Appendix A. 2017 Baseline and 2030 Technology Scenario Emissions Inventory Documentation

This technical analysis report documents the methodology and assumptions used to produce the greenhouse gas (GHG) inventory for Maryland's on-road portion of the transportation sector. Statewide emissions have been estimated for the 2017 baseline and 2030 forecast technology scenario based on the most recent traffic trends. The inventory was calculated by estimating emissions for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Those emissions were then converted to carbon dioxide equivalents that are measured in the units of million metric tons (mmt CO_2e). Carbon dioxide represents about 97 percent of the transportation sector's GHG emissions.

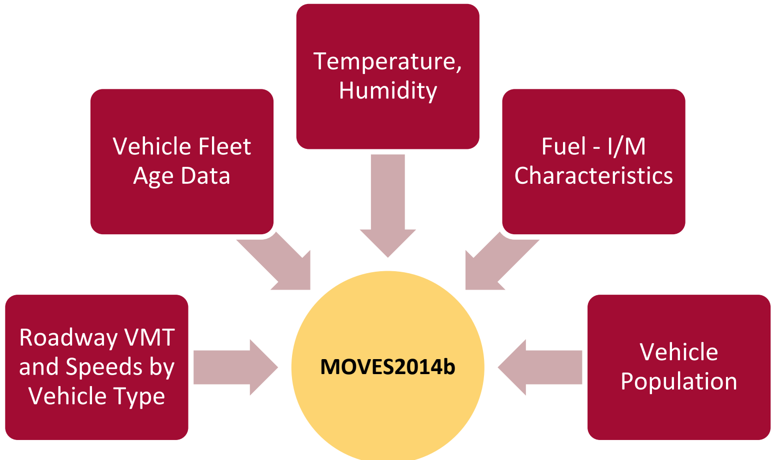
The on-road portion of the inventory was developed using EPA's emissions model MOVES2014b (Motor Vehicle Emissions Simulator) released in August 2018. The MOVES2014b model improves estimates of emissions from nonroad mobile sources and does not change the on-road emissions results of MOVES2014a. With MOVES, greenhouse gases are calculated from vehicle energy consumption rates and vary by vehicle operating characteristics including speed, engine size, and vehicle age.

On-Road Analysis Process

The data, tools and methodologies employed to conduct the on-road vehicle GHG emissions inventory were developed in close consultation with MDE and are consistent with the *MOVES2014, MOVES2014a, and MOVES2014b Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, EPA-420-B-18-039, August 2018*. MOVES2014b incorporates all existing CAFE standards in place in 2017 plus: a) medium/heavy duty greenhouse gas standards for model years 2014-2018, b) light duty greenhouse gas standards for model years 2017-2025, and c) Tier 3 fuel and vehicle standards for model years 2017-2025.

As illustrated in Figure A.1, the MOVES2014b model has been integrated with local traffic, vehicle fleet, environmental, fuel, and control strategy data to estimate statewide emissions.

Figure A.1 Emission Calculation Data Process



The modeling assumptions and data sources were developed in coordination with MDE and are consistent with other SIP-related inventory efforts. The process represents a "bottom-up" approach to estimating statewide GHG emissions based on available roadway and traffic data. A "bottom-up" approach provides several advantages over simplified "top-down" calculations using statewide fuel consumption. These include:

- Addresses potential issues related to the location of purchased fuel. Vehicle trips with trip ends outside of the state (e.g. including "thru" traffic) create complications in estimating GHG emissions. For example, commuters living in Maryland may purchase fuel there but may spend much of their traveling in Washington D.C. The opposite case may include commuters from Pennsylvania working in Maryland. With a "bottom-up" approach, emissions are calculated for all vehicles using the transportation system.
- Allows for a more robust forecasting process based on historic trends of VMT or regional population and employment forecasts and their relationship to future travel. For example, traffic data can be forecasted using growth assumptions determined by the MPO through their analytic (travel model) and interagency consultation processes.

GHG emission values are reported as annual numbers for the 2017 baseline and 2030 technology scenarios. The annual values were calculated based on annual MOVES runs as summarized in Figure A.2. Each annual run used traffic volumes, and speeds that represent an annual average daily traffic (AADT) condition, and temperatures and fuel input parameters representing an average day in each month.

Figure A.2 Calculation of Annual Emissions

For the 2017 and 2030 technology scenario emissions inventories, the traffic data was based on roadway segment data obtained from the Maryland State Highway Administration (SHA). This data does not contain information on congested speeds and the hourly detail needed by MOVES. As a result, post-processing software (PPSUITE) was used to calculate hourly-congested speeds for each roadway link, apply vehicle type fractions, aggregate VMT and VHT, and prepare MOVES traffic-related input files. The PPSUITE software and process methodologies are consistent with that used for state inventories and transportation conformity analyses throughout Maryland.

Other key inputs including vehicle population, temperatures, fuel characteristics and vehicle age were obtained from and/or prepared in close coordination with MDE staff. The following sections summarize the key input data assumptions used for the inventory runs.

Summary of Data Sources

A summary of key input data sources and assumptions were developed in consultation with MDE and are consistent with the *MOVES2014, MOVES2014a, and Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, EPA-420-B-18-039, August 2018* and are provided in Table A.1. Many of these data inputs are consistent to those used for SIP inventories and conformity analyses. Several data items require additional notes:

- Traffic volumes and VMT are forecasted for the 2030 technology scenario analysis. A discussion of forecasted traffic volumes and vehicle miles of travel (VMT) is discussed in more detail in the following section.
- Vehicle population is a key input that has an important impact on start and evaporative emissions. The MOVES Model requires the population of vehicles by the thirteen source type categories.   For light duty vehicles, vehicle population inputs were prepared and provided by MDE for base year (2017). For the analysis year 2030, the vehicle population was forecasted based on projected household and population growth obtained from state and MPO sources. For heavy-duty trucks, vehicle population was calculated from VMT using MOVES default estimates for the typical miles per vehicle by source type (e.g. vehicle type). The PPSUITE post processor automatically prepares the vehicle population file under this method.
- The vehicle mixes are another important file that is used to disaggregate total vehicle volumes and VMT to the 13 MOVES source types.   The vehicle mix was calculated based on 2017 SHA vehicle type pattern percentages by functional class, which disaggregates volumes to four vehicle types: light-duty vehicles, heavy-duty vehicles, buses, and motorcycles. As illustrated in Figure A.3, from these four vehicle groups, MOVES default Maryland county VMT distributions by source type was used to divide the four groups into each of the MOVES 13 source types.

Figure A.3 Defining Vehicle Types

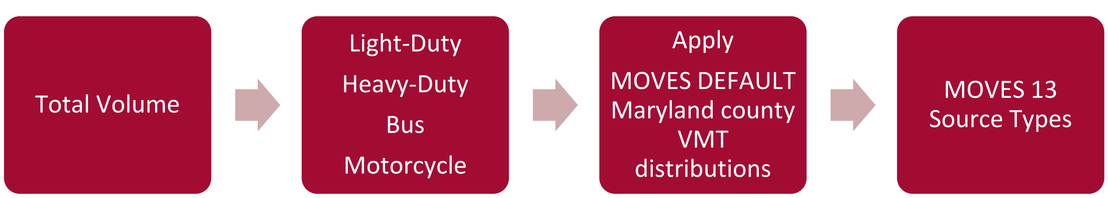


Table A.1 Summary of Key Data Sources

Data Item	Source	Description	Difference between 2017 and 2030Technology
Roadway Characteristics	2017 MDOT SHA Universal Database	Includes lanes, segment distance, facility type, speed limit	*Same Data Source*
Traffic Volumes	2017 MDOT SHA Universal Database	Average Annual Daily Traffic Volumes (AADT)	Volumes forecasted for 2030 technology scenario
Seasonal Adjustments	SHA 2017 *ATR Station Reports in the Traffic Trends System Report Module* from the MDOT SHA website	Used to develop day and month VMT fractions as inputs to MOVES to disaggregate annual VMT to daily and monthly VMT	*Same Data Source*
VMT	Highway Performance Monitoring System 2017	Used to adjust VMT to the reported 2017 HPMS totals by county and functional Class	VMT forecasted for 2030 technology scenario
Hourly Patterns	MDOT SHA 2016 *Traffic Trends System Report Module* from the SHA website	Used to disaggregated volumes and VMT to each hour of the day	*Same Data Source*
Vehicle Type Mix	2017 MDOT SHA vehicle pattern and hourly distribution data; MOVES default Maryland county VMT distributions	Used to split traffic volumes to the 13 MOVES vehicle source types	*Same Data Source*
Ramp Fractions	MOVES Defaults	MOVES Defaults	*Same Data Source*
Vehicle Ages	2017 Maryland Registration data; MOVES national default age distribution data	Provides the percentage of vehicles by each model year age	*Used 2017 registration data for light duty vehicles and MOVES2014 national default data for source types 61 & 62.*
Hourly Speeds	Calculated by PPSUITE Post Processor	Hourly speed distribution file used by MOVES to estimate emission factors	Higher volumes produce lower speeds in 2030
I/M Data	Provided by MDE	Based on current I/M program	Different I/M Program Characteristics
Fuel Characteristics	Provided by MDE	Fuel characteristics vary by year	Different Fuel Characteristics
Temperatures	Provided by MDE	Average Monthly Temperature sets	*Same Data Source*
Vehicle Population	Light duty vehicles: used vehicle population data provided by MDE for 2017 baseline and applied growth rates to forecast population to 2030	Number of vehicles by MOVES source type which impact forecasted start and evaporative emissions	2030 based on projected demographic and VMT growth

	Heavy duty trucks: Calculated by PPSUITE Post Processor; MOVES Default Miles/Vehicle Population Data

Traffic Volume and VMT Forecasts

The traffic volumes and VMT within the MDOT SHA traffic database were forecast to estimate future year emissions. Several alternatives are available to determine forecast growth rates, ranging from historical VMT trends to the use of MPO-based travel models that include forecast demographics for distinct areas in each county. For the 2030 technology scenario, the forecasts were determined based on historic trends of 1990-2017 highway performance monitoring system (HPMS) VMT growth. The average statewide annualized growth rate through 2030 for this scenario is 1.2 percent. Table A.2 summarizes the growth rates by county.

Table A.2 VMT Annual Growth Rates (Per Maryland CAP) for 2030 Technology Scenario

County	2030 Technology (Based on 1990-2017 HPMS)
Allegany	0.6%
Anne Arundel	1.2%
Baltimore	1.0%
Calvert	2.3%
Caroline	1.3%
Carroll	1.3%
Cecil	1.8%
Charles	1.6%
Dorchester	0.9%
Frederick	1.8%
Garrett	1.5%
Harford	1.1%
Howard	2.2%
Kent	0.0%
Montgomery	0.9%
Prince George's	1.1%
Queen Anne's	2.0%
Saint Mary's	1.5%
Somerset	0.8%
Talbot	1.4%
Washington	1.6%
Wicomico	1.7%
Worcester	0.5%
Baltimore City	0.2%
Statewide	**1.2%**

Table A.3 summarizes total 2017 baseline and 2030 forecast VMT by vehicle type.

Table A.3 2017 Baseline and 2030 Technology Scenario - VMT by Vehicle Type

Annual VMT (millions)	2017 Baseline	2030 Technology
Light-Duty	55,799	64,633
Medium/Heavy-Duty Truck & Bus	4,093	4,759
TOTAL VMT (in millions)	59,892	69,392

The analysis process (e.g. using PPSUITE post processor) re-calculates roadway speeds based on the forecast volumes. As a result, future year emissions are sensitive to the impact of increasing traffic growth on regional congestion.

Vehicle Technology Adjustments

The MOVES2014b emission model includes the effects of the following post-2017 vehicle programs on future vehicle emission factors:

- **National Program Phase 2 (Model Years 2017-2025)** – The light-duty vehicle fuel economy for model years between 2017 and 2025 are based on the October 15, 2012 Rule "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards" (EPA-HQ-OAR-2010-0799 and No. NHTSA-2010-0131). The new fuel economy improvements apply to model years 2017 to 2025. The standards are projected to result in an average 163 gram/mile of CO_2 in model year 2025. This equates to an average fuel economy of 54.5 mpg.
- **Maryland Clean Car Program** – The Maryland Clean Car Program implements California's low emissions vehicle (LEV) standards to vehicles purchased in Maryland starting with model year 2011. By creating a consistent national fuel economy standard, the 2012-2016 National Program and the Phase 2 2017-2025 National Program, which closely resemble the California program, replaces Maryland's Clean Car Program for those model years. As a result, the GHG reduction credits for the Maryland Clean Car Program, apply only to 2011 model year vehicles and post-2011 electric vehicles that meet the California's zero emission program (ZEV) requirement.
- **National 2014-2018 Medium and Heavy Vehicle Standards** – The medium- and heavy- duty vehicle fuel economy for model years between 2014-2018 are based on the September 15, 2011 Rule "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles". The rulemaking has adopted standards for three main regulatory categories: combination tractors, heavy-duty pickups and vans, and vocational vehicles. For combination tractors, the final standard will achieve 9 to 23 percent of reduction in carbon dioxide (CO2) emissions and fuel consumption by the 2017 model year compared to the 2010 baseline. For heavy-duty pickup trucks and vans, separate standards have been established for gasoline and diesel trucks, which will achieve up to a 10 percent reduction for gasoline vehicles and a 15 percent reduction for diesel vehicles by the 2018 model year (12 and 17 percent respectively if accounting for air conditioning leakage). Lastly, for vocational vehicles, the final standards would achieve CO2 emission reductions from six to nine percent by the 2018 model year.

Emission Results

The 2017, and 2030 technology scenarios emission results for the Maryland statewide GHG inventories are provided in Table A.4 for 2017 Baseline, and A.5 for the 2030 technology scenario. Within each table, emissions are also provided by fuel type and vehicle type.

Table A.4 2017 Annual On-Road GHG Emissions (mmt)

	VMT (Millions)	CO_2	CH_4	N_2O	CO_2e
TOTAL	**59,892**	**28.41**	**0.00102**	**0.00062**	**28.62**
By Fuel Type					
Gasoline	55,028	22.105	0.000620	0.000609	22.302
Diesel	4,544	6.164	0.000343	0.000010	6.176
CNG	12.3	0.015	0.000049	0.000001	0.016
E-85	307	0.122	0.000006	0.000002	0.122
By MOVES Vehicle Type					
Motorcycle	266	0.098	0.000008	0.000001	0.099
Passenger Car	25,592	8.788	0.000198	0.000211	8.855
Passenger Truck	26,209	11.859	0.000403	0.000349	11.973
Light Commercial Truck	3,731	1.561	0.000054	0.000034	1.572
Intercity Bus	124	0.220	0.000005	0.000000	0.220
Transit Bus	82	0.107	0.000052	0.000001	0.108
School Bus	195	0.183	0.000011	0.000001	0.183
Refuse Truck	35	0.062	0.000002	0.000000	0.062
Single Unit Short-haul Truck	1,367	1.384	0.000067	0.000019	1.391
Single Unit Long-haul Truck	81	0.076	0.000004	0.000000	0.077
Motor Home	19	0.019	0.000001	0.000000	0.020
Combination Short-haul Truck	531	0.934	0.000022	0.000001	0.935
Combination Long-haul Truck	1,659	3.114	0.000191	0.000003	3.120

Table A.5 2030 Technology Scenario Annual On-Road GHG Emissions (mmt)

	VMT (Millions)	CO_2	CH_4	N_2O	CO_2e
TOTAL	**69,392**	**24.23**	**0.00090**	**0.00040**	**24.37**
By Fuel Type					
Gasoline	61,698	16.980	0.000291	0.000373	17.098
Diesel	5,390	6.592	0.000547	0.000012	6.609
CNG	14.7	0.017	0.000041	0.000001	0.018
E-85	2,290	0.643	0.000024	0.000014	0.648
By MOVES Vehicle Type					
Motorcycle	310	0.115	0.000009	0.000001	0.115
Passenger Car	29,559	6.821	0.000130	0.000148	6.868
Passenger Truck	30,464	9.432	0.000212	0.000205	9.498
Light Commercial Truck	4,300	1.270	0.000035	0.000027	1.279
Intercity Bus	143	0.242	0.000007	0.000000	0.242
Transit Bus	93	0.115	0.000045	0.000001	0.116
School Bus	229	0.201	0.000013	0.000001	0.202
Refuse Truck	41	0.070	0.000002	0.000000	0.070
Single Unit Short-haul Truck	1,594	1.501	0.000092	0.000010	1.507
Single Unit Long-haul Truck	89	0.078	0.000005	0.000000	0.078
Motor Home	22	0.022	0.000001	0.000000	0.022
Combination Short-haul Truck	489	0.810	0.000027	0.000001	0.811
Combination Long-haul Truck	2,059	3.556	0.000322	0.000004	3.565