	VOC from HC
Diesel/Alternative/Clean	1991-1993	NOx	14,000 and above	5	8	
Diesel/Alternative/Clean	1991-1993	PM	14,000 and above	0.25	0.4	
Diesel/Alternative/Clean	1991-1993	CO	14,000 and above	15.5	24.8	
Diesel/Alternative/Clean	2007+	VOC	14,000 and above	0.15	0.2397	VOC from NMHC
Diesel/Alternative/Clean	2007+	NOx	14,000 and above	0.2	0.32	
Diesel/Alternative/Clean	2007+	PM	14,000 and above	0.01	0.016	
Diesel/Alternative/Clean	2007+	CO	14,000 and above	15.5	24.8	
Diesel/Alternative/Clean	2004-2006	VOC	14,000 and above	1.3689	2.1902	VOC from HC
Diesel/Alternative/Clean	2004-2006	NOx	14,000 and above	4	6.4	
Diesel/Alternative/Clean	2004-2006	PM	14,000 and above	0.1	0.16	
Diesel/Alternative/Clean	2004-2006	CO	14,000 and above	15.5	24.8	
Diesel/Alternative/Clean	1998-2003	VOC	14,000 and above	1.3689	2.1902	VOC from HC
Diesel/Alternative/Clean	1998-2003	NOx	14,000 and above	4	6.4	
Diesel/Alternative/Clean	1998-2003	PM	14,000 and above	0.1	0.16	
Diesel/Alternative/Clean	1998-2003	CO	14,000 and above	15.5	24.8	
Diesel/Alternative/Clean	2007+	VOC	under 14,000	0.15	0.19	VOC from NMHC
Diesel/Alternative/Clean	2007+	NOx	under 14,000	0.2	0.25	
Diesel/Alternative/Clean	2007+	PM	under 14,000	0.01	0.01	
Diesel/Alternative/Clean	2007+	CO	under 14,000	15.5	19.38	
Diesel/Alternative/Clean	2004-2006	VOC	under 14,000	1.3689	1.71	Assumed same as 1998-2003; VOC from HC
Diesel/Alternative/Clean	2004-2006	NOx	under 14,000	4	5.00	Assumed same as 1998-2003

Diesel/Alternative/Clean	2004-2006	PM	under 14,000	0.1	0.13	
Diesel/Alternative/Clean	2004-2006	CO	under 14,000	15.5	19.38	
Diesel/Alternative/Clean	1998-2003	VOC	under 14,000	1.3689	1.71	VOC from HC
Diesel/Alternative/Clean	1998-2003	NOx	under 14,000	4	5.00	
Diesel/Alternative/Clean	1998-2003	PM	under 14,000	0.1	0.13	
Diesel/Alternative/Clean	1998-2003	CO	under 14,000	15.5	19.38	
Diesel/Alternative/Clean	1994-1997	VOC	under 14,000	1.3689	1.71	VOC from HC
Diesel/Alternative/Clean	1994-1997	NOx	under 14,000	5	6.25	
Diesel/Alternative/Clean	1994-1997	PM	under 14,000	0.1	0.13	
Diesel/Alternative/Clean	1994-1997	CO	under 14,000	15.5	19.38	
Diesel/Alternative/Clean	1991-1993	VOC	under 14,000	1.3689	1.71	VOC from HC
Diesel/Alternative/Clean	1991-1993	NOx	under 14,000	5	6.25	
Diesel/Alternative/Clean	1991-1993	PM	under 14,000	0.25	0.31	
Diesel/Alternative/Clean	1991-1993	CO	under 14,000	15.5	19.38	
Gasoline	2008+	VOC	All weights	0.1451	0.16	VOC from NMHC
Gasoline	2008+	NOx	All weights	0.2	0.2	EPA standard in g/mi used
Gasoline	2008+	PM	All weights	0.01	0.01	
Gasoline	2008+	CO	All weights	37.1	8.1	EPA standard in g/mi used
Gasoline	2005-2007	VOC	All weights	1.7727	2.01	VOC from HC
Gasoline	2005-2007	NOx	All weights	1	1	EPA standard in g/mi used
Gasoline	2005-2007	PM	All weights	0.01	0.01	Assumed same as 2008+
Gasoline	2005-2007	CO	All weights	37.1	8.1	EPA standard in g/mi used
Gasoline	1998-2004	VOC	All weights	1.7727	2.01	VOC from HC
Gasoline	1998-2004	NOx	All weights	1	1.13	Assumed same as 2005-2007
Gasoline	1998-2004	PM	All weights	0.01	0.01	Assumed same as 2008+
Gasoline	1998-2004	CO	All weights	37.1	42.07	
Gasoline	1991-1997	VOC	All weights	1.7727	2.01	VOC from HC
Gasoline	1991-1997	NOx	All weights	1	1.13	Assumed same as 2005-2007
Gasoline	1991-1997	PM	All weights	0.01	0.01	Assumed same as 2008+