

**APPENDIX A:**  
**Emissions Estimation Utilities for Moves-Based Emissions Inventories**

## **TTI EMISSIONS ESTIMATION UTILITIES FOR MOVES2014A-BASED EMISSIONS INVENTORIES**

The following is a summary of utilities developed by TTI (written in the Visual Basic programming language) for producing detailed, link-based, hourly, and 24-hour emissions estimates for on-road mobile sources using the latest version of EPA's MOVES model (MOVES2014a). These utilities produce inputs used with the MOVES model, make special adjustments to the emissions factors (when required), and multiply them with travel model link-based or Highway Performance Monitoring System (HPMS)-based (virtual link) activity estimates to produce emissions at user-specified temporal and spatial scales.

The main utilities for calculating hourly and 24-hour emissions using MOVES are TRANSVMT, VirtualLinkVMT, VehPopulationBuild, OffNetActCalc, MOVESactivityInputBuild, MOVESfleetInputBuild, RatesCalc, RatesAdj, and EmsCalc. The TRANSVMT and VirtualLinkVMT prepare the link VMT and speeds activity input. The VehPopulationBuild utility builds the vehicle population used to calculate the off-network activity. The OffNetActCalc utility builds the SHP, starts, SHI, and APU hours required to estimate emissions using the rate-per-activity emissions rates produced by the RatesCalc or RatesAdj utilities. The MOVESactivityInputBuild and MOVESfleetInputBuild utilities build inputs used in MOVES. The RatesCalc utility assembles the emissions rates from the MOVES output in terms of rate-per-activity, including rate-per-SHP for the evaporative emissions processes. The RatesAdj utility makes special adjustments to the emissions rates when required. The EmsCalc utility calculates emissions by hourly time periods, producing a tab-delimited summary file (including 24-hour totals), hourly link emissions output files (optional), and an optional tab-delimited summary file by MOVES source classification code (SCC).

A process flow diagram follows the utility descriptions.

### **TRANSVMT**

The TRANSVMT utility post-processes travel demand models (TDMs) to produce hourly, on-road vehicle, seasonal and day-of-week specific, directional link VMT, and speed estimates. The TRANSVMT utility processes a TDM traffic assignment by multiplying the link volumes by the appropriate HPMS, seasonal, or other VMT factors. Hourly factors are then used to distribute the link VMT to each hour in the day. A speed model is used to estimate the operational time-of-day link speeds for each direction. Since intrazonal links are not included in the TDM, special intrazonal links are created and the VMT and speeds for these special links are estimated using the intrazonal trips from the trip matrix and the zonal radii. The link VMT and speeds produced by TRANSVMT are subsequently input to the EmsCalc utility for applying the MOVES-based emissions factors (as well as with other utilities to develop off-network activity estimates).

### **VirtualLinkVMT**

The VirtualLinkVMT utility post-processes county HPMS average annual daily traffic (AADT) VMT, centerline miles, and lane miles by functional classification and area type (from the Texas Department of Transportation's [TxDOT's] annual Roadway Inventory Functional

Classification Record [RIFCREC]) to produce hourly, on-road vehicle fleet, seasonal and day-of-week specific actual or projected VMT, and directional operational speed estimates. These estimated VMT and speeds are produced for up to 42 directional HPMS functional classification/area type combinations, or “links.” The VirtualLinkVMT utility was developed for use in areas that do not have TDM networks, as well as for inventory applications for which network link-based detail is not required. The main inputs to VirtualLinkVMT are:

- County HPMS data sets, which include AADT VMT, centerline miles, and lane miles by HPMS area type and functional class;
- County-level VMT control totals;
- Hourly VMT distributions; and
- Speed model inputs to include volume/delay equation parameters adapted for HPMS, and free-flow speeds and lane capacities by HPMS functional classification and area type.

VirtualLinkVMT initially scales the county HPMS AADT VMT at the link level to the appropriate VMT (e.g., uses a county-level VMT control total-to-AADT ratio to produce seasonal, day-of-week specific VMT). Hourly factors and directional split factors are applied to the adjusted VMT on each link to estimate the hourly, directional VMT (and volumes) by HPMS link. Congested speed models, each for the high- and low-capacity links, are used to estimate the hourly operational speeds by direction for each link. The operational speeds are based on volume/capacity (v/c)-derived directional delay (minutes/mile) applied to the estimated free-flow speeds for each link. The virtual link VMT and speeds produced using the VirtualLinkVMT utility are an input to the emissions calculation utility, EmsCalc (as well as with other utilities to develop off-network activity estimates).

## VehPopulationBuild

The VehPopulationBuild utility builds the sourcetypeyear data files in a format consistent with the MOVES input database table and the SUT/fuel type population input file (can be used with the EmsCalc utility to estimate emissions or the OffNetActCalc utility to estimate starts and SHP) using the VMT mix and the Texas Department of Motor Vehicles (TxDMV) registration data sets. The TxDMV registration data sets are three sets of registration data (an age registration data file, a gas trucks registration data file, and a diesel trucks registration data file) that list 31 years of registration data. The primary inputs to this utility are:

- County ID file, which specifies the county for which the output will be calculated;
- Age registration data file, which lists 31 years of registration data for the Passenger Vehicle, Motorcycles, Trucks <=6000, Trucks >6000 <=8500, Total Trucks <=8500, Gas Trucks >8500, Diesel Trucks >8500, Total Trucks >8500, and Total All Trucks vehicle categories;
- Gas trucks registration data file, which lists 31 years of registration data for the Gas >8500, Gas >10000, Gas >14000, Gas >16000, Gas >19500, Gas >26000, Gas >33000, Gas >60000, and Gas Totals gas truck categories;

- Diesel trucks registration data file, which lists 31 years of registration data for the Diesel >8500, Diesel >10000, Diesel >14000, Diesel >16000, Diesel >19500, Diesel >26000, Diesel >33000, Diesel >60000, and Diesel Totals diesel truck categories;
- VMT mix by TxDOT district, MOVES SUT, and MOVES fuel type;
- TxDOT district name file, which specifies the VMT mix TxDOT district;
- MOVES default database;
- Population factor file (optional); and
- Year ID file (optional, only used if population factors are used), which specifies the year for calculating the output.

For the desired county (from the county ID file), the age registration data (for the Passenger Vehicle, Motorcycles, Trucks <=6000, Trucks >6000 <=8500, and Total Trucks <=8500 vehicle categories) are saved in an age registration data array. The gas truck registration data (for the Gas >8500, Gas >10000, Gas >14000, Gas >16000, Gas >19500, Gas >26000, Gas >33000, and Gas >60000 gas truck categories) are saved in the gas truck section of the diesel/gas registration data array. The diesel truck registration data (for the Diesel >8500, Diesel >10000, Diesel >14000, Diesel >16000, Diesel >19500, Diesel >26000, Diesel >33000, and Diesel >60000 diesel truck categories) are saved in the diesel truck section of the diesel/gas registration data array. The age registration data array and the diesel/gas registration data array are combined to form the registration category data array (seven categories for 31 years of data and the total) using the combinations in the Registration Categories table.

### Registration Categories.

Registration Category	Vehicle Category	Data Location
1	Passenger Vehicle	Age registration data array
2	Motorcycles	Age registration data array
3	Total Trucks <=8500	Age registration data array
4	Diesel >8500, Diesel >10000, Diesel >14000, Diesel >16000	Diesel/gas registration data array
5	Diesel >19500, Diesel >26000, Diesel >33000, Diesel >60000	Diesel/gas registration data array
6	Gas >8500, Gas >10000, Gas >14000, Gas >16000	Diesel/gas registration data array
7	Gas >19500, Gas >26000, Gas >33000, Gas >60000	Diesel/gas registration data array

The registration category data array is used to fill the SUT population array (by SUT and fuel type) for all vehicles except long-haul trucks. Each SUT/fuel type combination is assigned the total registrations from one or more of the registration categories in the registration category data array. The SUT/Registration Category Correlation table shows the SUTs and their associated registration category in the registration category data array.

### SUT/Registration Category Correlation.

SUT	Registration Category
11	2
21	1
31, 32	3
41, 42, 43, 51, 52, 54	4 + 6
61	5 + 7

SUT population factors are calculated by SUT/fuel type using the data from the VMT mix input for all SUTs except motorcycles (SUT 11) and the long-haul trucks (SUTs 53 and 62) and saved in the SUT population factors array. For SUT 21, the fuel type VMT mix is divided by the total VMT mix for SUT 21. For SUT 31, the fuel type VMT mix is divided by the total VMT mix for SUTs 31 and 32. The same process applies to SUT 32. For SUT 41, the fuel type VMT mix is divided by the total VMT mix for SUTs 41, 42, 43, 51, 52, and 54. The same process applies to SUTs 42, 43, 51, 52, and 54. For SUT 61, the fuel type VMT mix is divided by the total VMT mix for SUT 61.

For SUT 11, the SUT population factor for fuel type 1 (gasoline) is set 1 with all other factors set to 0. For SUT 53, the SUT population factors by fuel type are calculated by dividing the fuel type VMT mix for SUT 53 by the fuel type VMT mix for SUT 52. For SUT 62, the SUT population factors by fuel type are calculated by dividing the fuel type VMT mix for SUT 62 by the fuel type VMT mix for SUT 61, therefore creating a ratio of long-haul and short-haul trucks.

The SUT population factors and the population factor (if desired) are applied to the SUT population array for all SUTs except SUT 53 and 62. For SUT 53, the SUT population factors for SUT 53 are applied to the SUT population array for SUT 52. For SUT 62, the SUT population factors for SUT 62 are applied to the SUT population array for SUT 61.

Using the appropriate MySQL code, a new sourcetypeyear database table is created. The data in the SUT population array is aggregated by fuel type and used to fill the sourcetypeyear database table, along with the yearID, salesGrowthFactor, and migrationrate. For the yearID, the year of the registration data is used, unless a population factor is used, in which case the year from the year ID input is used. The salesGrowthFactor and migrationrate for each SUT is set 1. A text format of this database table is written by the utility as well. The SUT/fuel type population input file is written using the SUT population array.

### OffNetActCalc

The OffNetActCalc calculates the analysis scenario (i.e., year, season, day-type) SHP, starts, SHI, and APU hours by hour, SUT, and fuel type used to estimate emissions using the EmsCalc utility. The SHI and APU hours are only calculated for SUT 62, fuel type 2 (CLht\_Diesel). The SHP is calculated using either the TDM or the virtual link-based link VMT and speeds (same as used in the distance-based emissions estimation), the 24-hour or time period VMT mix

(by roadway type and SUT/fuel type), and the SUT/fuel type population (from the VehiclePopulationBuild utility). The starts activity is calculated using the SUT/fuel type population and the starts per vehicle (typically the MOVES default). The SHI and APU hours are a function of hotelling hours. This utility has two options for calculating the hotelling hours. Using the first option, the analysis scenario 24-hour hotelling hours is calculated using a user-supplied extended idle factor to the source hours operating (SHO). However, this method of estimating the hotelling hours as a direct function of the SHO does not consider the availability of locations where extended idling may occur. The second option (and suggested method) uses base data (24-hour hotelling, link VMT and speeds, and VMT mix), the analysis scenario data used to calculate the SHP, and the analysis scenario SHP to calculate the analysis scenario 24-hour hotelling hours.

For the analysis scenario first hourly VMT and speeds input, the utility applies the appropriate VMT mix (either the 24-hour VMT mix or the appropriate time period VMT mix as assigned by the user) to each link that has the desired county code; thus distributing the link VMT to each SUT/fuel type, which is added to the hourly SUT/fuel type VMT. The link VMT by SUT/fuel type is divided by the link speed to calculate the link VHT (or SHO) by SUT/fuel type, which is added to the SUT fuel/type VHT. This calculation process is repeated for each analysis scenario VMT and speeds input; therefore producing the analysis scenario hourly values for VMT by SUT/fuel type and for VHT by SUT/fuel type.

The analysis scenario hourly SUT/fuel type speed, total hours (or source hours), and SHP are then calculated. For each hour and SUT/fuel type, the hourly SUT/fuel type VMT is divided by the hourly SUT/fuel type VHT to calculate the hourly SUT/fuel type speed. The hourly SUT/fuel type total hours are set equal to the SUT/fuel type population. The hourly SUT/fuel type SHP is calculated by subtracting the hourly SUT/fuel type VHT (or SHO) from the hourly SUT/fuel type total hours. If the calculated SHP is negative (i.e., SHO is greater than the total hours), the SHP is set to 0.

To calculate the analysis scenario 24-hour hotelling hours under option 1 (as a direct function of SHO), the utility multiplies the CLhT\_Diesel analysis scenario 24-hour SHO by the user-supplied extended idle factor, which represents the amount of extended idle time that must occur per SHO. For option 2 (as a function of base hotelling data), the utility calculates the base 24-hour CLhT\_Diesel VMT using the base VMT and speeds inputs and the base VMT mix with the same procedure used in the analysis scenario SHP calculations. The 24-hour analysis scenario CLhT\_Diesel VMT is then divided by the 24-hour base CLhT\_Diesel VMT to create a scaling factor, which is then applied to the base 24-hour hotelling hours to calculate the analysis scenario 24-hour hotelling hours.

The utility then calculates the analysis scenario hourly hotelling hours. The analysis scenario hourly CLhT\_Diesel SHO (from the SHP calculation process) is converted to hourly VHT fractions. The hourly hotelling fractions are calculated as the inverse of the hourly VHT fractions. The hourly hotelling fractions are then applied to the analysis scenario 24-hour hotelling hours to calculate the hourly hotelling hours. For each hour, the hourly hotelling hours are then compared to the hourly CLhT\_Diesel SHP. For those hours where the hotelling hours are greater than the SHP, hotelling hours are set to the SHP for that hour.

The utility then calculates the SHI fraction and the APU fraction using the source type age distribution (same distribution used in the MOVES runs), the relative mileage accumulation rates, and the hotelling activity distribution. Travel fractions for SUT 62 (CLhT) by ageID (0 through 30) are calculated by multiplying the age distribution by the appropriate relative mileage accumulation rate, which is then converted into a distribution by dividing the individual travel fraction (ageID 0 through 30) by the sum of the travel fractions. These travel fractions are then applied to the appropriate operating mode fractions from the hotelling activity distribution (operating mode 200) and summed to calculate the SHI fraction. Using a similar process, the APU fraction is calculated using the operating mode fractions for operating mode 201. For each hour the analysis scenario hotelling hours are multiplied by the SHI fraction to calculate the analysis scenario SHI activity and by the APU fraction to calculate the analysis scenario APU hours.

### **MOVEActivityInputBuild**

The MOVEActivityInputBuild utility builds the roadtypedistribution, hourvmtfraction, avgspeeddistribution, roadtype, hpmsvtypeday, sourcetypedayvmt, year, state, zone, zoneroadtype, monthvmtfraction, and dayvmtfraction data files in a format consistent with the MOVES input database tables using the link-based hourly VMT and speeds developed with the TRANSVMT or VirtualLinkVMT utility, the VMT mix, and the MOVES defaults. The utility also has the option of building the sourcetypeage (adjusted to reflect the 24-hour VMT mix), starts, and hotellinghours data files in a format consistent with the MVOES input database tables using the output from the OffNetActCalc utility, along with inputs from the MOVES runs and the MOVES defaults. The primary inputs to this utility are:

- Link-based hourly VMT and speeds developed with the TRANSVMT or VirtualLinkVMT utility;
- County ID file which specifies the county number in the link-based hourly VMT and speeds for which the output will be calculated;
- VMT roadway type designations, which lists associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types (same as used with the EmsCalc utility);
- 24-hour or time period VMT mix by roadway type, MOVES source type, and MOVES fuel type (same as used with the EmsCalc utility);
- Day ID, which specifies the MOVES day ID for calculating the output;
- Year ID, which specifies the year for calculating the output;
- Link/Ramp designations, which designates each link roadway type/area type combination to either ramp or non-ramp;
- MOVES default database;
- Month ID, which specifies the month for calculating the output;
- sourcetypeyear, SUT age, and sourcetypeage inputs from the MOVES runs (optional, only if sourcetypeage table output is to be created);

- Starts output from the OffNetActCalc utility (optional, only if starts table output is to be created); and
- Hotelling, extended idle, and APU hours output from the OffNetActCalc utility (optional, only if hotelling table output is to be created).

For each link in the link-based hourly VMT and speeds in which the county number matches the desired county ID, the link VMT is saved in a VMT summary array based on hour, link functional class, and link area type. The link VHT (link VMT/link speed) is saved in a VHT summary array based on hour, link functional class, link area type, and MOVES average speed bin ID (determined using the MOVES average speed bins and the link speed). The link VHT is also saved in a road type VHT array based on link functional class and link area type, and, if the link is specified as ramp by the link/ramp designations specified by the user, the VHT is additionally saved in the ramp segment of the road type VHT array.

A MOVES roadway type array by MOVES roadway type (roadTypeID codes 2 through 5) is also created using the data in the VMT summary array and VMT roadway type designations. For the link road types designated a MOVES road type of 6 or 8, the VMT is added to MOVES road type 2 in the MOVES roadway type array. For the link road types designated a MOVES road type of 7 or 9, the VMT is added to MOVES road type 4 in the MOVES roadway type array. An hourly VMT array (by MOVES SUT, MOVES roadway type, and hour) is formed using the data in the VMT summary array, the VMT roadway type designations, and the VMT mix. If the time period VMT mix is used, each hour is assigned a time period by the user. Otherwise, the same 24-hour VMT mix is used for all hours. An average speed distribution array (by MOVES SUT, MOVES roadway type, hour, and MOVES speed bin) is created using the VHT summary array and the VMT mix. Using the appropriate MySQL code, the MOVES roadtypedistribution, hourvmtfraction, and avgspeeddistribution default values are extracted and saved for later use.

The VMT in the MOVES roadway type array is used to produce the roadway type distribution array by MOVES SUT and MOVES roadway type. This VMT is converted to a distribution by MOVES SUT (i.e., the total for a SUT over the five MOVES roadway types should equal 1), with the distribution value for MOVES roadway type 0 (Off-Network) equal to 0. The utility writes the tab-delimited roadtypedistribution table output (optional).

The VMT in the hourly VMT array is added to the hourly VMT fraction array (by SUT, MOVES roadway type, and hour) and for those roadway types where the VMT for all hours is greater than 0, this VMT is converted to an hourly distribution. For those roadway types where the VMT is equal to 0, a value of 1 is placed in the first hour, followed by 0 in the remaining hours. The utility writes the tab-delimited hourvmtfraction table output (optional). For those SUTs where the VMT mix is greater than 0, the hourly VMT fraction array is used. Otherwise, the MOVES hourvmtfraction default values are used.

The VHT in the average speed distribution array is converted to a distribution by SUT, MOVES roadway type, hour/day (combination of hour and the day ID specified by the user), and MOVES average speed bin. The utility writes the tab-delimited avgspeeddistribution table output (optional). For those SUTs where the VMT mix is greater than 0, the average speed distribution array is used. Otherwise, the MOVES avgspeeddistribution default values are used.

The VHT in the road type VHT array is converted to a proportion of ramp VHT by dividing the ramp segment of the road type VHT array by the total VHT for the road type in the road type VHT. The utility writes the tab-delimited roadtype table output (optional). If the ramp fraction for roadTypeID 2 is greater than 0, then roadTypeID 6 (with rampFraction equal to 0) and roadTypeID 8 (with rampFraction equal to 1) are also added to the roadtype database table. If the ramp fraction for roadTypeID 4 is greater than 0, then roadTypeID 7 (with rampFraction equal to 0) and roadTypeID 9 (with rampFraction equal to 1) are also added to the roadtype database table.

The VMT in the hourly VMT array is aggregated to create the 24-hour HPMS vehicle type VMT array. Each SUT is assigned an HPMS vehicle type (SUT 11 is HPMS vehicle type 10; SUTs 21, 31 and 32 are HPMS vehicle type 25; SUTs 41, 42, and 43 are HPMS vehicle type 40; SUTs 51, 52, 53, and 54 are HPMS vehicle type 50; and SUTs 61 and 62 are HPMS vehicle type 60). The utility writes the tab-delimited hpmsvtypeday table output (optional).

The VMT in the hourly VMT array is also aggregated by SUT to create the 24-hour SUT VMT array. Using this VMT data, the utility writes the tab-delimited sourcetypedayvmt output table (optional) in a format consistent with the MOVES input.

Using the appropriate MySQL code, the fuel year ID is extracted from the MOVES default year database table for the user-supplied year ID. The tab-delimited year table output is written (optional) using the user-supplied year ID and the extracted fuel year ID. The “isbaseYear” data is written as well (automatically set to “Y”).

The utility also produces two tab-delimited summary output files. A tab-delimited VMT summary is output by hour, link road type, and link area type for the user-specified county. A tab-delimited VHT summary is output by hour, link road type, link area type, and MOVES average speed bin for the user-specified county.

The utility creates five other tab-delimited outputs (state, zone, zoneroadtype, monthvmtfraction, and dayvmtfraction tables) using the user-supplied inputs. For the state table (optional), the utility extracts the data from the MOVES default state database table where the state ID is 48 and writes this data to the tab-delimited state table output. For the zone table (optional), the utility extracts the data from the MOVES default zone data for the county ID greater than 48000 and county ID less than 49000 and writes this data to the tab-delimited zone table output with the start allocation factors, idle allocation factors, and SHP allocation factors replaced with values of 1.

For the zoneroadtype table (optional), the utility extracts the MOVES default zoneroadtype data where the zone ID greater than 480000 and zone ID less than 490000 and writes this data to the tab-delimited zoneroadtype table output, with the SHO allocation factors replaced with values of 1. For the monthvmtfraction table (optional), the utility extracts the data from the MOVES default monthvmtfraction table and writes the data to the tab-delimited monthvmtfraction table output with the month VMT fraction set to 1 for the user-supplied month ID and 0 for all other months. For the dayvmtfraction table (optional), the utility extracts the data from the MOVES default dayvmtfraction table and writes this data to the tab-delimited

dayvmtfraction table output with the day VMT fraction is set to 1 for the user-supplied day ID and 0 for all other months.

For the sourcetypeage table output (optional, also needed if the hoteling hours table output is to be created), the utility calculates the adjusted relative mileage accumulation rates (MAR) by multiplying the input relative MAR (categorized by SUT and age from the sourcetypeage input) by the SUT-specific relative MAR adjustment factors (one factor per SUT applied across all age categories). These adjustment factors are calculated using inventory SUT VMT fractions within each HPMS vehicle type and the sum of the SUT-specific normalized travel fractions within each HPMS vehicle type. The inventory SUT VMT fractions within each HPMS vehicle type are calculated by dividing the 24-hour SUT VMT by the 24-hour HPMS vehicle type VMT for the respective SUT.

For the sum of the SUT-specific normalized travel fractions within each HPMS vehicle type, the utility uses the same calculation procedures used by MOVES to calculate the normalized travel fractions. The SUT vehicle population is distributed to each age category using the SUT age distribution input. Using the sum of the vehicle population by HPMS vehicle type, the SUT population fraction for each age category within each HPMS vehicle type is calculated by dividing the SUT vehicle population by age by the sum of the vehicle population by HPMS vehicle type. The utility then calculates the initial travel fractions (by SUT and age) by multiplying the SUT population fraction for each age category within each HPMS vehicle type by the relative MAR input.

These initial travel fractions are then normalized within each HPMS vehicle type to produce the SUT and age-specific normalized travel fractions within each HPMS vehicle type. The utility then calculates the SUT-specific relative MAR adjustment factors by dividing the inventory SUT VMT fractions within each HPMS vehicle type by the sum of the SUT and age-specific normalized travel fractions (i.e., aggregated across the age category for each SUT); resulting in one SUT-specific relative MAR adjustment factor for each SUT.

For the starts table output (optional), the utility aggregates the SUT/fuel type hourly starts input (output from the OffNetActCalc utility) by SUT and multiplies the SUT hourly starts by the SUT age distribution (by SUT) to distribute the hourly SUT starts to each age category. The SUT hourly starts by age are written to the starts table output file, along with the user-supplied monthID, yearID, dayID (used to form the output hourDayID), and zoneID (set using the user-supplied county FIPS code).

For the hoteling hours table output (optional), the utility uses travel fractions specific to SUT 62 to distribute the hourly hoteling hours input (output from the OffNetActCalc utility) to each age category. These travel fractions are calculated by multiplying the SUT 62 age distribution by the calculated relative mileage accumulation rates (MOVES defaults adjusted so to reflect the emissions inventory 24-hour VMT mix) for each age category and dividing by the sum of the product for all the age categories. These travel fractions are multiplied by the hourly hoteling hours input and written to the hoteling hours table output, along with the user-supplied dayID (used to form the output hourDayID), monthID, yearID, and zoneID (set using the user-supplied county FIPS code).

## **MOVESfleetInputBuild**

The MOVESfleetInputBuild utility builds the sourcetypeagedistribution database table and fuel/engine fraction inputs to MOVES using the TxDOT registration data sets and the MOVES default database tables. The TxDOT registration data sets are three sets of registration data (an age registration data file, a gas trucks registration data file, and a diesel trucks registration data file) that list 31 years of registration data. The primary inputs to this utility are:

- Age registration data file, which lists 31 years of registration data for the Passenger Vehicles, Motorcycles, Trucks <=6000, Trucks >6000 <=8500, Total Trucks <=8500, Gas Trucks >8500, Diesel Trucks >8500, Total Trucks >8500, and Total All Trucks vehicle categories;
- Gas trucks registration data file, which lists 31 years of registration data for the Gas > 8500, Gas > 10000, Gas > 14000, Gas > 16000, Gas > 19500, Gas > 26000, Gas > 33000, Gas > 60000, and Gas Totals gas truck categories;
- Diesel trucks registration data file, which lists 31 years of registration data for the Diesel > 8500, Diesel > 10000, Diesel > 14000, Diesel > 16000, Diesel > 19500, Diesel > 26000, Diesel > 33000, Diesel > 60000, and Diesel Totals diesel truck categories;
- SUT data sources input, which specifies the data source for each SUT to use when building the sourcetypeagedistribution database table;
- Fuel/engine fractions data sources input, which specifies the data source for each SUT to use when building the fuel/engine fractions;
- Default sourcetypeage distribution input;
- MOVES default database; and
- Year ID file (optional, only if year is not the registration data year as in a future year analysis), which specifies the year for calculating the output.

The SUT data sources input lists the data source for each SUT, either a single county, multiple counties, state, or MOVES default. As this input is processed, the utility maintains a list of the input sources. The same applies to the fuel/engine fractions, except data source inputs are only valid for source types 52, 53, and 61 (other are not valid due to data limitations and source type 62 are all considered diesel).

For each county (or state total) in the list of the input sources, the age registration data (for the Passenger Vehicle, Motorcycles, Trucks <=6000, Trucks >6000 <=8500, and Total Trucks <=8500 vehicle categories) are saved in an age registration data array. The gas truck registration data (for the Gas > 8500, Gas > 10000, Gas > 14000, Gas > 16000, Gas > 19500, Gas > 26000, Gas > 33000, and Gas > 60000 gas truck categories) are saved in the gas truck section of the diesel/gas registration data array. The diesel truck registration data (for the Diesel > 8500, Diesel > 10000, Diesel > 14000, Diesel > 16000, Diesel > 19500, Diesel > 26000, Diesel > 33000, and Diesel > 60000 diesel truck categories) are saved in the diesel truck section of the diesel/gas registration data array.

The age registration data array and the diesel/gas registration data array are combined to create the registration category data array (a total of seven categories for 31 years of data and the total) using the combinations in the Registration Categories table. The county is compared to the data sources for each SUT in the SUT data sources input. If the county is found for a given source type, then the 31 years of registration data from the source type's corresponding category in the registration category data array are added to the SUT age distribution array. The table SUTs/Registration Categories Correlation for SUT Age Distribution shows the source types and their corresponding registration categories.

#### **SUTs/Registration Categories Correlation for SUT Age Distribution.**

<b>SUT</b>	<b>Registration Category</b>
11	2
21	1
31, 32	3
52, 53	4
61, 62	5

A similar process is followed for the fuel/engine fractions array. However, only SUTs 52, 53, 61, and 62 are processed due to data limitations. The registration data are saved in the fuel/engine fractions array based on fuel type. The table SUTs/Registration Categories Correlation for Fuel/Engine Fractions shows the SUTs and their corresponding registration categories.

#### **SUTs/Registration Categories Correlation for Fuel/Engine Fractions.**

<b>SUT</b>	<b>Fuel Type</b>	<b>Registration Category</b>
52, 53	Diesel	4
	Gas	6
61	Diesel	5
	Gas	7
62	Diesel	5 + 7
	Gas	None – all are assumed diesel

After processing all of the counties, the data from the default sourcetypeage distribution input are processed and the data for the registration data year are saved in the default age distribution array. For each source type in which the registration data are to be used for the age distribution, the 31 years of registration data in the SUT age distribution array are converted to a distribution by dividing the source type yearly registration data by the source type total registration data. For each source type in which the defaults are to be used, the defaults values from the default age distribution array are copied to the SUT age distribution array.

The MOVES default fuel/engine fractions are extracted from the MOVES default database (using the appropriate code for MySQL) and saved in the default fuel/engine fractions array. For source types 52, 53, and 61, the source type yearly registration data in the fuel/engine fractions array are converted to fuel/engine fractions by dividing the yearly source type diesel registration data by the sum of the yearly source type diesel registration data and the yearly source type gas registration data.

If the year ID input is used, then these fuel/engine fractions are adjusted to match the year from the year ID input. If the year from the year ID input is greater than the registration data year, then the first fuel/engine fraction is extended to match the year from the year ID input and the appropriate number of years is dropped from the end of the fuel/engine fractions to maintain the appropriate distribution. If the year from the year ID input is less than the registration data year, then the last fuel/engine fraction is extended to match the year from the year ID input and the appropriate number of years is dropped from the beginning of the fuel/engine fractions to maintain the appropriate distribution. For source type 62, all of the fuel/engine fractions in the fuel/engine fractions array are set to a value of 1.

Using the appropriate MySQL code, a new sourcetypeagedistribution database table is created and the data from the SUT age distribution array, along with the year ID (either from the registration data or the year ID input), are used to fill the new database table. A text format of this database table may be written as well. Using the appropriate MySQL code, a new AVFTfuelengfraction database table is created and the data from the fuel/engine fractions array are used to fill the new database table for SUTs 52, 53, 61, and 62. For all other SUTs, the default fuel/engine fraction array data for the appropriate year (either the registration data year or the year ID input) are used to fill the new database table. A text format of this database table may be written as well.

## RatesCalc

The RatesCalc utility calculates emissions rates in terms of rate/SHP for the evaporative emissions processes using the data in the CDB used in the MOVES emissions rates run and the MOVES default database. The utility also creates copies of the rateperdistance, rateperhour, and rateperstartemissions rate tables to include the units for each pollutant. If not specified, emissions rates are assembled for each pollutant and process combination (excluding total energy and the refueling emissions processes) in the MOVES emissions rate tables. The utility also uses the movesrun database table, along with a pollutant energy or mass lookup table (mass, TEQ, or gmole), to determine the units of the emissions rates, which are added to the emissions rate tables, which will allow the user to specify any of the units available in MOVES for the MOVES emissions rate run. The type of activity used for the emissions rate calculation is determined by the process, shown in the MOVES2014a Emissions Process and Corresponding Activity for Rate-per-Activity Emissions Rates table.

## MOVES2014a Emissions Process and Corresponding Activity for Rate-per-Activity Emissions Rates.

MOVES2014a Emissions Process	Activity	Emissions Rate Units
Running Exhaust	Miles Traveled	Rate/Mile
Crankcase Running Exhaust	Miles Traveled	Rate/Mile
Start Exhaust	Starts	Rate/Start
Crankcase Start Exhaust	Starts	Rate/Start
Extended Idle Exhaust	Extended Idle Hours	Rate/Extended Idle Hour
Crankcase Extended Idle Exhaust	Extended Idle Hours	Rate/Extended Idle Hour
Auxiliary Power Exhaust	APU Hours	Rate/APU Hour
Evaporative Permeation	Miles Traveled Source Hours Parked	Rate/Mile Rate/SHP
Evaporative Fuel Vapor Venting	Miles Traveled Source Hours Parked	Rate/Mile Rate/SHP
Evaporative Fuel Leaks	Miles Traveled Source Hours Parked	Rate/Mile Rate/SHP
Brake Wear	Miles Traveled	Rate/Mile
Tire Wear	Miles Traveled	Rate/Mile

For the rateperdistance (rate/mile emissions rates) emissions rate table, the utility creates a copy of the emissions rates in the specified output database with the table name ttirateperdistance. If specific pollutants are specified, only the emissions rates for those pollutants are copied to the ttirateperdistance table. Otherwise, the entire rateperdistance table is copied to the ttirateperdistance table. The utility also adds a “Units\_Per\_Activity” field to the ttirateperdistance table and fills that field based on the pollutants energy or mass designation (mass, TEQ, or gmole). For those pollutants designated as mass, the mass units from the movesrun table are added to the “Units\_Per\_Activity” field. For those pollutants designated as gmole, the mass units from the movesrun table, along with the text “-mole” (i.e., pound-mole or gram-mole) are added to the “Units\_Per\_Activity” field. For those pollutants designated as TEQ, the text “TEQ” is added to the “Units\_Per\_Activity” field. No unit conversions are performed in this utility. The rateperstart and rateperhour, emissions rate tables are processed in a similar manner to produce the ttirateperstart and ttirateperhour, emissions rate tables.

For the evaporative emissions rates, the utility uses the CDB from the MOVES run and the MOVES default database to replicate the MOVES vehicle population and SHP calculation process. Using the emissions rates from the rateperprofile and ratepervehicle emissions rate tables, the utility calculates the rate-per-SHP emissions rates by multiplying the emissions rate by the appropriate vehicle population and dividing by the appropriate SHP value. These rate-per-SHP emissions rates are then saved in the ttiratepershp emissions rate table. Similar to

the previous RatesCalc emissions rate tables, the “Units\_Per\_Activity” field is added to the ttiratepershp table and filled based on the pollutants energy or mass designation.

### RatesAdj

The RatesAdj utility applies emissions rate adjustments to an emissions rate database table produced by RatesCalc utility (ttirateperdistance, ttirateperstart, ttirateperhour, or ttiratepershp) or by this utility to produce a new emissions rate database table in the same format as the input emissions rate database table. The emissions rate adjustments can be linear adjustments that are applied to all emissions rates or can be applied by SUT, fuel type, pollutant, and process (adjustments may also include roadway type, average speed bin, and hour). The user has the option of selecting which pollutants will be in the new emissions rate database table, along with the output units of the emissions rates. This allows the user to perform any unit conversions between mass units (i.e., pounds to grams or pound-mole to gram-mole) without providing any addition adjustment factors. Unit conversions between unit types (i.e., gram-moles to grams or TEQ to grams) are not performed internally by the utility. These types of conversions must be made using the emissions rate adjustment factors. The utility also has the option for combining multiple emissions rate database tables into one new emissions rate database table, if the input emissions rate database tables are in the same format.

For the first input emissions rate database table, the utility extracts the emissions rates for the specified pollutants (or all the pollutants if not specified) from the input database emissions rate table, applies the emissions rate adjustments (if necessary) and any unit conversion adjustments, and saves these adjusted emissions rates. If more than one emissions rate database table is input, then the utility performs a similar calculation process to the first input emissions rate database table for each input emissions rate database table. If pollutants are found in more than one input emissions rate database table, the adjusted emissions rates are summed to produce one emissions rate.

After processing all of the input emissions rate database tables, the utility creates a new emissions rate database table in the same format as the first input emissions rate database table and writes the adjusted emissions rates to this new emissions rate database table. Using MySQL code, the utility also creates a minimum and maximum emissions rate summary for each input emissions rate table and the output emissions rate table by pollutant, process, and source type/fuel type, which is written to a tab-delimited file specified by the user.

### EmsCalc

The EmsCalc utility estimates the hourly link emissions for one user-specified county using the emissions factors (either from RatesCalc or RatesAdj), the 24-hour or time period VMT mix, the hourly link VMT and speeds activity estimates (either from TRANSVMT or VirtualLinkVMT), and the off-network activity (SHP, starts, and SHI). This utility produces a tab-delimited output summary (including hourly and 24-hour totals) and hourly link emissions output files (optional). The primary inputs to EmsCalc are:

- Emissions factors from RatesCalc or RatesAdj;
- Link-based hourly VMT and speeds developed with the TRANSVMT or VirtualLinkVMT utility. For each link, the following information is input to EmsCalc:

link start node, link end node, link county number, link roadway type number, link area type number, link VMT, and link operational speed estimate;

- 24-hour or time period VMT mix by roadway type, MOVES SUT, and MOVES fuel type;
- Off-network activity (SHP, starts, SHI, and APU hours) by hour and SUT/fuel type;
- VMT roadway type designations, which lists associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types;
- Pollutants input file, which specifies which pollutant/process combinations for which the emissions calculations will be performed and their respective units in the tab-delimited output;
- SCC input file (optional, only if the activity and emissions by SCC are to be created); and
- SCC pollutants input file (optional, only if the activity and emissions by SCC are to be created).

The emissions estimation can be categorized by two basic types based on the type of emissions factors: the roadway-based emissions and the off-network-based emissions. For the roadway-based emissions (ttirateperdistance emissions factors), the VMT for each link is distributed to each of the SUT/fuel type combinations listed in the VMT mix by roadway type (as designated in the VMT roadway type designations). If the time period VMT mix is input, each hour is assigned a time period by the user. Otherwise, the 24-hour VMT mix is used for all hours. For each pollutant/process combination in the pollutants input file, the emissions factors are selected based on the emissions rate roadway type (as designated in the VMT roadway type designations) and the link speed for each SUT/fuel type combinations listed in the VMT mix. For link speeds greater than 75 mph, the emissions factors for 75 mph are used. For link speeds less than 2.5 mph, the emissions factors for 2.5 mph are used. For those link speeds that fall between the 16 MOVES speeds, the emissions factors are interpolated using the emissions factor interpolation methodology in the following section. These SUT/fuel type combination-specific emissions factors are multiplied by the SUT/fuel type combination-specific VMT to estimate the mobile source emissions for that link by SUT/fuel type combination. If the activity and emissions by SCC are to be created, the activity and emissions are also aggregated by SCC using the SCC input file and by SCC pollutant using the SCC pollutants input file (thus allowing the user the option to combine multiple MOVES pollutants into one more aggregate pollutant).

For the off-network emissions, the ttirateperstart, ttirateperhour, and ttiratepershp emissions rates (by SUT/fuel type) are multiplied by the appropriate activity, which is determined by the emissions process (see table MOVES2014a Refueling Emissions Process and Corresponding Activity for Rate-per-Activity Emissions Rates). If the activity and emissions by SCC are to be created, the activity and emissions are also aggregated by SCC using the SCC input file and by SCC pollutant using the SCC pollutants input file (thus allowing the user the option to combine multiple MOVES pollutants into one more aggregate pollutant).

The emissions estimates are output in a tab-delimited file (including all of the SUT/fuel type combinations listed in the VMT mix on a single line, separated by a tab character) for the specified county by pollutant, link roadway type, and SUT/fuel type combination for each of the

specified episode time periods. A 24-hour (or total if all 24 hours are not specified) output is also included in the tab-delimited file. Only those pollutant/process combinations in the pollutants input file with tab-delimited output units other than “NONE” will appear in the tab-delimited output file. Prior to output, any unit conversions between mass units (i.e., pounds to grams or pound-mole to gram-mole) are performed by the utility. Unit conversions between unit types (i.e., gram-moles to grams or TEQ to grams) are not performed internally by the utility (these type of unit conversions must be done using the RatesAdj utility). This tab-delimited file also includes hourly and 24-hour summaries of the off-network activity and VMT, VHT, and speed by link road type. Link emissions may also be output by county, pollutant, process, and each SUT/fuel type combination. If specified, the tab-delimited activity and emissions by SCC output file is also created, which lists the activity and emissions for each SCC pollutant by SCC.

#### *Emissions Factor Interpolation Methodology*

To calculate emissions factors for link speeds that fall between two of the 16 MOVES speed bin speeds, an interpolation methodology similar to the methodology used with MOBILE6 is used. This methodology interpolates each emissions factor using a factor developed from the inverse link speed and the inverse high and low bounding speed bin speeds. The following is an example for a link speed of 41.2 mph.

The interpolated emissions factor ( $EF_{Interp}$ ) is expressed as:

$$EF_{Interp} = EF_{LowSpeed} - FAC_{Interp} \times (EF_{LowSpeed} - EF_{HighSpeed})$$

Where:

$EF_{LowSpeed}$  = emissions factor (EF) corresponding to the speed below the link speed;

$EF_{HighSpeed}$  = EF corresponding to the speed above the link speed; and

$FAC_{Interp}$  =  $(1/Speed_{link} - 1/Speed_{low}) / (1/Speed_{high} - 1/Speed_{low})$

Given that:

$EF_{LowSpeed}$  = 0.7413 g/mi;

$EF_{HighSpeed}$  = 0.7274 g/mi;

$Speed_{link}$  = 41.2 mph;

$Speed_{low}$  = 40 mph; and

$Speed_{high}$  = 45 mph.

$$FAC_{Interp} = (1/41.2 \text{ mph} - 1/40 \text{ mph}) / (1/45 \text{ mph} - 1/40 \text{ mph})$$

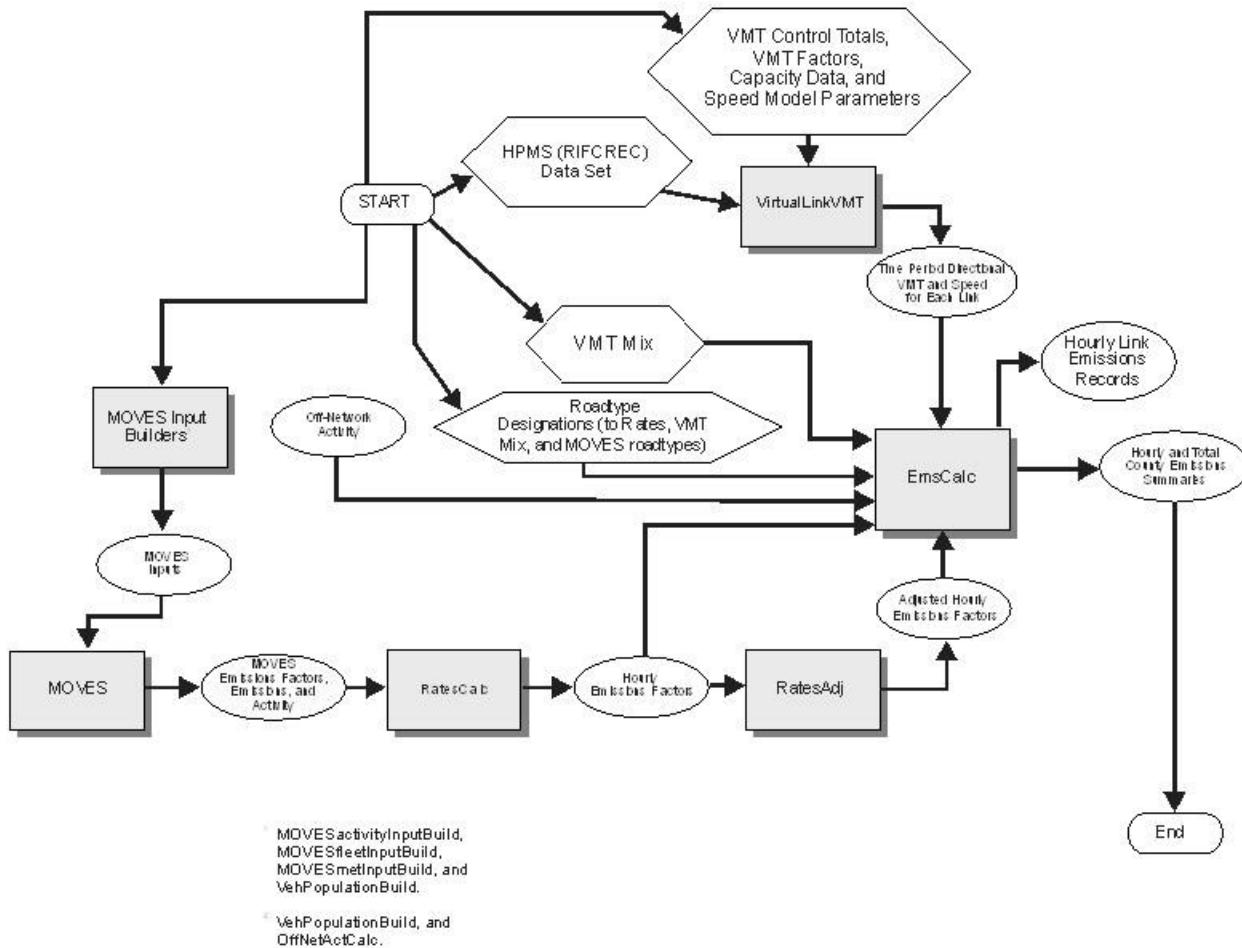
$$= (-0.00073) / (-0.00278)$$

$$= 0.26214$$

$$EF_{Interp} = 0.7413 \text{ g/mi} - (0.26214) \times (0.7413 \text{ g/mi} - 0.7274 \text{ g/mi});$$

$$= 0.7377 \text{ g/mi}$$

## HPMS / Virtual Link-Based Emissions Estimation Process



## **TTI EMISSIONS ESTIMATION UTILITIES FOR MOVES2014A-BASED REFUELING EMISSIONS**

The following is a summary of emissions estimation utilities developed by TTI for producing refueling emissions using the latest version of EPA's MOVES model. These utilities calculate emissions rates using the output from MOVES, make special adjustments to the emissions factors (when required), and multiply them with travel model link-based or HPMS-based (virtual link) activity estimates and off-network activity (produced using the utilities discussed in the previous sections) to produce emissions at user-specified temporal and spatial scales.

The main utilities for calculating hourly and 24-hour refueling emissions using MOVES are RatesCalcRF, RatesAdjRF, and EmsCalcRF. The RatesCalcRF utility assembles the refueling emissions rates from the MOVES output in terms of rate-per-activity. The RatesAdjRF utility makes special adjustments to the emissions rates when required. The EmsCalcRF utility calculates refueling emissions by hourly time periods, producing a tab-delimited summary file (including 24-hour totals), hourly link emissions output files (optional), and an optional tab-delimited summary file by MOVES source classification code (SCC).

### **RatesCalcRF**

The RatesCalcRF utility estimates emissions rates in terms of rate-per-activity (i.e., grams-per-mile, grams-per-start, and grams-per-SHI) using the data in the movesoutput (emissions output) and movesactivityoutput (activity output) database tables produced by a MOVES emissions rate run. If not specified, refueling emissions rates are calculated for each pollutant and process combination in the movesoutput database table. The utility also uses the movesrun database table to determine the units of the emissions in the movesoutput table, which will allow the user to specify any of the units available in MOVES for the MOVES emissions rate run. The type of activity used for the refueling emissions rate calculation is determined by the process, as the table below shows.

### **MOVES2014a Refueling Emissions Process and Corresponding Activity for Rate-per-Activity Emissions Rates.**

<b>MOVES2014a Emissions Process</b>	<b>Activity</b>	<b>Emissions Rate Units</b>
Refueling Displacement Vapor Loss	Miles Traveled Starts Extended Idle Hours APU Hours	Rate/Mile Rate/Start Rate/Extended Idle Hour Rate/APU Hour
Refueling Spillage Loss	Miles Traveled Starts Extended Idle Hours APU Hours	Rate/Mile Rate/Start Rate/Extended Idle Hour Rate/APU Hour

For the rate/mile emissions rates, the utility creates a copy of the refueling emissions rates in the specified output database with the table name ttirateperdistanceRF. If specific pollutants are specified, only the emissions rates for those pollutants are copied to the ttirateperdistanceRF table. Otherwise, all of the refueling emissions rates are copied to the ttirateperdistanceRF table. The utility also adds a “Units\_Per\_Activity” field to the ttirateperdistanceRF table and fills that

field based on the pollutants energy or mass designation (mass, TEQ, or gmole). For those pollutants designated as mass, the mass units from the movesrun table are added to the “Units\_Per\_Activity” field. For those pollutants designated as gmole, the mass units from the movesrun table, along with the text “-mole” (i.e., pound-mole or gram-mole) are added to the “Units\_Per\_Activity” field. For those pollutants designated as TEQ, the text “TEQ” is added to the “Units\_Per\_Activity” field. No unit conversions are performed in this utility.

The off-network refueling emissions are not directly linked to one of the activity categories (i.e., starts, SHI, and APU hours). For the rate-per-activity off-network refueling emissions rates, the utility uses the movesoutput and movesactivityoutput tables to calculate the emissions rates. Since SUT 62 has all three activity types, factors are needed to split the off-network refueling emissions into the three activity types. Using MySQL, the utility extracts the hourly total energy data from the movesoutput table for processID 2 (starts), processID 90 (SHI), and processID 91 (APU hours) and calculates the activity factors by dividing the total energy data for each processID by the hourly total (processID 2 + processID 90 + processID 91). The utility then creates a temporary table for the SUT 62 SHI-based refueling emissions factors and populates that table using MySQL by joining the hourly off-network refueling emissions from the movesoutput table, the activity factor for SHI (processID 90), and the activity (activityTypeID 3 for SHI) from the movesactivityoutput table. The emissions rate is then calculated by multiplying the emissions by the appropriate activity factor and divided by the activity. A similar process is used to create the temporary table for the SUT 62 APU-based refueling emissions factors (using the movesoutput table, the activity factor for APU hours, and the APU activity) and the temporary table for the SUT 62 starts-based refueling emissions factors.

For the remaining source types, the only activity included in the refueling emissions is the starts (no activity factors are needed). Using MySQL, the utility creates a temporary table for the starts-based refueling emissions factors and populates that table using MySQL by joining the hourly off-network refueling emissions from the movesoutput table for these source types and the starts activity from the movesactivityoutput table. The emissions rate is then calculated by dividing the emissions by the activity.

The utility then creates the final refueling emissions rate tables. The utility copies the emissions rates from the temporary SUT 62 start-based emissions rates table and temporary starts-based emissions rates table for the remaining SUTs to the ttirateperstartRF table using MySQL. The utility also copies the emissions rates from the temporary SUT 62 SHI-based emissions rates (with an activityTypeID 3) table and temporary SUT 62 APU-based emissions rates table (with activityTypeID 13) to the ttirateperhourRF table. Similar to the ttirateperdistanceRF table, the “Units\_Per\_Activity” field is added to the ttirateperstartRF and ttirateperhourRF tables and filled based on the pollutants energy or mass designation.

## RatesAdjRF

The RatesAdjRF utility applies emissions rate adjustments to a refueling emissions rate database table produced by the RatesCalcRF utility (ttirateperdistanceRF, ttirateperstartRF, or ttirateperhourRF) or by this utility to produce a new emissions rate database table in the same format as the input emissions rate database table. The emissions rate adjustments can be linear adjustments that are applied to all emissions rates or can be applied by SUT, fuel type, pollutant,

and process (adjustments may also include roadway type, average speed bin, and hour). The user has the option of selecting which pollutants will be in the new emissions rate database table, along with the output units of the emission rates. This allows the user to perform any unit conversions between mass units (i.e., pounds to grams or pound-mole to gram-mole) without providing any addition adjustment factors. Unit conversions between unit types (i.e., gram-moles to grams or TEQ to grams) are not performed internally by the utility. These types of conversions must be made using the emissions rate adjustment factors. The utility also has the option for combining multiple emissions rate database tables into one new emissions rate database table, if the input emissions rate database tables are in the same format.

For the first input emissions rate database table, the utility extracts the emissions rates for the specified pollutants (or all the pollutants if not specified) from the input database emissions rate table, applies the emissions rate adjustments (if necessary) and any unit conversion adjustments, and saves these adjusted emissions rates. If more than one emissions rate database table is input, then the utility performs a similar calculation process to the first input emissions rate database table for each input emissions rate database table. If pollutants are found in more than one input emissions rate database table, the adjusted emissions rates are summed to produce one emissions rate.

After processing all of the input emissions rate database tables, the utility creates a new emissions rate database table in the same format as the first input emissions rate database table and writes the adjusted emissions rates to this new emissions rate database table. Using MySQL code, the utility also creates a minimum and maximum emissions rate summary for each input emissions rate table and the output emissions rate table by pollutant, process, and source type/fuel type, which is written to a tab-delimited file specified by the user.

### **EmsCalcRF**

The EmsCalcRF utility estimates the hourly refueling emissions for one user-specified county using the refueling emissions factors (either from RatesCalcRF or RatesAdjRF), the VMT mix, the hourly link VMT and speeds activity estimates (either from TRANSVMT or VirtualLinkVMT), and the off-network activity (starts, SHI, and APU hours). This utility produces a tab-delimited output summary (including hourly and 24-hour totals) and hourly link emissions output files (optional). The primary inputs to EmsCalcRF are:

- Refueling emissions factors from RatesCalcRF or RatesAdjRF;
- Link-based hourly VMT and speeds developed with the TRANSVMT or VirtualLinkVMT utility. These link VMT and speeds are the same data files used to estimate the on-road mobile emissions using EmsCalc. For each link, the following information is input to EmsCalcRF: link start node, link end node, link county number, link roadway type number, link area type number, link VMT, and link operational speed estimate;
- 24-hour or time period VMT mix by roadway type, MOVES SUT, and MOVES fuel type (same VMT mix used to estimate the on-road mobile emissions using EmsCalc);
- Off-network activity (starts, SHI, and APU hours) by hour and SUT/fuel type (same off-network activity used to estimate the on-road mobile emissions using EmsCalc);

- VMT roadway type designations, which lists associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types;
- Pollutants input file, which specifies which pollutant/process combinations for which the emissions calculations will be performed and their respective units in the tab-delimited output;
- SCC input file (optional, only if the activity and emissions by SCC are to be created); and
- SCC pollutants input file (optional, only if the activity and emissions by SCC are to be created).

The refueling emissions estimation can be categorized by two basic types based on the type of emissions factors: the roadway-based emissions calculations and the off-network based emissions calculations. For the roadway-based emissions calculations (ttirateperdistanceRF emissions factors), the VMT for each link is distributed to each of the SUT/fuel type combinations listed in the VMT mix by roadway type (as designated in the VMT roadway type designations). If the time period VMT mix is input, each hour is assigned a time period by the user. Otherwise, the 24-hour VMT mix is used for all hours. For each pollutant/process combination in the pollutants input file, the emissions factors are selected based on the emissions rate roadway type (as designated in the VMT roadway type designations) and the link speed for each SUT/fuel type combination listed in the VMT mix. For link speeds greater than 75 mph, the emissions factors for 75 mph are used. For link speeds less than 2.5 mph, the emissions factors for 2.5 mph are used. For those link speeds that fall between the 16 MOVES speeds, the emissions factors are interpolated using the emissions factor interpolation methodology in the following section. These SUT/fuel type combination-specific emissions factors are multiplied by the SUT/fuel type combination-specific VMT to estimate the mobile source emissions for that link by SUT/fuel type combination. If the activity and emissions by SCC are to be created, the activity and emissions are also aggregated by SCC using the SCC input file.

For the off-network emissions, the ttirateperstartRF and ttirateperhourRF emissions rates (by SUT/fuel type) are multiplied by the appropriate activity, which is determined by the emissions process. If the activity and emissions by SCC are to be created, the emissions are also aggregated by SCC using the SCC input file (activity are not included for the off-network emissions because the each emissions process uses multiple activity types) and by SCC pollutant using the SCC pollutants input file (thus allowing the user the option to combine multiple MOVES pollutants into one more aggregate pollutant).

The refueling emissions estimates are output in a tab-delimited file (including all of the SUT/fuel type combinations listed in the VMT mix on a single line, separated by a tab character) for the specified county by pollutant and SUT/fuel type combination for each of the specified episode time periods. A 24-hour (or total if all 24 hours are not specified) output is also included in the tab-delimited file. Only those pollutant/process combinations in the pollutants input file with tab-delimited output units other than “NONE” will appear in the tab-delimited output file. Prior to output, any unit conversions between mass units (i.e., pounds to grams or pound-mole to gram-mole) are performed by the utility. Unit conversions between unit types (i.e., gram-moles to grams or TEQ to grams) are not performed internally by the utility (these types of unit conversions must be performed using the RateAdjRF utility). This tab-delimited file also includes hourly and 24-hour summaries of the off-network activity and VMT, VHT, and speed.

Link emissions may also be output by county, pollutant, process, and each SUT/fuel type combination. If specified, the tab-delimited activity and emissions by SCC output file is also created, which lists the activity and emissions for each SCC pollutant by SCC.

## TTI EMISSIONS ESTIMATION UTILITIES FOR MOVES2014A-BASED TOTAL ENERGY CONSUMPTION

The following is a summary of utilities developed by TTI (written in the Visual Basic programming language) for producing total energy consumption (TEC) using the latest version of EPA's MOVES model (MOVES2014a). These utilities calculate emissions rates using the output from MOVES, make special adjustments to the emissions factors (when required), and multiply them with travel model link-based or HPMS-based (virtual link) activity estimates and off-network activity (produced using the utilities discussed in the previous sections) to produce emissions at user-specified temporal and spatial scales.

The main utilities for calculating hourly and 24-hour TEC using MOVES are RatesCalcTEC, RatesAdjTEC, and TECCalc. The RatesCalcTEC utility assembles the TEC rates from the MOVES output in terms of rate-per-activity. The RatesAdjTEC utility makes special adjustments to the TEC rates when required. The TECCalc utility calculates TEC by hourly time periods, producing a tab-delimited summary file (including 24-hour totals).

### RatesCalcTEC

The RatesCalcTEC utility assembles the TEC rates in terms of rate-per-activity (i.e., joules per mile, joules per start, and joules per SHI) into one output database. If not specified, TEC rates are copied for each process in the TEC rate tables. The utility also uses the movesrun database table to determine the units of TEC in the MOVES tables, which will be added to the output TEC rate database tables, allowing the user to specify any of the units available in MOVES. The type of activity associated with the TEC rates is determined by the process, as the table MOVES2014a Total Energy Consumption Process and Corresponding Activity for Rate-per-Activity TEC Rates shows.

### MOVES2014a Total Energy Consumption Process and Corresponding Activity for Rate-per-Activity TEC Rates.

MOVES2014a Emissions Process	Activity	Emissions Rate Units
Running Exhaust	Miles Traveled	Rate/Mile
Start Exhaust	Starts	Rate/Start
Extended Idle Exhaust	Extended Idle Hours	Rate/Extended Idle Hour
Auxiliary Power Exhaust	APU Hours	Rate/APU Hour

For the rate/mile emissions rates, the utility creates a copy of the TEC rates in the specified output database with the table name ttirateperdistanceTEC. If specific processes are specified, only the TEC rates for those processes are copied to the ttirateperdistanceTEC table. Otherwise,

all of the TEC rates are copied to the ttirateperdistanceTEC table. The utility also adds a “Units\_Per\_Activity” field to the ttirateperdistanceTEC table and fills that field with the energy units extracted from the movesrun database table. The rateperstart and rateperhourTEC rate tables are processed in a similar manner to produce the ttirateperstartTEC and ttirateperhourTEC rate tables.

### RatesAdjTEC

The RatesAdjTEC utility applies emissions rate adjustments to a TEC rate database table produced by the RatesCalcTEC utility (ttirateperdistanceTEC, ttirateperstartTEC, or ttirateperhourTEC) or by this utility to produce a new emissions rate database table in the same format as the input emissions rate database table. The emissions rate adjustments can be linear adjustments that are applied to all emissions rates or can be applied by SUT, fuel type, pollutant, and process (adjustments may also include roadway type, average speed bin, and hour). The user has the option of selecting which units will be in the new TEC rate database table. This allows the user to perform any unit conversions between energy units (i.e., joules to) without providing any addition adjustment factors. The utility also has the option for combining multiple emissions rate database tables into one new emissions rate database table, if the input emissions rate database tables are in the same format.

For the first input emissions rate database table, the utility extracts the TEC rates for the from the input database TEC rate table, applies the rate adjustments (if necessary) and any unit conversion adjustments, and saves these adjusted TEC rates. If more than one TEC rate database table is input, then the utility performs a similar calculation process to the first input TEC rate database table for each input TEC rate database table. If more than one TEC rate table is, the adjusted TEC rates are summed to produce one TEC rate.

After processing all of the input TEC rate database tables, the utility creates a new TEC rate database table in the same format as the first input emissions rate database table and writes the adjusted TEC rates to this new TEC rate database table. Using MySQL code, the utility also creates a minimum and maximum TEC rate summary for each input emissions rate table and the output emissions rate table by process and source type/fuel type, which is written to a tab-delimited file specified by the user.

### TECcalc

The TECcalc utility estimates the hourly TEC for one user-specified county using the TEC rates (either from RatesCalcTEC or RatesAdjTEC), the VMT mix, the hourly link VMT and speeds activity estimates (either from TRANSVMT or VirtualLinkVMT), and the off-network activity (either vehicle population or starts, SHI, and APU hours). This utility produces a tab-delimited output summary (including hourly and 24-hour totals). The primary inputs to EmsCalcTEC are:

- TEC rates from RatesCalcTEC or RatesAdjTEC;
- Link-based hourly VMT and speeds developed with the TRANSVMT or VirtualLinkVMT utility. These link VMT and speeds are the same data files used to estimate the on-road mobile emissions using EmsCalc. For each link, the following information is input to TECcalc: link start node, link end node, link county number, link

roadway type number, link area type number, link VMT, and link operational speed estimate;

- 24-hour or time period VMT mix by roadway type, MOVES SUT, and MOVES fuel type (same VMT mix used to estimate the on-road mobile emissions using EmsCalc);
- Off-network activity (starts, SHI, and APU hours) by hour and SUT/fuel type (same off-network activity used to estimate the on-road mobile emissions using EmsCalc);
- VMT roadway type designations, which lists associations of the link roadway types/area type combination to the VMT mix, emissions rate, and MOVES roadway types; and
- Pollutants input file, which specifies which pollutant/process combinations for which the calculations will be performed and their respective units in the tab-delimited output.

The TEC estimation can be categorized by two basic types based on the type of TEC rates: the roadway-based TEC calculations and the off-network based TEC calculations. For the roadway-based TEC calculations ( $\text{ttirateperdistanceTEC}$  rates), the VMT for each link is distributed to each of the SUT/fuel type combinations listed in the VMT mix by roadway type (as designated in the VMT roadway type designations). If the time period VMT mix is input, each hour is assigned a time period by the user. Otherwise, the 24-hour VMT mix is used for all hours. For each pollutant/process combination in the pollutants input file, the emissions factors are selected based on the emissions rate roadway type (as designated in the VMT roadway type designations) and the link speed for each SUT/fuel type combinations listed in the VMT mix. For link speeds greater than 75 mph, the TEC rates for 75 mph are used. For link speeds less than 2.5 mph, the TEC rates for 2.5 mph are used. For those link speeds that fall between the 16 MOVES speeds, the TEC rates are interpolated using the emissions factor interpolation methodology in the following section. These SUT/fuel type combination-specific TEC rates are multiplied by the SUT/fuel type combination-specific VMT to estimate the mobile source TEC for that link by SUT/fuel type combination.

For the off-network TEC, the  $\text{ttirateperstartTEC}$  and  $\text{ttirateperhourTEC}$  rates (by SUT/fuel type) are multiplied by the appropriate activity, which is determined by the emissions process (see table MOVES2014a Total Energy Consumption Process and Corresponding Activity for Rate-per-Activity TEC Rates)

The TEC estimates are output in a tab-delimited file (including all of the SUT/fuel type combinations listed in the VMT mix on a single line, separated by a tab character) for the specified county by SUT/fuel type combination for each of the specified episode time periods. A 24-hour (or total if all 24 hours are not specified) output is also included in the tab-delimited file. Only those pollutant/process combinations in the pollutants input file with tab-delimited output units other than “NONE” will appear in the tab-delimited output file. Prior to output, any unit conversions between energy units (i.e., kilojoules to joules) are performed by the utility. This tab-delimited file also includes hourly and 24-hour summaries of the off-network activity and VMT, VHT, and speed.