City-based Optimization Model for Energy Technologies: COMET - New York City

Documentation

Appendix F

DISCLAIMER

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation of use.

**APPENDIX F**

**Documentation of Transportation Sector Emission Factors Updates**

|  |  |
| --- | --- |
| **To:** | Office of Research and Development, US EPA |
| **From:** | ICF |
| **Date:** | June 10, 2020 |
| **Re:** | Summary Memorandum, WA 3-06: Transportation Sector Improvements to the Urban Scale MARKAL/TIMES Based Energy Systems Model |

**Background and Project Overview**

The main objective of this work assignment (WA) is to provide EPA with improved representation of light- and heavy-duty on-highway mobile emissions sources for use in the TIMES database by updating the emission factors to be consistent with those obtained from county level data simulated with the EPA’s MOVES emissions model and other relevant sources. This includes the effects of EPA’s Tier 3 standards set new vehicle emissions and fuel sulfur standards to reduce emissions beginning in 2017. The TIMES database characterizes mobile source emissions from light- and heavy- duty on-road vehicles and off-highway vehicles from 2010 through 2055. Emissions are specified by vehicle class, fuel type, vintage year, and boroughs. These updated emission factors will be used by EPA to update the transportation emissions modeling structure in TIMES and improve the representation of light-duty and heavy-duty vehicles, accounting for the unique vehicle mix associated with dense urban areas such as NYC (e.g., including the high proportion of taxis and commercial delivery trucks).

This memorandum represents the final product of the WA. It summarizes the data sources and methodology used in and describes the results. The main outputs of this work – the tables emission factors themselves – are included as data files.

**LDV and HDV Emission Factors**

Scope

ICF developed a set of emission factors for both light- and heavy-duty on-highway mobile sources representing seven downstate counties and the 55 upstate counties with EPA’s MOVES2014b emissions model. All 13 vehicle categories in MOVES were included in this analysis. MOVES vehicle categories are listed in the Glossary section.

The requested factors cannot be computed directly with MOVES. Instead, we obtained them by first conducting the MOVES simulations then postprocessing the MOVES outputs with custom MySQL scripts. The final output was then combined into Excel summary tables of emission factors – all normalized to distance traveled and reported as grams per mile (g/mi) – resolved by pollutant, emission process, year of operation, vehicle type, fuel, vintage, and location. Data files are stored in the repository associated with the COMET-NYC documentation.

The following describes the resolution in the output emission factors:

* Pollutants: NOx, Primary PM10 (exhaust, tire wear, brake wear), Primary PM2.5 (exhaust, tire wear, brake wear), SO2, Volatile Organic Compounds (VOC) (exhaust, evaporative, and refueling) CO, elemental (EC) and organic (OC) carbon particulate, CH4, N2O, NH3, and Atmospheric CO2.
* Processes: All exhaust components will include both running and starting processes separately, and tailpipe and crankcase emissions combined. (HDV extended idle and auxiliary power unit (APU) exhaust are not considered but may be later addressed if Task 4 is activated.) For VOC, exhaust, evaporative, and refueling are processed separately, with the various components of each combined. All pollutants are combined into four categories (1) refueling, (2) tire and break wear, (3) combustion, and (4) other/evaporative. Evaporative emission processes include three MOVES categories: permeation, fuel vapor venting, and fuel leaks.
* Calendar Years: Annual values are reported for every year from 2010 through 2029, and then every 5th year from 2030 through 2050, the furthest forecast year in MOVES.
* Vehicle Age: All vehicle model years available in MOVES were simulated individually. We then aggregated results in 5-year age increments as outline below. This resolution allows degradation of pollutant emissions over the equipment life to be represented in the emission factors.
  + 0-4,
  + 5-9,
  + 10-14,
  + 15-19, and
  + ≥20
* Spatial Resolution: All analyses were performed with county-level resolution. Two approaches were used, distinguishing between the upstate and downstate counties of New York.
  + For the 7 NYC and Long Island counties (“NYCLI”), we modeled each of the five counties of NYC (New York (Manhattan), Kings (Brooklyn), Bronx (The Bronx), Richmond (Staten Island), and Queens (Queens)) and the two additional Long Island counties (Nassau, Suffolk) individually. Each county was modeled with custom input resolution based on information obtained from the New York State Dept. of Environmental Conservation (NYSDEC).
  + For the remaining 55 counties in NYS, we modeled individual counties, then summarized results in aggregate for the region. This included all counties for exhaust simulations. For evaporative simulations we used a representative county approach.
* Fuel: MOVES includes five fuel types for on-road vehicles: Gasoline, Diesel, Compressed Natural Gas (CNG), Ethanol (E-85), and Electricity. All were included in each of the MOVES simulations, relying on MOVES’ assignment of fuels to vehicle types.
* Vehicle Type/Source Category: We modeled all 13 MOVES vehicle types and 10 weight- and category-based registration classes. All were included in the MOVES simulations.

Appendix B of this appendix includes translation tables useful for interpreting these values.

We conducted the MOVES simulations in emission inventory mode to accommodate the prescribed reporting units. We established the ratio between the emissions and activity (distance traveled) to create activity-weighted emission factors in the specified units and with the specified resolution from the MOVES outputs for the vehicle-fuel-technology combinations available in the model. This is described further in the following section. Speed, meteorology, fuel subtypes, and other factors included in the MOVES processing but not of interest for the TIMES database are not included in the final output emission factors, although they are in the MySQL MOVES input and output databases.

The results presented here do not estimate emission factors for those vehicle categories where emissions are not directly estimable from MOVES. This includes categories not included in the MOVES model such as H2-fueled vehicles, explicit resolution for hybrid vehicles, and other fuels or other non-combustion vehicle types not included for on-road vehicles in MOVES. Grid-powered electric vehicles are included when represented in MOVES, however these have zero tailpipe emissions. Upstream (well-to-tank) emissions are not considered here.

MOVES Methodology

**NY State – Upstate Counties**

County-resolved outputs may be obtained from two analysis scales in MOVES. The National Scale relies on national model default input data apportioned to counties in a manner that does not consider factors that may differ regionally, such as age distribution. A national scale model run may not provide an accurate portrayal of specific emission differences between counties, for example, but requires considerably fewer resources and allows multiple years and counties in a single simulation. The emission factors used for the 55-county upstate (“NYS55”) values in the COMET-NYC are less resolved than those for NYC, considered in aggregate for the upstate region, and thus do not need the same level of input resolution. They were modeled with a national scale approach and all default inputs.

ICF divided the national-scale simulations into two parts: exhaust and evaporative process runs to accommodate processing requirements. We created MOVES “runspec” (\*.mrs) files for each year and completed simulations in batches. Exhaust runs include all 55 counties and all hours for each modeled year. These simulations used annual pre-aggregation to speed processing. We conducted individual simulations for all years 2010-2029, and every 5th year from 2030-2050. Evaporative runs were made with hourly preaggregation. These simulations take an enormous amount of computer time. To accomplish these runs within the project window, we used a “representative” county approach and only simulated two months of the year: January and July. These were made for the same set of years as the exhaust simulations.

The representative county approach investigated input values for all counties in the NYS55 region and identified a single county that best matched the “average” inputs across the region. Chemung County (located roughly in the middle of the state east-to-west and on the southern edge along the PA state border) was selected as the representative county for the 55 county upstate simulations based on the SCC distribution and the population of vehicles. We first considered a representative county for NYS55 based on age distribution, but no difference was seen as all counties have the same age distribution at the national scale. We then explored differences in the SCC distribution, where differences do occur. We picked the county where the SCC distribution best matched statewide distribution and that had roughly the median number of vehicles of all statewide counties. We tested the representative county theory by processing evaporative emission factors and comparing results from the 55-county simulation to the one representative county simulation. Chemung County showed about 10% higher evaporative emission rates when normalized to distance (g/mi) than seen in the statewide average. This could be due to different meteorology, fuel RVP, altitude or other factors which matter to evaporative emissions beyond the parameters used in selecting the county. This slightly higher evaporative emission rate was discussed with EPA and considered negligible given the advantage in model run times (42 minutes per year vs. 34 hours per year for statewide simulations, both running only two months).

**NYC and Long Island Counties**

There is an emphasis on county-level resolution of emission factors in the downstate region of New York City and Long Island (NYCLI) in the COMET-NYC. ICF performed county-level simulations for Bronx, Kings, Nassau, New York, Queens, Richmond, and Suffolk counties. In a county scale application, the user replaces the national default allocations with local data. These simulations are more complex and limited to only one year and one county per simulation.

These higher resolution simulations were made using custom county-scale MOVES input databases, which we created based on data collected from *New York State’s Department of Environmental Conservation (NYSDEC)*. To identify and obtain this information, we first surveyed a variety of agencies that may have available MOVES inputs or data. We reached out to various New York environmental agencies that were likely to have relevant MOVES input data. Ultimately, we identified a contact at NYSDEC through a contact ICF has with NYSDOT related to air quality issues in the state. NYSDEC prepares data inputs for both SIP analyses and for submission to US EPA for use in the NEI. NYSDEC had existing input data for years 2011 and 2017. These two datasets are distinct. 2017 differs from 2011 in format and content. Notably, NYSDEC has recharacterized growth in the 2017 dataset. Also, the 2017 dataset is in database format while the 2011 is in spreadsheets. At the time of collection, NYSDEC had prepared the 2017 dataset for the NEI and given it to EPA but not yet run it. Both the 2011 and 2017 datasets have NY-specific data for every county in NYS. The 2017 data received from NYSDEC also includes growth factors and guidance on developing later years from this dataset. NYSDEC also provided the database "moves2014\_nylev" which contains inputs corresponding to NYS’ low emission vehicle standards program.

Following NYSDEC guidance, we used both the 2011 and 2017 data to linearly interpolate population and VMT for intermediate years (extrapolate for 2010). We used the 2017 growth factors to linearly grow the 2017 data for all later years. We also followed NYSDEC guidance to update the inspection and maintenance table (I/M) for all years and used the NYLEV database for all years after 2014. The FOIL document for data collection and NYSDEC guidance are included as Appendix C of this appendix. Each input database contains 34 tables, corresponding to various MOVES inputs. To account for changes in vehicle miles traveled (VMT) and vehicle population over time, ICF determined the linear growth rates between 2011 and 2017, by vehicle type. The VMT and population for each year were calculated in Microsoft Excel and then added to each database in MySQL. All input databases are provided in the folder titled “Appendix A”.

MOVES Outputs

**NY State – Upstate Counties**

Output databases for the 55-county upstate runs (“NYS55”) are provided in Appendix A of this appendix. (Note there are no input databases for the NYS55 runs as national default values in MOVES were used.) The appendix has output files separated into evaporative and exhaust files. These are in two subfolders in the folder C.output\_databases in Appendix A of this appendix.

The initial exhaust simulations were conducted with “STATE” output resolution, including the 55 counties in aggregate. Although these completed without error and were successfully postprocessed, when compared to the more highly resolved NYCLI values, they were seen to have emissions values roughly an order of magnitude lower than expected. All NYS55 exhaust simulations were later rerun with “COUNTY” level output resolution and again postprocessed to aggregate over the region. These, too, ran without any errors or indication of failures and produced emission factor values that fall within with expected ranges for given vehicle and fuel types. The results of this latter set are presented here. All outputs from the corrected exhaust simulations are in a separate folder in Appendix A: C.output\_databases/NYS55\_Exhaust/, in the databases “/nys55\_20xx\_out\_server/”. All corrected exhaust outputs are identified in the database with MOVESRunID=1.

The output databases for the NYS55 evaporative simulations also includes the initial, incorrect version of the exhaust outputs noted above. The evaporative simulations are in the Appendix A folder C.output\_databases/NYS55\_Evaporative/, in the output databases “/nys55\_20xx\_out/”. These all are identified with MOVESRunID=2 except years 2010 (MOVESRunID=3) and 2011 (MOVESRunID=4). Only these evaporative outputs are correct and should be taken from these databases.

**NYC and Long Island Counties**

As with the NYS55 simulations, we divided the county-scale NYCLI simulations into two parts: exhaust and evaporative emission runs. The same input databases were used for both. As with NYS55, exhaust simulations represent annual aggregated inputs run for the entire year. Evaporative simulations utilize hourly inputs run for January and July and annualized on output. Every county-year combination was executed with corresponding runspec (\*.mrs) files and runs managed through batch files. Runs were conducted on three different computers. To avoid overwriting outputs, each output database from different computers was assigned its own output name accordingly (“\*\_out”, “\*\_out\_sh”, and “\*\_out\_server”). It should be noted that in some cases there are discrepancies in the pre- and post-2017 emission factors and trends. This is notable for vehicle types where inputs differ substantially in the pre- and post-2017 data and in cases with low populations. For example, we saw some irregular trends for HPMS Vehicle Type IDs 40 and 50. (See the first table in Appendix B for explanation of these vehicle types.) This is likely due to the differences in datasets from the two years provided by NYSDEC and the interpolation.

All final outputs from the exhaust simulations are in a separate folder in Appendix A: C.output\_databases/NYCLI\_Exhaust/. Outputs are in the databases “/nycli\_zzzz\_20xx\_out/”, “/nycli\_zzzz\_20xx\_out\_sh/”, and “/nycli\_zzzz\_20xx\_out\_server/”, where zzzz represents the county name and 20xx represents the analysis year. For exhaust simulations, all corrected outputs are identified in the databases with MOVESRunID=1 except Bronx county for years 2016 and 2026 which should rely on outputs from MOVESRunID=2.

All final outputs from the evaporative simulations are in a separate folder in Appendix A: C.output\_databases/NYCLI\_Evaporative/. Outputs are in the databases “/nycli\_zzzz\_20xx\_out/” and “/nycli\_zzzz\_20xx\_out\_sh\_evap/”, where zzzz represents the county name and 20xx represents the analysis year. For the evaporative simulations, all corrected outputs are identified in the databases as follows:

* 2010-2016 all use MOVESRunID=2 except Bronx county for year 2016 which relies on outputs from MOVESRunID=3.
* 2017-2020 all use MOVESRunID=1.
* 2021-2025 all MOVESRunID=1 except Queens county for years 2023 and 2025, which rely on MOVESRunID=2.
* 2026-2050 all use MOVESRunID=1 except New York and Suffolk counties for year 2026, which rely on MOVESRunID=2.

Postprocessing

We developed and applied custom MySQL postprocessing scripts to extract the values indicated above from the MOVES output databases. Broadly, each of these individual scripts do the same four steps:

1. Pollutant types are filtered to just those listed above. (Many of the pollutants considered require ancillary species not reported here.) These are first eliminated. Emissions are then summed over road types and other parameters (including counties for the NYS55 simulations). Emissions categories are then assigned by translating between MOVES categories and those in the MARKAL model. These are described in the second-to-last table of Appendix B, “MOVES Emission Process ID Numbers and Corresponding Indices Used in Processing”. Vehicle ages are then calculated from model and calendar year and binned into the ranges shown in the last table of Appendix B of this appendix, “Age Bins Used in Processing”. Intermediate values are saved in each output database.
2. Emissions are aggregated to the processes and age categories considered here. Intermediate emission values are saved in each output database.
3. Activity values (distance traveled) are processed in an approach similar to Steps 1 and 2 for emissions. Intermediate activity values are saved in each output database.
4. The intermediate activity and emission tables are then combined to create distance-normalized emission rates. These rates tables are saved in each output database.

This sequence is applied to each year (and each county for the NYCLI), as well as the separate exhaust and evaporative outputs from MOVES. A final processing script then aggregates the rates from each individual MOVES output database into two final database tables for each case: one for exhaust and one for evaporative that show all pollutants, processes, ages, and years in standalone tables. This is done for both the NYS55 and NYCLI simulations. These four tables are those exported to flat files and included in the results spreadsheets.

**Results**

All results from the postprocessing are compiled into the two Excel workbooks included in Appendix A of this appendix under the folder D.processed\_outputs. File NYCLI\_EmissionRates\_052820.xlsx includes the results for each county in the “downstate” NYCLI region. File NYS55\_EmissionRates\_060720.xlsx includes all results for the “upstate” NYS55 region, in aggregate. Both files include tables of the outputs postprocessed with the MySQL scripts, the summary tables shown as Excel pivot tables, and summary tables of emission factor results only.

**Post-processing raw emission rate files from MOVES to MHDV COMET-NYC**

Documentation for “COMET\_NYC\_2021\_TRN\_HDV\_v0.1\_AZ.xlsx” updates. By A. Zalesak

1-19-2022

* Added sheet “NewEmisData”. This sheet contains the new borough-specific MOVES emissions data that I processed for TM, TB, and THS. My processing (performed Summer 2021) involved using an average of the emission factors provided for each vehicle by source class, regulatory class, and age bin, weighted by VMT. This produces a unique value for each COMET vehicle category (e.g., TB) per fuel type, year, borough, and pollutant. To this sheet, I added the processed data that corresponds to vehicle types and fuels that exist as technologies in this COMET workbook. This data includes emission factors for 11 pollutants: CO, NOx, Methane, N2O, NH3, SO2, VOC, Atmospheric CO2, PM10, PM2.5, and PM2.5 OC. All have exact matches in the COMET workbook except for PM2.5 OC. The COMET workbook additionally has BC and OC categories.
* Expanded each row in the sheet “TechData\_HDV\_EMIS” to five rows, one for each region 2-6, for technologies that are active in the model (not \*starred). I did not expand the rows for inactive technologies since I would not overwrite their emissions data. I opted to make changes only where necessary.
* Changed the value in column H, “Fuel”, of the sheet “TechData\_HDV\_EMIS” from CNG to GSL for active TM and THS technologies using CNG. This change was necessary since our new MOVES data does not contain CNG-specific emission factors for TM or THS.
* Updated emission factors for active TB, TM, and THS technologies for pollutants CO, NOx, Methane, N2O, NH3, SO2, VOC, Atmospheric CO2, PM10, and PM2.5 in the years 2010-2050, with the exception of H2 technologies (whose emissions are all 0). Excel formulas draw these values from the appropriate cells in “NewEmisData”.
  + As an example, the formula for cell U8, corresponding to R2 TBDSLE NOx in 2010, is: =SUMIFS(NewEmisData!E:E, NewEmisData!$A:$A, $G8, NewEmisData!$B:$B, $A8, NewEmisData!$C:$C, $H8, NewEmisData!$D:$D, U$6)
  + This formula can be read as: sum of emission factors if vehicle name = vehicle name, Region = Region, fuel = fuel, and pollutant = pollutant, in the column corresponding to 2010.
* Updated emission factors for above technologies and pollutants in the years 2005 and 2055 by pointing 2005 cells to their 2010 neighbors and 2055 cells to their 2050 neighbors. This is necessary because the MOVES data only includes the years 2010-2050.
* Pointed all cells under the pollutants CO2T, NOXT, SO2T, PM10T, and PM25T to their corresponding cells under CO2, NOX, SO2, PM10, and PM25, except for NOXT 2005 because there is no corresponding 2005 column for NOX.
* Highlighted all modified cells yellow.

**Post-processing raw emission rate files from MOVES to LDV COMET-NYC**

Documentation for COMET\_NYC\_2021\_TRN\_LDV\_v1.0\_AZ.xlsx. by A. Zalesak

2-5-2022

* Corrected the following typos:
  + “TechData\_All” line 65, column B.
    - “TLSSDHEV20” à “TLSSELC”
  + “TechData\_All” line 75, column B.
    - “TLSSELC” à “TLLSELC”
* Expanded each tech (even inactive) to 5 rows.
* Made a formula to determine the region value for every set of 5 rows by having the first row add a \* to the word “R2” if the cell it had mapped from (in Technologies for existing and in TechData\_All for new) started with a \*. The following cells just added to the number next to R to get R3, R4, R5, and R6. This system ensures that technologies inactivated in the other sheets get inactivated here automatically.
* Added the following formula to each cell to draw the appropriate emission factor from the data in the sheet called “NewEmisData”. Since pickup trucks are by themselves in source class 31, the formula first checks whether the technology is a pickup truck or another type of LDV and pulls data from a “NewEmisData” row labeled “Pickup” or “LDV”, respectively.
  + =$I209\*IF($G209="Pickup", SUMIFS(NewEmisData!E:E, NewEmisData!$A:$A, "Pickup", NewEmisData!$B:$B, $A209, NewEmisData!$C:$C, $H209, NewEmisData!$D:$D, K$6), SUMIFS(NewEmisData!E:E, NewEmisData!$A:$A, "LDV", NewEmisData!$B:$B, $A209, NewEmisData!$C:$C, $H209, NewEmisData!$D:$D, K$6))
  + This formula can be read as
  + = adjustment factor \* {if vehicle type = “Pickup”, sum the emission factors if vehicle name = “Pickup”, Region = Region, fuel = fuel, and pollutant = pollutant, in the column corresponding to 2010, else do the same with vehicle name = “LDV”}

**Assumptions for COMET-NYC Emission Factor Updates**

Mapping from MOVES to COMET/TIMES vehicle categories

MOVES data was disaggregated into source class, regulatory class, and vintage groups. In the data used for updating TIMES, the vintages were model year. In the data used for updating COMET, the vintages were simple age bins. Relevant categories were averaged using their vehicle-miles-traveled (VMT) as weights. This process was performed individually for each fuel type and region across every year and pollutant.

| MOVES classification | | COMET-NYC classification\* | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Source class | Regulatory Class\*\* | TL non-pickup | TL pickup | TC | TBT | TBS | TM | THS | THL |
| 21 (passenger car) | - | ü |  |  |  |  |  |  |  |
| 31 (passenger truck) | - |  | ü |  |  |  |  |  |  |
| 32 (light commercial truck) | - |  |  | ü |  |  |  |  |  |
| 42 (transit buses) | - |  |  |  | ü |  |  |  |  |
| 43 (school buses) | - |  |  |  |  | ü |  |  |  |
| 51 (refuse trucks) | 41 |  |  |  |  |  | ü |  |  |
| 42 |  |  |  |  |  | ü |  |  |
| 46 |  |  |  |  |  |  | ü |  |
| 47 |  |  |  |  |  |  | ü |  |
| 52 (single unit short haul truck) | 41 |  |  |  |  |  | ü |  |  |
| 42 |  |  |  |  |  | ü |  |  |
| 46 |  |  |  |  |  |  | ü |  |
| 47 |  |  |  |  |  |  | ü |  |
| 53 (single unit long haul truck) | - |  |  |  |  |  |  |  | ü |
| 61 (combination short haul truck) | - |  |  |  |  |  |  | ü |  |
| 62 (combination long haul truck) | - |  |  |  |  |  |  |  | ü |

MOVES to TIMES mapping. \*EPAUS9rT categories: TL=light duty, TC=commercial truck, TBT=transit bus, TBS=school bus, TM=medium-duty truck, THS=heavy-duty short-haul truck, THL=heavy-duty long-haul truck. \*\*Regulatory classes shown only when a subset is used. 41= Class 2b Trucks with 2 Axles and at least 6 Tires or Class 3 Trucks (8,500 lbs < GVWR <= 14,000 lbs), 42= Class 4 and 5 Trucks (14,00 lbs < GVWR <= 19,500 lbs), 46= Class 6 and 7 Trucks (19,500 lbs < GVWR < =33,000 lbs), 47= Class 8a and 8b Trucks (GVWR > 33,000 lbs).

COMET uses the vehicle categories TL non-pickup, TL pickup, TC, TB, TM, and THS. The same mapping for TIMES was used for updating COMET but MOVES source classes 42 and 43 were combined for the TB category using a weighted average.

Manual Changes/Substitutions for Emissions

Some vehicle/fuel type combinations were not represented by the MOVES data, so substitutions were needed. Other times, data was missing for only some years or boroughs (COMET only).

| Model | Vehicle/Fuel Type | Fuel Type | Year | Region | Substitution |
| --- | --- | --- | --- | --- | --- |
| COMET and TIMES | All | Electric | All | All | Zero emissions for all pollutants except PM2.5 and PM10, which use only the tire- and brake-wear components of the respective emissions from the analogous diesel vehicle. |
| COMET | Light-duty pickup and non-pickup | Biofuel | 2010 and 2011 | All | Corresponding 2012 values used |
| COMET | Source class 51 | Gasoline and diesel | 2010 and 2011 | All | Corresponding 2012 values used |
| COMET | Source class 51 | Gasoline and diesel | 2010-2016 | Richmond County | Corresponding State-level values used from previous MOVES dataset |
| TIMES | All | LPG | All | All | Gasoline |
| TIMES | All | DHEV | All | All | Diesel |
| TIMES | All | B20 | All | All | Diesel, with modifications: CO and PM 13% lower, NOX 2% higher as per1 |
| TIMES | TC | CNG | All | All | Corresponding State-level values used in COMET |
| TIMES | TM, THS, THL | CNG | 2010-2011 | All | Corresponding State-level values used in COMET |

1 Alternative Fuels Data Center (https://afdc.energy.gov/vehicles/diesels\_emissions.html)

**Glossary of MOVES acronyms**

The following tables translate MOVES indices and those developed for our analysis.

MOVES Vehicle Types

|  |  |  |
| --- | --- | --- |
| sourceTypeID | HPMSVtypeID | sourceTypeName |
| 11 | 10 | Motorcycle |
| 21 | 25 | Passenger Car |
| 31 | 25 | Passenger Truck |
| 32 | 25 | Light Commercial Truck |
| 51 | 50 | Refuse Truck |
| 52 | 50 | Single Unit Short-haul Truck |
| 53 | 50 | Single Unit Long-haul Truck |
| 54 | 50 | Motor Home |
| 43 | 40 | School Bus |
| 42 | 40 | Transit Bus |
| 41 | 40 | Intercity Bus |
| 61 | 60 | Combination Short-haul Truck |
| 62 | 60 | Combination Long-haul Truck |

MOVES Default Fuel Types

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| fuelTypeID | defaultFormulationID | fuelTypeDesc | humidityCorrectionCoeff | humidityCorrectionCoeffCV | fuelDensity | subjectToEvapCalculations |
| 1 | 10 | Gasoline | 0.0038 | NULL | 2839 | Y |
| 2 | 20 | Diesel Fuel | 0.0026 | NULL | 3167 | N |
| 3 | 30 | Compressed Natural Gas (CNG) | 0 | NULL | NULL | N |
| 4 | 40 | Liquefied Petroleum Gas (LPG) | 0 | NULL | 1923 | N |
| 5 | 50 | Ethanol (E-85) | 0.0038 | NULL | 2944 | Y |
| 9 | 90 | Electricity | 0 | NULL | NULL | N |

MOVES Vehicle Registration Classes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| regClassID | | regClassName | | regClassDesc | |
| 0 | Doesn't Matter | | Doesn't Matter | |
| 10 | MC | | Motorcycles | |
| 20 | LDV | | Light Duty Vehicles | |
| 30 | LDT | | Light Duty Trucks | |
| 40 | LHD <= 10k | | Class 2b Trucks with 2 Axles and 4 Tires (8,500 lbs < GVWR <= 10,000 lbs) | |
| 41 | LHD <= 14k | | Class 2b Trucks with 2 Axles and at least 6 Tires or Class 3 Trucks (8,500 lbs < GVWR <= 14,000 lbs) | |
| 42 | LHD45 | | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | |
| 46 | MHD67 | | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | |
| 47 | HHD8 | | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | |
| 48 | Urban Bus | | Urban Bus (see CFR Sec 86.091\_2) | |

Table of MOVES Pollutant ID Numbers

| pollutantID | pollutantName | NEIPollutantCode | shortName |
| --- | --- | --- | --- |
| 1 | Total Gaseous Hydrocarbons | HC | Total Gas HC |
| 2 | Carbon Monoxide (CO) | CO | CO |
| 3 | Oxides of Nitrogen (NOx) | NOX | NOx |
| 5 | Methane (CH4) | CH4 | Methane (CH4) |
| 6 | Nitrous Oxide (N2O) | N2O | N2O |
| 20 | Benzene | 71432 | Benzene |
| 21 | Ethanol |  | Ethanol |
| 22 | MTBE | 1634044 | MTBE |
| 23 | Naphthalene particle | 91203 | Naphthalene P |
| 24 | 1,3-Butadiene | 106990 | 1,3-Butadiene |
| 25 | Formaldehyde | 50000 | Formaldehyde |
| 26 | Acetaldehyde | 75070 | Acetaldehyde |
| 27 | Acrolein | 107028 | Acrolein |
| 30 | Ammonia (NH3) | NH3 | NH3 |
| 31 | Sulfur Dioxide (SO2) | SO2 | SO2 |
| 32 | Nitrogen Oxide (NO) | NO | NO |
| 33 | Nitrogen Dioxide (NO2) | NO2 | NO2 |
| 34 | Nitrous Acid (HONO) | 7782-77-6 | HONO |
| 35 | Nitrate (NO3) | PM25\_PRI | PM2.5 NO3 |
| 36 | Ammonium (NH4) | PM25\_PRI | PM2.5 NH4 |
| 40 | 2,2,4-Trimethylpentane | 540841 | 2,2,4-Trimethylpentane |
| 41 | Ethyl Benzene | 100414 | Ethyl Benzene |
| 42 | Hexane | 110543 | Hexane |
| 43 | Propionaldehyde | 123386 | Propionaldehyde |
| 44 | Styrene | 100425 | Styrene |
| 45 | Toluene | 108883 | Toluene |
| 46 | Xylene | 1330207 | Xylene |
| 51 | Chloride | PM25\_PRI | PM2.5 Cl |
| 52 | Sodium | PM25\_PRI | PM2.5 Na |
| 53 | Potassium | PM25\_PRI | PM2.5 K |
| 54 | Magnesium | PM25\_PRI | PM2.5 Mg |
| 55 | Calcium | PM25\_PRI | PM2.5 Ca |
| 56 | Titanium | PM25\_PRI | PM2.5 Ti |
| 57 | Silicon | PM25\_PRI | PM2.5 Si |
| 58 | Aluminum | PM25\_PRI | PM2.5 Al |
| 59 | Iron | PM25\_PRI | PM2.5 Fe |
| 60 | Mercury Elemental Gaseous | 200 | Hg Egas |
| 61 | Mercury Divalent Gaseous | 201 | Hg Dgas |
| 62 | Mercury Particulate | 202 | Hg Part |
| 63 | Arsenic Compounds | 93 | As |
| 65 | Chromium 6+ | 18540299 | Cr+6 |
| 66 | Manganese Compounds | 7439965 | Mn |
| 67 | Nickel Compounds | 7440020 | Ni |
| 68 | Dibenzo(a,h)anthracene particle | 53703 | Dibenzo(a,h)anthracene P |
| 69 | Fluoranthene particle | 206440 | Fluoranthene P |
| 70 | Acenaphthene particle | 83329 | Acenaphthene P |
| 71 | Acenaphthylene particle | 208968 | Acenaphthylene P |
| 72 | Anthracene particle | 120127 | Anthracene P |
| 73 | Benz(a)anthracene particle | 56553 | Benz(a)anthracene P |
| 74 | Benzo(a)pyrene particle | 50328 | Benzo(a)pyrene P |
| 75 | Benzo(b)fluoranthene particle | 205992 | Benzo(b)fluoranthene P |
| 76 | Benzo(g,h,i)perylene particle | 191242 | Benzo(g,h,i)perylene P |
| 77 | Benzo(k)fluoranthene particle | 207089 | Benzo(k)fluoranthene P |
| 78 | Chrysene particle | 218019 | Chrysene P |
| 79 | Non-Methane Hydrocarbons | NMHC | NMHC |
| 80 | Non-Methane Organic Gases | NMOG | NMOG |
| 81 | Fluorene particle | 86737 | Fluorene P |
| 82 | Indeno(1,2,3,c,d)pyrene particle | 193395 | Indeno(1,2,3,c,d)pyrene P |
| 83 | Phenanthrene particle | 85018 | Phenanthrene P |
| 84 | Pyrene particle | 129000 | Pyrene P |
| 86 | Total Organic Gases | TOG | TOG |
| 87 | Volatile Organic Compounds | VOC | VOC |
| 88 | NonHAPTOG | NHTOG | NHTOG |
| 90 | Atmospheric CO2 | CO2 | Atmospheric CO2 |
| 91 | Total Energy Consumption |  | Total Energy |
| 92 | Petroleum Energy Consumption |  | Petrol Energy |
| 93 | Fossil Fuel Energy Consumption |  | Fossil Energy |
| 98 | CO2 Equivalent | CO2 | CO2 Equivalent |
| 99 | Brake Specific Fuel Consumption (BSFC) | NULL | BSFC |
| 100 | Primary Exhaust PM10 - Total | PM10-PRI | PM10 Total Exh |
| 106 | Primary PM10 - Brakewear Particulate | PM10\_PRI | PM10 Brakewear |
| 107 | Primary PM10 - Tirewear Particulate | PM10\_PRI | PM10 Tirewear |
| 110 | Primary Exhaust PM2.5 - Total | PM25-PRI | PM2.5 Total Exh |
| 111 | Organic Carbon | PM25\_PRI | PM2.5 OC |
| 112 | Elemental Carbon | PM25\_PRI | PM2.5 EC |
| 115 | Sulfate Particulate | PM25\_PRI | PM2.5 Sulfate |
| 116 | Primary PM2.5 - Brakewear Particulate | PM25\_PRI | PM2.5 Brakewear |
| 117 | Primary PM2.5 - Tirewear Particulate | PM25\_PRI | PM2.5 Tirewear |

MOVES Emission Process ID Numbers and Corresponding Indices Used in Processing

|  |  |  |  |
| --- | --- | --- | --- |
| processID | processName | Emission Category | Emission Subcategory |
| 1 | Running Exhaust | Combustion (3) | Run (1) |
| 2 | Start Exhaust | Combustion (3) | Start (2) |
| 9 | Brakewear | TWBW (2) | na |
| 10 | Tirewear | TWBW (2) | na |
| 11 | Evap Permeation | Other (4) | na |
| 12 | Evap Fuel Vapor Venting | Other (4) | na |
| 13 | Evap Fuel Leaks | Other (4) | na |
| 15 | Crankcase Running Exhaust | Combustion (3) | Run (1) |
| 16 | Crankcase Start Exhaust | Combustion (3) | Start (2) |
| 17 | Crankcase Extended Idle Exhaust | na | na |
| 18 | Refueling Displacement Vapor Loss | Fueling (1) | na |
| 19 | Refueling Spillage Loss | Fueling (1) | na |
| 90 | Extended Idle Exhaust | na | na |
| 91 | Auxiliary Power Exhaust | na | na |
| 99 | Well-to-Pump | na | na |

Age Bins Used in Processing

|  |  |
| --- | --- |
| Age Bin | Age in Year (CY-MY) |
| 0 | 0-4 |
| 1 | 5-9 |
| 2 | 10-14 |
| 3 | 15-19 |
| 4 | and ≥20) |