

**Development of MANE-VU Onroad Mobile Source Emissions for  
2007 and 2020 using MOVES**

**Prepared for:**

Northeast States for Coordinated Air Use Management (NESCAUM)

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## **1. Introduction**

NESCAUM has estimated onroad mobile source emissions for 10 jurisdictions in the Mid-Atlantic/Northeast Visibility Union (MANE-VU) region using MOVES (Motor Vehicle Emissions Simulator). The jurisdictions are Connecticut (CT), Delaware (DE), District of Columbia (DC), Maine (ME), Maryland (MD), Massachusetts (MA), New Hampshire (NH), New Jersey (NJ), Rhode Island (RI), and Vermont (VT). This work is part of the regional effort to help states develop State Implementation Plans (SIPs) for ground-level ozone and fine particulate matter (PM<sub>2.5</sub>), as well as demonstrate reasonable progress towards improved visibility under the federal regional haze rule.

### **1.1 The EPA MOVES model**

MOVES is a computer program designed by the U.S. Environmental Protection Agency (EPA) Office of Transportation and Air Quality (OTAQ) to estimate air pollutant emissions from mobile sources. It replaces EPA's previous emissions model for on-road mobile sources, MOBILE6.2. This new emission modeling system currently estimates emissions from cars, trucks, and motorcycles (EPA, 2010). MOVES allows air quality planners to estimate on-road mobile source emissions from the existing vehicle fleet, as well as emission reductions from potential strategies to address mobile source pollution.

### **1.2 Rationale for using MOVES "lookup tables" approach**

Since early 2010, NESCAUM, participating agencies, OTAQ, and OAQPS have worked together to develop an acceptable and practical approach for estimating mobile emissions for the region within a reasonable period of time. The consensus was to use the MOVES "lookup tables" approach coupled with a two fuel season assumption representing summer and winter conditions.

MOVES can be run in two manners: 1) an "inventory" mode that provides emission inventory estimates as mass, and 2) an "emissions rate" mode that produces "lookup tables" of emission factors as mass per unit activity. The lookup tables must be post-processed to produce an inventory of mass emissions.

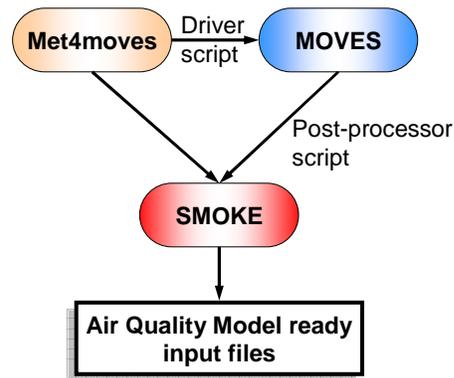
While it is more accurate to run MOVES on a daily basis to retain the hourly temperature influence on mobile source emissions, it is prohibitively time consuming to model an entire year for all counties in the MANE-VU region if using the inventory approach. As such, EPA developed the SMOKE-MOVES Integration Tool for use with the lookup table approach in an effort to minimize the number of MOVES runs needed, thus reducing the time required to model an entire year.

The SMOKE-MOVES Integration Tool was released on July 14, 2010 (see Figure 1). An updated version MOVES2010a was released later in 2010 to further improve runtime. Using this tool, a large number of MOVES runs are required to generate a package of emission factor lookup tables to estimate emissions for one county over one month or one fuel season. The Integration Tool provides scripts to conduct MOVES preprocessing,

MOVES runs, MOVES post-processing, and SMOKE processing that generates CMAQ-ready emission files. The Integration Tool formats the MOVES emission rate look up tables for SMOKE, but extra preprocessing is required separately to re-format MOVES activity input data (vehicle miles traveled, vehicle population by type, and average speed) for use by SMOKE to generate mass emissions from the emission rate look up tables.

## SMOKE-MOVES has three parts

- Met4MOVES: Meteorological data preprocessor
  - Determines which temperatures and humidity are needed for counties within the modeling domain
- MOVES is run to create emissions factors
  - MOVES 2010
  - Driver script
  - Post-processing script converts factors into format needed by SMOKE
- SMOKE processing applies the emission factors to the activity data to compute grid-cell emissions



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Figure source: M. Houyoux, Summary of SMOKE-MOVES Integration Tool, v3, 2010.

**Figure 1. SMOKE-MOVES Integration Tool.**

## 2. MOVES Input Data Collection and Conversion

### 2.1 MOVES inputs submitted by states

#### 2.1.1 MOVES inputs imported by County Data Manager

The required MOVES inputs for SIP modeling include vehicle population, vehicle age distribution, vehicle average speed distribution, vehicle miles traveled (VMT), month VMT distribution, day VMT distribution, hour VMT distribution, road VMT distribution, ramp fraction, fuel supply, fuel formulation, inspection and maintenance (I/M) program, and meteorology. The MOVES county data manager can be used to import these 13 inputs into the MOVES input database.

A county-based input organization scheme and naming convention was developed for states to submit MOVES inputs. Table 1 gives the full list of MOVES input tables for

each county. In addition, NESCAUM also extracted from the MOVES2010 default database and constructed an input template file for states to use as a reference.

**Table 1. Required onroad inputs in MOVES format for each county**

File names	Data Tab names
StateCountyFips_Year_input_yyyymmdd.xls	Met
	sourceTypePopulation
	sourceTypeAgeDistribution
	hpmsVTypeVMT
	monthVMTFraction
	dayVMTFraction
	hourVMTFraction
	AvgSpeedDistribution
	roadTypeDistribution
	rampFraction
	fuelSupply
	fuelFormulation
	IMCoverage

Among the ten jurisdictions modeled by NESCAUM, six (CT, DE, MD, MA, NJ, and VT) submitted 2007 MOVES inputs. The four others (DC, ME, NH, and RI) elected to submit MOBILE6 inputs or EPA vmt converter files plus vehicle populations that are required by MOVES but not by MOBILE6.

MACTEC and MARAMA reviewed the state submitted inputs to ensure that the files were correctly formatted, contained all required information, and that the information conformed to standard codes or data entry types for each data element, and represented the model year. Feedback and results from each quality assurance review was provided to each state for any data requiring change or clarification. Based on this feedback, onroad inputs were developed and transferred to NESCAUM.

**2.1.2 Early NLEV and Cal LEV programs**

NESCAUM collected information regarding the early adoption of NLEV and California (Cal) LEV programs by states in the MANE-VU region, which is shown in Table 2.

For NLEV, the table of emission rates contained in the default MOVES2010a database includes the effects of the NLEV standards beginning with the 2001 model year. The default database, however, does not include NLEV standards for the 1999 and 2000 model years adopted by some MANE-VU states. EPA provided separately an early NLEV database for 1999 and 2000 that contained a set of alternate hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) start and running emission rates. Therefore if states adopted NLEV standards prior to 2001, the early NLEV database was used for MOVES modeling.

**Table 2. Early NLEV and Cal LEV I & II**

State	Early NLEV	Cal LEV in 2007	Cal LEV in future years
CT	Yes	No	No LEV I; LEV II from 2008
DE	Yes	No	LEV II from 2014
DC	Yes	No	LEV II from 2012
ME	Yes	LEV I from 2001; LEV II from 2004	LEV I from 2001; LEV II from 2004
MD	Yes	No	No LEV I; LEV II from 2011
MA	No	LEV I from 1995; LEV II from 2004	LEV I from 1995; LEV II from 2004
NH	Yes	No	No
NJ	Yes	No	No LEV I; LEV II from 2009
RI	Yes	No	No LEV I; LEV II from 2008
VT	No	LEV I from 2000; LEV II from 2004	LEV I from 2000; LEV II from 2004

The Cal LEV standards are different from the federal standards and are not included in the default MOVES2010a database. A tailored EPA Cal LEV database needs to be included in MOVES modeling for a state adopting Cal LEV that depends on the adopting year. EPA has created a separate input database for those states that have adopted the Cal LEV program, which provides a set of alternate HC, CO, and NO<sub>x</sub> start and running emission rates for model years 1994 through 2050, including both the LEV I and LEV II California standards.

## **2.2 Developing MOVES input databases**

Refueling emissions are simulated in MOVES inventory runs because they are not included in MOVES lookup table runs. The MOVES input databases were developed primarily for MOVES inventory runs, but these were useful for MOVES lookup table runs as well. MOVES inventory runs convert VMT and VPOP from MOVES format to SCC types that are required by SMOKE processing of the emission rate lookup tables. In addition, the step of data importing also provides a layer of quality assurance for the state-submitted inputs.

### **2.2.1 2007 MOVES input databases**

CT, DE, MD, MA, NJ, and VT submitted 2007 onroad inputs in MOVES format. The MOVES county data manager was employed in batch mode to import the inputs into a

MOVES MySQL database for each county in a state. For meteorology, MD, MA, and NJ submitted 2007 monthly average meteorology for their counties, while the NMIM 2007 meteorology provided by MARAMA was imported for CT, DE, and VT.<sup>1</sup>

DC, NH, and RI ran EPA vmt converter and prepared vehicle populations for DC or the state's counties. To build up the MOVES MySQL input database, NESCAUM imported the vehicle population provided, and used the annual VMT, road VMT distribution, and vehicle age distribution contained in the vmt converter files. The 2007 NMIM meteorology was imported for DC and each county in the states. The other inputs listed in Table 1 were extracted from the MOVES2010a default databases for DC and each county in the states, which include vehicle average speed distribution, month VMT distribution, day VMT distribution, hour VMT distribution, ramp fraction, fuel supply, fuel formulation, and inspection and maintenance (I/M) programs.

ME provided for each of its counties the 2007 vehicle population, the 2005 SCC level VMT, and 2007 VMT growth factors versus 2005. NESCAUM grew the 2005 VMT to 2007 and converted them to MOVES format by using the EPA vmt converter. The default MOBILE6 registration data were used in the converter. To build MOVES MySQL input database, NESCAUM imported the vehicle population provided, and used the annual VMT, road VMT distribution, and vehicle age distribution contained in the ME VMT converter files. The 2007 NMIM meteorology was imported for each county in ME. The other inputs listed in Table 1 were extracted from the MOVES2010 default databases.

### **2.2.2 2020 MOVES input databases**

CT, MD, and NJ submitted a complete set of inputs (13 tables in total) for 2020 for each county in their states. The inputs were imported directly to MOVES MySQL input databases.

DC submitted vehicle population and vehicle miles traveled for 2020. The 2020 I/M and 2012 fuel supply were exported from the MOVES2010a default database. The District submitted 2007 inputs for vehicle age distribution, road type distribution, ramp fraction, and HourVMTFraction. The 2007 NMIM meteorology was used. The other inputs are exported from the MOVES2010a default database.

DE submitted vehicle population, vehicle miles traveled, and average speed distribution for 2020. The DE 2012 fuel supply and 2020 I/M are exported from the MOVES2010a default database. State-submitted 2007 inputs were imported for the other tables.

ME submitted vehicle population and vehicle miles traveled for 2020. The ME 2012 fuel supply and 2020 I/M were exported from a MOVES2010a default database. The state-

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<sup>1</sup> Following completion of this work, DE discovered an error in its 2007 VMT activity inputs for New Castle County that also was reflected in 2020 VMT activity inputs. DE has corrected the VMT activity inputs for New Castle County, and this county has been re-run in SMOKE-MOVES for 2007 and 2020 by VA DEQ.

submitted 2007 inputs were used for source type age distribution and road type distribution. The 2007 NMIM meteorology was used. The remaining tables were exported from the MOVES2010a default database.

NH submitted vehicle population and vehicle miles traveled for 2020. The NH 2012 fuel supply and 2020 I/M were exported from MOVES2010a default database. State-submitted 2007 inputs were used for source type age distribution and road type distribution. The 2007 NMIM meteorology was used. The remaining tables were exported from the MOVES2010a default database.

RI submitted vehicle miles traveled and road type distribution for 2020. 2007 VPOP and vehicle age distribution, and the 2007 NMIM meteorology were used. The RI 2012 fuel supply and 2020 I/M and the other inputs were exported from the MOVES2010a default database.

VT submitted vehicle population and vehicle miles traveled for 2020. The VT 2012 fuel supply and 2020 I/M were exported from the MOVES2010a default database. The 2007 NMIM meteorology was used. State-submitted 2007 inputs were imported for the other tables.

### ***2.3 Selection of representative counties and fuel months***

The MOVES lookup table runs produce a set of emission rates according to speed and temperature for each combination of source and road types. A group of counties in a state can be represented by one county and can share common emission rate lookup tables if they have the same I/M programs, fuel parameters, fleet age distribution, and similar meteorology. Meteorological similarity is required for simulating emission rates of vapor venting evaporation that rely on temperature profiles. Table 3 lists the number of representative counties identified by using the criteria of same I/M, fuel, vehicle age distribution, and similar meteorology in a state. The selection is based on a summary submitted by each state. The representative county cross-reference file used by SMOKE modeling is listed in the Appendix.

Similar to the concept of representative county, the fuel month reduces the computational time of MOVES by using a single month to represent a set of months as long as the fuel parameters are the same or similar among the months. The fuel Reid vapor pressure (RVP) is used as the index to group months into summer or winter fuel seasons. Table 4 lists the fuel months of the 10 jurisdictions. July is the summer fuel month that represents May to September for most states, and February is the winter fuel month that represents October to April. Note that DE and DC have different fuel seasons from the other states. Note also that the same fuel was used for all 2007 summer months in most states as listed in Table 4, except for MD and NJ, which have slightly different RVPs that vary within 0.5 psi on a monthly basis in summer. The RVP varies within 3.0 psi among winter months. The fuel month cross-reference file used by SMOKE modeling is attached in the Appendix.

**Table 3. States and representative counties**

State	County*	# of Counties	# of Representative Counties*
CT	<i>Fairfield; Hartford</i> (Litchfield, Tolland, Windham); <i>New Haven</i> (Middlesex, New London)	8	3
DE	<i>Kent; New Castle; Sussex</i>	3	3
DC	<i>District of Columbia</i>	1	1
ME	<i>Androscoggin</i> (Kennebec, Knox, Lincoln, Sagadahoc, York); <i>Aroostook</i> (Franklin, Hancock, Oxford, Penobscot, Piscataquis, Somerset, Waldo, Washington); <i>Cumberland</i>	16	3
MD	<i>Allegany</i> (Garrett); <i>Anne Arundel</i> (Baltimore, Carroll, Cecil, Harford, Howard, Queen Anne's, Baltimore City); <i>Calvert</i> (Charles, Frederick, Montgomery, Prince George's); <i>Caroline</i> (Dorchester, Talbot, Wicomico); <i>Kent; St. Mary's; Somerset</i> (Worcester); <i>Washington</i>	24	8
MA	<i>Hampden</i> (Berkshire, Franklin, Hampshire); <i>Middlesex</i> (Barnstable, Bristol, Dukes, Essex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester)	14	2
NH	<i>Belknap</i> (Carroll, Cheshire, Coos, Grafton, Merrimack, Sullivan); <i>Hillsborough</i> (Rockingham, Strafford)	10	2
NJ	<i>Atlantic</i> (Cape May, Ocean); <i>Cumberland</i> (Burlington, Camden, Gloucester, Mercer, Salem); <i>Monmouth; Morris</i> (Bergen, Essex, Hudson, Hunterdon, Middlesex, Passaic, Somerset, Sussex, Union, Warren)	21	4
RI	<i>Providence</i> (Bristol, Kent, Newport, Washington)	5	1
VT	<i>Addison</i> (Bennington, Chittenden, Rutland, Windham, Windsor); <i>Caledonia</i> (Essex, Franklin, Grand Isle, Lamoille, Orange, Orleans, Washington)	14	2
	Total	116	29

\* County name in italics denotes a representative county. Counties in parenthesis are those represented by the immediately preceding representative county.

**Table 4. Fuel months for DC and states**

State	Summer Fuel Month: July	Winter Fuel Month: February
CD, ME, MD, MA, NH, NJ, RI, VT	May to September	October to April
DE	May to October	November to April
DC	April to October	November to March

### 3. MOVES Inventory Runs

The primary purpose of conducting MOVES inventory runs is to convert VMT and VPOP from MOVES format to SCC level for SMOKE processing. Another purpose is to calculate the refueling emissions. The description of vehicle type codes by 7-digit SCC is given in Table 5. The converted VPOP and VMT are summarized by the 12 SCC vehicle types for each state in this report. The vehicle description codes are those given by the User's Guides for the SMOKE-MOVES Integration Tool, Appendix B.

**Table 5. Vehicle type codes by SCC and descriptions**

SCC	Description
2201001	LDGV: Light Duty Gasoline Vehicles
2201020	LDGT1: Light Duty Gasoline Trucks 1
2201040	LDGT2: Light Duty Gasoline Trucks 2
2201070	HDGV: Heavy Duty Gasoline Trucks
2201080	MC: Motorcycles
2230001	LDDV: Light Duty Diesel Vehicles
2230060	LDDT: Light Duty Diesel Trucks
2230071	2BHDDV: Heavy Duty Diesel Vehicles 2B
2230072	LHDDV: Light Heavy Duty Diesel Vehicles 3, 4, 5
2230073	MHDDV: Medium Heavy Duty Diesel Vehicles 6, 7, 8A
2230074	HHDDV: Heavy Heavy Duty Diesel Vehicles 8B
2230075	BUSES: Diesel Transit, Urban and School Buses

### 3.1 2007 VPOP and VMT

Figure 2 presents the annual VPOP for each jurisdiction by 12 SCC vehicle types. Figure 3 plots the VPOP percentage of each vehicle type over the total VPOP. One interesting observation is that the percentages of light duty gasoline vehicles population (2201001, LDGV) and light duty gasoline trucks population (2201020 and 2201040, LDGT) reverse among states. For example, ME has the lowest percentage of LDGV, while its percentage of LDGT is the highest among states. In contrast, the percentage of LDGV in VT is the second highest, while the percentage of LDGT is the lowest. Other than these, the vehicle type distribution is fairly consistent among states, e.g., over 95% of the vehicle population is gasoline-fueled in all of the 10 jurisdictions.

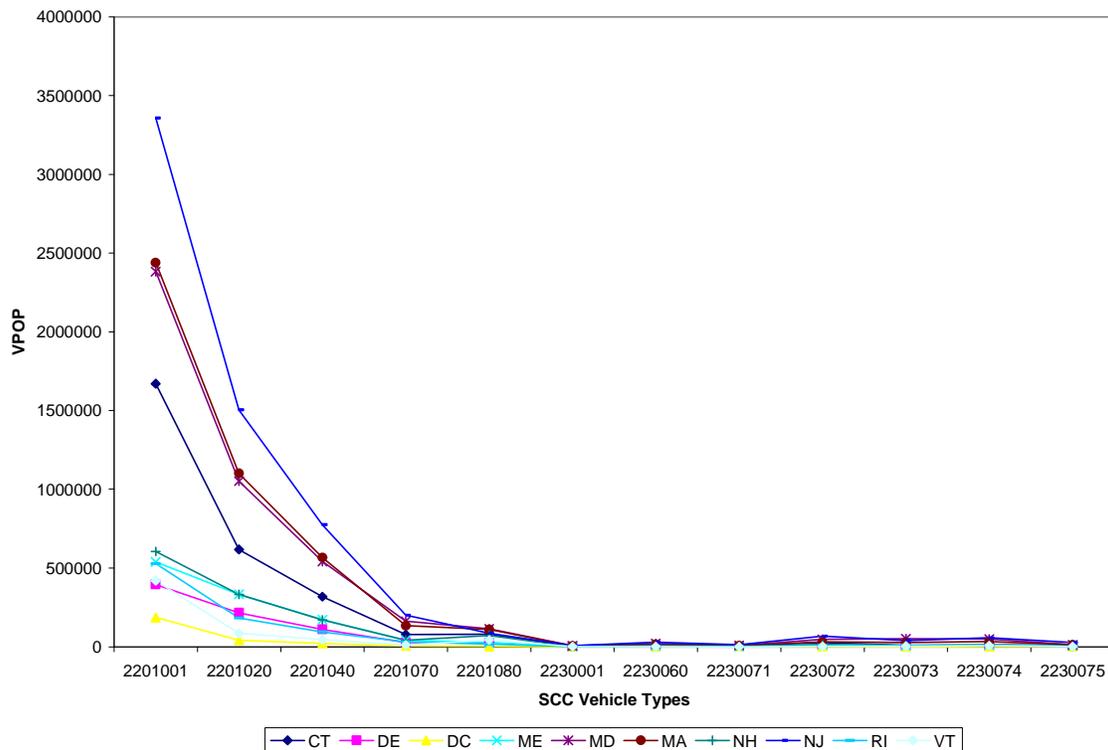
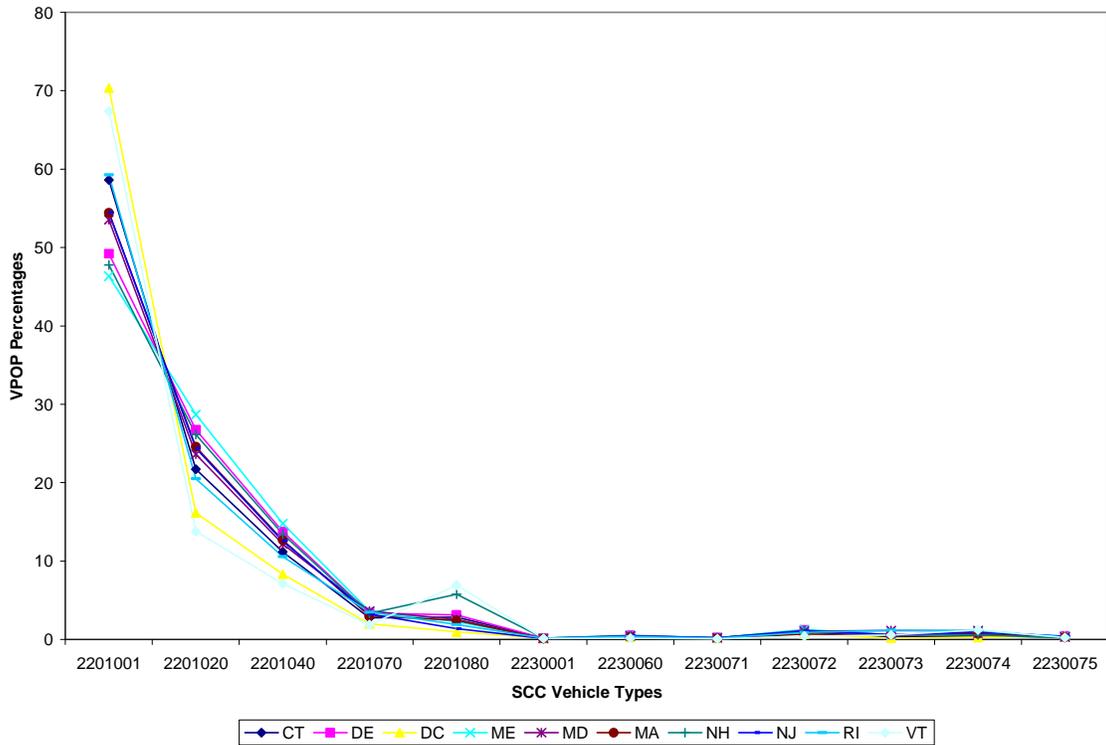


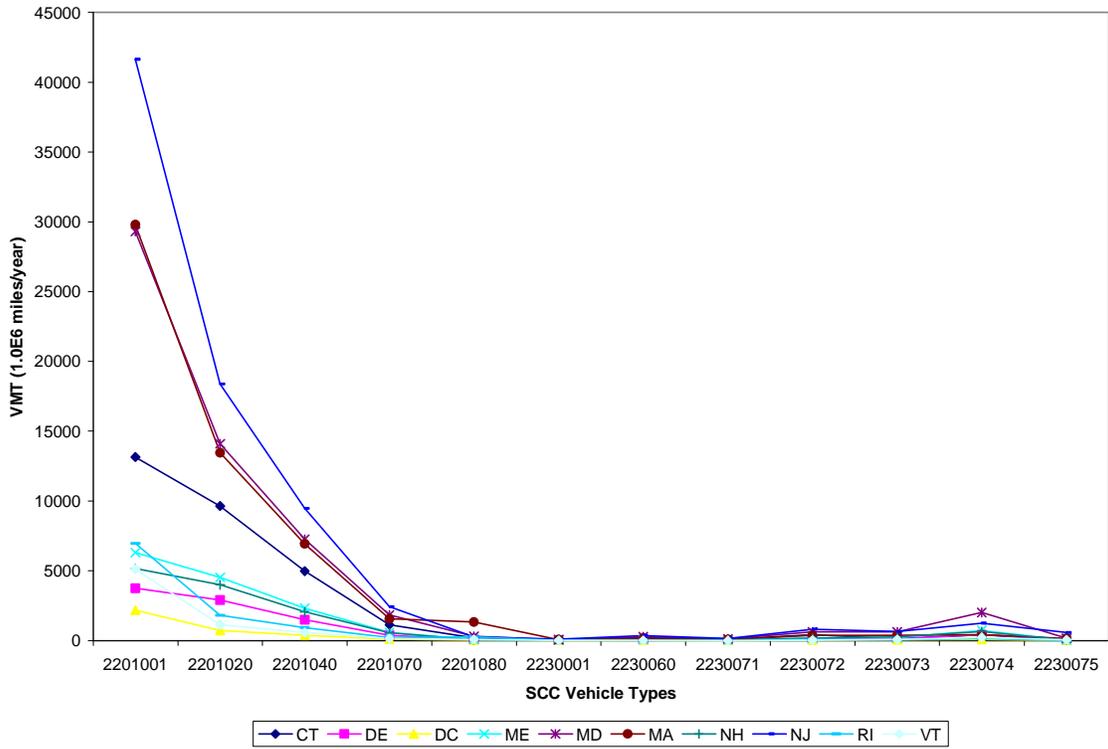
Figure 2. 2007 VPOP



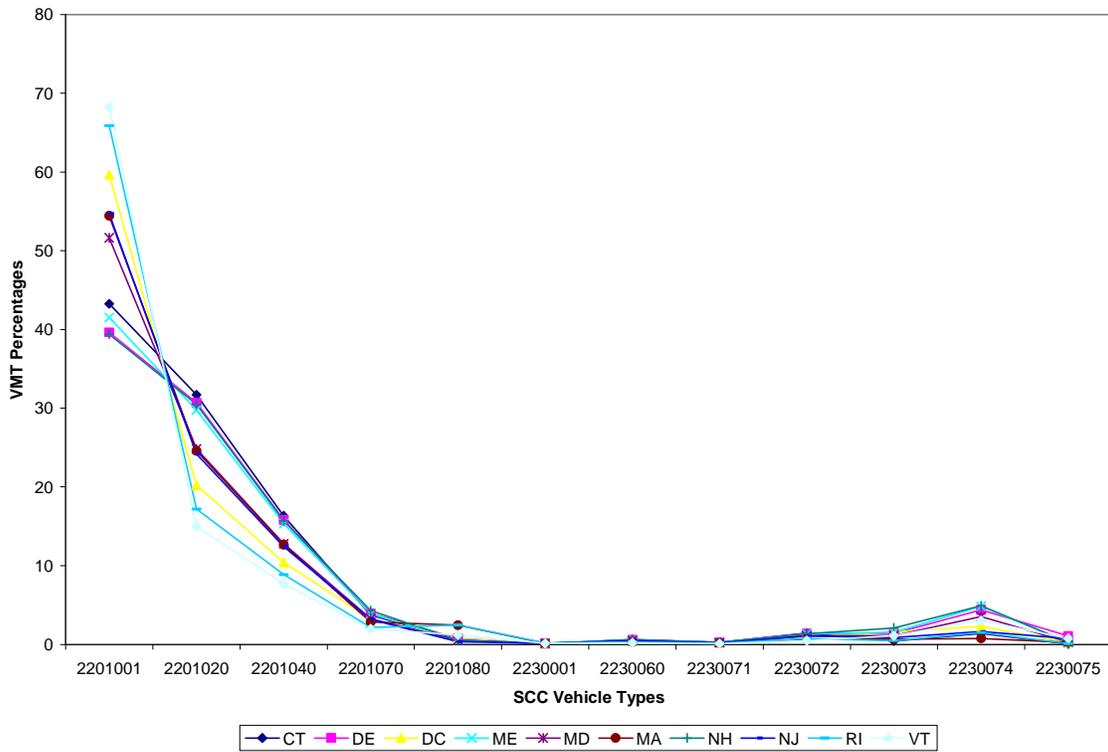
**Figure 3. 2007 VPOP Percentages**

Figure 4 presents the annual VMT for each jurisdiction by 12 SCC vehicle types. Figure 5 plots the VMT percentage of each vehicle type over the total VMT. Similar to the vehicle population distribution, the percentages of LDGV VMT (2201001) and LDGT VMT (2201020 and 2201040) reverse among states. However, the average VMT percentage of diesel vehicles is higher than their VPOP percentage in most states. This is more clearly seen in Figure 6 where the ratio of VMT over VPOP is plotted for each vehicle type.

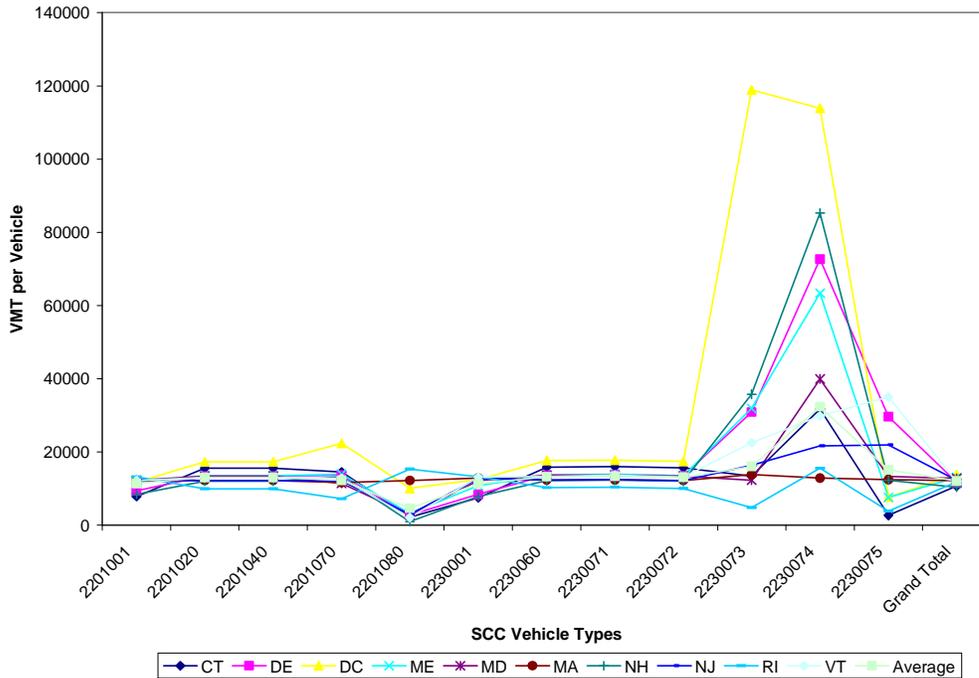
The above analysis of VMT and VPOP also provides a way to quality assure the inputs. For example, it was found in the first round of analysis that the NJ VPOP was about one third of the VPOP of MD and MA, while the VMT in NJ was higher than MD and MA. It was also found that the motorcycle VMT was comparable to that of light duty gasoline vehicles in RI. As a result, NJ and RI reviewed and made revisions to the inputs to render the VPOP and VMT consistent with other states.



**Figure 4. 2007 Annual VMT (1.0E6 miles/year)**



**Figure 5. 2007 VMT percentages**



**Figure 6. 2007 VMT/VPOP ratios**

### 3.2 2020 VPOP and VMT

Figures 7 – 9 give the VPOP, VMT, and the ratios of VMT/VPOP for 2020. The overall increase from 2007 to 2020 is about 14 percent, with some vehicle types having larger increases and some having smaller increases. The VPOP and VMT distributions among vehicle types are similar to 2007 and are not plotted. However, the 2020 VMT/VPOP ratio in NJ is several times higher than the other states, and is currently under review.

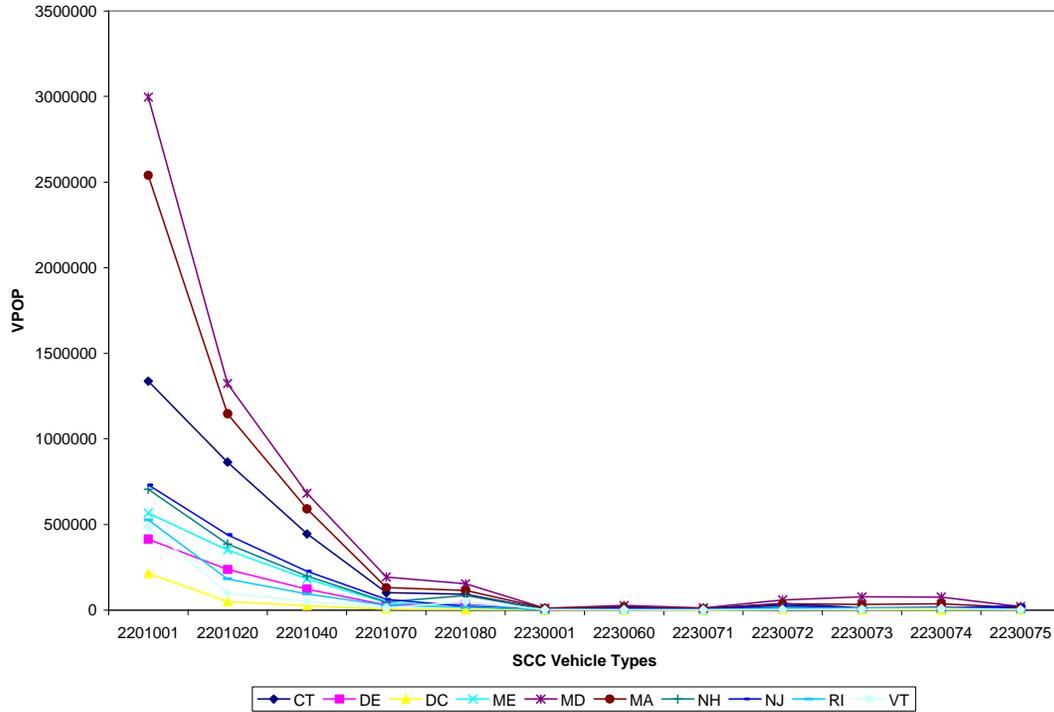


Figure 7. 2020 VPOP

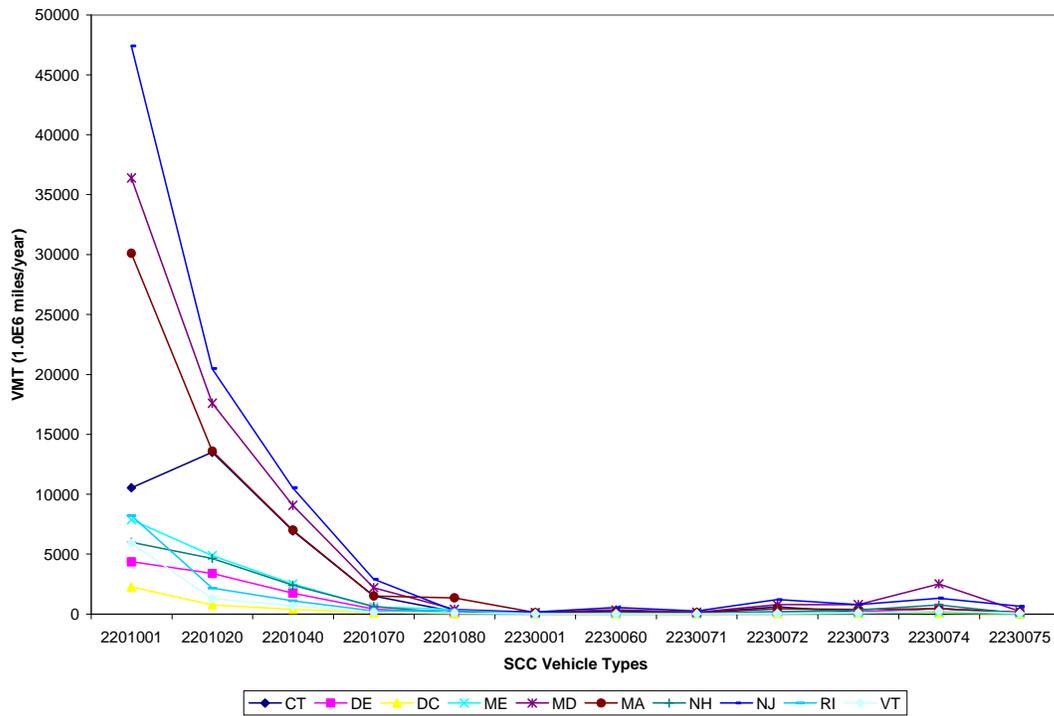
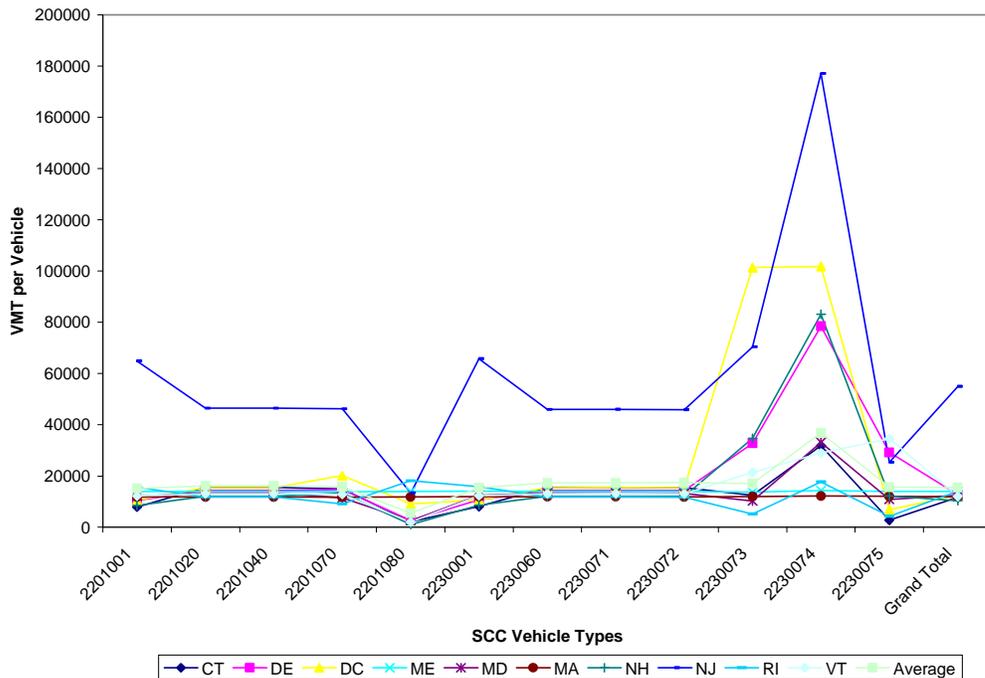


Figure 8. 2020 VMT

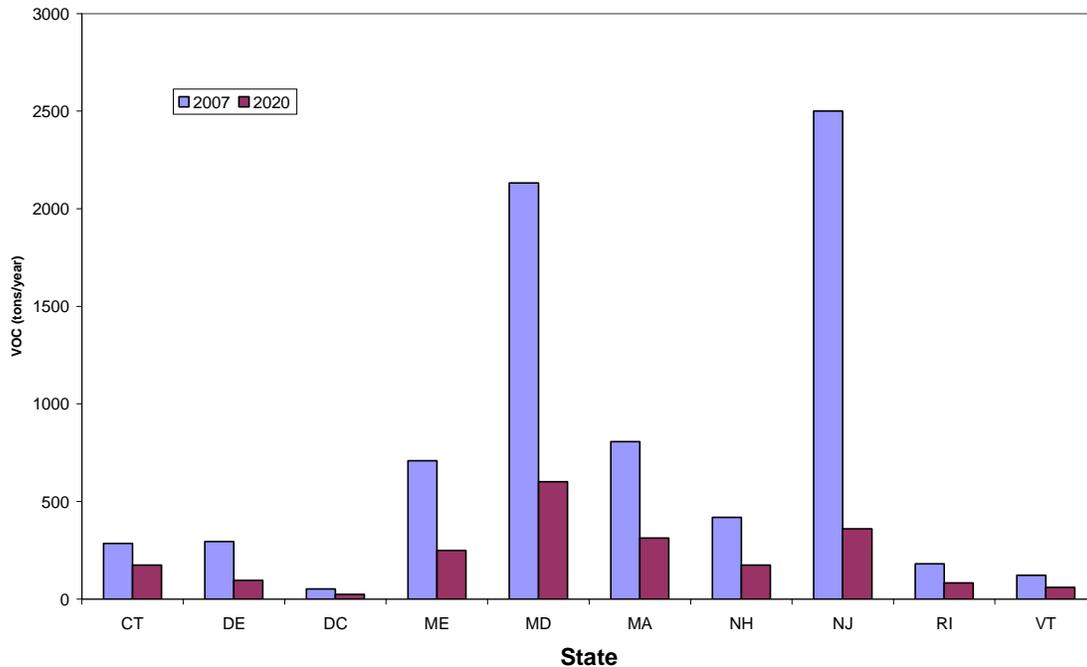


**Figure 9. 2020 VMT/VPOP ratios**

### 3.3 Refueling Emissions

Emissions of VOCs and associated air toxics occur when gasoline vapor escapes during refueling. Refueling emissions arise from two processes: 1) vapor displacement and 2) spills. Stage II refueling control programs are intended to reduce the emissions associated with both processes. The onboard refueling vapor recovery system (ORVR) installed on newer vehicles is designed to minimize the refueling losses without Stage II controls. These reductions are already accounted for by MOVES, so that the additional control of Stage II will only affect the remaining refueling losses from these ORVR vehicles and from older vehicles without ORVR.

Refueling emissions are calculated in MOVES inventory runs because they are not included in MOVES lookup table runs. They are then transferred to area source categories. Figure 10 plots the 2007 and 2020 refueling emissions. The 2020 refueling emissions are significantly lower than 2007 emissions in most states. The Stage II control efficiencies between the two years are similar; therefore the decrease is probably due to wider installation of ORVR in the future model year vehicles.

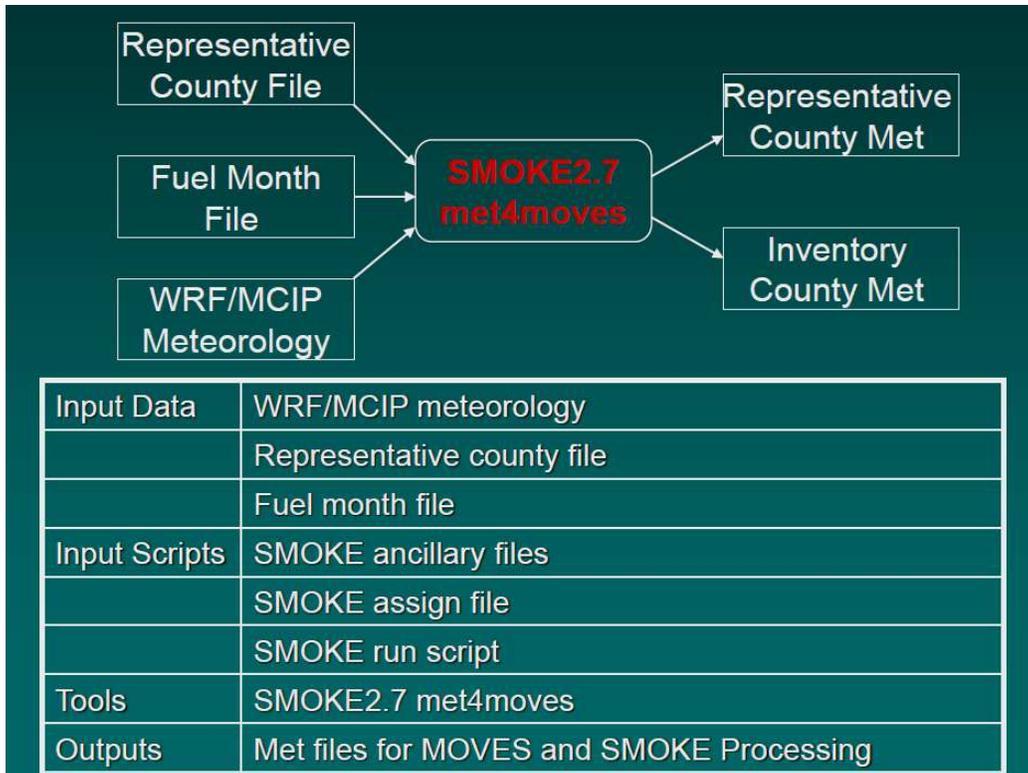


**Figure 10. VOC refueling emissions in 2007 and 2020**

## **4. Preprocessing for MOVES Lookup Table Runs and SMOKE**

### ***4.1 Preparing meteorology inputs for MOVES lookup table runs***

Met4moves is a meteorological preprocessor that determines minimum and maximum temperatures, temperature profiles, and average relative humidity (RH) for each representative county in MOVES lookup table runs. The required inputs are the representative county cross-reference file and the fuel month cross-reference file that are determined in Section 2.3 and are attached in the Appendix. The gridded hourly temperature and RH inputs are from 2007 WRF meteorology processed with MCIP. The other required SMOKE ancillary files and scripts are adopted from the release of the SMOKE-MOVES Integration Tool. Figure 11 gives a simplified flow chart of met4moves processing.



**Figure 11. A simplified flow chart of met4moves input and output files**

#### **4.2 Preparing age, fuel, I/M, VMT and VPOP for representative counties**

Emission rates in MOVES default database are laid out by age groups because vehicle emissions deteriorate with age. The most rapid change in emissions occurs between vehicle ages of 4 to 10 years. MOVES lookup tables produced by the SMOKE-MOVES Integration Tool do not retain the information of vehicle model year or age. Therefore, a representative county must have the same vehicle age distribution as the counties it represents.

Emission rates also vary with fuel parameters and I/M programs. Fuel adjustments and the selection of I/M or non-I/M base emission rates are carried out in MOVES lookup table runs, and these two factors are not handled in SMOKE processing. As with the vehicle age distribution, a representative county should have the same fuel supply and I/M programs as the counties it represents.

VMT and VPOP are interpolating variables in MOVES lookup tables. They are required in MOVES lookup table runs because the ratio of VMT and VPOP determines the fraction of parking operations in each hour. Two of the three lookup tables, the table of rate per vehicle and the table of rate per profile, are affected by the ratio of VMT and VPOP. The table of rate per mile is not affected.

The tables of vehicle age distribution, fuel supply and fuel formulation, and I/M programs are exported from MOVES input databases for each representative county for MOVES lookup table runs. VMT and VPOP are exported and added for each county group associated with a representative county.

### **4.3 Preparing VMT, VPOP, and SPEED for SMOKE processing**

MOVES VMT inputs are provided by 6 HPMS vehicle types, and MOVES VPOP inputs are classified into 13 MOVES source types. However, SMOKE processing needs VMT by 144 SCC codes, which is composed of 12 Aerometric Information Retrieval System (AIRS) AMS road types and 12 MOBILE6 vehicle types as listed in Table 5. SMOKE also requires VPOP to be classified by 12 MOBILE6 vehicle types. MOVES inventory runs in Section 3 convert VMT and VPOP from MOVES format to SCC format for every county as required for SMOKE processing.

The MOVES speed distribution is composed of vehicle hours traveled (VHT) fractions for 16 speed bins for every hour. It is also distributed by MOVES source and road types according to weekday or weekend for every month. The SMOKE-required speed is an annual average speed<sup>2</sup> for each combination of the 12 MOBILE6 vehicle types and 12 AIRS AMS road classes. The MOVES speed distributions are converted for SMOKE processing by utilizing the VHT speed distribution and the VMT fraction distributions (hour, day, and month) for every county.

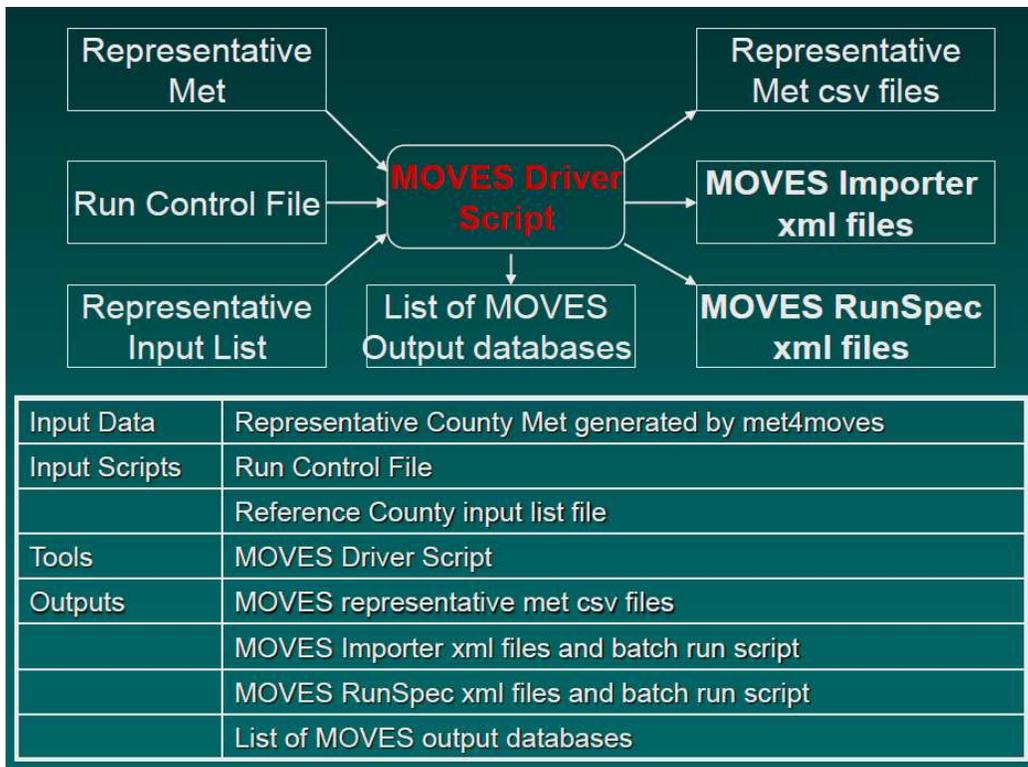
## **5. MOVES Lookup Table Runs**

### **5.1 Run MOVES driver script**

The MOVES driver script generates scripts and files for each representative county for MOVES lookup table runs. (1) It converts meteorological files from the output format of met4moves to MOVES-required comma separated value (csv) format; (2) it generates all required MOVES importer files on how to build county-level MySQL input databases; (3) it creates the MOVES RunSpec files to instruct each MOVES lookup table run; and (4) it generates batch run script files to build up MOVES input databases and to run MOVES lookup tables from the Windows command prompt. Figure 12 gives the flow diagram of MOVES driver script input and output files. The run control file and the representative list file are attached in the Appendix.

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<sup>2</sup> SMOKE can also accept 24-hour speed profiles that vary by SCC and weekday/weekend. Using varying speed profiles rather than average speed may be an important factor affecting emissions.



**Figure 12. A flow diagram of MOVES run script input and output files**

### **5.2 Running MOVES lookup tables**

MOVES input databases must be created before running MOVES lookup tables. There are about 50 MOVES runs to generate one package of MOVES lookup tables for one representative county for one month or fuel season. Each run needs its own input database because the temperature profiles are different. Figure 13 gives the flow chart for running MOVES importer.

The required inputs to run MOVES lookup tables include MOVES input databases, the RunSpec files, and the batch run script. Three emission rates tables are generated for each representative county, which are the rate per distance (RPD) lookup table, the rate per vehicle (RPV) lookup table, and the rate per profile (RPP) lookup table.

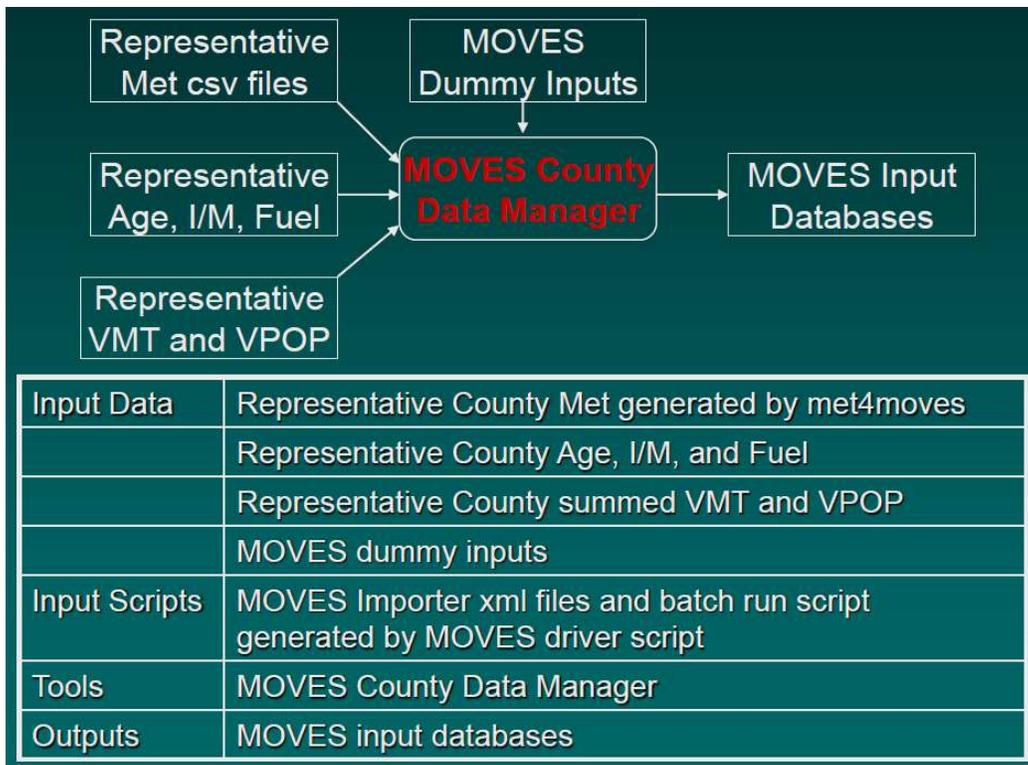
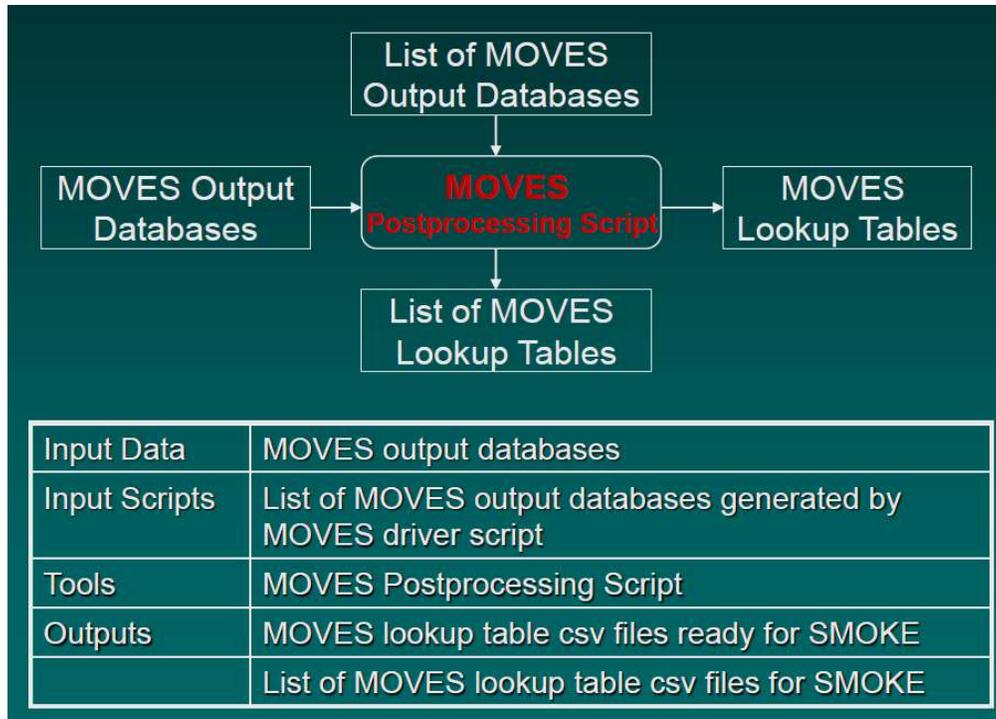


Figure 13. A flow chart of MOVES importer input and output files

### 5.3 Postprocessing of MOVES lookup tables

A MOVES postprocessing script transforms the table outputs produced by MOVES lookup table runs into new tables for SMOKE processing. Several transformations are performed by the postprocessing script, including creating a county field, cross-tabbing the pollutant IDs, and adjusting PM species emission rates for air quality modeling. Figure 14 gives the flow chart for the postprocessing of MOVES lookup tables.



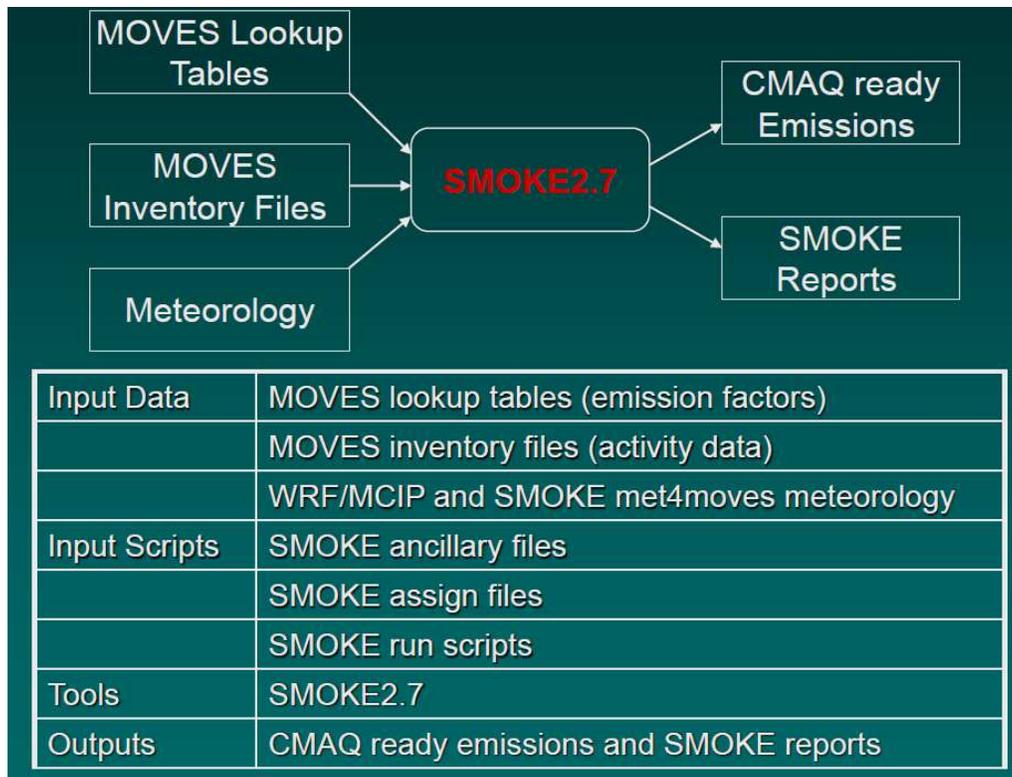
**Figure 14. A flow chart of the postprocessing of MOVES lookup tables**

## 6. SMOKE Processing

MOVES emission rates tables are generated from lookup table runs. SMOKE processes the emission rates tables to emissions by coupling the emission rates in the tables to their relevant meteorological (temperature) and activity inputs (VMT, VPOP, and SPEED). Figure 15 gives a simplified flow chart for the SMOKE processing.

Regional MOVES modeling centers at NESCAUM, NY DEC, VA DEQ, and PA DEP ran MOVES lookup tables and provided emission rates tables and SMOKE inventories and other state-specific ancillary files. NY DEC merged regional files and set up the SMOKE modeling platform. The first round of 2007 SMOKE MOVES runs were split between NY DEC, NESCAUM, and VA DEQ because it took weeks to finish the annual modeling. The processing speed was improved dramatically with SMOKE 2.7.5b, and NY DEC processed SMOKE for 12 jurisdictions for the whole year thereafter.

The daily SMOKE MOVES emission reports were processed to monthly summaries by using the script developed by VA DEQ. The summaries were then processed to annual state level emissions according to 7 digit SCCs. The results are presented in Section 6.1 and Section 6.2 for 2007 and 2020.

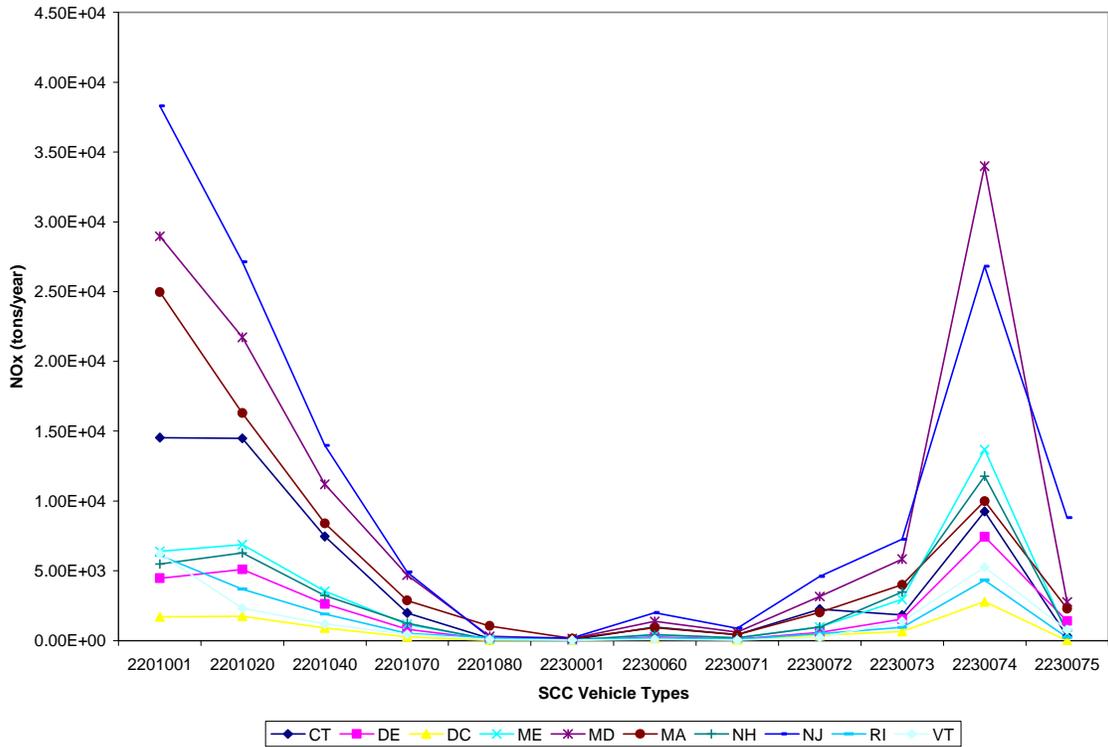


**Figure 15. A simplified flow chart of SMOKE processing of MOVES lookup tables**

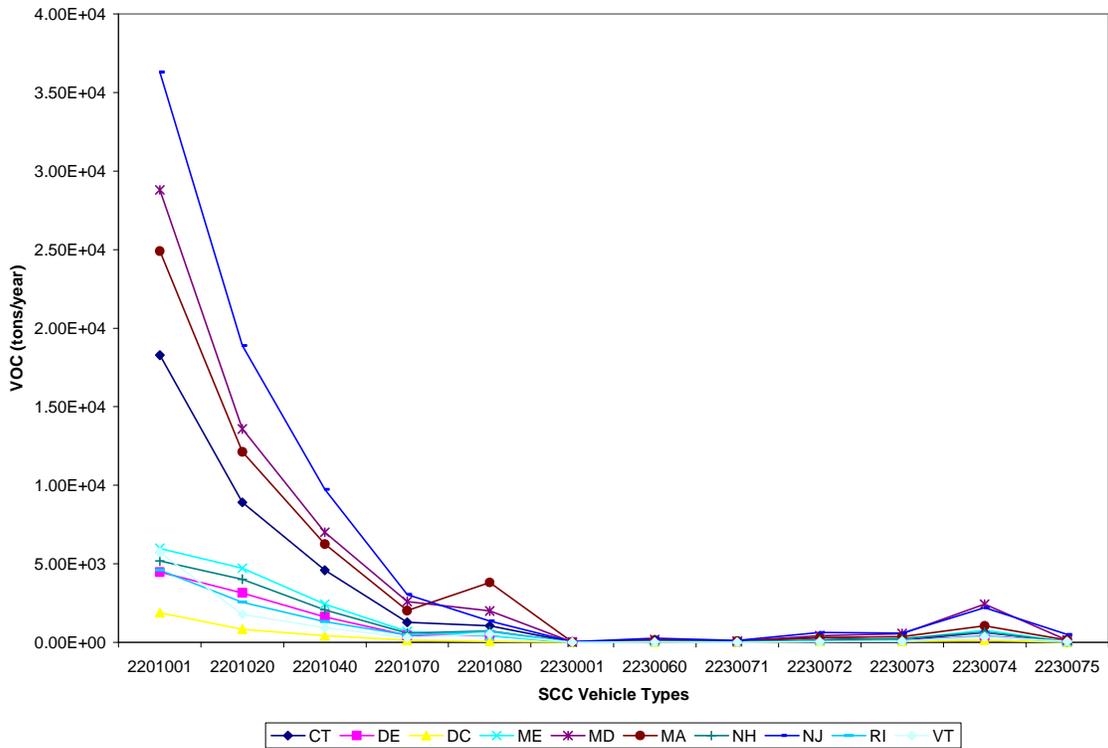
### **6.1 2007 SMOKE MOVES emissions**

Figures 16 and 17 present 2007 onroad mobile NO<sub>x</sub> and VOC emissions summarized from SMOKE MOVES reports, respectively. Figure 16 shows that the top vehicle types contributing to NO<sub>x</sub> emissions are LDGV (2201001), HDDV 8a and 8b (2230074), and LDGT (2201020). Figure 17 shows that LDGV dominates for VOC emissions, followed by LDGT (2201020 and 2201040). The VOC emissions from diesel vehicles are only a small fraction of gasoline vehicles.

When compared with 2007 annual VMT presented in Figure 4, emissions are roughly proportionally to VMT for the same type of vehicle. A comparison across vehicle types reveals that the emission rates of LDGV are smaller than other vehicle types, and the NO<sub>x</sub> emission rates of diesel vehicles are obviously higher than gasoline vehicles. The distribution of PM<sub>10</sub> and PM<sub>2.5</sub> emissions among vehicle types are similar to NO<sub>x</sub>, while the distribution of CO, SO<sub>2</sub>, and NH<sub>3</sub> emissions are similar to VOC. These results are consistent with the general emission characteristics of gasoline and diesel vehicles.



**Figure 16. 2007 NOx emissions summarized from SMOKE MOVES reports**



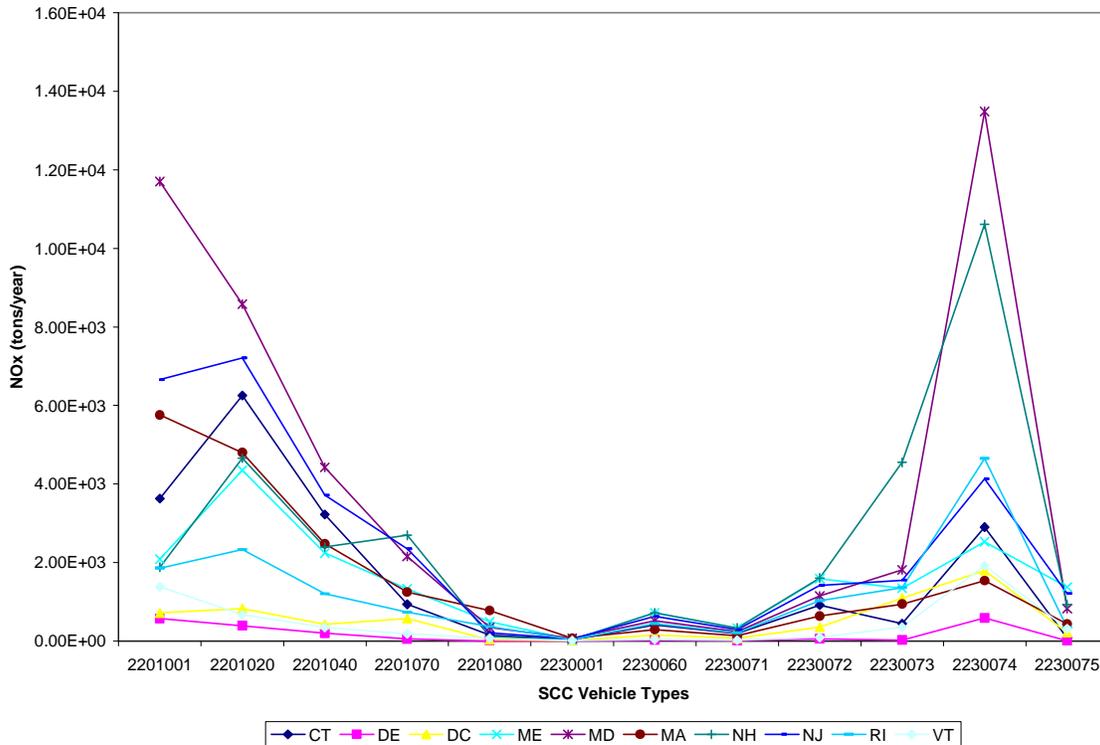
**Figure 17. 2007 VOC emissions summarized from SMOKE MOVES reports**

## 6.2 2020 SMOKE MOVES emissions

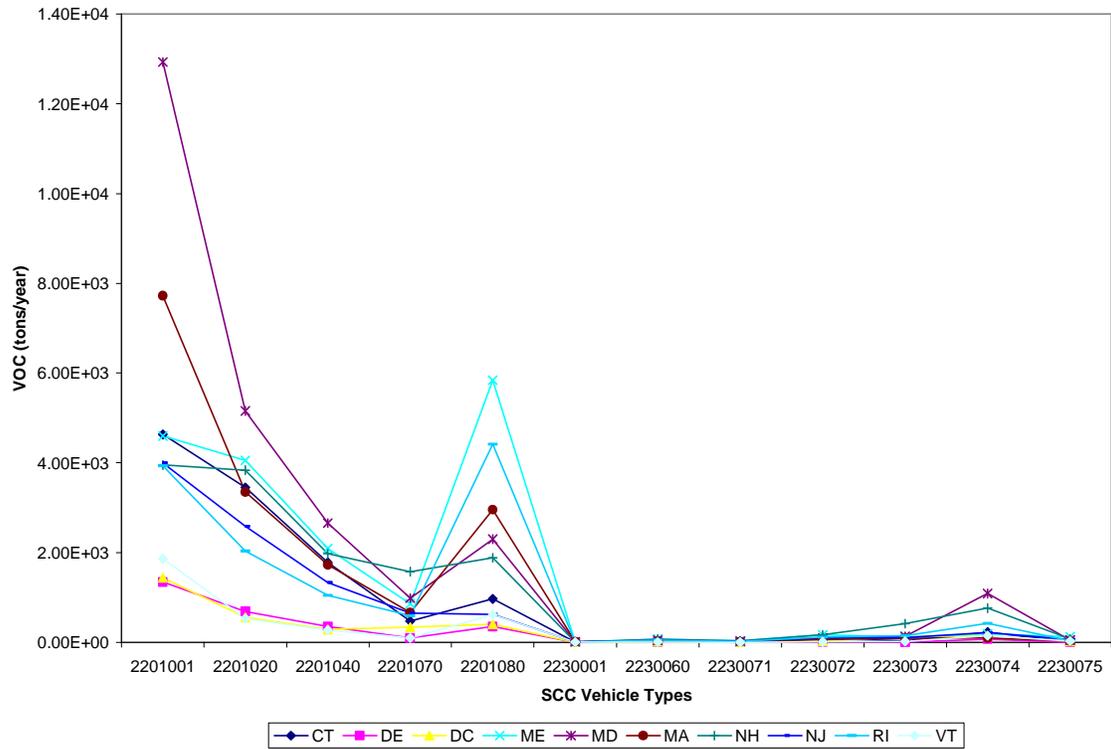
Figure 18 and 19 present 2020 onroad mobile NO<sub>x</sub> and VOC emissions summarized from SMOKE MOVES reports, respectively. The figures show that modeled 2020 emissions have decreased significantly from 2007 emissions. Because VMT and VPOP increased in 2020 from 2007 levels as discussed in section 3.2, the emissions decrease must be due to changes in emission factors.

The overall characteristics of the emissions distribution among vehicle types in 2020 are similar to 2007. Figure 18 reveals that the top vehicle types contributing to NO<sub>x</sub> emissions are LDGV (2201001), HDDV 8a and 8b (2230074), and LDGT (2201020). Figure 19 shows that LDGV dominates for VOC emissions, followed by LDGT (2201020 and 2201040). There are also some clear differences in the 2020 emissions distribution compared to 2007. Examples are the lower 2020 NO<sub>x</sub> emissions from LDGV than LDGT in many states, and the more prominent 2020 VOC emissions from motorcycles (2201080, MC).

Note that the 2020 emissions are not final yet due to the issue of NJ VPOP that is currently under review. The 2020 emissions from NJ are expected to change when its VPOP is revised.



**Figure 18. 2020 NO<sub>x</sub> emissions summarized from SMOKE MOVES reports**



**Figure 19. 2020 VOC emissions summarized from SMOKE MOVES reports**

## 7. References

M. Houyoux, Summary of SMOKE-MOVES Integration Tool, v3, 2010.

U.S. Environmental Protection Agency, Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity, EPA-420-B-10-023, 2010.

U.S. Environmental Protection Agency, Instructions for Using LEV and NLEV Inputs for MOVES, EPA-420-B-10-003, 2010.

U.S. Environmental Protection Agency, Installation Guide for the SMOKE-MOVES Integration Tool. Prepared by Baek, B.H. (University of North Carolina), 2010.

U.S. Environmental Protection Agency, User's Guide for the SMOKE-MOVES Integration Tool. Prepared by Baek, B.H. (University of North Carolina) and DenBleyker, A. (ENVIRON), 2010.

## 8. Appendix

### 8.1 The representative county cross-reference file

0	09	001	0	09	001
0	09	003	0	09	003
0	09	005	0	09	003
0	09	013	0	09	003
0	09	015	0	09	003
0	09	007	0	09	009
0	09	009	0	09	009
0	09	011	0	09	009
0	10	001	0	10	001
0	10	003	0	10	003
0	10	005	0	10	005
0	11	001	0	11	001
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0	23	013	0	23	001
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0	23	023	0	23	001
0	23	031	0	23	001
0	23	003	0	23	003
0	23	007	0	23	003
0	23	009	0	23	003
0	23	017	0	23	003
0	23	019	0	23	003
0	23	021	0	23	003
0	23	025	0	23	003
0	23	027	0	23	003
0	23	029	0	23	003
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0	24	003	0	24	003
0	24	005	0	24	003
0	24	013	0	24	003
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0	24	029	0	24	029
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0	24	017	0	24	009
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0	24	033	0	24	009
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0	24	043	0	24	043

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## **8.2 The fuel month cross-reference file**

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10001	7	9
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50005	2	11
50005	2	12

### **8.3 The run control file for MOVES lookup table runs**

Below is the run control file for 2007 MOVES lookup table runs. For 2020 runs, change 2007 to 2020. The same meteorology file is valid for both years.

```
DBHOST      = localhost
BATCHRUN    = manevu_2007_o3_pm
OUTDIR      = C:\Documents and Settings\hyang\My Documents\MOVES\Lookup_Table_Run\manevu_2007_o3_pm\
MOVESHOME   =
MODELYEAR   = 2007
POLLUTANTS  = ozone, pm
DAYOFWEEK   = WEEKDAY, WEEKEND
METFILE     = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MET_2007\MOVES_otc12_2007.txt

##POLLUTANTS = TOXICS, ghg, ozone, pm
```

### **8.4 The representative county list file for MOVES lookup table runs**

The representative county list file is the 2007 MOVES lookup table runs. For 2020 runs, place the 2020 state inputs in a new folder (e.g., “\MANEVU\_rep\_2020\”) and change the folder name in the corresponding list file.

```
<REPCOUNTY>
FIPS = 09001
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09001_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09001_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09001_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09001_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09001_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09001_VMT.csv
<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 09003
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09003_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09003_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09003_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09003_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09003_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09003_VMT.csv
```

```

<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 09009
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09009_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09009_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09009_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09009_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09009_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\09009_VMT.csv
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