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

Prepared for:

Northeast States for Coordinated Air Use Management

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1. Introduction

NESCAUM has estimated onroad mobile source emissions for 10 jurisdictions in the Mid-Atlantic/Northeast Visibility Union region (MANE-VU) 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 (PM2.5), 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 reductions from potential strategies to address mobile source pollution.

1.2 Reasons to choose the MOVES lookup table approach

MOVES can be run in two manners: 1) an "Inventory" approach that provides emission inventory estimates as mass, and 2) an "Emissions Rate" approach that produces "lookup tables" of emission rates 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 impact on mobile source emissions, it is prohibitively time consuming to model an entire year for all counties in the MANE-VU region using the inventory approach. As such, EPA undertook an effort to develop the SMOKE-MOVES Integration Tool for use with the lookup table approach in an effort to minimize the number of MOVES runs needed.

The SMOKE-MOVES Integration Tool was released on July 14, 2010 (see Figure 1). An updated version to improve runtime was released later in 2010 with MOVES1010a. Using this tool, a large number of MOVES runs are required to generate a package of lookup tables to estimate emissions for one county over one month or one fuel season. The Integrated Tool provides scripts to conduct MOVES preprocessing, MOVES runs, MOVES post-processing, and SMOKE processing that generates CMAQ-ready emission files. In order to use this tool in the MANE-VU region, extra preprocessing is required to convert activity input data from MOVES to MOBILE6 format as is required by the SMOKE-MOVES Integration Tool.

Since early 2010, NESCAUM, participating states, 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 lookup table approach coupled with a two fuel season assumption representing summer and winter conditions.

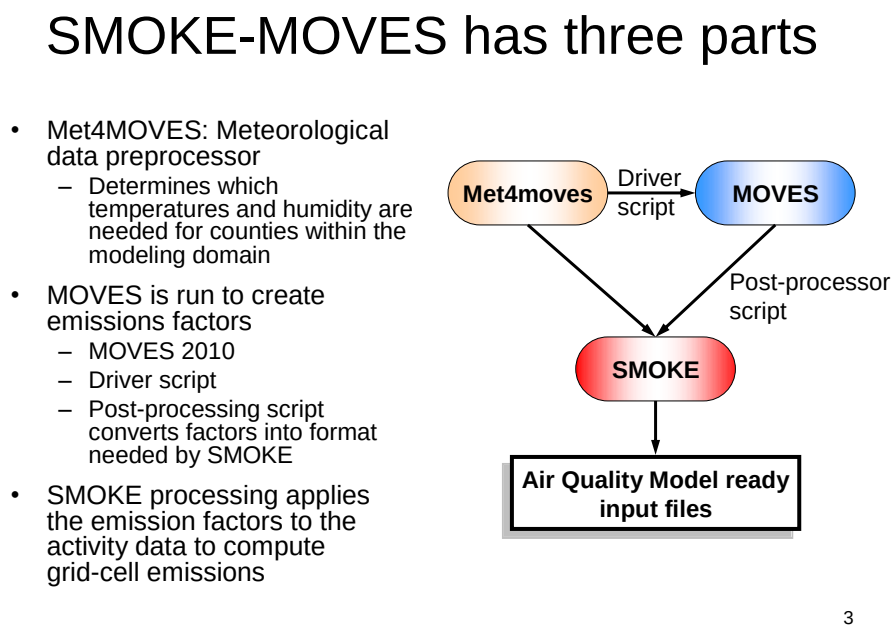


Figure 1. SMOKE-MOVES Integration Tool.

(Source: M. Houyoux, Summary of SMOKE-MOVES Integration Tool, v3, 2010)

2. MOVES Input Data Collection and Conversion

2.1 MOVES inputs submitted by states

2.1.1 MOVES inputs that can be 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. MOVES county data manager can be used to import these 13 inputs into the MOVES input database.

Working with Mohamed Khan from MDE and Steve Potter from CT DEP, NESCAUM develop a county-based input organization scheme and naming convention 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
	Document (Optional)
	General

Among the 10 jurisdictions modeled by NESCAUM, six (CT, DE, MD, MA, NJ, and VT) submitted 2007 MOVES inputs. The four others (DC, ME, NH, and RI) selected 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 QA 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

The information regarding the adoption of Early NLEV and California (Cal) LEV programs by states in the MANE-VU region was collected by NESCAUM and is listed in Table 2.

The table of emission rates contained in the default MOVES2010a database includes the effects of the NLEV standards beginning with the 2001 model year. However, it does not include the effects of the 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 programs 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. EPA has created a separate input database for those states that have adopted the Cal LEV program that provides a set of alternate HC, CO, and NOx start and running emission rates for model years from 1994 until 2050, including both the LEV1 and LEV2 California standards. Therefore, 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.

2.2 Build up MOVES input databases

MOVES input databases were built up primarily for MOVES inventory runs, but these are useful for MOVES lookup table runs as well. MOVES inventory runs convert VMT and VPOP from MOVES format to SCC level that are required by SMOKE processing of the emission rate lookup tables. In addition, the step of data importing also provides a layer of QA of the state submitted inputs. Furthermore, refueling emissions are simulated in MOVES inventory runs since they are not included in MOVES lookup table runs.

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 them 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.

DC, NH, and RI ran EPA vmt converter and prepared vehicle populations for DC and each state county. 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 2.1.1 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 2.1.1 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 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-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 IM 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 Select representative counties and fuel months

The MOVES lookup table runs produce emission rates broken down by speed and temperature for each combination of source and road types. Therefore a group of counties in a state can be represented by one county and share one set of emission rate lookup tables as long as 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 the summary submitted by each state. The representative county cross-reference file used by SMOKE modeling is listed in the Appendix.

Table 3. States and representative counties

State	County*	# of Counties	# of Representative Counties*
CT	*Fairfield*, *Hartford*, Litchfield, Middlesex, *New Haven*, New London, Tolland, Windham	8	3
DE	*Kent*, *New Castle*, *Sussex*	3	3

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

* County name in italics denotes a representative county.

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. DE and DC have different fuel seasons from the other states. It is noted that the same fuel was actually used during the entire 2007 summer 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 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 those 12 SCC vehicle types for each state in this report.

Table 5. Vehicle type codes by SCC and descriptions

SCC7	Description
2201001	LDGV: Light Duty Gasoline Vehicles
2201020	LDGT12: Light Duty Gasoline Trucks 1 and 2
2201040	LDGT34: Light Duty Gasoline Trucks 3 and 4
2201070	HDGV: Heavy Duty Gasoline Trucks
2201080	MC: Motorcycles
2230001	LDDV: Light Duty Diesel Vehicles
2230060	LDDT: Light Duty Diesel Trucks
2230071	HDDV: Heavy Duty Diesel Vehicles 2b
2230072	HDDV: Heavy Duty Diesel Vehicles 3 to 5
2230073	HDDV: Heavy Duty Diesel Vehicles 6 and 7
2230074	HDDV: Heavy Duty Diesel Vehicles 8a and 8b
2230075	HDDB: Diesel Transit, Urban and School Buses

3.1 2007 VPOP and VMT

Table 6 lists the annual VPOP for each jurisdiction by 12 SCC vehicle types. Figure 2 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.

Table 6. 2007 VPOP

SCC7	CT	DE	DC	ME	MD	MA	NH	NJ	RI	VT
2201001	1671050	396357	185991	539360	2382703	2438773	605827	3357336	527413	420844
2201020	618619	215547	42780	333789	1051527	1101444	331602	1504690	182471	86130
2201040	318682	111039	22038	171952	541695	567410	170825	775143	94000	44370
2201070	78435	27322	5301	42096	161709	134654	42351	200816	31149	11787
2201080	80670	25106	2574	26610	113718	109741	73309	85656	16955	43175
2230001	4445	1182	376	1647	6157	5397	1850	7829	1342	799
2230060	11776	4136	805	6372	20134	14005	6290	28882	3266	1191
2230071	5243	1829	360	2821	9002	6430	2785	12947	1456	525
2230072	27744	9741	1899	14960	46956	31120	14757	67419	8000	2774
2230073	9819	4186	498	7441	51589	26675	7668	39917	10755	3689
2230074	13431	5697	740	11608	50410	33040	7533	57559	10140	7683
2230075	9207	3397	1092	5137	13158	12495	2995	26274	2589	1623
Total	2849120	805540	264454	1163792	4448758	4481186	1267793	6164467	889536	624591

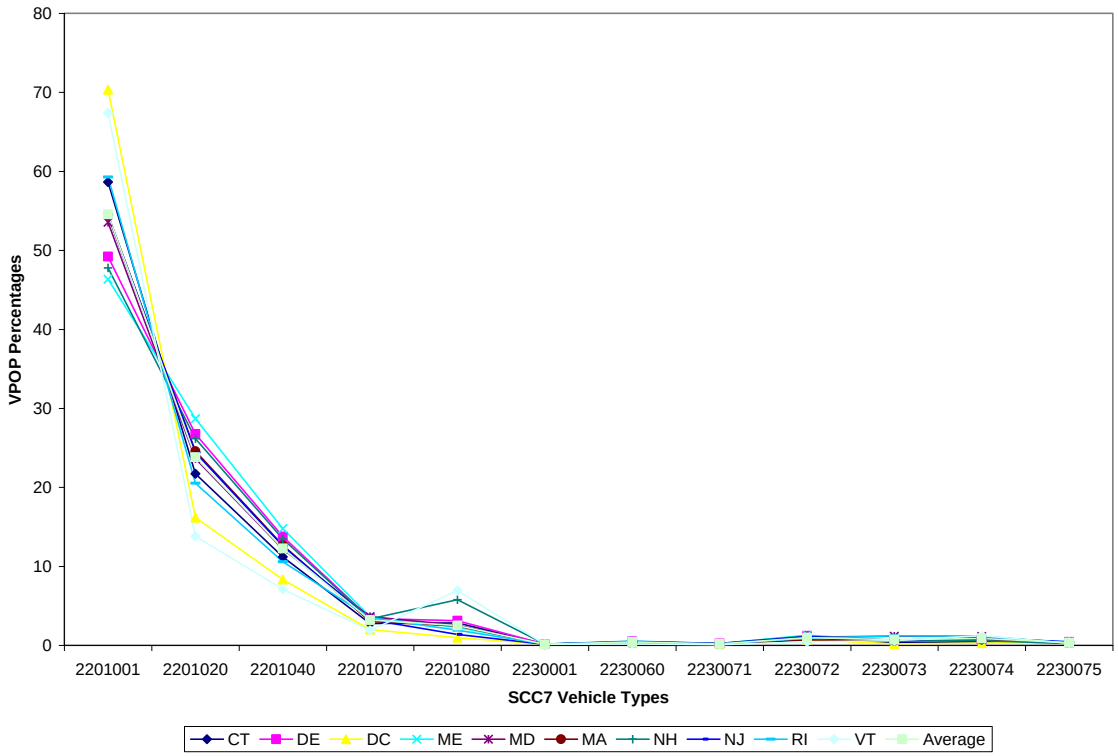


Figure 2. 2007 VPOP Percentages

Table 7 lists the annual VMT for each jurisdiction by 12 SCC vehicle types. Figure 3 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, LDGT) 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 4 where the ratio of VMT over VPOP is plotted for each vehicle type.

Table 7. 2007 Annual VMT (1.0E6 miles/year)

SCC7	CT	DE	DC	ME	MD	MA	NH	NJ	RI	VT
2201001	13154.98	3745.69	1303.98	6313.23	29310.27	29792.13	5160.49	41630.21	6955.47	5133.53
2201020	9640.40	2899.49	1276.69	4525.04	14096.12	13458.10	3990.78	17907.17	1816.45	1126.15
2201040	4966.26	1493.68	657.69	2331.08	7261.63	6932.95	2055.85	9224.90	935.75	580.14
2201070	1139.36	372.22	158.60	589.23	1841.96	1570.46	560.83	2658.97	225.35	150.64
2201080	180.21	71.67	18.33	86.67	319.64	1341.42	72.04	257.45	259.76	89.34
2230001	33.45	9.97	2.81	17.89	74.74	69.54	14.63	99.98	17.80	10.50
2230060	187.38	56.62	24.60	87.30	274.33	172.90	76.50	488.61	33.53	15.87
2230071	84.01	25.32	11.06	39.31	123.30	79.71	34.45	217.26	15.14	7.16
2230072	434.06	131.44	57.06	202.13	630.96	380.84	177.01	1152.21	80.12	36.43
2230073	131.89	129.48	38.10	237.08	633.61	368.26	274.59	677.15	51.88	83.10
2230074	425.81	413.94	116.43	735.90	2012.92	425.12	642.13	1202.78	157.95	229.33
2230075	24.92	100.66	0.09	39.23	175.78	155.39	36.97	573.81	9.91	56.80
Total	30402.73	9450.19	3665.43	15204.08	56755.26	54746.81	13096.28	76090.51	10559.10	7518.99

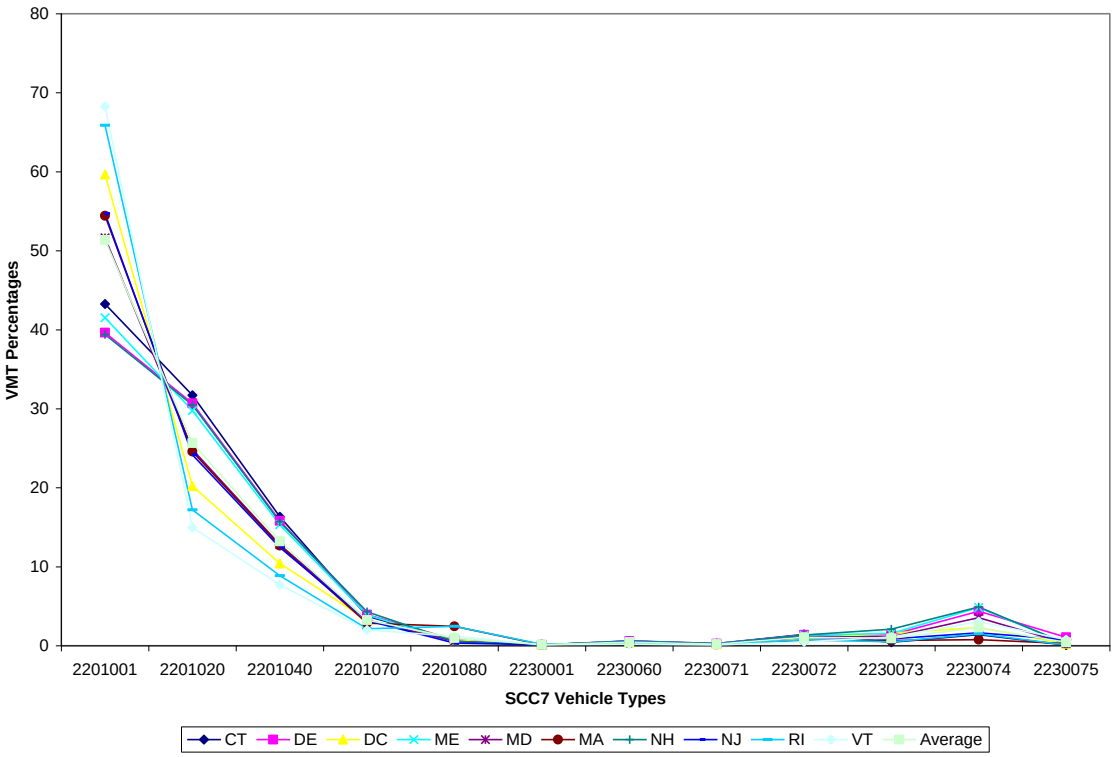


Figure 3. 2007 VMT percentages

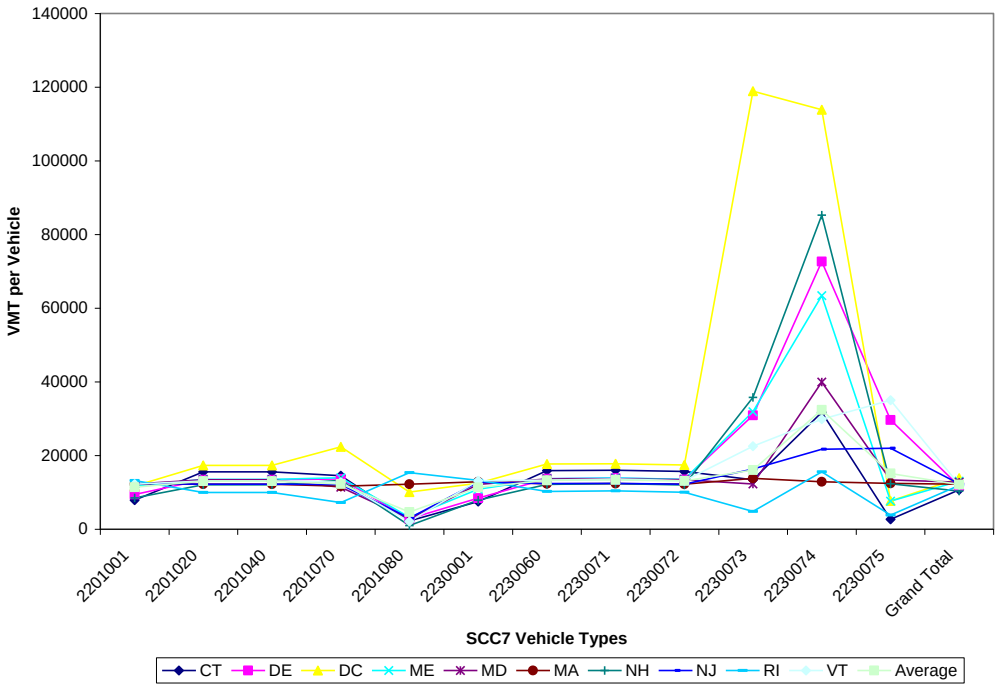


Figure 4. 2007 VMT/VPOP ratios

The summary of VMT and VPOP 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.

3.2 2020 VPOP and VMT

Figures 5 – 7 give the VPOP percentages, VMT percentages, and the ratios of VMT/VPOP for 2020. The distribution among vehicle types is similar to 2007. However, the 2020 VMT/VPOP ratio in NJ is several times higher that the other states, and is currently under review.

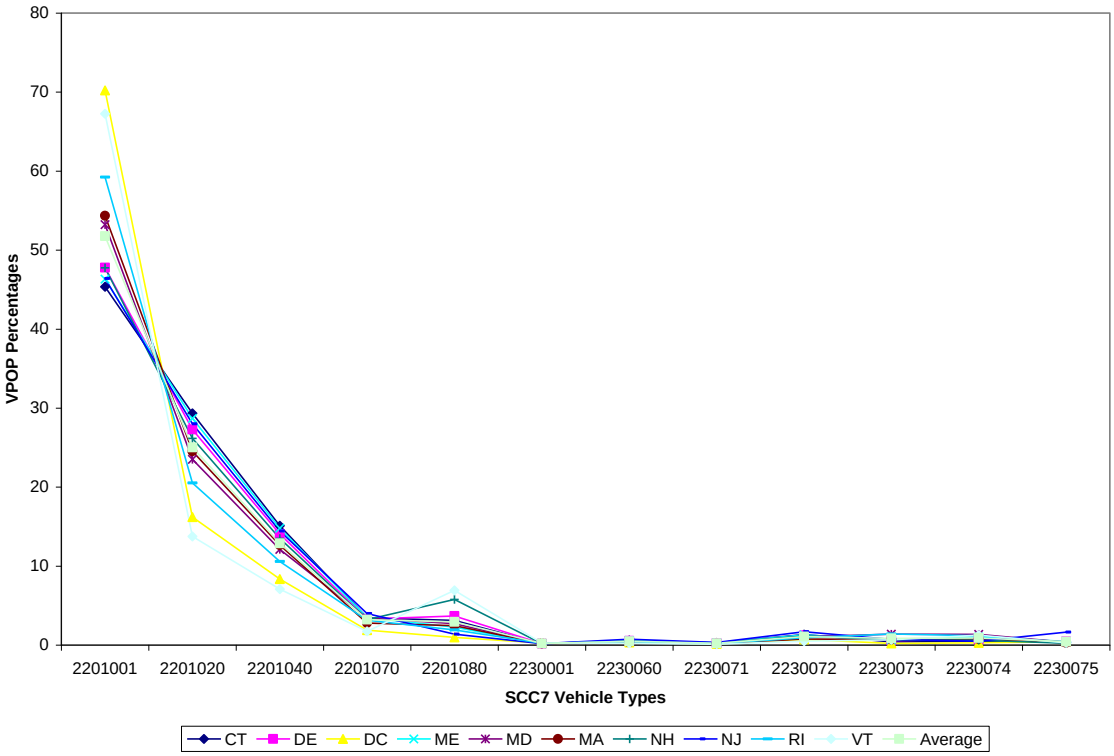


Figure 5. 2020 VPOP percentages

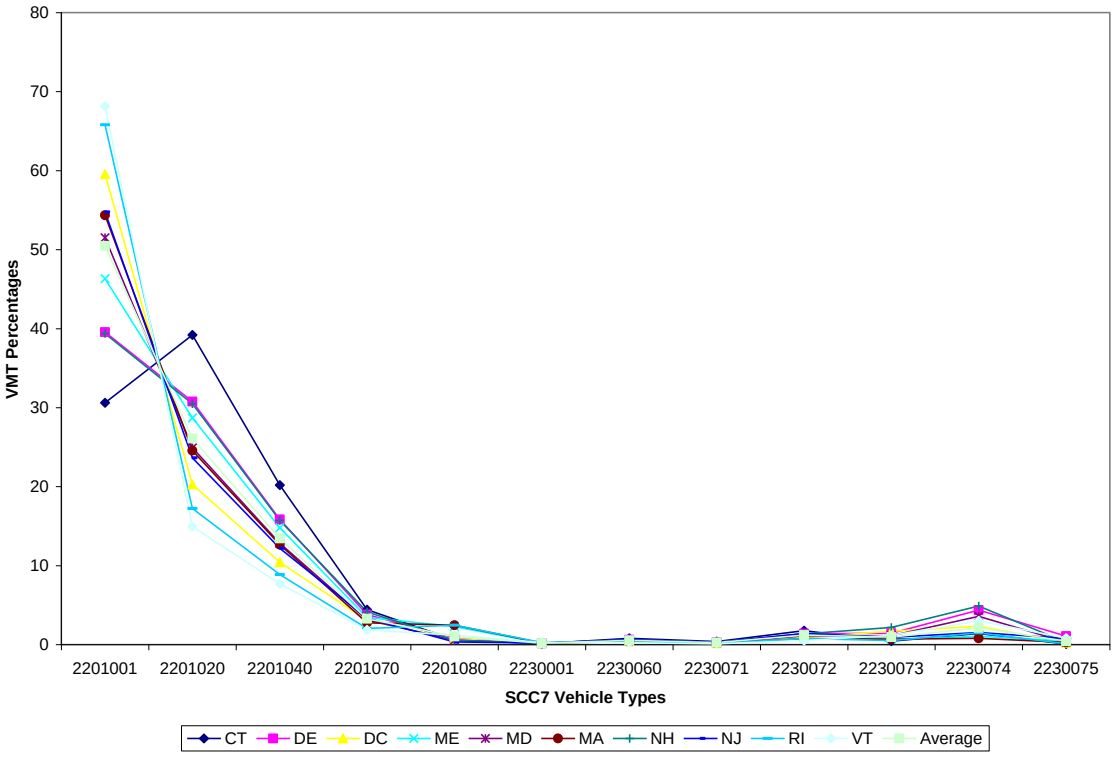


Figure 6. 2020 VMT percentages

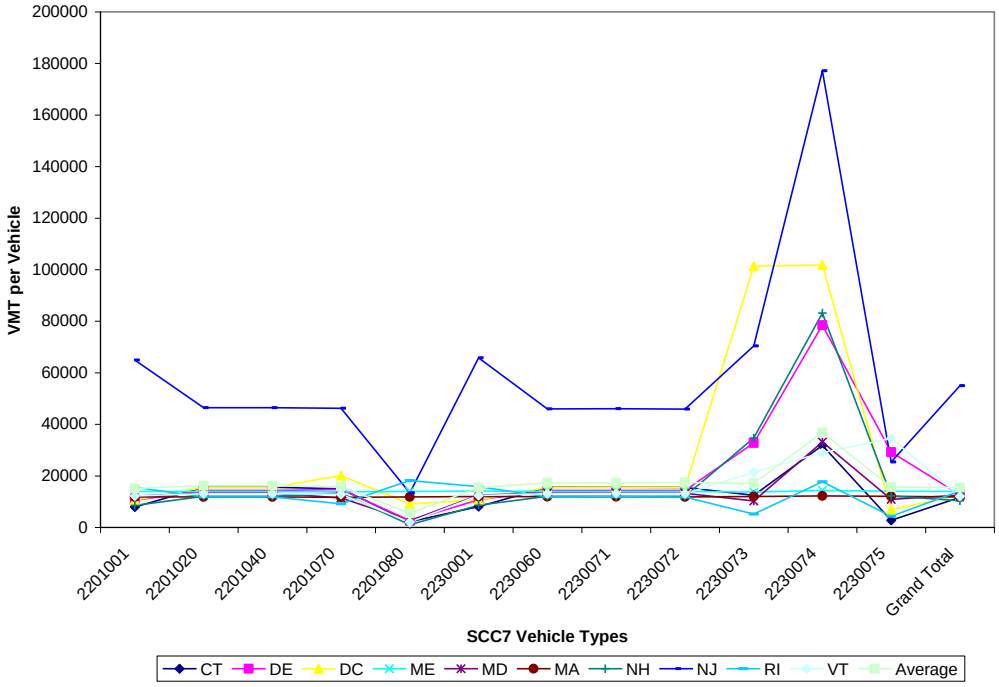


Figure 7. 2020 VMT/VPOP ratios

3.3 Refueling Emissions

Emissions of VOCs and associated air toxics occur when gasoline vapor escapes during refueling. Refueling emissions arise from two processes: vapor displacement and spills. Stage II refueling control programs are intended to reduce the emissions associated with both processes. The onboard refueling recovery system (ORVR) installed on modern vehicles are 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 these aged 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 8 plots the 2007 and 2020 refueling emissions. The 2020 refueling emissions are significantly lower than 2007 in most states. The Stage II control efficiencies between the two years are similar, therefore the decrease may be due to wider installation of ORVR in the future model year vehicles.

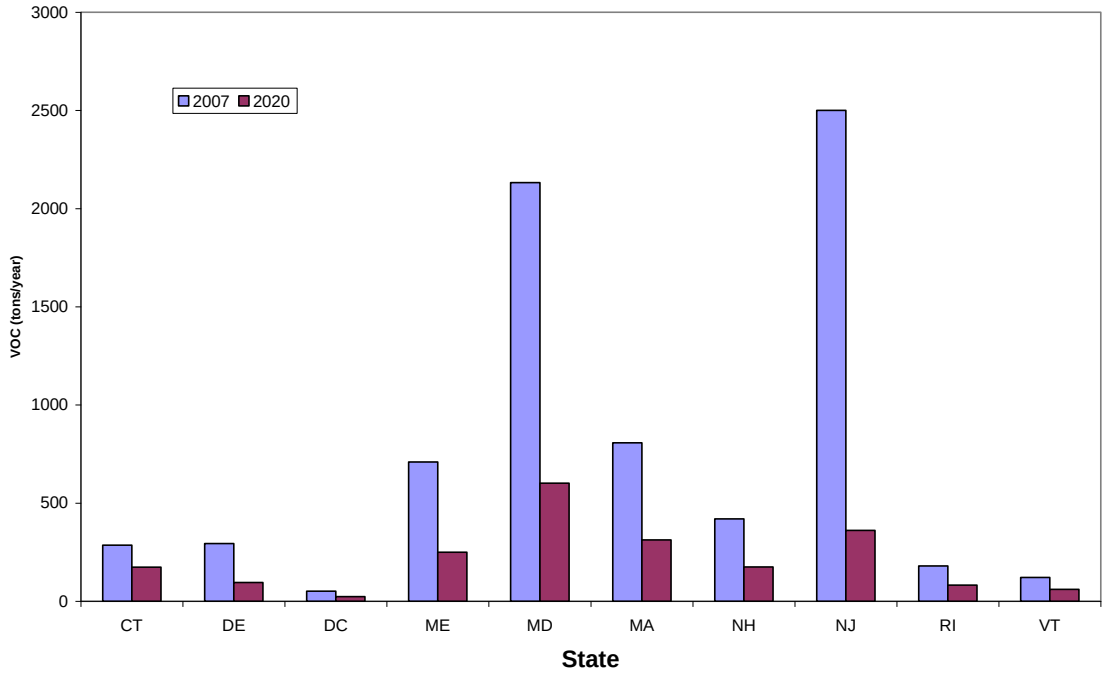
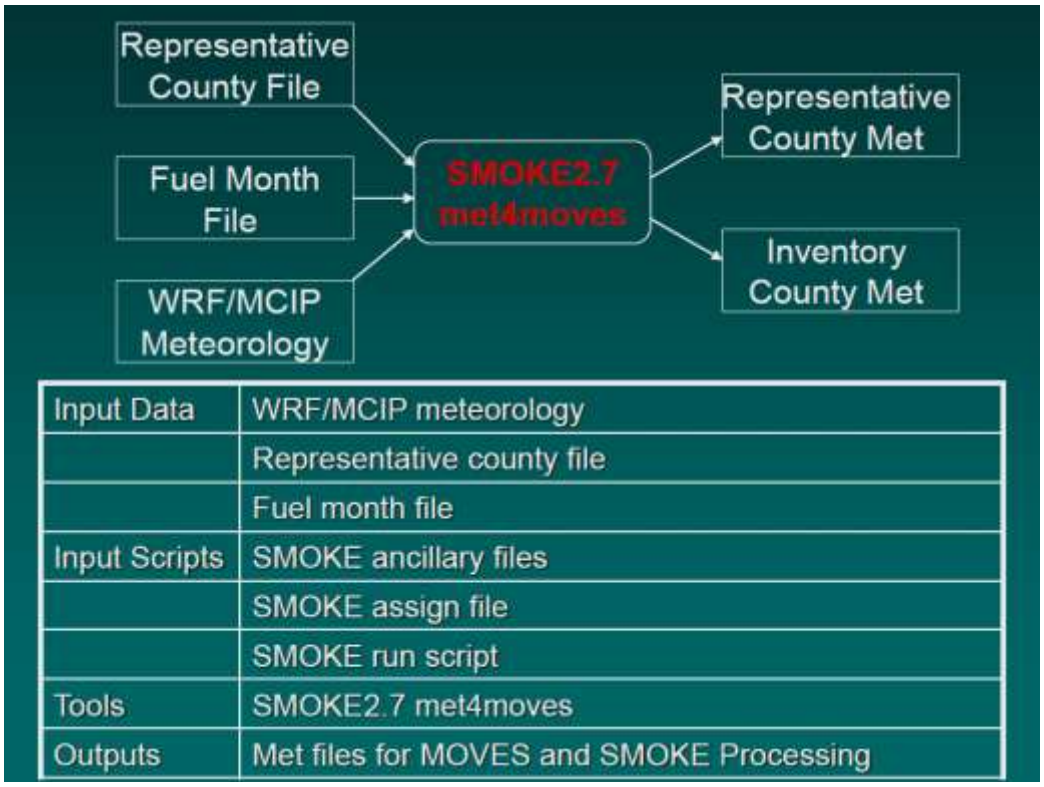


Figure 8. VOC refueling emissions in 2007 and 2020

4. Preprocessing for MOVES Lookup Table Runs and SMOKE

4.1 Prepare 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, the representative county cross-reference file and the fuel month cross-reference file, 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 9 gives a simplified flow chart of met4moves processing.



Input Data	WRF/MCIP meteorology
	Representative county file
	Fuel month file
Input Scripts	SMOKE ancillary files
	SMOKE assign file
	SMOKE run script
Tools	SMOKE2.7 met4moves
Outputs	Met files for MOVES and SMOKE Processing

Figure 9. A simplified flow chart of met4moves input and output files

4.2 Prepare age, fuel, I/M, VMT and VPOP for representative counties

Emission rates in MOVES default database are laid out by age groups since 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 since 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 Prepare VMT, VPOP, and SPEED for SMOKE processing

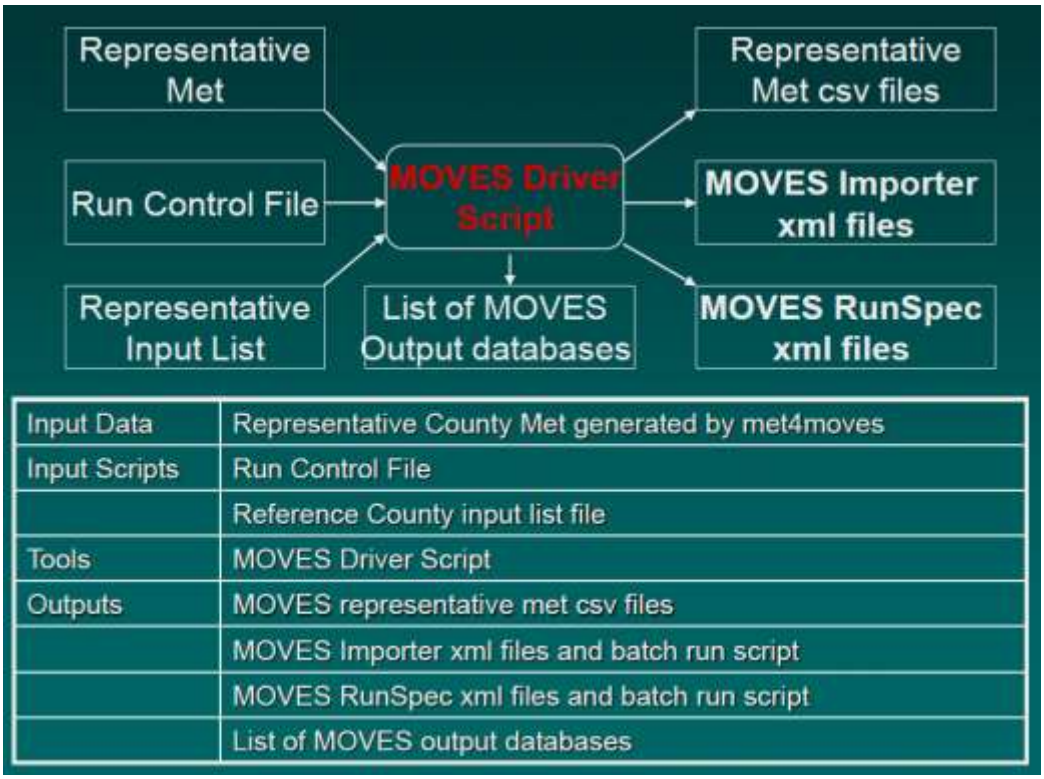
MOVES VMT inputs are provided by 6 HPMS vehicle types, and MOVES VPOP inputs are classified into 13 MOVES source types. However, SMOKE processing needs VMT by 144 SCC codes, which is composed of 12 Aerometric Information Retrieval System (AIRS) AMS road types and 12 MOBILE6 vehicle types as listed in 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 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 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 10 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.



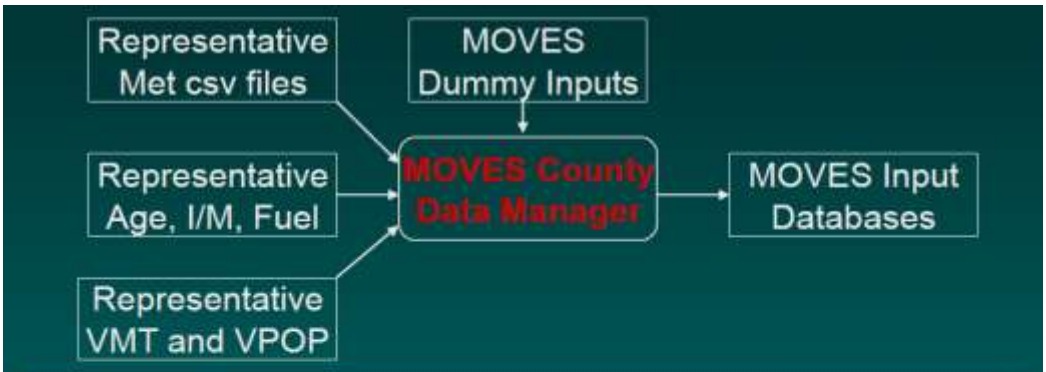
Input Data	Representative County Met generated by met4moves
Input Scripts	Run Control File
	Reference County input list file
Tools	MOVES Driver Script
Outputs	MOVES representative met csv files
	MOVES Importer xml files and batch run script
	MOVES RunSpec xml files and batch run script
	List of MOVES output databases

Figure 10. A flow diagram of MOVES run script input and output files

5.2 Run 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 11 gives the flow chart of 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.

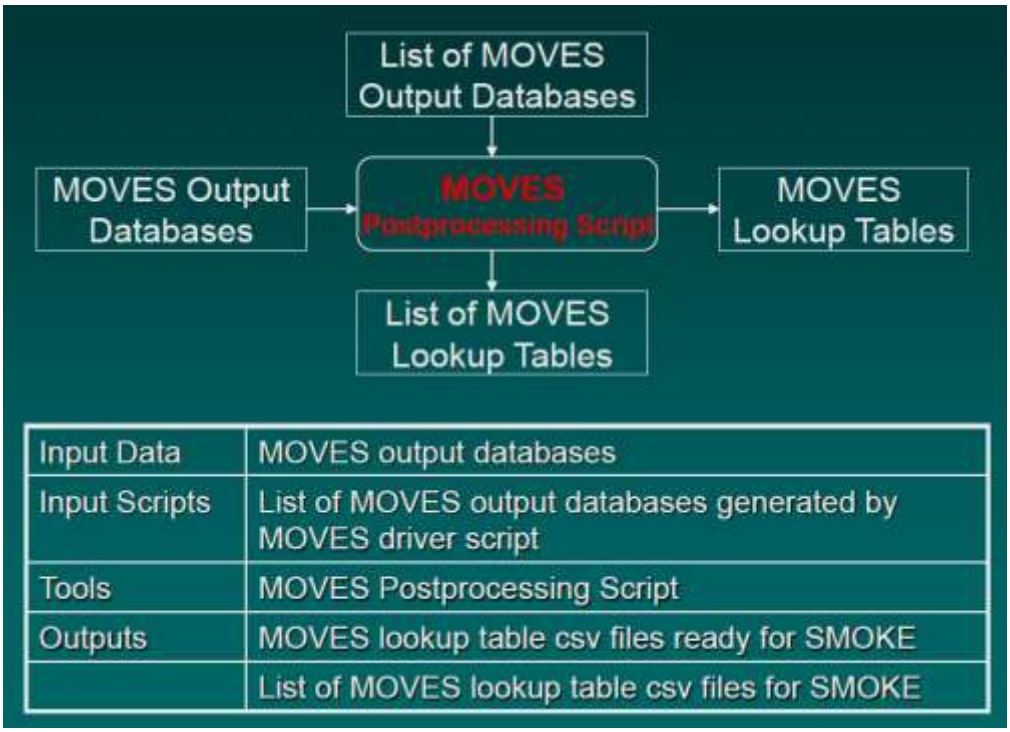


Input Data	Representative County Met generated by met4moves
	Representative County Age, I/M, and Fuel
	Representative County summed VMT and VPOP
	MOVES dummy inputs
Input Scripts	MOVES Importer xml files and batch run script generated by MOVES driver script
Tools	MOVES County Data Manager
Outputs	MOVES input databases

Figure 11. 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 12 gives the flow chart of the postprocessing of MOVES lookup tables.

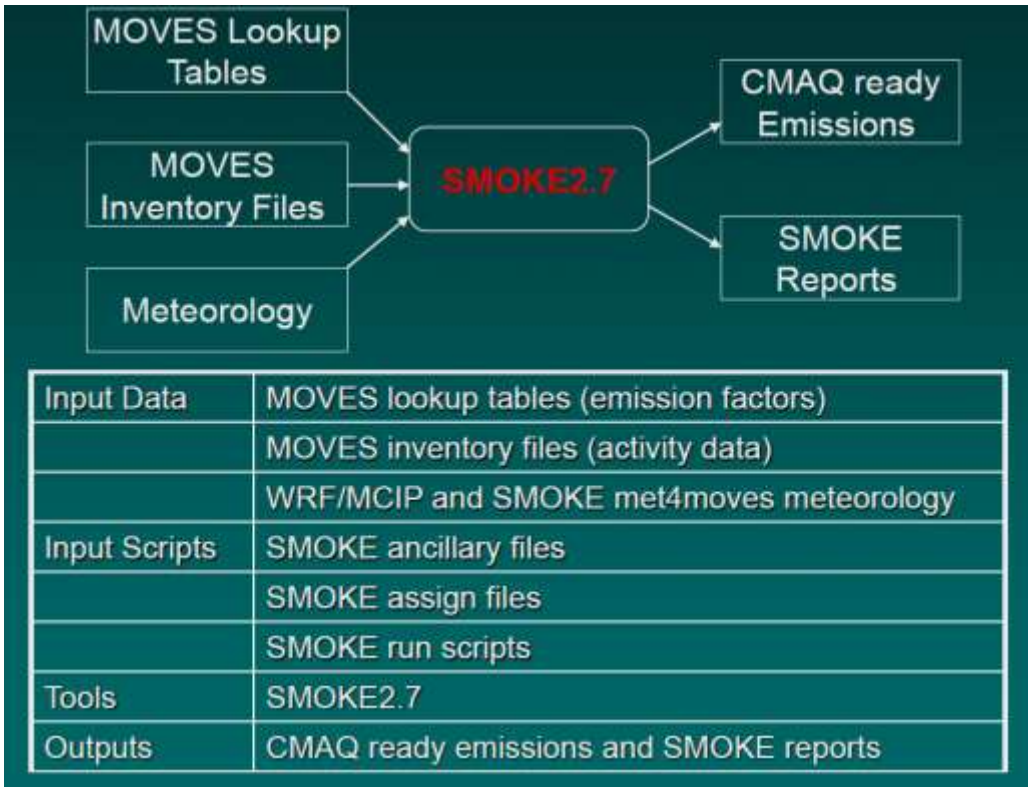


Input Data	MOVES output databases
Input Scripts	List of MOVES output databases generated by MOVES driver script
Tools	MOVES Postprocessing Script
Outputs	MOVES lookup table csv files ready for SMOKE
	List of MOVES lookup table csv files for SMOKE

Figure 12. A flow chart of the postprocessing of MOVES lookup tables

6. SMOKE Processing

MOVES lookup table runs generate emission rates tables. SMOKE processes the emission rates tables to emissions by interpolating temperatures and speed and incorporating VMT and VPOP inventories. Figure 13 gives a simplified flow chart of the SMOKE processing.



Input Data	MOVES lookup tables (emission factors)
	MOVES inventory files (activity data)
	WRF/MCIP and SMOKE met4moves meteorology
Input Scripts	SMOKE ancillary files
	SMOKE assign files
	SMOKE run scripts
Tools	SMOKE2.7
Outputs	CMAQ ready emissions and SMOKE reports

Figure 13. A simplified flow chart of SMOKE processing of MOVES lookup tables

6.1 2007 SMOKE-MOVES emissions

6.2 2020 SMOKE-MOVES emissions

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
0	23	001	0	23	001
0	23	011	0	23	001
0	23	013	0	23	001
0	23	015	0	23	001
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
0	23	005	0	23	005
0	24	003	0	24	003
0	24	005	0	24	003
0	24	013	0	24	003
0	24	025	0	24	003
0	24	027	0	24	003
0	24	510	0	24	003
0	24	015	0	24	003
0	24	035	0	24	003
0	24	029	0	24	029
0	24	009	0	24	009
0	24	017	0	24	009
0	24	021	0	24	009
0	24	031	0	24	009
0	24	033	0	24	009
0	24	037	0	24	037
0	24	011	0	24	011
0	24	019	0	24	011
0	24	041	0	24	011
0	24	045	0	24	011
0	24	039	0	24	039
0	24	047	0	24	039
0	24	001	0	24	001
0	24	023	0	24	001
0	24	043	0	24	043

```
0     25    003   0     25    013
0     25    011   0     25    013
0     25    013   0     25    013
0     25    015   0     25    013
0     25    001   0     25    017
0     25    005   0     25    017
0     25    007   0     25    017
0     25    009   0     25    017
0     25    017   0     25    017
0     25    019   0     25    017
0     25    021   0     25    017
0     25    023   0     25    017
0     25    025   0     25    017
0     25    027   0     25    017
0     33    001   0     33    001
0     33    003   0     33    001
0     33    005   0     33    001
0     33    007   0     33    001
0     33    009   0     33    001
0     33    013   0     33    001
0     33    019   0     33    001
0     33    011   0     33    011
0     33    015   0     33    011
0     33    017   0     33    011
0     34    003   0     34    027
0     34    013   0     34    027
0     34    017   0     34    027
0     34    019   0     34    027
0     34    023   0     34    027
0     34    027   0     34    027
0     34    031   0     34    027
0     34    035   0     34    027
0     34    037   0     34    027
0     34    039   0     34    027
0     34    041   0     34    027
0     34    025   0     34    025
0     34    001   0     34    001
0     34    009   0     34    001
0     34    029   0     34    001
0     34    005   0     34    011
0     34    007   0     34    011
0     34    011   0     34    011
0     34    015   0     34    011
0     34    021   0     34    011
0     34    033   0     34    011
0     44    001   0     44    007
0     44    003   0     44    007
0     44    005   0     44    007
0     44    007   0     44    007
0     44    009   0     44    007
0     50    001   0     50    001
0     50    003   0     50    001
0     50    007   0     50    001
0     50    021   0     50    001
0     50    025   0     50    001
0     50    027   0     50    001
0     50    005   0     50    005
```

```
0      50     009    0      50     005
0      50     011    0      50     005
0      50     013    0      50     005
0      50     015    0      50     005
0      50     017    0      50     005
0      50     019    0      50     005
0      50     023    0      50     005
```

8.2 The fuel month cross-reference file

```
09001 2      1
09001 2      2
09001 2      3
09001 2      4
09001 7      5
09001 7      6
09001 7      7
09001 7      8
09001 7      9
09001 2      10
09001 2      11
09001 2      12
09003 2      1
09003 2      2
09003 2      3
09003 2      4
09003 7      5
09003 7      6
09003 7      7
09003 7      8
09003 7      9
09003 2      10
09003 2      11
09003 2      12
09009 2      1
09009 2      2
09009 2      3
09009 2      4
09009 7      5
09009 7      6
09009 7      7
09009 7      8
09009 7      9
09009 2      10
09009 2      11
09009 2      12
10001 2      1
10001 2      2
10001 2      3
10001 2      4
10001 7      5
10001 7      6
10001 7      7
10001 7      8
10001 7      9
10001 7      10
```

```
10001 2     11
10001 2     12
10003 2     1
10003 2     2
10003 2     3
10003 2     4
10003 7     5
10003 7     6
10003 7     7
10003 7     8
10003 7     9
10003 7     10
10003 2     11
10003 2     12
10005 2     1
10005 2     2
10005 2     3
10005 2     4
10005 7     5
10005 7     6
10005 7     7
10005 7     8
10005 7     9
10005 7     10
10005 2     11
10005 2     12
11001 2     1
11001 2     2
11001 2     3
11001 7     4
11001 7     5
11001 7     6
11001 7     7
11001 7     8
11001 7     9
11001 7     10
11001 2     11
11001 2     12
23001 2     1
23001 2     2
23001 2     3
23001 2     4
23001 7     5
23001 7     6
23001 7     7
23001 7     8
23001 7     9
23001 2     10
23001 2     11
23001 2     12
23003 2     1
23003 2     2
23003 2     3
23003 2     4
23003 7     5
23003 7     6
23003 7     7
```

```
23003 7     8
23003 7     9
23003 2     10
23003 2     11
23003 2     12
23005 2     1
23005 2     2
23005 2     3
23005 2     4
23005 7     5
23005 7     6
23005 7     7
23005 7     8
23005 7     9
23005 2     10
23005 2     11
23005 2     12
24001 2     1
24001 2     2
24001 2     3
24001 2     4
24001 7     5
24001 7     6
24001 7     7
24001 7     8
24001 7     9
24001 2     10
24001 2     11
24001 2     12
24003 2     1
24003 2     2
24003 2     3
24003 2     4
24003 7     5
24003 7     6
24003 7     7
24003 7     8
24003 7     9
24003 2     10
24003 2     11
24003 2     12
24009 2     1
24009 2     2
24009 2     3
24009 2     4
24009 7     5
24009 7     6
24009 7     7
24009 7     8
24009 7     9
24009 2     10
24009 2     11
24009 2     12
24011 2     1
24011 2     2
24011 2     3
24011 2     4
```

```
24011 7     5
24011 7     6
24011 7     7
24011 7     8
24011 7     9
24011 2     10
24011 2     11
24011 2     12
24029 2     1
24029 2     2
24029 2     3
24029 2     4
24029 7     5
24029 7     6
24029 7     7
24029 7     8
24029 7     9
24029 2     10
24029 2     11
24029 2     12
24037 2     1
24037 2     2
24037 2     3
24037 2     4
24037 7     5
24037 7     6
24037 7     7
24037 7     8
24037 7     9
24037 2     10
24037 2     11
24037 2     12
24039 2     1
24039 2     2
24039 2     3
24039 2     4
24039 7     5
24039 7     6
24039 7     7
24039 7     8
24039 7     9
24039 2     10
24039 2     11
24039 2     12
24043 2     1
24043 2     2
24043 2     3
24043 2     4
24043 7     5
24043 7     6
24043 7     7
24043 7     8
24043 7     9
24043 2     10
24043 2     11
24043 2     12
25013 2     1
```

```
25013 2     2
25013 2     3
25013 2     4
25013 7     5
25013 7     6
25013 7     7
25013 7     8
25013 7     9
25013 2     10
25013 2     11
25013 2     12
25017 2     1
25017 2     2
25017 2     3
25017 2     4
25017 7     5
25017 7     6
25017 7     7
25017 7     8
25017 7     9
25017 2     10
25017 2     11
25017 2     12
33001 2     1
33001 2     2
33001 2     3
33001 2     4
33001 7     5
33001 7     6
33001 7     7
33001 7     8
33001 7     9
33001 2     10
33001 2     11
33001 2     12
33011 2     1
33011 2     2
33011 2     3
33011 2     4
33011 7     5
33011 7     6
33011 7     7
33011 7     8
33011 7     9
33011 2     10
33011 2     11
33011 2     12
34027 2     1
34027 2     2
34027 2     3
34027 2     4
34027 7     5
34027 7     6
34027 7     7
34027 7     8
34027 7     9
34027 2     10
```

```
34027 2     11
34027 2     12
34025 2     1
34025 2     2
34025 2     3
34025 2     4
34025 7     5
34025 7     6
34025 7     7
34025 7     8
34025 7     9
34025 2     10
34025 2     11
34025 2     12
34001 2     1
34001 2     2
34001 2     3
34001 2     4
34001 7     5
34001 7     6
34001 7     7
34001 7     8
34001 7     9
34001 2     10
34001 2     11
34001 2     12
34011 2     1
34011 2     2
34011 2     3
34011 2     4
34011 7     5
34011 7     6
34011 7     7
34011 7     8
34011 7     9
34011 2     10
34011 2     11
34011 2     12
44007 2     1
44007 2     2
44007 2     3
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44007 7     5
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44007 7     7
44007 7     8
44007 7     9
44007 2     10
44007 2     11
44007 2     12
50001 2     1
50001 2     2
50001 2     3
50001 2     4
50001 7     5
50001 7     6
50001 7     7
```

```
50001 7     8
50001 7     9
50001 2     10
50001 2     11
50001 2     12
50005 2     1
50005 2     2
50005 2     3
50005 2     4
50005 7     5
50005 7     6
50005 7     7
50005 7     8
50005 7     9
50005 2     10
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
<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 10001
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10001_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10001_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10001_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10001_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10001_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10001_VMT.csv
<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 10003
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10003_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10003_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10003_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10003_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10003_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10003_VMT.csv
<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 10005
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10005_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10005_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10005_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10005_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10005_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\10005_VMT.csv
<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 11001
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\11001_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\11001_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\11001_fuelsupply.csv
```

```
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\11001_fuelformulation.csv
POP = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\11001_VPOP.csv
HPMSVMT = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\11001_VMT.csv
<ENDREPCOUNTY>
<REPCOUNTY>
FIPS = 23001
AGE = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\23001_age.csv
IM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\23001_IM.csv
FUELSUPPLY = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\23001_fuelsupply.csv
FUELFORM = C:\Documents and Settings\hyang\My Documents\MOVES\State Inputs\MANEVU_rep_2007\23001_fuelformulation.csv
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