United States Environmental Protection Agency

Air and Radiation

EPA420-P-04-020
December 2004

MOVES2004 Highway Vehicle Population and Activity Data

Draft

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1. Introduction

This report documents the default "fleet" and "activity" data used by MOVES2004 in order to estimate energy consumption and emissions of methane (CH_4) and nitrous oxide (N_2O) for all on-road sources from calendar years 1999 through 2050, for each county in the U.S. Fleet data refers to information characterizing the vehicle fleet such as population estimates, age distributions, survival rates, sales growth rates, and distribution across "source bins" used to estimate energy and emissions. Activity data refers to information characterizing how the fleet operates, such as: vehicle miles traveled (VMT), VMT growth, average speed distributions, and driving patterns.

The report focuses on the data sources for fleet and activity data and methodology used to produce the default estimates. The base year for MOVES2004 is 1999, so most of the data is anchored to this year; sales and VMT growth rates which allow projection through 2050 are also documented as well. All of the fleet and activity data discussed in this report are contained in a series of data tables in the MOVES Default database. Where space allows, the resulting default data are also presented in this report; otherwise the reader is directed to the database itself to view the data. The report is structured so that each section (for Sections 3 through 19) is centered on a different database table (entity); and the subsections are the data fields (attributes) within that table. This report focuses just on the data and methods used to populate fleet and activity data – it does not document the structure of the database itself, or how the data is used in the MOVES2004 calculations. This information is contained in the separate document, "MOVES2004 Software Design Reference Manual"; the reader is encouraged to first read this manual in order to fully understand the context of the data presented in this report.

While many of the fleet and activity data concepts will be familiar to users of MOBILE (e.g. VMT), MOVES2004 does introduce several new concepts with regard to vehicle classification and activity characterization. There are two primary reasons for this: first, the MOVES design is substantially different from MOBILE in order to support multi-scale analysis, and second MOVES is designed to reconcile internally fundamental differences between how activity data is collected and characterized, and how emission data is collected and characterized. With regard to multi-scale analysis, MOVES uses a "modal" approach to estimating energy and emissions based on discrete vehicle power bins, and characterizes energy rates on a time basis (e.g. grams per hour) instead of the traditional mile basis (e.g. grams per mile). This approach requires activity data to generate the distribution of activity in modal bins, and for conversions of mile-based activity data (VMT) to time-based activity data (e.g. source hours operating, or SHO); the process for this is discussed in detail in the Software Design Reference Manual.

With regard to reconciling differences between activity and emission data, a long-standing challenge in the generation of on-road mobile source emission inventories is the disconnect between how vehicle activity data sources characterize vehicles and how emission or fuel economy regulations characterize vehicles. An example of this is how vehicles are characterized by the Highway Performance Monitoring System (HPMS) – by a combination of the number of tires and axles – and EPA's weight-based emission classifications such as LDV, LDT1, LDT2 etc.

Reconciling activity and emissions data generally requires “mapping” between the two. The MOBILE series of models have traditionally grouped vehicles according to the EPA emission classifications, and provided external guidance on mapping these categories to the sources of activity data, such as HPMS. MOVES is designed to take these mappings into account internally, so that the casual user of MOVES will not have to deal with external mapping. Doing this, however, requires some complexity in the design. Vehicles are characterized both according to activity patterns and energy/emission performance, and are mapped internal to the model. Thus the model uses data for both the activity and energy/emission methods of characterization. On the activity side, vehicles are grouped into “Source Use Types”, or use types, defined as groups expected to have unique activity patterns. Because HPMS data is a fundamental source of activity, the MOVES use types are defined as subsets of HPMS vehicles classifications. These use types are shown in Table 1-1. The majority of activity data presented in this document are based on these classifications.

To characterize factors important for energy consumption and emissions, the MOVES design has implemented the concept of “Source Bins”. Unique source bins are defined by those characteristics with the largest influence on fuel (energy) consumption and emissions. Source bins are defined completely separate from use types, but are mapped to source use types internal to MOVES by the Source Bin Distribution Generator, discussed in the Software Design Reference Manual. The distributions of source bin attributes (e.g. fuel type, vehicle weight and engine size) used to generate the overall mapping of source bins to source use types are also included in Section 7 of this document. The energy and emission rates themselves are documented in a separate report, “MOVES2004 Energy and Emission Inputs”.

The data tables and fields discussed in this report are shown in Table 1-2.

Table 1-1. MOVES SourceTypes

SourceType ID	SourceType	HPMS Vehicle Class
11	Motorcycles	Motorcycles
21	Passenger Cars	Passenger Cars
31	Passenger Trucks (primarily personal use)	Other Two-Axle/Four Tire, Single Unit
32	Light Commercial Trucks (other use)	Other Two-Axle/Four Tire, Single Unit
41	Intercity Buses (non-school, non-transit)	Buses
42	Transit Buses	Buses
43	School Buses	Buses
51	Refuse Trucks	Single Unit
52	Single Unit Short-haul Trucks	Single Unit
53	Single Unit Long-haul Trucks	Single Unit
54	Motor Homes	Single Unit
61	Combination Short-haul Trucks	Combination
62	Combination Long-haul Trucks	Combination

“Long-haul” trucks are defined as trucks for which most trips are 200 miles or more.

Table 1-2. MOVES Database Elements Covered in This Report

Database Table Name*	Fields
SourceTypeYear	SourceTypePopulation SalesGrowthFactor MigrationRate
SourceTypeModelYear	ACPenetrationFraction
SourceTypeAge	SurvivalRate RelativeMAR FunctioningACFraction
SourceTypeAgeDistribution	AgeFraction
SourceBinDistribution*	SourceBinActivityFraction
SourceUseType	RollingTerm RotatingTerm DragTerm SourceMass
RoadTypeDistribution	RoadTypeVMTFraction
AvgSpeedDistribution	AvgSpeedFraction
HPMSVtypeYear	HPMSBaseYearVMT BaseYearOffNetVMT VMTGrowthFactor
MonthVMTFraction	MonthVMTFraction
DayVMTFraction	DayVMTFraction
HourVMTFraction	HourVMTFraction
DriveSchedule	AverageSpeed
DriveScheduleSecond	Speed
DriveScheduleAssociation	SourceTypeID RoadTypeID DriveScheduleID IsRamp
SourceTypeHour	StartsPerSHO IdleSHOFactor
ZoneYearRoadType	SHOAllocFactor
ZoneYear	IdleAllocFactor StartAllocFactor
SCCVTypeDistribution	SCCVTypeFraction
MonthGroupHour	AC Activity Terms (A, B & C)

*See also Table 7-1, listing tables and fields used by the SourceBinGenerator.

2. Data Sources

A number of organizations collect data relevant to this report. The most important sources used to populate the vehicle population and activity portions of MOVES database are described here. These sources are referred to throughout this document by the abbreviated name given in this description, but the reference citation is only given here.

2.1. VIUS97

Every five years the U.S. Census Bureau conducts the Vehicle Inventory and Use Survey (VIUS)[1] to collect data on the physical characteristics and activity of U.S. trucks. The 1997 survey is a sample of private and commercial trucks that were registered in the U.S. on July 1, 1997. The survey excludes automobiles, motorcycles, government-owed vehicles, ambulances, buses, motor homes and nonroad equipment. For MOVES, VIUS97 provides information to characterize trucks by SourceType and to estimate age distributions.

2.2. Polk NVPP® and TIP®

R.L. Polk & Co. is a private company providing automotive information services. The company maintains two databases relevant for MOVES: the National Vehicle Population Profile (NVPP®)[2] and the Trucking Industry Profile (TIP®Net) Vehicles in Operation database.[3] The first focuses on light-duty cars and trucks, the second focuses on medium and heavy-duty trucks. Both compile data from state vehicle registration lists. For MOVES2004, EPA is using the 1999 NVPP® and TIP®.

2.3. FHWA *Highway Statistics*

Each year the Federal Highway Administration's (FHWA) Office of Highway Policy Information publishes *Highway Statistics*. This volume summarizes a vast amount of roadway and vehicle data from the states and other sources. For MOVES, we will use data on vehicle registrations and vehicle miles traveled (VMT), summarized in four tables. [4] [5] [6] [7]. Hereafter, references will be to FHWA MV-1, MV-10, VM-1, and VM-2. For the 1999 base year, we used *Highway Statistics 1999*. For 2000-2002 VMT growth rates, we used the 2000, 2001 and 2002 versions.

2.4. FTA National Transit Database

The Federal Transit Administration (FTA) summarizes financial and operating data from U.S. mass transit agencies in the National Transit Database (NTD).[8] For MOVES2004, we used 1999 data from the report, "Age Distribution of Active Revenue Vehicle Inventory: Details by Transit Agency."

2.5. School Bus Fleet Fact Book

The School Bus Fleet 1999 Fact Book includes estimates, by state, of number of school buses and total miles traveled.[9] The Fact Book is published by Bobit Publications.

2.6. MOBILE6

In some cases, we have been able to use data from MOBILE6 with only minor adaptation. The MOBILE6 data is documented in technical reports, particularly M6.FLT.002

"Update of Fleet Characterization Data for Use in MOBILE6 - Final Report."[10] Additional MOBILE6 documentation is available on the web at http://www.epa.gov/otaq/m6.htm

2.7. Annual Energy Outlook & National Energy Modeling System

The Annual Energy Outlook (AEO) [11] describes Department of Energy forecasts for future energy consumption. The National Energy Modeling System (NEMS) is used to generate these projections based on economic and demographic projections. We used *AEO2004* to forecast VMT growth and vehicle sales growth.

2.8. Transportation Energy Data Book

Each year, Oak Ridge National Laboratory produces the DOE Transportation Energy Data Book (TEDB). This book summarizes transportation and energy data from a variety of sources. For MOVES2004, we relied on Edition 22, published in September 2002[12] and Edition 23, published in October 2003.[13]

2.9. Oak Ridge National Laboratory Light-duty Vehicle Database

Oak Ridge National Laboratory Center for Transportation Analysis has compiled a database of light-duty vehicle information which combines EPA Test vehicle data and Ward's Automotive Inc. data spanning 1976 – 2001.[14] We used this database to determine weight distributions for light trucks by model year.

3. SourceTypeYear

SourceTypeYear consist of three fields—**SourceTypePopulation, SalesGrowthFactor**, and **Migration Rate**. Each field is described in terms of what information it contains, the sources of the data used for the field, and, when applicable, tables providing certain data points used in determining the field parameters.

3.1. SourceTypePopulation

The SourceTypePopulation field stores the total population of vehicles by SourceType for a given base year and domain: in this case, the entire United States in 1999. Some of the values are taken directly from the indicated sources; other values needed to be derived from available data and are not found explicitly in any of the data sources.

SourceTypePopulation provides base year populations and provides the basis for Total Activity Generator calculation of populations in calendar years after the base year. These populations are, in turn, used to generate travel fractions by age and SourceType and to allow allocation of VMT by age.

The primary sources for calendar year 1999 vehicle population data are the FHWA *Highway Statistics* Tables MV-1 and MV-10 and the Polk NVPP® and TIP® databases. The Transportation Energy Data Book (TEDB22) explains three factors that account for differences between the two sources:

1. Polk data includes only vehicles that were registered on July 1 of 1999. FHWA data includes all vehicles that have been registered at any time throughout the year and thus may include vehicles that were retired during the year or may double count vehicles registered in two or more states.
2. Polk and FHWA may differ in how they classify some minivans and SUVs as trucks or automobiles. (This difference is less important since 1990).
3. FHWA includes all non-military Federal vehicles. Polk data includes only those Federal vehicles that are registered within a state.

Also, FHWA data is available for Puerto Rico, but Puerto Rico does not appear to be included in our Polk data set. MOVES will cover Puerto Rico and the Virgin Islands. In addition, Polk collects data on Gross Vehicle Weight (GVW) class 3 vehicles in both the NVPP® and TIP® databases, but the values are not the same. Polk staff recommended using the TIP® values.[15] Finally, our Polk data set includes school buses and motor homes (which can be counted separately), but does not include "non-school buses."

The Department of Transportation's National Household Transportation Survey (NHTS) combines the previous National Personal Transportation Survey and the American Travel Survey to collect data on personal travel patterns and includes data on both personal trucks and automobiles.[16] This data is included in Table 3-1, but is not used in MOVES because it is two years newer than the FHWA and Polk data, and it excludes non-household vehicles. Values from the three sources are compared in Table 3-1.

Table 3-1. Vehicle Population Comparisons 1999

Data Source	Motorcycles	Automobiles	Trucks (total)	Buses (total)	Motor Homes
FHWA (w Puerto Rico and Federal vehicles)	4,173,869	134,480,432	83,178,092	732,189	na
FHWA (w/o Puerto Rico and Federal vehicles)		131,076,551	81,060,369		
Polk NVPP® & TIP®	na	126,868,744	80,323,528*	na	902,949
NHTS (2001)	*4,951,747*	*115,914,908*	*80,499,939*		*1,446,469*

*Excluding motor homes and NVPP® GVW3 trucks.

For automobiles and trucks, it is possible to do a direct comparison of Polk and FHWA data. To estimate the MOVES population, we adjust the FHWA data to account for double-counting by multiplying the total FHWA population by the ratio of the Polk population to the FHWA population without Federal vehicles and Puerto Rican vehicles.

$$\text{Adjusted Population} = \text{FHWA}_{\text{w federal \& PR}} * (\text{Polk}/\text{FHWA}_{\text{w/o federal \& PR}})$$

This leads to the values in Table 3-2.

Table 3-2. Adjusted Vehicle Populations

	Population
Automobiles	130,163,354
Trucks (total)	83,007,993

For MOVES, total trucks are sub-classified into seven SourceTypes. The proportion of total trucks in each subtype was estimated using VIUS97 responses for Axle Arrangement, Primary Area of Operation, Body Type and Major Use as detailed in Table 3-3.

With these definitions and with vehicles that lack AREAOP codes assigned proportionally to the corresponding SourceTypes, we computed the distributions in Table 3-4. These distributions were multiplied by the total truck population from Table 3-2 to derive population values for MOVES.

Table 3-3. VIUS97 Codes Used for Distinguishing Truck SourceTypes.

SourceType	Axle Arrangement	Primary Area of Operation	Body Type	Major Use
Passenger Trucks	2 axle/4 tire (AXLRE= 1,5,6,7)	any	any	personal transportation (MAJUSE=20)
Light Commercial Trucks	2 axle/4 tire (AXLRE= 1,5,6,7)	any	any	any but personal transportation
Refuse Trucks	Single Unit (AXLRE = 2-4, 8-16)	off-road, local or short-range (AREAOP <=4)	garbage hauler (BODTYP=30)	any
Single Unit Short-haul Trucks	Single Unit (AXLRE = 2-4, 8-16)	off-road, local or short-range (AREAOP <=4)	any except garbage hauler	any
Single Unit Long-haul Trucks	Single Unit (AXLRE = 2-4, 8-16)	long-range (AREAOP >=5)	any except garbage hauler	any
Combination Short-haul Trucks	Combination (AXLRE >=17)	off-road, local or medium (AREAOP <=4)	any	any
Combination Long-haul Trucks	Combination (AXLRE >=17)	long-range (AREAOP >=5)	any	any

Table 3-4. 1999 Truck SourceType Distribution and Populations

SourceType	Percent	Population
Passenger Trucks	68.90%	57,190,192
Light Commercial Trucks	23.02%	19,106,257
Refuse Trucks	0.11%	88,607
Single Unit Short-haul Trucks	5.39%	4,470,798
Single Unit Long-haul Trucks	0.32%	264,435
Combination Short-haul Trucks	1.31%	1,084,366
Combination Long-haul Trucks	.97%	803,337
Total	100.00%	83,007,993

For buses, we needed to distribute the total buses from FHWA to the three MOVES classes. Additional information on bus numbers was available from the FTA NTD, Polk TIP®, and the School Bus Fleet Fact Book, and the American Bus Association "Motorcoach Census 2000".[17] The FTA NTD provides population numbers for a variety of transit options. To determine the number of transit buses, we summed their counts for Articulated Motor Buses, Motor Bus Class A, B & C, and Double Decked buses.

Table 3-5. Bus Population Comparisons 1999

Data Source	Total Buses	Intercity Buses	Transit Buses	School Buses
FHWA MV-1	732,189			
FHWA MV-10 (excludes PR)	728,777			592,029*
FTA NTD			55,706	
Polk TIP®				460,178
School Bus Fleet Fact Book				429,086
Motorcoach Census**		44,200		

* Includes some church & industrial buses.
** Includes Canada.

As Table 3-5 shows, estimates of school bus numbers vary. We chose to use the FHWA value because it includes church and industrial buses that we believe have activity patterns more similar to school buses than to intercity buses. To calculate the number of buses for the categories needed for MOVES, we used the FHWA school bus value and the FTA transit bus value. We assigned the remaining total FHWA buses (732,189-592,029-55,706 = 84,454) to the intercity category. Note this value substantially exceeds the estimate of intercity buses provided by the Motorcoach Census.

For the remaining categories, motorcycles and motor homes, we used the only available data. For motorcycles we used the FHWA value from table MV-1. For motor homes we used the population from the Polk TIP® database.

Table 3-6 summarizes the 1999 vehicle populations proposed for use in MOVES2004.

3.2. SalesGrowthFactor

The SalesGrowthFactor field stores a multiplicative factor indicating changes in sales by SourceType for calendar years after the base year. It determines the number of new vehicles added to the vehicle population each year, and is expressed relative to the previous year's sales. For example, 1 means no change from previous year sales levels, 1.02 means a two percent increase in sales, and 0.98 means a two percent decrease in sales. SalesGrowthFactor is used in the Total Activity Generator calculation of source type populations for calendar years after the base year, meaning calendar years 2000 through 2050 in MOVES2004.

Table 3-6. 1999 SourceType Populations for MOVES

SourceType ID	SourceType	1999 Population
11	Motorcycles	4,173,869
21	Passenger Cars	130,163,354
31	Passenger Trucks	57,190,192
32	Light Commercial Trucks	19,106,257
41	Intercity Buses	84,454
42	Transit Buses	55,706
43	School Buses	592,029
51	Refuse Trucks	88,607
52	Single Unit Short-haul Trucks	4,470,798
53	Single Unit Long-haul Trucks	264,435
54	Motor Homes	902,949
61	Combination Short-haul Trucks	1,084,366
62	Combination Long-haul Trucks	803,337

SalesGrowthFactor estimates were derived from actual sales data from TEDB23 (2003), whose primary source is Ward's Motor Vehicle Facts and Figures, and from sales projections from *AEO2004*. Beyond 2025, SalesGrowthFactor was set to 1, indicating no growth in sales. The data sources and methodology by source use type are detailed following:

- Passenger Cars: SalesGrowthFactors for calendar year 2000 and 2001 were derived from total sales numbers reported in the TEDB23 Table 4.5. Factors for calendar years 2002 through 2025 were derived from new car sales estimates of presented in *AEO2004* Supplemental Table 45, generated by NEMS.
- Motorcycles: SalesGrowthFactors for calendar year 2000 and 2001 were computed from sales values in the Motorcycle Industry Council Statistical Annual.[18] SalesGrowthFactors for years 2002 through 2025 were set equal to those for passenger cars.
- Passenger Trucks/Commercial Trucks: SalesGrowthFactor for calendar year 2000 and 2001 were derived from total sales numbers reported in the TEDB23 Table 4.6. Factors for Calendar year 2002 through 2025 were derived from new light truck sales estimates presented in *AEO2004* Supplemental Table 45, generated by NEMS.
- Buses, Single Unit Trucks, Motor Homes: Calendar years 2000-2001 based on sales as reported in TEDB23 Table 5.3 (gross weight range 10,000-33,000 lbs). Years 2002 through 2025 calculated from medium-duty truck sales projections from *AEO2004* Supplemental Table 55.
- Combination Trucks, Refuse Trucks: Calendar years 2000-2001 based on sales as reported in TEDB23 Table 5.3 (gross weight range 33,001 and greater pounds). Years 2002 through 2025 calculated from heavy-duty truck sales projections found in *AEO2003* Supplemental Table 55.

The resulting SalesGrowthFactors by use type are shown in Table 3-7:

Table 3-7. SalesGrowthFactor by Calendar Year and Use Type

Calendar Year	Passenger Cars, Motorcycles	Passenger Trucks Light Comm. Trucks	All Buses, Single-Unit Trucks, Motor Homes	Refuse Trucks, Combination Trucks
2000	1.017*	1.039	0.968	0.809
2001	0.952*	1.037	0.850	0.660
2002	0.962	1.001	0.821	1.043
2003	0.980	0.966	0.981	0.925
2004	1.001	1.067	1.050	1.050
2005	1.017	1.028	1.107	1.162
2006	1.010	1.024	1.085	1.121
2007	1.002	1.014	1.031	1.025
2008	0.996	1.011	1.017	1.020
2009	0.995	1.010	1.006	1.006
2010	0.997	1.016	1.002	0.993
2011	1.001	1.018	1.000	0.987
2012	0.994	1.015	1.005	1.002
2013	1.001	1.022	1.018	1.020
2014	0.996	1.013	1.010	1.013
2015	0.997	1.013	1.003	0.996
2016	1.006	1.022	1.004	0.989
2017	1.011	1.026	1.017	1.011
2018	1.010	1.027	1.020	1.018
2019	1.005	1.021	1.003	0.989
2020	1.003	1.020	1.007	0.997
2021	0.992	1.007	0.996	0.988
2022	0.999	1.014	1.008	1.005
2023	1.003	1.020	1.016	1.017
2024	1.004	1.022	1.018	1.018
2025	1.005	1.025	1.023	1.027

*The table values for 2000 & 2001 apply only to cars. Motorcycle values are 1.317 and 1.197, respectively.

MOBILE6 also projected vehicle sales in order to calculate vehicle counts[46]. MOVES SalesGrowthFactors are based on more recent information.

3.3. MigrationRate

The MigrationRate field stores a yearly multiplicative factor used to estimate how many vehicles join or leave the population of a SourceType in the given domain in a given year. We expect this field will be most useful when modeling emissions on relatively small geographic scale.

For the initial MOVES release, the domain is the entire U.S. and we are using a simplifying assumption of no migration: that is, a migration rate of 1.

4. SourceTypeModelYear

SourceTypeModelYear stores the field **ACPenerationFraction,** which is the fraction of vehicles equipped with air conditioning, by source type and model year. ACPenetrationRate is used in the calculation of the A/C adjustment in the MOVES emission rate calculators.

Default data used for MOVES2004 is taken directly from MOBILE6.[19] Base market penetration data by model year were gathered from Ward's Automotive Handbook for light-duty vehicles and light-duty trucks through the 1995 Model Year. This information was available from 1972 for cars and from 1975 for trucks. Year-to-year rates are more variable in the first few years of available data, so values for earlier model years will be estimated by applying the 1972 and 1975 rates for cars and trucks, respectively. In the later years, the rate of increase becomes more steady. Projections beyond 1995 were developed by taking the average yearly rate of increase from the last five years of available data and applying them to each subsequent year until a predetermined cap was reached. A cap of 98% was placed on cars and 95% on trucks under the assumption that there will always be vehicles sold without air conditioning systems, more likely on trucks than cars. The caps are in place by the 1999 model year and will remain for subsequent years. For MOVES, the light-duty vehicle rates were applied to passenger cars, and the light-duty truck rates were applied to all other use types (except motorcycles, for which AC penetration is assumed to be zero).

5. SourceTypeAge

Three fields comprise SourceTypeAge in MOVES2004—**SurvivalRate, Relative MAR**, and **FunctioningACFraction**. Each one is described below, including data sources and some relevant data points used in the model.

5.1. SurvivalRate

The SurvivalRate field describes the fraction of vehicles of a given SourceType and Age (relative to the total number originally sold) that remain on the road one year to the next. SurvivalRate is used in the Total Activity Generator in the calculation of source type populations by age in calendar years after the base year.

The data for all SourceTypes except motorcycles came from the Transportation Energy Data Book (TEDB22, unchanged for version 23). For Passenger Cars we used survival rates for the 1990 model year (TEDB22, Table 6.9). For Passenger Trucks and Light Commercial Trucks we used survival rates for the 1990 model year (TEDB22, Table 6.10).

SurvivalRate for all other SourceTypes were from the Heavy-Duty rates for the 1980 model year (TEDB22, Table 6.11). The 1990 model year rates were not used because they were significantly higher than the other model years in the analysis (e.g. 45 percent survival rate for 30 year-old trucks), and seemed unrealistically high. While limited data exists to confirm this judgment, a snapshot of 5-year survival rates can be derived from VIUS 1992 and 1997 results for comparison. According to VIUS, the average survival rate for model years 1988-1991 between the 1992 and 1997 surveys was 88 percent. The comparable survival rate for 1990 model year Heavy-Duty vehicles from TEDB was 96 percent, while the rate for 1980 model year trucks was 91 percent. This comparison lends credence to the decision that the 1980 model year survival rates are more in line with available data.

TEDB22 does not include scrappage rates for GVWR 10,000-26,000 vehicles, so it was necessary to apply the Heavy-Duty rates to predominantly Medium-Duty use types.

SurvivalRates for motorcycles were calculated based on regression of data provided by the Motorcycle Industry Council (MIC).[20]

SurvivalRates are shown in Table 5-1.

The concept of SurvivalRates as used in MOVES differs from that used in the MOBILE6 model[46]. In MOBILE6, survival rates were applied to the each vehicle class fleet as a whole. Different survival rates were used for different ranges of calendar years in developing vehicle counts for MOBILE6. In MOVES, a separate SurvivalRate is applied to each age in each SourceType fleet. These SurvivalRates by age are based on the observed scrappage of a single model year (1980 or 1990) over time. These SurvivalRates in MOVES are used for all model years in a SourceType in all calendar years.

Table 5-1. SurvivalRate by Age and SourceType

Age	Motorcycles	Passenger Cars	Passenger Trucks Light Comm. Trucks	All Other SourceTypes
0	0.99	1.00	1.00	1.00
1	0.99	1.00	1.00	1.00
2	0.98	1.00	1.00	1.00
3	0.97	1.00	1.00	1.00
4	0.96	1.00	0.99	0.99
5	0.96	1.00	0.97	0.97
6	0.95	0.99	0.94	0.95
7	0.94	0.96	0.91	0.92
8	0.93	0.93	0.87	0.89
9	0.92	0.89	0.83	0.86
10	0.92	0.84	0.78	0.83
11	0.91	0.80	0.73	0.79
12	0.90	0.75	0.68	0.75
13	0.89	0.70	0.63	0.72
14	0.89	0.65	0.58	0.68
15	0.88	0.60	0.53	0.64
16	0.87	0.55	0.48	0.60
17	0.86	0.50	0.43	0.56
18	0.85	0.45	0.38	0.52
19	0.85	0.40	0.33	0.48
20	0.84	0.35	0.29	0.44
21	0.83	0.31	0.25	0.41
22	0.82	0.27	0.21	0.37
23	0.82	0.24	0.18	0.34
24	0.81	0.20	0.15	0.31
25	0.80	0.17	0.13	0.28
26	0.79	0.15	0.10	0.25
27	0.78	0.12	0.08	0.22
28	0.78	0.10	0.07	0.20
29	0.77	0.08	0.05	0.18
30	0.76	0.07	0.04	0.16

5.2. Relative MAR

The Relative Mileage Accumulation Rate (Relative MAR) is listed for each MOVES SourceType and Age. The Relative MAR is computed as the annual MAR divided by the highest MAR within the HPMS vehicle class. Table 1-2 lists the groupings of the MOVES SourceTypes within the six HPMS Vehicle Classes. The following discussion refers to the Source Type ID numbers (often in parentheses) found in this table.

For most SourceTypes, the annual MARs were derived from the MARs developed for MOBILE6. These were mapped from the MOBILE6 Vehicle Classes to the MOVES SourceTypes. We then used regression to smooth these initial MARs and to extend the MARs from 25 to 30 ages.

5.2.1. Motorcycles and Passenger Cars

The initial MARs for passenger cars (category 21) and motorcycles (category 11) were set to equal those in MOBILE6.

5.2.2. Trucks

The initial MARs for truck categories 31, 32, 51, 52, 53, 61, and 62 in MOVES were calculated based on weighting fractions assigned to the MOBILE6 truck classes. We used VIUS97 values for Gross Vehicle Weight (PKGVW) to determine weighting fractions by model year. To separate Light-Duty Trucks 1 and Light-Duty Trucks 2, which are distinguished by Loaded Vehicle Weights, we used information from the Oak Ridge National Lab Light Duty Vehicle database. To separate Class 2a and 2b trucks, we used information from the Oak Ridge National Laboratory Report by Davis and Truitt.[21] The initial MARs for the MOVES truck categories were then calculated as the product of the weighting fractions and the MARs from MOBILE6.

5.2.3. Buses

For the School Buses (category 43) the initial MARs were taken from the MOBILE6 value for diesel school buses (HDDBS). As in MOBILE6, the same annual MAR was used for each age. The MOBILE6 value of 9,939 miles per year came from the 1997 School Bus Fleet Fact Book.

For Transit Buses (category 42), the initial MARs were taken from the MOBILE6 values for diesel transit buses (HDDBT). This mileage data was obtained from the 1994 Federal Transportation Administration survey of transit agencies. [22]

For Intercity Buses (category 41), the initial MARs were taken from Motorcoach Census 2000.[23] The data did not distinguish vehicle age, so the same MAR was used for each age.

5.2.4. Motor Homes

For motor homes (category 54), the initial MARs were taken from an independent research study[24] conducted in October 2000 among members of the Good Sam Club. The members are active recreation vehicle (RV) enthusiasts who own motor homes, trailers and trucks. The average annual mileage was estimated to be 4,566 miles. The data did not distinguish vehicle age, so the same MAR was used for each age.

5.2.5. Calculating Relative MARs

In order to smooth the data and to extend the MARs from the 25 ages in MOBILE6 to the 30 ages in MOVES, we used statistical regression to determine the curves that best fit the data for years starting in 1997 and going back to 1973 (ages 1 to 25). Table 5-2 presents the resulting regression equations for each MOVES category. Note, as in MOBILE6, the motorcycle values were estimated as a linear function to age 12. Ages 13 through 30 are then estimated as a constant.

Table 5-2. Equations for Calculating Annual Mileage Accumulation Rates

MOVES Source Type	Source Type ID	Regression Equation	R^2 from Regression
Motorcycles	11	na	na*
Passenger Cars	21	$y=0.1568e^{-0.0506x}$	1.0
Passenger Trucks	31	$y=0.0002x^2-0.0118x + 0.2096$	0.998
Light Commercial Trucks	32	$y=0.0002x^2-0.0129x+0.2196$	0.998
Refuse Trucks	51	$y=0.8674e^{-0.1148x}$	0.904
Single Unit Short-haul Trucks	52	$y=0.4289e^{-0.0990x}$	0.990
Single Unit Long-haul Trucks	53	$y=0.3339e^{-0.0762x}$	0.864
Motor Homes	54	y=0.0457	na
Intercity Buses	41	y=0.6000	na
Transit Buses	42	$y=0.46659e^{-0.0324x}$	na*
School Buses	43	y=0.0994	na
Combination Short-haul Trucks	61	$y=0.0016x^2-0.0762x +0.9655$	0.977
Combination Long-haul Trucks	62	$y=0.0021x^2-0.0887x+1.0496$	0.879

* For Motorcycles and Transit Buses, the equations from MOBILE6 were used

The values calculated from the equations were then used to calculate the relative MARs by computing the ratio of the value for each SourceType and age to the highest value within the HPMS class.

5.3. FunctioningACFraction

The FunctioningACFraction field indicates the fraction of the air-conditioning equipped fleet with fully functional A/C systems, by source type and vehicle age. A value of 1 means all systems are functional. This is used in the calculation of total energy to account for vehicles without functioning A/C systems. Default estimates were developed for all source types using the “unrepaired malfunction” rates used for 1992-and-later model years in MOBILE6.[25] These were applied to all source use types except motorcycles, which were assigned a value of zero for all years.

Table 5-3. FunctioningACFraction by Age (All Use Types Except Motorcycles)

Age	FunctioningAC Fraction
0	1
1	1
2	1
3	1
4	0.99
5	0.99
6	0.99
7	0.99
8	0.98
9	0.98
10	0.98
11	0.98
12	0.98
13	0.96
14	0.96
15	0.96
16	0.96
17	0.96
18	0.95
19	0.95
20	0.95
21	0.95
22	0.95
23	0.95
24	0.95
25	0.95
26	0.95
27	0.95
28	0.95
29	0.95
30	0.95

6. SourceTypeAgeDistribution

This element of the MOVES2004 contains the field **AgeFraction**, which stores values that describe the age distribution of a SourceType in the base year. AgeFractions are determined differently for various SourceTypes, as the following describes.

6.1. Motorcycles

To determine age fractions for motorcycles, we began with Motorcycle Industry Council estimates of the number of motorcycles in use by model year in 1998. We used the estimates of sales growth and survival rates to grow these population estimates to 1999, then computed age fractions. These fractions are summarized in Table 6-1.

6.2. Passenger Cars

To determine age fractions for passenger cars, we began with Polk NVPP® 1999 data on car registration by model year. However, this data presents a snapshot of registrations on July 1, 1999, and we needed age fractions as of December 31, 1999. To adjust the values, we used monthly data from the Polk new car database to estimate the number of new cars registered in the months July through December 1999. Model Year 1998 cars were added to the previous estimate of "Age 1" cars and Model Year 1999 and 2000 cars were added to the "Age 0" cars. We then computed fractions by age. These fractions are summarized in Table 6-1.

6.3. Trucks

To determine age fractions for passenger trucks, light commercial trucks, refuse trucks, short-haul and long-haul single unit trucks and short-haul and long-haul combination trucks, we used data from the VIUS97 database. Vehicles in the VIUS97 database were assigned to MOVES source types as summarized in Table 3-3.

VIUS97 does not include a model year field and records ages as 0 through 10 and 11-and-greater. Because we needed greater detail on the older vehicles, we followed the practice used for MOBILE6 and determined the model year for some of the older vehicles by using the responses to the VIUS97 questions "How did you obtain this vehicle?" (VIUS field "OBTAIN") and "When did you obtain this vehicle?" (VIUS field "ACQYR") to derive the model year of the vehicles that were obtained new. These derived model years also were used for much of the source bin distribution work described later in this report.

To calculate age fractions, it was important to account for the inconsistent methodologies used for the older and newer vehicles. Thus, for each source type, we adjusted the age 11-and-older vehicle counts by dividing the original count by model year by the fraction of the older vehicles that were coded as "obtained new." This created an array of adjusted vehicle counts by model year for calendar year 1997. This 1997 array may overestimate the fraction of mid-aged vehicles since the fraction of vehicles purchased new likely declines with time; however, we believe the procedure is reasonable given the limited data available.

We then used the sales growth for 1997 and 1998 from TEDB22 Tables 7.6 and 8.3 and the scrappage rates from TEDB22 Tables 6.10 and 6.11 to grow the population to the 1999 base year and then we calculated age fractions. These fractions are summarized in Table 6-1.

6.4. Intercity Buses

We were not able to identify a data source for estimating age distributions of intercity buses. Because the purchase and retirement of these buses is likely to be driven by general economic forces rather than trends in government spending, we will use the age distribution that was derived for short-haul combination trucks, described previously. While we believe this choice is reasonable given the lack of data, we welcome suggestions of improved data sources or algorithms to improve the intercity bus age fractions used in future versions of the MOVES database.

6.5. School Buses and Motor Homes

To determine the age fractions of School Buses and Motor Homes, we used information from the Polk TIP® 1999 database. School Bus and Motor Home counts were available by model year. Unlike the Polk data for passenger cars, these counts reflect registration at the end of the calendar year and, thus, did not require adjustment. We converted model year to age and calculated age fractions. These are summarized in Table 6-1.

6.6. Transit Buses

To determine the age fractions for Transit Buses, we used data from the Federal Transit Administration database. In particular, we used responses to 1999 Form 408, which included counts of in-use vehicles by year of manufacture.

To properly account for the fraction of Age 0 vehicles at the end of 1999, it was necessary to adjust the counts for model-year-1999 vehicles to account for the different reporting periods of the various transit organizations. The counts were adjusted proportionally depending on the month in which the fiscal year ended. The adjusted counts were used to calculate the age fractions.

Table 6-1. 1999 Age Fractions for MOVES Source Types

	SourceType												
Age	**11**	**21**	**31**	**32**	**41**	**42**	**43**	**51**	**52**	**53**	**54**	**61**	**62**
0	0.094714	0.081475	0.08535	0.117527	0.09124	0.062424	0.079424	0.053361	0.071217	0.173083	0.073713	0.09124	0.168908
1	0.093476	0.06084	0.077167	0.106259	0.072783	0.077118	0.065977	0.042567	0.059567	0.144768	0.045616	0.072783	0.134739
2	0.075459	0.062471	0.07186	0.098951	0.062335	0.074172	0.064695	0.036457	0.047165	0.114627	0.07393	0.062335	0.115399
3	0.068103	0.058685	0.09132	0.09387	0.054827	0.072682	0.059353	0.082125	0.053342	0.059639	0.048698	0.054827	0.115399
4	0.061255	0.069053	0.096596	0.098437	0.075047	0.062732	0.07985	0.09917	0.064028	0.062123	0.060515	0.075047	0.12002
5	0.056974	0.060901	0.094721	0.082957	0.061137	0.057646	0.040606	0.064919	0.065817	0.104159	0.060804	0.061137	0.081687
6	0.051956	0.061327	0.080811	0.07331	0.053356	0.050384	0.051098	0.058788	0.050153	0.08065	0.044092	0.053356	0.065744
7	0.043254	0.056453	0.063061	0.047932	0.041102	0.04612	0.043455	0.026059	0.039507	0.018942	0.040781	0.041102	0.040851
8	0.037016	0.057629	0.059255	0.04581	0.048557	0.049186	0.058484	0.073815	0.039877	0.013911	0.031984	0.048557	0.03045
9	0.035495	0.057889	0.050885	0.041843	0.05662	0.075902	0.069647	0.065308	0.048617	0.068272	0.04417	0.05662	0.031176
10	0.033575	0.061101	0.051119	0.044191	0.057585	0.060917	0.041921	0.052269	0.062773	0.072438	0.060195	0.057585	0.030707
11	0.038755	0.058577	0.045676	0.038966	0.05531	0.05059	0.052586	0.072611	0.056501	0.048926	0.056322	0.05531	0.027311
12	0.046127	0.053134	0.042863	0.033072	0.058511	0.04886	0.055609	0.059178	0.047723	0.011957	0.05743	0.058511	0.007322
13	0.042189	0.047721	0.037329	0.028084	0.050309	0.043448	0.051232	0.074901	0.058442	0.002737	0.044695	0.050309	0.007708
14	0.038313	0.039086	0.019511	0.018968	0.0449	0.039355	0.046432	0.040258	0.041881	0.005549	0.050087	0.0449	0.009884
15	0.034497	0.030594	0.013223	0.013196	0.035235	0.032043	0.037449	0.041688	0.023386	0.005545	0.053065	0.035235	0.005095
16	0.030742	0.018665	0.007979	0.004868	0.014107	0.032094	0.014449	0.012119	0.036565	0	0.036308	0.014107	0.001042
17	0.027049	0.012461	0.003568	0.001972	0.011903	0.018085	0.011057	0.01351	0.018857	0.002432	0.02215	0.011903	0.0008
18	0.023416	0.010356	0.002169	0.003003	0.010321	0.008203	0.013562	0.011952	0.017918	0.001752	0.012724	0.010321	0.002546
19	0.019845	0.008542	0.001659	0.001351	0.013225	0.023051	0.013786	0.002947	0.018627	0	0.001733	0.013225	0.000825
20	0.016334	0.01012	0.001279	0.001305	0.00779	0.007056	0.011776	0.002976	0.014052	0.000157	0.013844	0.00779	0.000648
21	0.012885	0.007927	0.001328	0.002379	0.005953	0.003185	0.010385	0.002823	0.01564	0.006238	0.019059	0.005953	0.000383
22	0.009497	0.006039	0.00051	0.000791	0.006081	0.000651	0.010678	0	0.005687	0.000338	0.0267	0.006081	0.000584
23	0.00617	0.003858	0.000413	0.000641	0.002208	0.001267	0.007299	0.005242	0.006819	0.000596	0.016931	0.002208	0
24	0.002904	0.002324	8.11E-05	8.66E-05	0.002572	0.000873	0.009192	0.001453	0.006557	0.000259	0.004455	0.002572	0.000427
25	0	0.002771	3.66E-05	6.19E-05	0.00236	0.000856	0	0.00345	0.00654	0	0	0.00236	0.000131
26	0	0	0.00012	5.64E-05	0.00184	0.000223	0	5.3E-05	0.006311	0.000901	0	0.00184	0.000146
27	0	0	7.54E-05	3.72E-05	0.001547	0.000377	0	0	0.01192	0	0	0.001547	0
28	0	0	6.78E-06	6.16E-05	0.001016	0.000274	0	0	0.00241	0	0	0.001016	6.83E-05
29	0	0	2.53E-05	9.05E-06	0.000223	5.14E-05	0	0	0.0012	0	0	0.000223	0
30	0	0	2.89E-06	5.35E-06	0	0.000171	0	0	0.000902	0	0	0	0

7. SourceBinDistribution

The SourceBinDistribution describes the characteristics of a SourceType population as a distribution among SourceBins. These SourceBins classify a vehicle by discriminators relevant for emissions and energy calculations: fuel and engine technology, average vehicle weight and engine displacement, model year group, and regulatory class.

While users can enter SourceBinDistributions directly, MOVES-GHG will usually generate the values in this table using values in a collection of other tables, which, in turn, need to be filled with accurate data. The SourceBinGenerator input tables are described in Table 7-1.

Table 7-1. Data Tables Used by SourceBinGenerator

Generator Table Name	Key Fields	Additional Fields	Notes
SourceTypePolProcess	SourceTypeID PolProcessID	isSizeWeightReqd isRegClassReqd isMYGroupReqd	Indicates which pollutant-processes the source bin distributions may be applied to and indicates which discriminators are relevant for each sourceType and polProcess (pollutant/process combination)
FuelEngFraction	SourceTypeID ModelYearID FuelTypeID EngTechID	fuelEngFraction	Joint distribution of vehicles with a given fuel type and engine technology. Sums to one for each sourceType & modelYear
SizeWeightFraction	SourceTypeID ModelYearID FuelTypeID EngTechID WeightClassID EngSizeID	sizeWeightFraction	Joint distribution of engine size and weight. Sums to one for each sourceType, modelYear and fuel/engtech combination.
RegClassFraction	SourceTypeID ModelYearID FuelTypeID EngTechID RegClassID	regClassFraction	Fraction of vehicles in a given "Regulatory Class." Sums to one for each sourceType, modelYear and fuel/engtech combination.
PollutantProcessModelYear	PolProcessID ModelYearID	modelYearGroupID	Assigns model years to appropriate model year groups.

The Source Bin generator code determines which discriminators are relevant for a given pollutant/process combination and multiplies the relevant fractions from the tables listed above to determine the detailed SourceBinDistribution for each combination of Pollutant, Process, SourceType, and Model Year.

More detailed descriptions of the SourceBin Distribution inputs for each SourceType follow. The Inputs for 2000-and-later vehicles of all SourceTypes are described in Section 7.7.

7.1. Motorcycles

For base year 1999, motorcycle distributions were assigned based on information from EPA motorcycle experts and from the Motorcycle Industry Council.

7.1.1. FuelEngFraction

We assume all motorcycles are powered by conventional gasoline engines.

7.1.2. SizeWeightFraction

The Motorcycle Industry Council "Statistical Annual" provides information on displacement distributions for highway motorcycles for model years 1990 and 1998. These were mapped to MOVES engine displacement categories. Additional EPA certification data was used to establish displacement distributions for model year 2000. We assumed that displacement distributions were the same in 1969 as in 1990, and interpolated between the established values to determine displacement distributions for all model years from 1990 to 1999.

We then applied weight distributions for each displacement category as suggested by EPA motorcycle experts. The average weight estimate includes fuel and rider. The weight distributions depended on engine displacement but were otherwise independent of model year. This information is summarized in Table 7-2.

Table 7-2. Motorcycle Engine Size and Average Weight Distributions for Selected Model Years

Displacement Category	1969 MY distribution (assumed)	1990 MY distribution (MIC)	1998 MY distribution (MIC)	2000 MY distribution (certification data)	Weight distribution (EPA staff)
0-169 cc (1)	0.118	0.118	0.042	0.015	100%: <= 500 lbs
170-279 cc (2)	0.09	0.09	0.05	0.035	50%: <= 500 lbs 50%: > 500 lbs <= 700 lbs
280+ cc (9)	0.792	0.792	0.908	0.95	30%: > 500 lbs, <= 700 lbs 70%: > 700lbs

7.1.3. RegClassFraction

All Motorcycles are assigned to the "Motorcycle" (MC) regulatory class.

7.2. Passenger Cars

For base year 1999, passenger car distributions were derived from the 1999 Polk NVPP®. The national files for domestic and imported cars were consolidated into a single file.

7.2.1. FuelEngFraction

The FuelEngFraction table assigns a fraction of each source type and model year to all relevant combinations of fuel type bin and engine technology bin.

The Polk fuel code was converted to the MOVES FuelTypeID using the mapping in Table 6-3. Note that convertible and flexible fueled vehicles are counted as gasoline-powered vehicles in MOVES2004 because most of these pre-1999 vehicles operate on gasoline most of the time. This approach differs from that of the Department of Energy and, likely, underestimates the number of vehicles operating on alternative fuels. On the national scale, the resulting difference in emissions is expected to be negligible.

Table 7-3. Mapping Polk Fuel Codes to MOVES.

Polk		**MOVES**	
FUEL_CD	**FUEL_NAME**	**FuelTypeID**	**Fuel Description**
C	DSL TURBO	2	Diesel
D	DIESEL	2	Diesel
E	ELECTRIC	9	Electric
F	GAS TURBO	1	Gasoline
G	GAS	1	Gasoline
N	NATURAL GAS	3	CNG
P	PROPANE	4	LPG
R	METHANOL	6	Methanol
V	CONVERTIBLE	1	Gasoline
X	FLEXIBLE	1	Gasoline

For each model year, the car counts for the MOVES fuels were summed and fractions were computed. Entries for which no fuel was reported were omitted from the calculations. For the 1999-and-earlier cars, electric vehicles were assigned to EngTechID “30" (electric only). All other 1999-and-earlier vehicles were assigned to EngTechID “1" (conventional). Additional analysis indicated a likely error in the Polk data (an entry for 1983 Ford Escorts powered by methanol). This fuel/engine fraction was removed and the 1983 values were renormalized.

7.2.2. SizeWeightFraction

The Polk cubic displacement values were converted to liters and assigned to the MOVES engine size bins. The weight ID was assigned by adding 300 lbs to the Polk curb weight and grouping into MOVES weight bins. For each fuel type, model year, engine size, and weight bin, the number of cars was summed and fractions were computed. In general, entries for which data was missing were omitted from the calculations. However, because no curb weight data was available from Polk for electric cars, additional analysis was performed. Based on data from the Electric Drive Association on electric vehicle sales[26], two-thirds of electric vehicles were assigned to weight class 35 and one third was assigned to weight class 40. Also, further analysis indicated a likely error in the Polk data (an entry for 1997 gasoline-powered Bentleys with engine size 5099 and weight class 20). This fraction was removed and the 1997 values were renormalized.

7.2.3. RegClassFraction

All Passenger Cars were assigned to the “Light-Duty Vehicle” (LDV) regulatory class.

7.3. Trucks

This section describes how default Source Bin information was compiled for Passenger Trucks, Light Commercial Trucks, Single-Unit Short-haul and Long-haul Trucks, and Combination Short-haul and Long-haul Trucks. Source Bin information for Buses, Refuse Trucks, and Motor Homes are described in separate sections following.

VIUS97 was the primary source for information on truck distributions. Information from VIUS97 was supplemented with information from MOBILE6 and from the Oak Ridge National Laboratory Light Duty Vehicle database.

VIUS97 records were assigned to SourceTypes as described above in Table 3-3. Not all SourceTypes had data for all model years, and no data was available beyond model year 1997. For years where no vehicles or only a few vehicles were surveyed by VIUS, we duplicated fractions from the nearest available model year.

7.3.1. FuelEngFraction

The VIUS97 ENGTYP field was converted to the MOVES FuelTypeID using the mapping in Table 7-4. Note, it was not possible to distinguish LPG and CNG vehicles using VIUS97. Based on historical data, we assigned the pre-1990 LPG/LNG vehicles to LPG and the 1990-and-later vehicles to CNG. While these vehicles form a very small portion of the national fleet, we would like to update this assignment if better information becomes available. Also, it was not possible to identify the fuel used for the VIUS category "Other." Vehicles in this category were omitted from the analysis and model year results were renormalized.

Table 7-4. Mapping VIUS97 ENGTYP to MOVES FuelTypeID

VIUS97		MOVES	
1	Leaded gasoline	1	Gasoline
2	Unleaded gasoline	1	Gasoline
3	Diesel	2	Diesel
4	Liquefied gas (petroleum (LPG) or natural (LNG))	3 or 4	CNG or LPG
5	Other		None

There were no electric-fueled trucks, so all 1999-and-earlier trucks were assigned to EngTechID "1" (conventional).

Table 7-5 summarizes the pre-1999 diesel fractions for MOVES general truck categories by model year. Because alternative fuels form a very small portion of the 1999-and-earlier fleet, the gasoline fractions can be estimated as one minus the diesel fractions listed here. For the exact gasoline fractions and alternative fuel fractions, see the MOVES database.

For light trucks, fuel distribution information is also available from Polk. While the Polk data cannot easily be mapped to the truck SourceTypes used in MOVES, if future resources allow, it would be instructive to compare the Polk distributions to the combined passenger truck and light commercial truck distributions. This could help estimate the uncertainty in the fuel fraction estimates for these vehicles.

Table 7-5. Diesel Fractions for Trucks

Source Type	Passenger Trucks 31	Light Commerical Trucks 32	Single-Unit Short-haul Trucks 52	Single-Unit Long-haul Trucks 53	Combination Short-haul Trucks 61	Combination Long-haul Trucks 62
Model Year						
1969	0.00000	0.00906	0.06238	0.47356	0.73282	1.00000
1970	0.00000	0.00906	0.06238	0.47356	0.73282	1.00000
1971	0.00000	0.00906	0.06238	0.47356	0.73282	1.00000
1972	0.00000	0.00906	0.01695	0.47356	0.73282	1.00000
1973	0.00000	0.00906	0.04465	0.47356	0.73282	1.00000
1974	0.00000	0.08203	0.02377	0.47356	0.73282	1.00000
1975	0.00000	0.02876	0.02130	0.47356	0.73282	1.00000
1976	0.00000	0.00000	0.06518	1.00000	0.73282	1.00000
1977	0.00000	0.00399	0.32805	1.00000	0.73282	1.00000
1978	0.00000	0.00083	0.01731	0.06120	0.73282	1.00000
1979	0.01392	0.04185	0.11083	1.00000	0.73282	1.00000
1980	0.00000	0.05703	0.15791	1.00000	0.73282	1.00000
1981	0.03557	0.03142	0.16825	0.20453	0.96590	1.00000
1982	0.00000	0.29896	0.19327	0.87629	0.94257	1.00000
1983	0.04182	0.15086	0.67377	1.00000	0.92500	1.00000
1984	0.00132	0.21648	0.57100	1.00000	0.91464	1.00000
1985	0.01633	0.17724	0.52692	0.99148	0.89852	1.00000
1986	0.01426	0.04786	0.42720	0.97560	0.95934	0.98152
1987	0.00188	0.02941	0.60714	0.94441	0.98601	1.00000
1988	0.00801	0.05089	0.43232	0.30001	0.96482	0.83667
1989	0.00706	0.05186	0.33462	0.71929	0.96268	0.99984
1990	0.00661	0.05723	0.47071	0.81014	0.98571	0.99701
1991	0.01442	0.07682	0.62245	0.30680	0.97919	0.99732
1992	0.01185	0.05506	0.50514	0.80948	0.97942	1.00000
1993	0.00995	0.07803	0.58491	0.35251	0.96928	1.00000
1994	0.01488	0.07562	0.60593	0.53482	0.99546	0.99873
1995	0.02141	0.07338	0.58120	0.82016	0.97506	0.99694
1996	0.00923	0.05300	0.60411	0.40650	0.98205	0.99864
1997	0.01002	0.04391	0.55462	0.51978	0.97667	0.99973
1998	0.01002	0.04391	0.55462	0.51978	0.97667	0.99973
1999	0.01002	0.04391	0.55462	0.51978	0.97667	0.99973

7.3.2. SizeWeightFraction

Engine size distributions for trucks were determined using the VIUS97 database. The VIUS97 database categorizes engine size by fuel type and the categories do not exactly match the MOVES categories. We mapped from the VIUS97 engine size categories to the MOVES engine size categories as described in Table 7-6. For comparison, the engine size ranges for both the VIUS97 and MOVES categories are listed in cubic inches displacement.

Table 7-6. Mapping VIUS97 Engine Size Categories to MOVES EngSizeID

VIUS PKCID	VIUS Range (CID)	EngSizeID	MOVES Range (CID)
Gasoline Engines			
1	1-99	20	0-122
2	100-149	2025	122-153
3	150-169	2530	153-183
4	170-199	3035	183-214
5	200-249	3540	214-244
6	250-269	4050	244-305
7	270-299	4050	244-305
8	300-309	4050	244-305
9	310-349	5099	305-6041
10	350-359	5099	305-6041
11	360-369	5099	305-6041
12	370-399	5099	305-6041
13	400-449	5099	305-6041
14	450-9999	5099	305-6041
15	Not reported		
Diesel Engines			
16	1-249	3540	183-214
17	250-299	4050	244-305
18	300-349	5099	305-6041
19	350-369	5099	305-6041
20	370-399	5099	305-6041
21	400-429	5099	305-6041
22	430-449	5099	305-6041
23	450-469	5099	305-6041
24	470-499	5099	305-6041
25	500-549	5099	305-6041
26	550-599	5099	305-6041
27	600-649	5099	305-6041
28	650-699	5099	305-6041
29	700-749	5099	305-6041
30	750-799	5099	305-6041
31	800-849	5099	305-6041
32	850-9999	5099	305-6041
33	Not reported		
Engines for other Fuels			
34	1-99	20	0-122
35	100-149	2025	122-153
36	150-199	2530	153-183
37	200-249	3540	214-244
38	250-299	4050	305-6041
39	300-349	5099	244-305
40	350-399	5099	305-6041
41	400-449	5099	305-6041
42	450-9999	5099	305-6041
43	Not reported		

Determining weight categories for light trucks was fairly complicated. The VIUS97 data combines information from two different survey forms. The first form was administered for VIUS "strata" 1 and 2 trucks: pickup trucks, panel trucks, vans (including mini-vans), utility type vehicles (including jeeps) and station wagons on truck chassis. The second form was administered for all other trucks. While both surveys requested information on engine size, only the second form requested detailed information on vehicle weight. Thus for strata 1 and 2 trucks, VIUS classifies the trucks only by broad average weight category (AVGCK): 6,000 lbs or less, 6,001-10,000 lbs, 10,001-14,000lbs, etc. To determine a more detailed average engine size and weight distribution for these vehicles, we used the Oak Ridge National Laboratory (ORNL) light-duty vehicle database to correlate engine size with vehicle weight distributions by model year.

In particular, for Source Types 31 and 32 (Passenger Trucks and Light Commercial Trucks):

- VIUS97 trucks of the SourceType in strata 3, 4, and 5 were assigned to the appropriate MOVES weight class based on VIUS detailed average weight information.
- VIUS97 trucks of the SourceType in strata 1 and 2 were identified by enginesizeID and broad average weight category.
- Strata 1 and 2 trucks in the heavier (10,001-14,000 lbs, etc) VIUS97 broad categories were matched one-to-one with the MOVES weight classes.
- For trucks in the lower broad categories (6,000 lbs or less and 6001-10,000 lbs), we used VIUS97 to determine the fraction of trucks by model year and fuel type that fell into each engine size/broad weight class combination (the "VIUS fraction")
- We assigned trucks in the ORNL light duty vehicle database to a weightclassID by adding 300lbs to the recorded curb weight and determining the appropriate MOVES weight class.
- For the trucks with a VIUS97 average weight of 6,000 lbs or less, we multiplied the VIUS97 fraction by the fraction of trucks with a given weightclassID among the trucks in the ORNL database that had the given engine size and an average weight of 6,000 lbs or less. Note, the ORNL database did not provide information on fuel type, so the same distributions were used for all fuels.
- Because the ORNL database included only vehicles with a GVW up to 8500 lbs, we did not use it to distribute the trucks with a VIUS97 average weight of 6,001-10,000 lbs. Instead these were distributed equally among the MOVES WeightClassIDs 70, 80, 90 and 100.

Source Types 52 and 53 (Long- and Short-haul Single Unit Trucks) also included some trucks in VIUS97 strata 1 and 2, thus a similar algorithm was applied.

- VIUS97 trucks of the Source Type in strata 3, 4, and 5 were assigned to the appropriate MOVES weight class based on VIUS97 detailed average weight information.

- VIUS97 trucks of the Source Type in strata 1 and 2 were identified by enginesizeID and broad average weight category.
- Strata 1 and 2 trucks in the heavier (10,001-14,000 lbs, etc) VIUS97 broad categories were matched one-to-one with the MOVES weight classes.
- For trucks in the lower broad categories (6,000 lbs-or-less and 6001-10,000 lbs), we used VIUS97 to determine the fraction of trucks by model year and fuel type that fell into each engine size/broad weight class combination (the "VIUS fraction")
- We did not believe the ORNL light duty vehicle database adequately represented single unit trucks. Thus, the trucks with a VIUS97 average weight of 6,000 lbs or less and an engine size less than 5 liters were distributed equally among the MOVES weight classes 20, 25, 30, 35, 40, 45, 50, and 60. Because no evidence existed of very light trucks among the vehicles with larger engines (5 liter or larger), these were equally distributed among MOVES weight classes 40, 45, 50 and 60.
- The trucks with a VIUS97 average weight of 6,001-10,000 lbs were distributed equally among the MOVES weight classes 70, 80, 90 and 100.

SourceTypes 61 and 62 (Long- and Short-haul combination trucks) did not include any vehicles of VIUS97 strata 1 or 2. Thus we used the detailed VIUS97 average weight information and engine size information to assign engine size and weight classes for all of these trucks.

7.3.3. RegClassFraction

Trucks were split between the regulatory classes "Light-Duty Trucks" (LDT) and "Heavy-Duty Trucks" (HDT) based on gross vehicle weight (GVW) (the maximum weight that a truck is designed to carry.)

In particular, we used the VIUS97 response "PKGVW" and the Davis & Truit report on Class 2b Trucks[27] to determine GVW fractions by fuel type. The VIUS97 PKGVW field is intended to identify the Polk weight class. Work for MOBILE6 using the VIUS97 precursor, TIUS 1992 indicated that the PKGVW measure in VIUS97 is problematic. It is taken from the truck VIN, but is not always consistent with the indicated average and maximum weight. (For example, the reported "maximum weight" often exceeded the PKGVW.) These problems were also seen in VIUS97. However, "maximum weight" was not available for smaller trucks, and the other measures of weight reported in VIUS97 were not consistent with the need for an indicator of the relevant emission standards. When the PKGVW led to unusual results, for example, particularly high fraction of LDT among combination trucks, we checked additional VIUS fields to determine if the PKGVW was mistaken. In some cases, the PKGVW was manually revised to a higher value and fractions were recomputed. In other cases, the PKGVW was consistent with the other fields, and the difference reflected the fact that our SourceType categories are based on axle counts and trailer configurations rather than weight. For example, a 6-tire ("dually") pickup that regularly pulls a trailer is classified as a "Combination Truck," although it is in the LDT regulatory class. Some model years had relatively high fractions of such trucks. It is likely these high values indicate a problem with small sample size for the model year, but they were left unchanged for now.

Also, because the split between the LDT and HDT regulatory class is at 8500 lbs, it was necessary to split the Polk GVW Class 2 into class 2a (6001-8500 lbs) and class 2b (8501-10,000 lbs). Davis & Truitt[28] report that, on average, 23.3 percent of Class 2 trucks are in Class 2b; 97.4 percent of Class 2a trucks are powered by gasoline, and 76 percent of Class 2b trucks are powered by gasoline. From this information, we estimate that 19.2 percent of gasoline-powered Class 2 trucks are Class 2b and that 73.7 percent of diesel-powered class 2 trucks are Class 2b.

The regulatory class fractions for trucks are listed below in Table 7-7 and Table 7-8. Fractions of LDT for gasoline- and diesel-fueled vehicles are provided separately. The remaining trucks are classified as HDT. Entries of "#N/A" indicate that no vehicles of that SourceType and FuelType were surveyed in that model year. Values for alternative-fuel vehicles are available in the MOVES database.

Table 7-7 Fraction of Light-Duty Trucks among Gasoline-Fueled Trucks

Model Year	SourceType					
	Passenger Trucks 31	**Light Commercial Trucks 32**	**Single-Unit Short-haul Trucks 52**	**Single-Unit Long-haul Trucks 53**	**Combination Short-haul Trucks 61**	**Combination Long-haul Trucks 62**
1967	0.902303	#N/A	#N/A	#N/A	#N/A	#N/A
1968	0.879238	#N/A	#N/A	#N/A	#N/A	#N/A
1969	1	#N/A	0.109337	#N/A	#N/A	#N/A
1970	0.983681	#N/A	0.046808	#N/A	#N/A	#N/A
1971	0.956315	#N/A	0.38324	#N/A	#N/A	#N/A
1972	0.957791	0.74768	0.683527	#N/A	#N/A	#N/A
1973	0.953535	0.59472	0.300171	0	#N/A	#N/A
1974	0.946371	0.65248	0.132987	0	#N/A	#N/A
1975	0.966522	0.724827	0.134558	0	#N/A	#N/A
1976	0.951185	0.883189	0.125404	#N/A	#N/A	#N/A
1977	0.887739	0.793622	0.061817	#N/A	#N/A	#N/A
1978	0.847443	0.809907	0.45065	0.62437	#N/A	#N/A
1979	0.863942	0.776929	0.255077	#N/A	#N/A	#N/A
1980	0.897151	0.74161	0.171485	#N/A	0	#N/A
1981	0.959489	0.893686	0.304625	0.643456	0	#N/A
1982	0.939455	0.719863	0.544875	0	0	#N/A
1983	0.95116	0.903414	0.494159	#N/A	0	#N/A
1984	0.937822	0.86782	0.332359	#N/A	0	#N/A
1985	0.933322	0.869615	0.253229	0.808384	0	#N/A
1986	0.945257	0.912692	0.30116	0	0.028698	0
1987	0.956912	0.896428	0.376371	0	0	#N/A
1988	0.958257	0.899821	0.580867	0.451689	0	0.775934
1989	0.956279	0.895456	0.594791	0.334361	0	0.808384
1990	0.955606	0.897817	0.530591	0	0	0
1991	0.967955	0.903363	0.448187	0.950832	0	0
1992	0.95438	0.913522	0.624044	0	0	#N/A
1993	0.957004	0.923815	0.59655	0.596423	0	#N/A
1994	0.949354	0.891218	0.593485	0.533585	0	0
1995	0.943815	0.883694	0.507255	0.015518	0	0
1996	0.953521	0.902039	0.655492	0.567117	0	0
1997	0.954686	0.924425	0.628248	0.501883	0	0

Table 7-8. Fraction of Light-Duty Trucks among Diesel-fueled Trucks

Model Year	SourceType					
	Passenger Trucks 31	Light Commercial Trucks 32	Single-Unit Short-haul Trucks 52	Single-Unit Long-haul Trucks 53	Combination Short-haul Trucks 61	Combination Long-haul Trucks 62
1967	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1968	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1969	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1970	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
1971	#N/A	#N/A	0	#N/A	#N/A	#N/A
1972	#N/A	#N/A	0	#N/A	#N/A	#N/A
1973	#N/A	0	0	#N/A	#N/A	#N/A
1974	#N/A	0	0	#N/A	#N/A	#N/A
1975	#N/A	0	0	0	#N/A	#N/A
1976	#N/A	#N/A	0	0	#N/A	#N/A
1977	#N/A	0	0	0	#N/A	#N/A
1978	#N/A	0	0	0	#N/A	#N/A
1979	0	0.072135	0	0	#N/A	#N/A
1980	#N/A	0.397873	0	0	0.009394	#N/A
1981	0.892664	0.118825	0	0	0	#N/A
1982	#N/A	0.271488	0.047107	0	0	#N/A
1983	0.54614	0.232866	0.219283	#N/A	0	#N/A
1984	0.262872	0.243221	0.019513	0	0	0
1985	0.259661	0.231416	0.041111	0	0.006796	0
1986	0.959781	0.133885	0.034369	0	0.001254	0
1987	0.262872	0.091469	0.013541	0	0	0
1988	0.254531	0.158459	0.078315	0.008054	0	0
1989	0.25772	0.200201	0.040286	0.069597	0	0.000507
1990	0.374882	0.176388	0.012528	0.121637	0.000596	0
1991	0.262244	0.203415	0.145307	0	0.002601	0
1992	0.260222	0.157783	0.095434	0.078572	0	0
1993	0.262872	0.242925	0.171617	0.433434	0.001354	0
1994	0.314785	0.243391	0.182654	0.132245	0	0
1995	0.262219	0.178734	0.092071	0.160888	0.001135	0
1996	0.307815	0.193289	0.12573	0.119779	0.000667	0
1997	0.26213	0.186986	0.082764	0.303336	0.002372	0.003932

7.4. Buses

Because buses are not included in VIUS97 and because the Polk data we had for school buses was incomplete, the source bin fractions for buses is based on a variety of data sources and assumptions. Values for transit buses, school buses, and intercity buses were calculated separately.

7.4.1. FuelEngFraction

We followed the Energy Information Administration (EIA) in assigning all intercity buses to conventional diesel engines (*AEO2004, Supplemental Table 34*).

The National Transit Database (NTD) responses to form 408 (Revenue Vehicle Information Form) included information classifying transit buses to a variety of fuel types by model year. The mapping from NTD fuel types to MOVES fuel types is summarized in Table 7-9. The resulting fractions by model year are summarized in Table 7-10.

Table 7-9. Mapping National Transit Database Fuel Types to MOVES Fuel Types

NTD code	NTD description	MOVES Fuel ID	MOVES Fuel Description
BF	Bunker fuel	na	
CN	Compressed natural gas	3	CNG
DF	Diesel fuel	2	diesel
DU	Dual fuel	2	diesel
EB	Electric battery	9	electric
EP	Electric propulsion	9	electric
ET	Ethanol	5	ethanol
GA	Gasoline	1	gasoline
GR	Grain additive	na	
KE	Kerosene	na	
LN	Liquefied natural gas	3	CNG
LP	Liquefied petroleum gas	4	LPG
MT	Methanol	6	methanol
OR	Other	na	

Table 7-10. Fuel Fractions for Transit Buses

Model Year	Gasoline	Diesel	CNG	LPG	Ethanol	Methanol	Electric
1969	0	1	0	0	0	0	0
1970	0	1	0	0	0	0	0
1971	0	1	0	0	0	0	0
1972	0	1	0	0	0	0	0
1973	0	1	0	0	0	0	0
1974	0	1	0	0	0	0	0
1975	0	1	0	0	0	0	0
1976	0	1	0	0	0	0	0
1977	0	1	0	0	0	0	0
1978	0	1	0	0	0	0	0
1979	0.033981	0.966019	0	0	0	0	0
1980	0	1	0	0	0	0	0
1981	0.002088	0.997912	0	0	0	0	0
1982	0.001894	0.992424	0	0	0	0	0.005682
1983	0	1	0	0	0	0	0
1984	0.001603	0.998397	0	0	0	0	0
1985	0	0.999565	0.000435	0	0	0	0
1986	0.00079	0.996447	0.002764	0	0	0	0
1987	0.001402	0.998598	0	0	0	0	0
1988	0.002377	0.997623	0	0	0	0	0
1989	0.00113	0.998306	0	0	0.000565	0	0
1990	0.002941	0.990271	0.006787	0	0	0	0
1991	0.003134	0.978064	0.018106	0	0	0	0.000696
1992	0.010769	0.933903	0.046417	0.000743	0	0.005941	0.002228
1993	0.003061	0.918707	0.07551	0.00068	0.001361	0	0.00068
1994	0.010711	0.900625	0.084796	0.000893	0	0	0.002975
1995	0.009555	0.835108	0.153153	0	0	0	0.002184
1996	0.017963	0.881825	0.097613	0.000709	0	0	0.001891
1997	0.012702	0.810162	0.174365	0.000462	0	0	0.002309
1998	0.012003	0.838409	0.1487	0	0	0	0.000889
1999	0.005998	0.878041	0.113296	0	0	0	0.002666

All 1999-and-earlier electric buses were assigned to EngTechID “30" (electric only). All other 1999-and-earlier buses were assigned to EngTechID “1" (conventional).

The available Polk data excluded fuel information on school buses and we were unable to locate any other source for bus fuel fractions. (The Union of Concerned Scientists estimates that about one percent of school buses are fueled by either CNG or propane, but does not provide estimates by model year.[29]) Thus we used the diesel fractions from MOBILE6, which were derived from Polk 1996 and 1997 data. We assigned non-diesel buses to gasoline. These fractions are summarized in Table 7-11. In the future it would be desirable to obtain up-to-date, detailed fuel information for school buses from Polk or some other source.

Table 7-11. Fuel Fractions for School Buses

Model Year	Gasoline	Diesel
1972	1	0
1973	1	0
1974	1	0
1975	0.991272	0.008728
1976	0.99145	0.00855
1977	0.976028	0.023972
1978	0.970936	0.029064
1979	0.95401	0.04599
1980	0.94061	0.05939
1981	0.736056	0.263944
1982	0.674035	0.325965
1983	0.676196	0.323804
1984	0.615484	0.384516
1985	0.484507	0.515493
1986	0.326706	0.673294
1987	0.265547	0.734453
1988	0.249771	0.750229
1989	0.229041	0.770959
1990	0.124036	0.875964
1991	0.089541	0.910459
1992	0.010041	0.989959
1993	0.120539	0.879461
1994	0.147479	0.852521
1995	0.114279	0.885721
1996	0.041539	0.958461

7.4.2. SizeWeightFraction

While the vast majority of buses of all types have engine displacement larger than five liters (EngSizeID=5099), it was difficult to find detailed information on average bus weight.

For intercity buses, we used information from Table II-7 of the FTA 2003 Report to Congress[30] that specified the number of buses in various weight categories. This information is summarized in below in Table 7-12. Note the FTA uses the term “over-the-road bus” to refer to the class of buses roughly equivalent to the MOVES “intercity bus” category. The FTA weight categories were mapped to the equivalent MOVES weight classes.

Table 7-12. FTA Estimate of Bus Weights

Weight (lbs)	MOVES Weight ClassID	MOVES Weight Range (lbs)	Number buses (2000)	Bus type
0-20,000			173,536	school & transit
20,000-30,000			392,345	school & transit
30,000-40,000	400	33,000-40,000	120,721	school & transit & intercity
40,000-50,000	500	40,000-50,000	67,905	intercity
total			754,509	

Using our 1999 bus population estimates (in Table3-1), we were able to estimate the fraction of all buses that were intercity buses and then to estimate the fraction of intercity buses in each weight bin. In particular:

Estimated number of intercity buses in 2000:

754,509 * (84,454/(84,454+55,706+592,029)) = 87,028

Estimated number of intercity buses 30,000-40,000 lbs:

87,028 - 67,905 = 19,123

Estimated intercity bus weight distribution:

Class 400 = 19,123/87,028 = 22%

Class 500 = 67,905/87,028 = 78%

This distribution was used for all model years.

For transit buses, we took average curb weights from Figure II-6 of the FTA Report to Congress[31]and added additional weight to account for passengers and alternative fuels. The resulting in-use weights were all in the range from 33,850 to 40,850. Thus all transit buses were assigned to the weight class "400" (33,000 - 40,000 lbs) for all model years. This estimate could be improved if more detailed weight information for transit buses becomes available.

For school buses, we used information from a survey of California school buses. While this data may not be representative of the national average distribution, it was the best data source available. The California data[32] provided information on number of vehicles by gross vehicle weight class and fuel as detailed in Table 7-13.

Table 7-13. California School Buses

	Gas	Diesel	Other	Total
LHDV	2740	4567	8	7315
MHDV	467	2065	2	2534
HHDV	892	11639	147	12678
Total	4099	18271	157	

To estimate the distribution of average weights among the MOVES weight classes, we assumed that the Light Heavy-Duty (LHDV) school buses were evenly distributed among weightClassIDs 70, 80, 90, 100, and 140. Similarly, we assumed the Medium Heavy-Duty (MHDV) school buses were evenly distributed among weightClassIDs 140, 160, 195, 260, and 330 and the Heavy Heavy-Duty (HHDV) school buses were evenly distributed among weightClassIDs 195, 260, 330, and 440.

The final default weight distributions for buses are summarized in Table 7-14.

7.4.3. RegClassFraction

All buses were assigned to the Heavy-Duty Truck regulatory class.

Table 7-14. Weight Distributions for Buses by Fuel Type

	Intercity Buses (41)	Transit Buses (42)	School Buses (43)	
Weight Class	Diesel	Diesel & Gas	Diesel	Gas
70			0.0500	0.1337
80			0.0500	0.1337
90			0.0500	0.1337
100			0.0500	0.1337
140			0.0726	0.1565
160			0.0226	0.0228
195			0.1819	0.0772
260			0.1819	0.0772
330			0.1819	0.0772
400	0.2197	1.0000	0.1593	0.0544
500	0.7800			

7.5. Refuse Trucks

Values for Refuse Trucks (Source Type 51) were computed from information in VIUS97.

7.5.1. FuelEngFraction

As for other trucks, we used the VIUS97 EngTyp field to estimate FuelType and Engine Technology Fractions. The Refuse Trucks classified in VIUS97 as "CNG or LPG" are assigned to CNG. All Refuse Trucks were assumed to have conventional internal combustion engines.

Table 7-15. Fuel Fractions for Refuse Trucks by Model Year

Model Year	Gasoline	Diesel	CNG
1984	0	1	0
1985	0.220605	0.779395	0
1986	0	1	0
1987	0	1	0
1988	0	1	0
1989	0.076055	0.922351	0.001594
1990	0.0175	0.9825	0
1991	0	1	0
1992	0.014675	0.985325	0
1993	0.005532	0.994468	0
1994	0.071123	0.928877	0
1995	0	1	0
1996	0	1	0
1997	0	1	0

7.5.2. SizeWeightFraction

Because the sample of Refuse Trucks in VIUS97 was small, the same SizeWeight distributions were used for all model years. As for other trucks, the EngineSize group was determined from the VIUS97 engine size categories and the WeightClass was determined from the VIUS97 reported average weight.

Table 7-16. Refuse Truck SizeWeight Fractions by Fuel Type

Engine Size	Weight Class	Gasoline	Diesel	CNG
3-3.5L	60	0.009008		
3.5-4L	100		0.000317	
3.5-4L	140	0.001919	0.007691	
3.5-4L	160		0.000822	
3.5-4L	195		0.000258	
3.5-4L	260		0.000741	
3.5-4L	400		0.001081	
4-5L	140	0.000000	0.000074	
>5L	80	0.147737	0.000000	
>5L	100	0.070203	0.006808	
>5L	140	0.134765	0.011626	
>5L	160	0.198498	0.003302	
>5L	195	0.054682	0.022762	
>5L	260	0.203838	0.062584	
>5L	330	0.021943	0.098921	
>5L	400	0.152009	0.101197	
>5L	500	0.003834	0.235437	
>5L	600	0.001563	0.333582	1.000000
>5L	800		0.110766	
>5L	1000		0.002031	

7.5.3. RegClassFraction

Using the VIUS97 data on gross vehicle weight, all Refuse Trucks were classified as Heavy-Duty Trucks.

7.6. Motor Homes

Determining source bin distribution for Motor Homes required a number of assumptions and interpolation due to the lack of detailed information. For each field, the following describes the information available, assumptions made, and how data points were determined.

7.6.1. FuelEngFraction

Detailed information on motor home fuel distribution was not available. Staff of the Recreational Vehicle Industry Association (RVIA) told us that the fraction of diesel motor homes had been relatively constant at 10 to 20 percent for many years.[33] This fraction began to increase steadily in the mid-1990s and is now 40%. Based on this information, we used linear interpolation to estimate the diesel fractions in Table 7-17. The remaining 1999-and-earlier motor homes are assumed to be gasoline-fueled. We assumed all 1999-and-earlier motor homes have conventional internal combustion engines.

Table 7-17. Diesel Fractions for Motor Homes.

Model Year	Fraction Diesel
1993-and-earlier	0.150000
1994	0.177778
1995	0.205556
1996	0.233333
1997	0.261111
1998	0.288889
1999	0.316667

7.6.2. SizeWeightFraction

No detailed information was available on average engine size and weight distributions for motor homes. We assumed all motor home engines were 5 L or larger. As a surrogate for average weight, we used information on gross vehicle weight provided in the Polk TIP® 1999 database by model year and mapped the Polk GVW Class to the MOVES weight bins. These values are likely to overestimate average weight and should be updated if better information becomes available. The Polk TIP® information did not specify fuel type, so we assumed that the heaviest vehicles in the Polk database were diesel-powered and the remainder are powered by gasoline. This led to the weight distributions in Table 7-18 and Table 7-19.

Table 7-18. Weight Fractions for Diesel Motor Homes by Model Year

Polk GVW bin	3	4	5	6	7	8
MOVES weight class	**140**	**160**	**195**	**260**	**330**	**400**
Model Year	**Diesel**					
1975	0.171431	0.792112	0.029828	0	0.006629	0
1976	0.637989	0.340639	0.018755	0.000436	0.002181	0
1977	0.68944	0.292308	0.012168	0.000277	0.005531	0.000277
1978	0.423524	0.574539	0	0.000387	0.00155	0
1979	0.096922	0.899344	0	0.001067	0.002667	0
1980	0.462916	0.537084	0	0	0	0
1981	0	0.941973	0	0.030174	0	0.027853
1982	0	0.868333	0	0.049	0.03	0.052667
1983	0	0.912762	0.000203	0.014845	0.030096	0.042094
1984	0	0.932659	0.000835	0.009183	0.036732	0.020592
1985	0	0.881042	0.001474	0.010761	0.083285	0.023438
1986	0	0.855457	0.013381	0.022962	0.089534	0.018667
1987	0	0.791731	0.085493	0.022498	0.087164	0.013113
1988	0	0.72799	0.148917	0.015469	0.093335	0.014289
1989	0	0.73298	0.128665	0.043052	0.082792	0.012511
1990	0	0.173248	0.614798	0.043628	0.149939	0.018387
1991	0	0	0.619344	0.063712	0.296399	0.020545
1992	0	0	0.551548	0.01901	0.385085	0.044356
1993	0	0	0.345775	0.471873	0.144844	0.037509
1994	0	0	0.45546	0.354386	0.159622	0.030531
1995	0	0	0.635861	0.163195	0.17468	0.026264
1996	0	0	0.553807	0.229529	0.184208	0.032456
1997	0	0	0.666905	0.193167	0.111299	0.028628
1998	0	0	0.267	0.335069	0.357508	0.040423
1999	0	0	0	0.736656	0.233886	0.029458

Table 7-19. Weight Fractions for Gasoline Motor Homes by Model Year

Polk GVW bin	3	4	5	6	7	8
MOVES weight class	140	160	195	260	330	400
Model Year	Gasoline					
1975	1	0	0	0	0	0
1976	1	0	0	0	0	0
1977	1	0	0	0	0	0
1978	1	0	0	0	0	0
1979	1	0	0	0	0	0
1980	1	0	0	0	0	0
1981	0.747723	0.252277	0	0	0	0
1982	0.732235	0.267765	0	0	0	0
1983	0.714552	0.285448	0	0	0	0
1984	0.641577	0.358423	0	0	0	0
1985	0.692314	0.307686	0	0	0	0
1986	0.720248	0.279752	0	0	0	0
1987	0.606635	0.393365	0	0	0	0
1988	0.459429	0.540571	0	0	0	0
1989	0.551601	0.448399	0	0	0	0
1990	0.543354	0.456646	0	0	0	0
1991	0.612025	0.322022	0.065952	0	0	0
1992	0.54464	0.373999	0.081361	0	0	0
1993	0.583788	0.361277	0.054935	0	0	0
1994	0.481099	0.361146	0.157755	0	0	0
1995	0.52997	0.198479	0.271551	0	0	0
1996	0.435959	0.289453	0.274588	0	0	0
1997	0.221675	0.433334	0.344991	0	0	0
1998	0.288222	0.581599	0.13018	0	0	0
1999	0.170133	0.392451	0.288411	0.149004	0	0

7.6.3. RegClassFraction

We assigned all motor homes to the Heavy-Duty Truck regulatory class.

7.7. SourceBinDistributions for 2000-and-later

MOVES2004 was designed to support a wide variety of future fuels and engine technologies, including compressed natural gas (CNG), liquified petroleum gas (LPG), and conventional internal combustion (CIC) and advanced internal combustion (AIC) engines. In particular, emission rates were developed to support the combinations of fuel and engine technology listed by SourceType in Table 7-20.

The various hybrid types were split into "moderate" and "full" categories because there are types of hybrids which get less of an efficiency increase from hybrid design due to larger engines and smaller electrical components. The less efficient designs we called "moderate" hybrids (like the Honda hybrids) to distinguish them from the more efficient, full hybrid designs (like the Toyota Prius). Both of these categories have significantly different energy rates and potentially different market shares. Conventional categories are split from advanced categories for a different reason. There have been significant improvements in internal combustion engines over time. The conventional versus advanced split is a crude accounting of these improvements. Hydrogen-fuel vehicles (including internal combustion, fuel cell and fuel cell-hybrid) are shown to have a small market share in future years, based on NEMS projections; however, these vehicles are not currently supported as the energy and emission rates for these vehicles are not included in the initial release of draft MOVES2004. When these rates are added to the model, the range of hydrogen technologies shown here will be supported. All of these technologies are further defined in the report, "Fuel Consumption Modeling of Conventional and Advanced Technology Vehicles in the Physical Emission Rate Estimator (PERE)," which is being written for the MOVES model.

Table 7-20. Supported Fuels and Technologies for 2000-and-later Model Years.

Fuel	Engine Technology	Motor-cycles	Passenger Cars, Light Passenger & Commercial Trucks	Transit & School Buses; Single-Unit Short Haul Trucks & Motor Homes	Intercity Buses	Refuse Trucks	Single Unit Long Haul Trucks	Combi-nation Short & Long Haul Trucks
Gasoline	Conventional IC	X	X	X		X	X	X
Gasoline	Advanced IC		X	X			X	X
Gasoline	CIC Hybrid Moderate		X	X				
Gasoline	CIC Hybrid Full		X	X				
Gasoline	AIC Hybrid Moderate		X	X				
Gasoline	AIC Hybrid Full		X	X				
Diesel	Conventional IC		X	X	X		X	X
Diesel	Advanced IC		X	X	X		X	X
Diesel	CIC Hybrid Moderate		X	X				
Diesel	CIC Hybrid Full		X	X				
Diesel	AIC Hybrid Moderate		X	X				
Diesel	Diesel AIC Hybrid Full		X	X		X		
CNG	Conventional IC		X	X		X	X	
LPG	Conventional IC		X	X		X	X	
Ethanol	Conventional IC		X	X		X	X	
Methanol	Conventional		X	X		X	X	

Fuel	Engine Technology	Motor-cycles	Passenger Cars, Light Passenger & Commercial Trucks	Transit & School Buses; Single-Unit Short Haul Trucks & Motor Homes	Intercity Buses	Refuse Trucks	Single Unit Long Haul Trucks	Combi-nation Short & Long Haul Trucks
	IC							
Gaseous Hydrogen	Advanced IC		To Be Added	To Be Added		To Be Added		
Gaseous Hydrogen	AIC Hybrid		To Be Added	To Be Added		To Be Added		
Gaseous Hydrogen	Fuel Cell Hybrid		To Be Added	To Be Added		To Be Added		
Gaseous Hydrogen	Fuel Cell		To Be Added	To Be Added		To Be Added		
Liquid Hydrogen	Fuel Cell Hybrid		To Be Added	To Be Added		To Be Added		
Liquid Hydrogen	Fuel Cell		To Be Added	To Be Added		To Be Added		
Electricity	Electric only		X	X		X		

The inputs for determining default SourceBinDistributions for model years 2000-and-later were generally based on fuel and engine technology projections from AEO2004 and on the 1999 calendar year regulatory class, size and weight distributions used in MOVES.

7.7.1. Motorcycles

We assumed that all 2000-and-later motorcycles were fueled by conventional gasoline engines, with the same size and weight distributions as in 1999. All motorcycles are in the "Motorcycle" regulatory class.

7.7.2. Passenger Cars, Light Passenger Trucks and Light Commercial Trucks

MOVES2004 supports a wide range of fuels and future engine technologies for passenger cars and light trucks.

The FuelEngFractions for these vehicles were determined from AEO2004. Supplemental Table 45 of the AEO2004 lists projected sales by technology type for light duty vehicles. Supplemental Table 56 lists projected technology penetrations for light duty vehicles. These values were mapped to the MOVES fuels and technologies to project fractions for model years 2001 through 2025. Fractions from 2001 were applied to model year 2000. Fractions from 2025 were applied to model years 2026 through 2050.

In particular, we analyzed passenger cars and light trucks separately. We assumed that vehicles listed as "flexible fueled" in AEO Table 45 would primarily operate on gasoline and mapped them to the MOVES category for gasoline-powered conventional internal combustion engines. Also, we assigned half of the AEO Table 45 gasoline hybrid vehicles to the MOVES gasoline-powered conventional internal combustion hybrid—"moderate" category and half to the gasoline-powered conventional internal combustion hybrid—"full" category. None were assigned to the MOVES advanced internal combustion hybrid categories. We made a similar split for diesel hybrids. Finally, to split the AEO "conventional" gasoline and diesel vehicles into MOVES conventional and advanced internal combustion categories, we used information from AEO Table 56, assigning all vehicles with gasoline direct injection or cylinder deactivation to the advanced internal combustion category. The resulting fuelEngFractions are listed in Table 7.21 and 7.22.

We used the size and weight distributions from 1999 for future years. Where a future fuel was not part of the fleet in 1999, we used the 1999 size and weight distribution for gasoline conventional internal combustion engines. Where a future diesel engine technology was not part of the fleet in 1999, we used the 1999 size and weight distribution for diesel conventional internal combustion engines.

All Passenger Cars were assigned to the Light Duty Vehicle (LDV) regulatory class. Light Trucks were distributed among the Light Duty Truck (LDT) and Heavy Duty Truck (HDT) regulatory classes. Where a future fuel was not part of the fleet in 1999, we used the regulatory class distribution for gasoline conventional internal combustion vehicles. Where a future diesel engine technology was not part of the fleet in 1999, we used the 1999 regulatory class distribution for diesel conventional internal combustion vehicles.

Table 7.21. Fuel and Engine Technology Fractions for 2000-and-later Passenger Cars

Model Year	Gasoline CIC	Gasoline AIC	Gasoline CIC Hybrid Mod	Gasoline CIC Hybrid Full	Diesel CIC	Diesel AIC	Diesel CIC Hybrid Mod	Diesel CIC Hybrid Full	CNG CIC	Ethanol (E85) CIC	Gaseous Hydrogen Fuel Cell Hybrid	Electric
2000	0.99701	0.00026	0.00078	0.00078	0.00081	--	--	--	0.00002	0.00007	--	0.00028
2001	0.99701	0.00026	0.00078	0.00078	0.00081	--	--	--	0.00002	0.00007	--	0.00028
2002	0.99512	0.00136	0.00120	0.00120	0.00074	--	--	--	0.00002	0.00007	--	0.00028
2003	0.99096	0.00272	0.00250	0.00250	0.00096	--	--	--	0.00002	0.00007	--	0.00027
2004	0.96369	0.00545	0.01433	0.01433	0.00184	0.00000	--	--	0.00002	0.00007	--	0.00027
2005	0.95946	0.00837	0.01495	0.01495	0.00191	0.00000	--	--	0.00002	0.00007	--	0.00026
2006	0.95173	0.01481	0.01562	0.01562	0.00186	0.00002	--	--	0.00002	0.00007	--	0.00025
2007	0.94111	0.02347	0.01635	0.01635	0.00235	0.00003	--	--	0.00002	0.00008	--	0.00025
2008	0.92946	0.03359	0.01709	0.01709	0.00239	0.00004	--	--	0.00002	0.00008	--	0.00024
2009	0.90863	0.04520	0.02167	0.02167	0.00242	0.00004	--	--	0.00002	0.00009	--	0.00024
2010	0.88936	0.06093	0.02146	0.02146	0.00285	0.00006	0.00177	0.00177	0.00002	0.00010	--	0.00023
2011	0.86848	0.07365	0.02550	0.02550	0.00282	0.00006	0.00181	0.00181	0.00002	0.00010	--	0.00023
2012	0.84843	0.09082	0.02547	0.02547	0.00284	0.00008	0.00326	0.00326	0.00002	0.00011	--	0.00024
2013	0.82957	0.10790	0.02613	0.02613	0.00290	0.00009	0.00340	0.00340	0.00002	0.00011	0.00012	0.00024
2014	0.81089	0.12427	0.02645	0.02645	0.00292	0.00010	0.00423	0.00423	0.00002	0.00012	0.00009	0.00024
2015	0.79319	0.14018	0.02711	0.02711	0.00298	0.00011	0.00436	0.00436	0.00002	0.00013	0.00020	0.00024
2016	0.77795	0.15510	0.02718	0.02718	0.00306	0.00012	0.00439	0.00439	0.00002	0.00013	0.00023	0.00025
2017	0.76278	0.17002	0.02726	0.02726	0.00314	0.00013	0.00439	0.00439	0.00002	0.00014	0.00024	0.00025
2018	0.75130	0.18112	0.02731	0.02731	0.00320	0.00013	0.00438	0.00438	0.00002	0.00014	0.00046	0.00025
2019	0.73958	0.19264	0.02733	0.02733	0.00332	0.00014	0.00440	0.00440	0.00002	0.00014	0.00045	0.00025
2020	0.73156	0.20051	0.02733	0.02733	0.00344	0.00014	0.00441	0.00441	0.00002	0.00015	0.00044	0.00025
2021	0.71839	0.21362	0.02727	0.02727	0.00356	0.00014	0.00442	0.00442	0.00002	0.00016	0.00047	0.00025
2022	0.71063	0.22125	0.02725	0.02725	0.00371	0.00014	0.00443	0.00443	0.00002	0.00016	0.00048	0.00025
2023	0.70685	0.22496	0.02723	0.02723	0.00384	0.00014	0.00441	0.00441	0.00002	0.00016	0.00049	0.00025
2024	0.70357	0.22794	0.02720	0.02720	0.00407	0.00014	0.00444	0.00444	0.00002	0.00017	0.00056	0.00025
2025	0.70063	0.23068	0.02716	0.02716	0.00430	0.00014	0.00445	0.00445	0.00002	0.00017	0.00058	0.00025
2026+	0.70063	0.23068	0.02716	0.02716	0.00430	0.00014	0.00445	0.00445	0.00002	0.00017	0.00058	0.00025

Table 7.22. Fuel and Engine Technology Fractions for 2000-and-later Light Trucks

Model Year	Gasoline CIC	Gasoline AIC	Gasoline CIC Hybrid Mod	Gasoline CIC Hybrid Full	Diesel CIC	Diesel AIC	Diesel CIC Hybrid Mod	Diesel CIC Hybrid Full	CNG CIC	LPG CIC	Gaseous Hydrogen Fuel Cell Hybrid	Electric
2000	0.95723	0.00019	--	--	0.04214	--	--	--	0.000005	0.00000	--	0.00043
2001	0.95723	0.00019	--	--	0.04214	--	--	--	0.000005	0.00000	--	0.00043
2002	0.95973	0.00080	--	--	0.03904	--	--	--	0.000005	0.00001	--	0.00043
2003	0.95233	0.00157	--	--	0.04567	--	--	--	0.000004	0.00001	--	0.00043
2004	0.90805	0.00322	0.01026	0.01026	0.06775	0.00003	--	--	0.000005	0.00000	--	0.00043
2005	0.88864	0.00534	0.01887	0.01887	0.06768	0.00010	--	--	0.000004	0.00001	0.00000	0.00048
2006	0.87335	0.02126	0.01953	0.01953	0.06494	0.00086	--	--	0.000004	0.00001	0.00000	0.00052
2007	0.83671	0.05941	0.01916	0.01916	0.06134	0.00369	--	--	0.000004	0.00001	0.00000	0.00052
2008	0.83460	0.05951	0.01964	0.01964	0.06240	0.00368	--	--	0.000004	0.00001	0.00000	0.00052
2009	0.83143	0.05994	0.02013	0.02013	0.06398	0.00368	--	--	0.000004	0.00001	0.00012	0.00058
2010	0.81513	0.06674	0.02046	0.02046	0.07237	0.00414	--	--	0.000004	0.00001	0.00011	0.00058
2011	0.80855	0.07359	0.02097	0.02097	0.07081	0.00443	--	--	0.000004	0.00001	0.00011	0.00057
2012	0.79112	0.09034	0.02146	0.02146	0.06935	0.00534	--	--	0.000004	0.00001	0.00025	0.00067
2013	0.77390	0.10570	0.02196	0.02196	0.06969	0.00606	--	--	0.000004	0.00001	0.00010	0.00062
2014	0.75524	0.12390	0.02245	0.02245	0.06848	0.00680	--	--	0.000004	0.00001	0.00009	0.00059
2015	0.73311	0.14355	0.02221	0.02221	0.06801	0.00749	0.00121	0.00121	0.000004	0.00001	0.00020	0.00078
2016	0.71683	0.15904	0.02222	0.02222	0.06839	0.00781	0.00123	0.00123	0.000004	0.00001	0.00021	0.00081
2017	0.69893	0.17593	0.02196	0.02196	0.06860	0.00807	0.00177	0.00177	0.000004	0.00001	0.00021	0.00081
2018	0.68217	0.19204	0.02196	0.02196	0.06843	0.00828	0.00177	0.00177	0.000004	0.00001	0.00042	0.00119
2019	0.66799	0.20529	0.02195	0.02195	0.06941	0.00827	0.00179	0.00179	0.000004	0.00001	0.00039	0.00115
2020	0.65718	0.21429	0.02128	0.02128	0.07011	0.00827	0.00305	0.00305	0.000004	0.00001	0.00037	0.00111
2021	0.65068	0.22022	0.02127	0.02127	0.07066	0.00827	0.00306	0.00306	0.000004	0.00001	0.00036	0.00112
2022	0.64469	0.22561	0.02127	0.02127	0.07128	0.00827	0.00308	0.00308	0.000004	0.00001	0.00034	0.00110
2023	0.63849	0.23209	0.02127	0.02127	0.07108	0.00827	0.00308	0.00308	0.000004	0.00001	0.00030	0.00107
2024	0.63780	0.23140	0.02124	0.02124	0.07239	0.00827	0.00311	0.00311	0.000004	0.00001	0.00031	0.00112
2025	0.63376	0.23473	0.02118	0.02118	0.07324	0.00827	0.00312	0.00312	0.000004	0.00001	0.00028	0.00110
2026+	0.63376	0.23473	0.02118	0.02118	0.07324	0.00827	0.00312	0.00312	0.000004	0.00001	0.00028	0.00110

7.7.3 Buses

Historically, school buses and transit buses have used a wide range of alternative fuels, while intercity buses have been powered almost exclusively by conventional diesel engines. For MOVES we anticipate this trend will continue. Because fuel and technology projections were not available from AEO, for MOVES defaults we carried 1999 distributions forward to 2050. These distributions are summarized in Table 7.23. Engine size and vehicle weight distributions were also carried forward from 1999. All buses were assigned to the Heavy-Duty Truck regulatory class.

Table 7.23. Fuel and Engine Technology Fractions for 2000-and-later Buses

	Diesel CIC	Gasoline CIC	CNG CIC	Electric
Intercity Buses	1	0	0	0
Transit Buses	0.878041	0.005998	0.113296	0.002666
School Buses	0.958461	0.041539	0	0

7.7.4. Motor Homes and Single Unit Short-haul and Long-haul Trucks

For Motor Homes and Single Unit Short-haul and Long-haul Trucks, MOVES uses the AEO2004 projections for medium duty vehicles. AEO Table 55 lists sales projections for medium-duty freight trucks powered by diesel, gasoline, liquified petroleum gas and compressed natural gas. These projections were used to compute future distributions for these fuels. Furthermore, AEO Table 146 lists technology penetrations for Class 4-6 freight vehicles. Gasoline direct injection trucks were assigned to the MOVES gasoline advanced internal combustion category and diesel trucks with “turbo, direct injection, thermal” engine improvements were assigned to the MOVES diesel advanced internal combustion category. The resulting distributions are summarized in Table 7.24.

We used the engine size and vehicle weight distributions from 1999 for future years. Where a future fuel was not part of the fleet in 1999, we used the 1999 size and weight distribution for gasoline conventional internal combustion vehicles. Where a future diesel engine technology was not part of the source type fleet in 1999, we used the 1999 size and weight distribution for diesel conventional internal combustion vehicles.

Table 7.24. Fuel and Engine Technology Fractions for 2000-and-later Motor Homes and Single-Unit Short-haul and Long-haul Trucks

Model Year	Gasoline CIC	Gasoline AIC	Diesel CIC	Diesel AIC	CNG CIC	LPG CIC
2000	0.23050	0	0.762812	0	0.004410	0.002283
2001	0.23050	0	0.762812	0	0.004410	0.002283
2002	0.22307	0	0.767655	0	0.006332	0.002944
2003	0.21608	0	0.772364	0	0.008224	0.003337
2004	0.20963	0	0.775387	0	0.011180	0.003804
2005	0.20377	0	0.777286	0	0.014343	0.004598
2006	0.19817	0	0.777746	0	0.018510	0.005574
2007	0.19271	0	0.777069	0	0.022619	0.007605
2008	0.18801	0	0.77743	0	0.026181	0.008376
2009	0.18386	0	0.778309	0	0.029125	0.008708
2010	0.18015	0	0.779640	0	0.031436	0.008770
2011	0.17683	0	0.781240	0	0.033166	0.008761
2012	0.17394	0	0.783217	0	0.034098	0.008749
2013	0.17144	0	0.785759	0	0.034260	0.008538
2014	0.16918	0	0.788316	0	0.034146	0.008356
2015	0.16712	0	0.791025	0	0.033797	0.008055
2016	0.16517	0	0.793481	0	0.033558	0.007786
2017	0.16350	0	0.606634	0.189632	0.033040	0.007191
2018	0.16177	0	0.604079	0.193720	0.032875	0.007558
2019	0.12344	0.036729	0.601740	0.197787	0.032762	0.007539
2020	0.12249	0.036198	0.600768	0.200256	0.032566	0.007722
2021	0.11863	0.038798	0.602232	0.200744	0.032155	0.007446
2022	0.11721	0.039069	0.603619	0.201206	0.031739	0.007157
2023	0.11635	0.038783	0.604494	0.201498	0.031478	0.007396
2024	0.11558	0.038527	0.605453	0.201818	0.031337	0.007283
2025	0.11489	0.038296	0.606397	0.202132	0.031155	0.007130
2026+	0.11489	0.038296	0.606397	0.202132	0.031155	0.007130

7.7.5. Refuse and Combination Trucks

For Refuse, Short-haul and Long-haul Combination Trucks, MOVES uses the AEO2004 projections for heavy-duty freight trucks. AEO Table 55 lists sales projections for heavy-duty freight trucks powered by diesel, gasoline, liquified petroleum gas and compressed natural gas. For refuse trucks, these projections were used directly to compute future distributions for these fuels. However, because MOVES does not support LPG- and CNG-fueled combination trucks, for combination trucks, these vehicles were assigned to the diesel category.

Furthermore, AEO Table 146 lists technology penetrations for Class 7-8 freight trucks. Trucks with "higher cylinder pressure", "improved injection & combustion" and "waste heat/thermal management" were assigned to the MOVES diesel advanced internal combustion category. The resulting distributions are summarized in Table 7.25.

We used the engine size and vehicle weight distributions from 1999 for future years. Where a future fuel or engine technology was not part of the source type fleet in 1999, we used the 1999 size and weight distribution for diesel conventional internal combustion vehicles.

All Refuse Trucks were assigned to the Heavy-Duty Truck regulatory class. Combination Trucks were distributed among the Light Duty Truck (LDT) and Heavy Duty Truck (HDT) regulatory classes. Where a future fuel or technology was not part of the source type fleet in 1999, we used the regulatory class distribution for diesel conventional internal combustion vehicles.

Table 7.25. Fuel and Engine Technology Fractions for Refuse Trucks and Short-haul and Long-haul Combination Trucks

	Refuse Trucks					Combination Trucks		
Model Year	**Gasoline CIC**	**Diesel CIC**	**Diesel AIC**	**CNG CIC**	**LPG CIC**	**Gasoline CIC**	**Diesel CIC**	**Diesel AIC**
2000	0.012972	0.984147	0	0.001766	0.001114	0.012972	0.987028	0
2001	0.012972	0.984147	0	0.001766	0.001114	0.012972	0.987028	0
2002	0.012949	0.983089	0	0.002539	0.001423	0.012949	0.987051	0
2003	0.012969	0.981930	0	0.003394	0.001708	0.012969	0.987031	0
2004	0.013023	0.980407	0	0.004594	0.001976	0.013023	0.986977	0
2005	0.013110	0.976878	0.001869	0.005902	0.002241	0.013110	0.985021	0.001869
2006	0.013222	0.971446	0.005396	0.007455	0.002482	0.013222	0.981382	0.005396
2007	0.013355	0.959230	0.015662	0.008941	0.002812	0.013355	0.970983	0.015662
2008	0.013509	0.929178	0.044167	0.010209	0.002937	0.013509	0.942324	0.044167
2009	0.013679	0.855626	0.116478	0.011237	0.002981	0.013679	0.869844	0.116478
2010	0.013861	0.702373	0.268796	0.012005	0.002965	0.013861	0.717343	0.268796
2011	0.014050	0.475144	0.495357	0.012531	0.002917	0.014050	0.490592	0.495357
2012	0.014244	0.329839	0.640275	0.012786	0.002855	0.014244	0.345480	0.640275
2013	0.014440	0.329806	0.640212	0.012787	0.002754	0.014440	0.345347	0.640212
2014	0.014635	0.329834	0.640266	0.012630	0.002636	0.014635	0.345099	0.640266
2015	0.014825	0.329892	0.640378	0.012403	0.002502	0.014825	0.344797	0.640378
2016	0.015008	0.329911	0.640415	0.012252	0.002413	0.015008	0.344576	0.640415
2017	0.015186	0.329942	0.640476	0.012083	0.002313	0.015186	0.344338	0.640476
2018	0.015359	0.329963	0.640517	0.011925	0.002237	0.015359	0.344125	0.640517
2019	0.015523	0.329937	0.640466	0.011853	0.002221	0.015523	0.344010	0.640466
2020	0.015683	0.329923	0.640438	0.011762	0.002194	0.015683	0.343879	0.640438
2021	0.015840	0.329937	0.640466	0.011617	0.002140	0.015840	0.343695	0.640466
2022	0.015991	0.329953	0.640497	0.011472	0.002086	0.015991	0.343511	0.640497
2023	0.016137	0.329951	0.640493	0.011366	0.002052	0.016137	0.343369	0.640493
2024	0.016278	0.329938	0.640468	0.011290	0.002026	0.016278	0.343254	0.640468
2025	0.016415	0.329930	0.640453	0.011208	0.001995	0.016415	0.343133	0.640453
2026+	0.016415	0.329930	0.640453	0.011208	0.001995	0.016415	0.343133	0.640453

8. SourceUseType

The SourceUseType table lists average vehicle mass and three average road load coefficients for each SourceType. The mass is listed in metric tons. The road load coefficients are a rolling term “A,” a rotatating term “B,” and a drag term “C.”

MOVES uses these coefficients to calculate vehicle specific power for each source type according to the equation:

$$VSP = \left(A/M \right) \bullet v + \left(B/M \right) \bullet v^2 + \left(C/M \right) \bullet v^3 + \left(a + g \bullet \sin\theta \right) \bullet v \,.$$

where A, B, and C are the road load coefficients in units of (kiloWatt second)/(meter tonne), (kiloWatt second^2)/(meter^2 tonne), and (kiloWatt second^3)/(meter^3 tonne), respectively. M is the mass of the vehicle in *kilograms*, g is the acceleration due to gravity (*9.8 meter/ second^2*), v is the vehicle speed in *meter/second*, a is the vehicle acceleration in *meter/second^2*, and $\sin\theta$ is the (fractional) road grade.

The values in the SourceUseType table were averaged from values in the Mobile Source Observation Database (MSOD). The values were weighted using the age and sourcebin distributions described elsewhere in this report. In particular, the average values were computed using the equation:

$$weightedvalue = \frac{\displaystyle\sum_{i=1,\, total\,\#\, of\ ages} \left\{ \beta_i \cdot \left(\frac{\displaystyle\sum_{j=1,\, total\,\#\, of\ sourcebins} \alpha_j \cdot unweightedvalue}{\displaystyle\sum_{j=1,\, total\,\#\, of\ sourcebins} \alpha_j} \right) \right\}}{\displaystyle\sum_{i=1,\, total\,\#\, of\ ages} \beta_i}$$

where the “unweighted value” was either the vehicle mid-point mass or one of the three different road load coefficients determined from the road load–vehicle mass relations described below: α_j were the sourceBinActivityFractions in the MOVES database and β_i were the ageFractions in the MOVES database. Age fractions were matched to model years for calendar year 1999 (i.e., Model Year 1999 corresponds to vehicle ageID of 0; Model Year1969 corresponds to ageID of 30.) Only sourcebins and ages with vehicles in the MSOD were used in these weightings. Thus, the “total number of sourcebins” in the MSOD and “total number of ages” in the MSOD were used to normalize the results.

8.1. SourceMass

The SourceMass was computed as the weighted average of the “mid-point” mass for the Weight Class associated with each sourcebin. Sourcebins not represented in the MSOD were excluded.

Table 8-1. MOVES Weight Classes

Weight ClassID	Weight Class Name	Midpoint Weight
0	Doesn't Matter	[NULL]
20	weight < 2000 pounds	1000
25	2000 pounds <= weight < 2500 pounds	2250
30	2500 pounds <= weight < 3000 pounds	2750
35	3000 pounds <= weight < 3500 pounds	3250
40	3500 pounds <= weight < 4000 pounds	3750
45	4000 pounds <= weight < 4500 pounds	4250
50	4500 pounds <= weight < 5000 pounds	4750
60	5000 pounds <= weight < 6000 pounds	5500
70	6000 pounds <= weight < 7000 pounds	6500
80	7000 pounds <= weight < 8000 pounds	7500
90	8000 pounds <= weight < 9000 pounds	8500
100	9000 pounds <= weight < 10000 pounds	9500
140	10000 pounds <= weight < 14000 pounds	12000
160	14000 pounds <= weight < 16000 pounds	15000
195	16000 pounds <= weight < 19500 pounds	17750
260	19500 pounds <= weight < 26000 pounds	22750
330	26000 pounds <= weight < 33000 pounds	29500
400	33000 pounds <= weight < 40000 pounds	36500
500	40000 pounds <= weight < 50000 pounds	45000
600	50000 pounds <= weight < 60000 pounds	55000
800	60000 pounds <= weight < 80000 pounds	70000
1000	80000 pounds <= weight < 100000 pounds	90000
1300	100000 pounds <= weight < 130000 pounds	115000
9999	130000 pounds <= weight	130000
5	weight < 500 pounds (for MCs)	350
7	500 pounds <= weight < 700 pounds (for MCs)	600
9	700 pounds <= weight (for MCs)	700

8.2. Road Load Coefficients

The information available on road load coefficients varied by regulatory class.

Motorcycle road load coefficients are typically parameterized [34] with mass dependent A and C terms which take into account rolling resistance and aerodynamic drag. Parameters adopted here are from the UN report:

A = 0.088M and C= 0.26 + 1.94x10-4M

where M is the inertial mass of the motorcycle and driver and has units of metric tonnes.

For vehicles with a weight of 8500 lbs or less, the road load coefficients were derived from the track road load horspower ($TRLHP_{@50mph}$) recorded in the MSOD.[35] The calculations applied the following empirical equations:[36]

$$A = 0.7457*(0.35/50*0.447) \quad * \; TRLHP_{@50mph}$$
$$B = 0.7457*(0.10/(50*0.447)^2) \quad * \; TRLHP_{@50mph}$$
$$C = 0.7457*(0.55/(50*0.447)^3) \quad * \; TRLHP_{@50mph}$$

For the heavier vehicles, no road load parameters were available in the MSOD. Instead EPA used the relationships of road load coefficent to vehicle mass from a study done by V.A. Petrushov,[37] as shown in Table 8-2. The mid-point mass for the sourcebin was used as the vehicle mass.

Table 8-2. Road Load Coefficients for Heavy-Duty Trucks, Buses, and Motor Homes

	8500 to 14000 lbs (3.855 to 6.350 tonne)	**14000 to 33000 lbs (6.350 to 14.968 tonne)**	**>33000 lbs (>14.968 tonne)**	**Buses and Motor Homes**
A(kW*s/m)/ M(tonne)	0.0996	0.0875	0.0661	0.0643
$B(kW*s^2/m^2)/$ M(tonne)	0	0	0	0
$C(kW*s^3/m^3)$ /M(tonne)	3.40×10^{-4} (mass is the average mass of the weight category)	1.97×10^{-4} (mass is the average mass of the weight category)	1.79×10^{-4} (mass is the average mass of the weight category)	$\frac{3.22}{mass(kg)} + 5.06 \times 10^{-5}$
	$\frac{1.47}{mass(kg)} + 5.22 \times 10^{-5}$	$\frac{1.93}{mass(kg)} + 5.90 \times 10^{-5}$	$\frac{2.89}{mass(kg)} + 4.21 \times 10^{-5}$	

In both cases, values of A, B, and C were computed for each SourceBin-associated vehicle in the MSOD and a weighted average was computed as described above. The final SourceMass and road load coefficients for all SourceTypes are listed in Table 8-3.

Table 8-3. SourceUseType Characteristics

Source TypeID	HPMS Vtype ID	SourceType Name	Rolling TermA (kW-s/m)	Rotating TermB (kW-s^2/m^2)	Drag TermC (kW-s^3/m^3)	Source Mass (metric tons)
11	10	Motorcycle	0.0251	0	0.000315	0.285
21	20	Passenger Car	0.031292	0.002002	0.000493	1.478803
31	30	Passenger Truck	0.044224	0.002838	0.000698	1.866865
32	30	Light Commercial Truck	0.047002	0.003039	0.000748	2.059793
41	40	Interstate Bus	1.295151	0	0.003715	19.59371
42	40	Urban Bus	1.0944	0	0.003587	16.55604
43	40	School Bus	0.746718	0	0.002176	9.069885
51	50	Refuse Truck	1.417049	0	0.003572	20.68453
52	50	Single-Unit Commercial Truck	0.561933	0	0.001603	7.641593
53	50	Single-Unit Delivery Truck	0.498699	0	0.001474	6.250466
54	50	Motor Home	0.617371	0	0.002105	6.734834
61	60	Combination Commercial Truck	1.963537	0	0.004031	29.32749
62	60	Combination Delivery Truck	2.081264	0	0.004188	31.40378

9. RoadTypeDistribution

MOVES will calculate emissions separately for each HPMS facility type and for "off-network" activity. The road type codes used in MOVES are listed in Table 9-1.

Table 9-1. Road Type Codes in MOVES

RoadTypeID	Description
1	Off Network
11	Rural Interstate
13	Rural Other Principal Arterial
15	Rural Minor Arterial
17	Rural Major Collector
19	Rural Minor Collector
21	Rural Local
23	Urban Interstate
25	Urban Other Freeways and Expressways
27	Urban Other Principal Arterial
29	Urban Minor Arterial
31	Urban Collector
33	Urban Local

For each SourceType, the **RoadTypeVMTFraction** field stores the fraction of total VMT that is traveled on each of the 13 roadway types.

For MOVES2004, we used data from 1999 FHWA Highway Statistics, Tables VM-1 and VM-2. VM-1 provides detail on VMT by vehicle type; VM-2 provides detail by roadway type. At the time of this analysis, VM-1 (October 2000) had not been updated, but VM-2 was updated in January 2002. We used the total values from the more recent VM-2 to distribute VMT by roadway type and allocated them to vehicle class in proportion to the values in VM-1. We then calculated road type VMT fractions for each HPMS Vehicle Type.

The FHWA Highway Statistics is currently considered the best available source for national information regarding vehicle miles traveled. However, there are problems and constraints associated with using the (mostly) self-reported data in Highway Statistics[65]. In many cases, locally derived VMT data may be more accurate when modeling local areas.

The VMT distributions in Table 9-2 assume that all VMT reported by HPMS is accumulated on one of the 12 HPMS roadway types. No VMT is currently assigned to the "off-network" category in the national defaults. See the discussion of BaseYearOffNetVMT in Section 11.2.

Table 9-2. Road Type Fractions by HPMS Vehicle Type

RoadTypeID	Motorcycles	Passenger Cars	Other 2 axle - 4 tire vehicles	Buses	Single unit trucks	Combination trucks
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.1040	0.0834	0.0846	0.1268	0.1149	0.3247
13	0.0928	0.0870	0.0908	0.1060	0.1174	0.1192
15	0.0643	0.0603	0.0630	0.0735	0.0815	0.0827
17	0.0845	0.0753	0.0807	0.1608	0.1054	0.0490
19	0.0235	0.0210	0.0225	0.0448	0.0294	0.0137
21	0.0509	0.0454	0.0486	0.0969	0.0635	0.0296
23	0.1598	0.1429	0.1381	0.0982	0.1209	0.1798
25	0.0579	0.0668	0.0650	0.0404	0.0506	0.0278
27	0.1326	0.1529	0.1489	0.0925	0.1158	0.0636
29	0.1060	0.1223	0.1190	0.0739	0.0926	0.0508
31	0.0444	0.0513	0.0499	0.0310	0.0388	0.0213
33	0.0792	0.0914	0.0890	0.0552	0.0692	0.0380
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

We are currently assuming identical VMT distributions for all SourceTypes within an HPMS Vehicle Type. However the MOVES model is designed to allow roadway type allocation by SourceType and one would expect the different SourceTypes to have different roadway type allocations. For example, the long-haul trucks generally would have a greater fraction of travel on rural interstates than the short-haul trucks. If such data becomes available we would like to update the database.

10. Average Speed Distribution

The AvgSpeedDistribution table provides the fraction of driving time for each SourceType, Road Type, Day, Hour, and Speed Bin in a field called **AvgSpeedFraction**. The values sum to one for each combination of SourceType, Road Type, Day, and Hour.

For MOVES2004, the urban driving values were derived from the default speed distributions (SVMT) in MOBILE6. The MOBILE6 speed fractions were adapted to MOVES converting the fraction of miles travelled to the fraction of time used, and by mapping from the MOBILE6 road types to the MOVES road types. This road type mapping is detailed in Table 10-1. The time fractions were normalized to add to one for each hour of the day over all 14 speed bins. The values for the off-network roadway type in MOVES2004 were set to null. The detailed distributions are available in the MOVES default database. See Table 9-1 for a description of the MOVES road type numbers used in Table 10-1. Only urban roadways obtain their values from the default MOBILE6 speed distributions.

Table 10-1. Mapping of MOVES Road Types to MOBILE6 Road Types.

	MOBILE6 Road Type			
	Arterial/Collector	**Freeway**	**Local**	**Ramp**
MOVES Road Type	27,29,31	23,25	33	--

Average speed used for rural driving relied on an analysis of recent driving data collected entirely in California under studies performed for the California Department of Transportation (Caltrans) performed by Sierra Research, Inc, [38] which is summarized here. Under these Caltrans driving studies, instrumented "chase cars" were equipped with laser rangefinders mounted behind the front grill of each chase car. The studies were performed in the Sacramento area, the San Francisco Bay area and the San Joaquin Valley. Another driving study was also conducted in the South Coast (i.e., Los Angeles Basin), but was conducted entirely in urbanized areas. Thus, this data was not used for the rural area analysis.

The datasets contained driving in both urban and rural areas. In the post-processing that was performed under each of these studies, the type of roadway the vehicle was traveling on during each second was also recorded in the output dataset. Since the datasets contained the Highway Performance Monitoring System (HPMS) Functional Class designation, it was easy to divide the driving data from these studies into rural functional class groups for creating average speed distributions. (The urban area travel in these datasets was discarded for this analysis.)

The average speed was calculated over each link traverse for the individual links in each data set. A link traverse is defined as a one-way driving traverse of the entire extent of a roadway link. A review of the links identified in the data showed that although distances of most links identified as above ranged between 0.5 to 5 miles, a few of the them were ten miles or longer. These longer links were generally restricted to limited access freeways and highways or remote county roads. In rural areas, the difference in average speeds calculated over conventionally defined links versus longer link sections as identified in the route-based driving studies is not likely to be significant because of the general lack of traffic congestion on these rural roads.

Once the average speed was calculated for each link traverse, it was allocated into one of sixteen speed bins defined by EPA for the purpose of calculating speed distributions for use in MOVES. The MOVES speed bins are shown in Table 10-2. An important point is that although the technical memo prepared by Sierra Research presents distributions based on the number of observations in each bin (i.e. unweighted), the distributions contained in the AvgSpeedDistribution table are weighted by the travel time on each link traverse, since AvgSpeedFraction is meant to capture the fraction of time spent in each bin.

Table 10-2. MOVES Speed Bin Categories.

Bin	Average Speed (mph)	Average Speed Range (mph)
1	2.5	speed < 2.5 mph
2	5	2.5 mph <= speed < 7.5 mph
3	10	7.5 mph <= speed < 12.5 mph
4	15	12.5 mph <= speed < 17.5 mph
5	20	17.5 mph <= speed < 22.5 mph
6	25	22.5 mph <= speed < 27.5 mph
7	30	27.5 mph <= speed < 32.5 mph
8	35	32.5 mph <= speed < 37.5 mph
9	40	37.5 mph <= speed < 42.5 mph
10	45	42.5 mph <= speed < 47.5 mph
11	50	47.5 mph <= speed < 52.5 mph
12	55	52.5 mph <= speed < 57.5 mph
13	60	57.5 mph <= speed < 62.5 mph
14	65	62.5 mph <= speed < 67.5 mph
15	70	67.5 mph <= speed < 72.5 mph
16	75	72.5 mph <= speed

The existing data from the studies used in this analysis were collected entirely in California. Thus, use of these California results to represent national rural speed distributions must include the critical assumption that average speeds within each HPMS functional class do not significantly vary across the U.S on rural roadways. The California chase car data also only included light-duty vehicles. Heavy-duty vehicles represent a significant fraction of rural area travel and were not targeted during these chase car studies.

11. HPMSVTypeYear

Three fields comprise HPMSVTypeYear in MOVES2004: HPMSBaseYearVMT, BaseYearOffNetVMT, and VMTGrowthFactor.

11.1. HPMSBaseYearVMT

The HPMSBaseYearVMT field stores the base year VMT for each HPMS Vehicle Type. This VMT was calculated from the FHWA VM-1 and VM-2 tables as for RoadTypeDistribution, but instead of calculating fractions, we calculated VMT sums by HPMS Vehicle Class. The resulting 1999 VMT by HPMS Vehicle Type is shown in Table 11-1.

11.2. BaseYearOffNetVMT

Off Network VMT refers to the portion of activity that is not included in travel demand model networks or any VMT that is not otherwise reflected in the other twelve categories. However, the reported HPMS VMT values, used to calculate the national averages discussed here, are intended to include all VMT. Thus, for MOVES2004, the BaseYearOffNetVMT will be zero for all Vehicle Types.

11.3. VMTGrowthFactor

The VMTGrowthFactor field stores a multiplicative factor indicating changes in total vehicle miles for calendar years after the base year. Total VMT data are reported according the HPMS vehicle classes discussed previously, i.e. passenger car, other 2-axle / 4-tire vehicle, single-unit truck, combination truck, bus and motorcycle. VMTGrowthFactor is expressed relative to the previous year's VMT; for example, 1 means no change from previous year VMT, 1.02 means a two percent increase in VMT, and 0.98 means a two percent decrease in VMT.

VMTGrowthFactor is used in the Total Activity Generator calculation of VMT for calendar years after the base year, meaning calendar years 2000 through 2050 in MOVES2004. It is important to note that VMTGrowthFactor is the key component for estimates of future activity in MOVES, because the level of total activity in future years for most emission processes — running, start and extended idle in MOVES2004 — is derived from projections of total VMT. Projections of future populations based on sales growth, survival rates, etc. only are used to allocate total VMT.

The sources for default estimates for VMTGrowthFactor are FHWA *Highway Statistics* for 2000 through 2002 and *AEO2004* for 2003 onward. Some additional analyses were required to allocate the more aggregate AEO estimates for light-duty vehicles and trucks to the MOVES Source Types.

Calendar years 2000 through 2002 growth factors were derived from estimates of total VMT data as reported by FHWA's *Highway Statistics*, Table VM-1. Total VMT data are reported according the HPMS vehicle classes discussed previously, i.e. passenger car, other 2-axle / 4-tire vehicle, single-unit truck, combination truck, and bus. For these years the growth factors are simply total VMT for the calendar year divided by total VMT from the previous year. The VMTGrowthFactors for 2000 through 2002 are shown in Table 11-1.

Table 11-1. BaseYearVMT and VMTGrowthFactor by HPMS Vehicle Class

HPMS Vehicle Class	1999 VMT	2000 Growth	2001 Growth	2002 Growth
Motorcycles	10,579,571,538	0.99	0.91	0.991
Passenger Cars	1,568,637,135,533	1.021	1.012	1.019
Other 2 axle - 4 tire vehicles	900,735,282,077	1.026	1.016	1.024
Buses	7,656,997,688	0.992	0.92	0.968
Single unit trucks	70,273,725,843	1.004	1.025	1.048
Combination trucks	132,358,287,321	1.021	1.003	1.015

Growth factors for calendar years 2003 through 2025 were calculated in the same manner as 2000-2002 using NEMS projections of total VMT as reported in *AEO2004*. These estimates are broken down by total Light-Duty (*AEO2004* Supplemental Table 48), total Medium-Duty, and total Heavy-Duty (*AEO2004* Supplemental Table 55). The growth factors derived from the *AEO2004* Medium-Duty VMT estimates were applied to the single-unit truck and bus HPMS vehicle classes. The growth factors derived from the *AEO2043* Heavy-Duty VMT estimates were applied to the combination truck vehicle class. VMTGrowthFactors derived from medium and heavy-duty vehicle *AEO2004* VMT projections are shown in Table 11-2.

Table 11-2. 2003 and later VMTGrowthFactors for Medium-Duty & Heavy-Duty Trucks

Calendar Year	Medium-Duty (Single Unit Trucks, Buses)	Heavy-Duty (Combination Trucks)
2003	1.003	1.007
2004	1.036	1.041
2005	1.030	1.041
2006	1.018	1.033
2007	1.016	1.029
2008	1.015	1.025
2009	1.018	1.026
2010	1.023	1.029
2011	1.025	1.028
2012	1.026	1.027
2013	1.028	1.028
2014	1.026	1.026
2015	1.025	1.024
2016	1.028	1.025
2017	1.030	1.027
2018	1.029	1.026
2019	1.026	1.022
2020	1.029	1.023
2021	1.027	1.021
2022	1.030	1.024
2023	1.030	1.025
2024	1.030	1.025
2025	1.031	1.028

Light-Duty VMT as reported in *AEO2004* Supplemental Table 48 applies to total light-duty growth from both cars and trucks; as such they do not reflect the higher growth rate of light trucks relative to passenger cars brought on by steadily increasing sales of light duty trucks. Separate VMTGrowthFactors for the Passenger Car and Other 2-axle/4-wheel Vehicle classes were therefore developed based on estimates of car and light truck populations from *AEO2004*. Using the *AEO2004* estimates of total light-duty VMT and vehicle population (i.e., stock) growth rates shown in Table 11-3, we calculated the "per-vehicle" VMT growth implied from these estimates (total VMT growth divided by population growth). Assuming that per-vehicle VMT growth is the same for cars and light trucks, we multiplied the total light-duty per-vehicle VMT growth factors by car and light truck population growth factors presented in AEO Supplemental Table 46. This produced the separate car and light truck VMT growth factors shown in Table 11-3, as the product of vehicle population growth and per-vehicle travel growth. The "car" rates derived from NEMS were applied to the MOVES source types Passenger Car and Motorcycle, and the "light truck" rates were applies to the MOVES source types Passenger Truck and Light Commercial Truck.

Table 11-3. 2003 and later VMTGrowthFactor Calculation for Passenger Cars and Trucks

Calendar Year	AEO Total Light-Duty Growth Factors			AEO Population Growth Factors		Calculated VMTGrowthFactor	
	VMT	Population	Per-Vehicle VMT	Cars	Light Trucks	Cars	Light Trucks
2003	1.019	1.024	0.995	1.003	1.063	0.997	1.057
2004	1.034	1.025	1.009	1.001	1.064	1.010	1.073
2005	1.027	1.024	1.002	1.001	1.061	1.003	1.063
2006	1.025	1.024	1.001	1.001	1.057	1.002	1.058
2007	1.023	1.023	1.001	1.001	1.053	1.002	1.054
2008	1.023	1.021	1.001	1.000	1.049	1.002	1.051
2009	1.023	1.020	1.002	1.000	1.046	1.002	1.048
2010	1.023	1.019	1.004	1.000	1.043	1.004	1.047
2011	1.023	1.019	1.005	1.000	1.040	1.005	1.045
2012	1.024	1.017	1.007	1.000	1.037	1.007	1.044
2013	1.025	1.017	1.008	1.000	1.035	1.008	1.044
2014	1.022	1.016	1.006	1.000	1.033	1.006	1.039
2015	1.021	1.015	1.006	0.999	1.031	1.005	1.037
2016	1.020	1.015	1.006	1.000	1.029	1.005	1.035
2017	1.020	1.015	1.005	1.001	1.028	1.006	1.034
2018	1.020	1.015	1.005	1.001	1.028	1.006	1.033
2019	1.020	1.015	1.005	1.002	1.027	1.007	1.032
2020	1.020	1.014	1.006	1.002	1.026	1.007	1.031
2021	1.020	1.013	1.006	1.001	1.024	1.007	1.030
2022	1.020	1.013	1.007	1.001	1.023	1.008	1.030
2023	1.020	1.013	1.007	1.001	1.022	1.009	1.030
2024	1.021	1.013	1.008	1.001	1.022	1.010	1.030
2025	1.022	1.013	1.009	1.002	1.022	1.011	1.031

12. Temporal Distributions of VMT

MOVES can estimate emissions for every hour of every day of the year. For this reason, annual VMT estimates need to be allocated to months, days, and hours.

A 1996 report from the Office of Highway Information Management (OHIM)[39] describes analysis of a sample of 5,000 continuous traffic counters distributed through the United States. EPA obtained the data used in the report and used it to generate inputs in the form needed for MOVES2004.

The report does not specify VMT by SourceType or Vehicle Type. Thus, we currently use the same value for all SourceTypes.

12.1. MonthVMTFraction

For MonthVMTFraction, we will use the data from the OHIM report's Figure 2.2.1 "Travel by Month, 1970-1995," but modified to fit MOVES specifications.

The figure shows VMT/day, normalized to January=1. For MOVES2004, we need the fraction of total VMT per month, with different values for leap year and non-leap year. We computed the fractions using the report values and the number of days in each month.

Table 12-1. MonthVMTFraction

Month	Normalized VMT/day	MOVES not Leap Year	MOVES Leap Year
January	1.0000	0.0731	0.0729
February	1.0560	0.0697	0.0720
March	1.1183	0.0817	0.0815
April	1.1636	0.0823	0.0821
May	1.1973	0.0875	0.0873
June	1.2480	0.0883	0.0881
July	1.2632	0.0923	0.0921
August	1.2784	0.0934	0.0932
September	1.1973	0.0847	0.0845
October	1.1838	0.0865	0.0863
November	1.1343	0.0802	0.0800
December	1.0975	0.0802	0.0800

12.2. DayVMTFraction

The OHIM report provides VMT percentage values for each day and hour of a typical week for urban and rural roadway types for various regions of the United States for both 1992 and 1995. The data obtained from the OHIM report is not disaggregated by month or

SourceType. The same values will be used for every month and SourceType. We used 1995 data (which is very similar to 1992) as it is displayed in Figure 2.3.2 of the OHIM report.

For the DayVMTFraction needed for MOVES2004, we summed the reported percentages for each day. Note, the report explains that data for “3am” refers to data collected from 3am to 4am. Thus data labeled “midnight” belongs to the upcoming day.

Table 12-2. DayVMTFractions

	Rural	Urban
Mon	0.1363	0.1442
Tues	0.1352	0.1489
Wed	0.1387	0.1516
Thurs	0.1442	0.1536
Fri	0.1668	0.1641
Sat	0.1447	0.1304
Sun	0.1342	0.1073
Total	1.0000	1.0000

We assigned the “Rural” fractions to the rural Roadtypes (11-21) and the “Urban” fractions to the urban Roadtypes (23-33). The correct distribution for “Off network” VMT is unknown. Since the majority of U.S. travel is urban, any VMT assigned to "Off network" will be assigned the urban distribution of DayVMTFractions. The MOVES2004 default VMT fraction on “Off-network” is zero.

12.3. HourVMTFraction

For HourVMTFraction we used the same data as for DayVMTFraction. We converted the OHIM report data to percent of day by dividing by the DayVMTFraction.

There are separate sets of HourVMTFractions for "Urban" and "Rural" roadway types. Roadway types were assigned as for DayVMTFraction. All SourceTypes use the same HourVMTFraction distributions. Table 12-3 shows only the "Urban" HourVMTFractions.

Table 12-3. HourVMTFractions

Hour	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	0.0235	0.0093	0.0095	0.0098	0.0103	0.0103	0.0198
2	0.0161	0.0059	0.0059	0.0061	0.0066	0.0068	0.0131
3	0.0121	0.0047	0.0048	0.0049	0.0053	0.0055	0.0100
4	0.0079	0.0044	0.0046	0.0046	0.0048	0.0049	0.0071
5	0.0064	0.0070	0.0071	0.0070	0.0071	0.0068	0.0072
6	0.0085	0.0188	0.0191	0.0189	0.0186	0.0172	0.0119
7	0.0147	0.0463	0.0478	0.0475	0.0464	0.0421	0.0215
8	0.0208	0.0700	0.0723	0.0719	0.0701	0.0644	0.0318
9	0.0292	0.0611	0.0627	0.0625	0.0611	0.0570	0.0423
10	0.0424	0.0509	0.0512	0.0507	0.0502	0.0487	0.0517
11	0.0542	0.0513	0.0499	0.0494	0.0494	0.0498	0.0602
12	0.0628	0.0557	0.0538	0.0537	0.0538	0.0549	0.0669
13	0.0731	0.0593	0.0570	0.0567	0.0568	0.0584	0.0699
14	0.0750	0.0594	0.0573	0.0570	0.0572	0.0592	0.0686
15	0.0757	0.0634	0.0616	0.0614	0.0614	0.0634	0.0685
16	0.0760	0.0721	0.0711	0.0707	0.0704	0.0709	0.0687
17	0.0756	0.0781	0.0779	0.0774	0.0768	0.0750	0.0675
18	0.0722	0.0786	0.0788	0.0785	0.0777	0.0739	0.0643
19	0.0646	0.0590	0.0595	0.0600	0.0601	0.0602	0.0595
20	0.0544	0.0428	0.0431	0.0437	0.0447	0.0474	0.0495
21	0.0458	0.0340	0.0344	0.0353	0.0360	0.0373	0.0404
22	0.0384	0.0298	0.0310	0.0317	0.0325	0.0339	0.0378
23	0.0299	0.0224	0.0235	0.0240	0.0252	0.0291	0.0341
24	0.0207	0.0156	0.0162	0.0167	0.0176	0.0228	0.0277

13. DriveSchedule

DriveSchedule refers to a second-by-second vehicle speed trajectory which is used in the determination of operating mode distribution, defined (for the running energy consumption pollutant/process) by Vehicle Specific Power (VSP) and vehicle speed. A key feature of MOVES is the capability to accommodate any number of drive schedules to represent driving patterns across source type, roadway type and average speed. For the national default case, MOVES2004 employs 40 drive schedules, mapped to specific source types and roadway types. The average speed of a driving schedule is used to determine the weighting of that schedule for a given roadway, based on the average speed of the roadway. Briefly, the calculated VSP distribution determined for a given driving schedule and the next nearest driving schedule which brackets the roadway average speed, are averaged together, weighted by the proximity of the roadway average speed to the driving schedule average speeds. In this way, the VSP distribution of any roadway average speed can be determined from two driving schedules, whose average speeds bracket the roadway average speed. This is presented in detail in the discussion of the Operating Mode Distribution Generator in the MOVES Design Documentation.

For brevity, the entire body of drive schedule information is not presented in this document. The reader is referred to the MOVES database, where three MOVES database tables encompass drive schedule information. **DriveSchedule** provides the average speed of traffic on the road type and the drive schedule name. **DriveScheduleAssoc** defines the set of schedules which represent combinations of source use type and road type. The schedules within a set are differentiated by the average speed of traffic on the road type. Although not defined as unique road types, freeway ramp cycles are accounted for as separate schedules; they will be associated with interstates and freeways. **DriveScheduleSecond** contains the second-by-second vehicle trajectories for each schedule. In some cases the vehicle trajectories are not contiguous; that is, they represent several unconnected microtrips.

Table 13-1 shows a complete list of the driving schedules used in the default case and their associated average speed.

Table 13-1. Default MOVES Drive Schedules

Drive Schedule Set	DriveScheduleName(ID)	AverageSpeed (mph)
Light-Duty Non-Freeway	Low Speed (101)	2.5
	New York City (102)	7.05
	Non-Freeway LOS EF (103)	11.55
	Non-Freeway LOS CD (104)	19.23
	Non-Freeway LOS AB (105)	24.75
Light-Duty Freeway	Freeway LOS G (151)	13.13
	Freeway LOS F (152)	18.61
	Freeway LOS E (153)	30.49
	Freeway LOS D (154)	52.87
	Freeway LOS AC (155)	59.66
	Freeway High Speed 1 (156)	63.23
	Freeway High Speed 2 (157)	68.21
	Freeway High Speed 3 (158)	75.99
	Freeway Ramp (199)	34.6
Medium Heavy-Duty Non-Freeway	5 mph (201)	1.81
	10 mph (202)	10.53
	15 mph (203)	15.55
	20 mph (204)	20.37
	25 mph (205)	24.36
	30 mph (206)	30.83
Medium Heavy-Duty Freeway	30 mph (251)	37.37
	40 mph (252)	45.3
	50 mph (253)	55.5
	60 mph (254)	60.06
	Ramp (299)	29.2
Heavy Heavy-Duty Non-Freeway	5 mph (301)	1.19
	10 mph (302)	10.75
	15 mph (303)	15.22
	20 mph (304)	19.81
	25 mph (305)	24.87
	30 mph (306)	30.81
Heavy Heavy-Duty Freeway	30 mph (351)	34.9
	40 mph (352)	46.89
	50 mph (353)	54.33
	60 mph (354)	59.5
	Ramp (399)	26.7
Bus Non-Freeway	Low Speed Urban (401)	15*
	30 mph flow (402)	30*
	45 mph flow (403)	45*
Refuse Truck	Refuse Truck Urban (501)	2.2

* Speed represents average of traffic the bus is traveling in, not the average speed of the bus, which is lower due to stops.

14. Drive Schedule Association

The DriveSchedules listed in Table 13-1 are associated with specific SourceTypes and RoadTypes as summarized in Table 14-1. This table is an aggregated representation of the information in DriveScheduleAssociation, which contains a mapping of every schedule to each SourceType across each of the 12 HPMS roadway types.

Table 14-1. Drive Schedule Mapping

<table>
<tr><th>Source Use Type</th><th>Interstate, Freeway/Expressway</th><th>Arterial, Collector</th><th>Local</th></tr>
<tr><td>Motorcycle</td><td colspan="3" rowspan="4">Light-Duty Non-Freeway Schedules
Light-Duty Freeway Schedules
Light-Duty Ramp Schedule</td></tr>
<tr><td>Passenger Car</td></tr>
<tr><td>Passenger Truck</td></tr>
<tr><td>Commercial Truck</td></tr>
<tr><td>Intercity bus</td><td colspan="3" rowspan="4">Medium Heavy-Duty Non-Freeway
Medium Heavy-Duty Freeway</td></tr>
<tr><td>Single Unit Short Haul</td></tr>
<tr><td>Single Unit Long Haul</td></tr>
<tr><td>Motor Home</td></tr>
<tr><td>Transit bus</td><td rowspan="3">Medium Heavy-Duty Freeway</td><td colspan="2" rowspan="2">Bus Non-Freeway
Medium Heavy-Duty Freeway
(50 mph & 60 mph)</td></tr>
<tr><td>School Bus</td></tr>
<tr><td>Refuse Truck</td><td>Bus Non-Freeway</td><td>Refuse Truck Local</td></tr>
<tr><td>Combination Short Haul</td><td colspan="3" rowspan="2">Heavy Heavy-Duty Freeway
Heavy Heavy-Duty Non-Freeway</td></tr>
<tr><td>Combination Long Haul</td></tr>
</table>

The default drive schedules listed in Tables 13-1 and 14-1 were developed from several sources. The majority of the light-duty cycles are identical to those developed for MOBILE6 and documented in report M6.SPD.001.[40] What we now refer to as "non-freeway" schedules are the same as the "arterial" cycles used in MOBILE6; the name change was made to reflect the application of these schedules to all non-freeway operation, including local roadways. The light-duty schedules not included in the MOBILE6 work are Low Speed, New York City, High Speed 2 and High Speed 3. Low Speed is a historic cycle used in the development of speed corrections for MOBILE5 and is meant to represent extreme stop-and-go "creep" driving. The New York City Cycle is a historic test schedule representing congested urban travel with lots of stop-and-go. It is used in EPA's running loss certification test procedure.[41]

High Speed 2 and 3 were developed specifically for MOVES2004. High Speed 1 was the highest speed schedule in MOBILE6, with an average speed of 63 mph. EPA received many comments with respect to MOBILE6 that this was not sufficient to capture the range of high speed freeway driving in-use. The increase in speed limits as well as vehicle performance within the past decade dictates the need to represent more extreme driving; High Speed 2 and 3 were developed to represent these conditions. High Speed 2 is a 240-second segment of the US06 certification compliance cycle, with an average speed of 68 mph and a maximum of 80 mph. High Speed 3 is 580-second segment of freeway driving from an in-use vehicle instrumented as part of EPA's On-Board Emission Measurement "Shootout" program,[42] with an average speed of 76 mph and a maximum of 90 mph. The addition of these schedules will serve to increase the capacity of MOVES to reflect the higher speed freeway operation seen on the road today. It should be noted, however, that these schedules are only applied in MOVES2004 if AverageSpeedDistribution contains operation in the highest speed bins; i.e. 70 mph and greater.

Medium-Duty and Heavy-Duty schedules were developed specifically for MOVES2004, based on work performed for EPA by Eastern Research Group (ERG), Inc. and documented in the report "Roadway-Specific Driving Schedules for Heavy-Duty Vehicles."[43] ERG analyzed data from 150 medium and heavy-duty vehicles instrumented to gather instantaneous speed and GPS measurements. ERG segregated the driving into freeway and non-freeway driving for medium and heavy-duty vehicles, then further stratified vehicles trips according the pre-defined ranges of average speed covering the range of vehicle operation. ERG characterized representative driving within each speed range, using distributions of vehicle specific power (VSP), speed and acceleration. Driving schedules were then developed for each speed bin by creating combinations of idle-to-idle "microtrips" until the representative target metrics were achieved. The schedules developed by ERG are, thus, not contiguous schedules which would be run on a chassis dynamometer, but are made up of non-continguous "snippets" of driving meant to represent target distributions. For use in MOVES2004, the highway heavy-duty schedules developed by ERG were modified to isolate operation on freeway ramps. The segments of freeway microtrips identified by ERG as taking place on on-and off-ramps were extracted and used to create medium-duty and heavy-duty ramp schedules (299 and 399). Thus, the schedules which represent on-freeway driving do not contain ramp operation. Another minor modification to the schedules for use in MOVES2004 was made to the time field in order to signify, within a drive schedule, when one microtrip ended and one began. The time field increments two seconds instead of one when each new microtrip begins. This two second increment signifies that these should not be regarded by the model as contiguous operation.

It is possible (but unlikely) that users will specify average speeds which exceed the range of schedules that apply to arterial and local roadways. In these cases, freeway schedules will be sometimes used to model these unusually high average speed cases. Logically, any roadway whose average speed approaches those of freeways is functionally approaching the behavior of a freeway schedule. Similarly, in cases where average freeway speeds are unusually low, non-freeway driving schedules may be used. The cases in which freeway schedules are available for non-freeway driving, and vice versa, are indicated in the mapping shown in Table 14-1.

15. SourceTypeHour

SourceTypeHours consists of two fields: **StartsPerSHO** and **IdleSHOFactor.**

15.1. StartsPerSHO

The StartsPerSHO field stores the factor used to determine the number of engine starts (trips) per hour of vehicle operation for each Source Type by day of the week and hour of the day. Each trip is assumed to begin with an engine start. After MOVES calculates the hours of operation, MOVES calculates the number of trips from the amount of hours of source operation. MOVES allows for unique values for trip starts per source hour of operation (SHO) for each source use type, each day of the week and each hour of the day.

Three basic sources for information regarding the number of engine starts per hour of vehicle operation were used for MOVES. The report, "Roadway-Specific Driving Schedules for Heavy-Duty Vehicles,"[44] combines data from several instrumented truck studies. The data was used to directly determine the trip starts and hours of vehicle operation by hour of the day for heavy-duty vehicles. Only non-parcel truck data was used. The data was grouped into medium heavy-duty trucks (19,501 lbs GVWR to 33,000 lbs. GVWR) and heavy heavy-duty trucks (greater than 33,000 lbs. GVWR). Data from weekdays and weekend days were grouped. All weekdays use the same hourly values and both weekend days use the same hourly values.

The estimate for light-duty passenger vehicles and light-duty trucks are derived from the instrumented vehicle data collected for the FTP Study in Spokane, Baltimore and Atlanta.[45] From this data the number of engine starts and hours of vehicle operation can be directly determined for each hour of the day. Data from weekdays and weekend days were grouped. All weekdays use the same hourly values and both weekend days use the same hourly values.

Engine start estimates for motorcycles and buses were derived from MOBILE6 estimates for the number of engine starts, the number of miles traveled and the average speeds. The number of engine starts per day are taken from the MOBILE6 default values. These values were carried over from previous versions of the MOBILE model and, to our knowledge, are not documented. The derivation of the number of miles traveled is described in the technical report, "Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Mileage Accumulation Rates and Projected Vehicle Counts for Use in MOBILE6."[46] The derivation of average speeds is described in the technical report, "Development of Methodology for Estimating VMT Weighting by Facility Type."[47]

Engine start estimates for refuse trucks and motor homes are assumed to be the same as for transit buses. This rough estimate is based on the assumption that, as in the case for transit buses, refuse trucks and motor homes are started infrequently as compared to the hours of operation.

Table 15-1 summarizes the average trip starts per source hour operating (SHO) from the various data sources. Though not the values used in the MOVES database (MOVES allows the number of trip starts per SHO to vary by hour of the day), the table shows the relative differences between the various vehicle classes and summarizes data sources.

Table 15-1. Data Sources for Trip Starts Per Source Hour of Operation (SHO)

Data Sources for Trip Starts Per Source Hour of Operation (SHO)			
SourceTypeID	SourceTypeName	Source of Data	Trip Starts per SHO Average
11	Motorcycle	MOBILE6	3.718
21	Passenger Car	LD Data	5.631
31	Passenger Truck	LD Data	5.631
32	Light Commercial Truck	LD Data	5.631
41	Intercity bus	Transit bus	1.879
42	Transit bus	MOBILE6	1.879
43	School Bus	MOBILE6	6.740
51	Refuse Truck	Transit bus	1.879
52	Single-Unit Commercial Truck	MD Data	3.404
53	Single-Unit Delivery Truck	MD Data	3.404
54	Motor Home	Transit bus	1.879
61	Combination Commercial Truck	HD Data	1.231
62	Combination Delivery Truck	HD Data	1.231

Using MOBILE6 Trip Information

The start estimates for motorcycles and buses were derived from MOBILE6 estimates for the number of engine starts, the number of miles traveled, and the average speeds. MOBILE6 divides the on-highway vehicle fleet into 28 separate vehicle classes. These classes are briefly described in Table 15-2.

Each vehicle class has estimates for the number of trips per day (engine starts), the number of miles traveled each day and the average speed traveled on all roadway types (defined as trip distance divided by full trip time, including delay). From these three parameters, it is possible to calculate the number of trips per hour of engine operation. Table 15-3 shows how this is calculated for each of the vehicle classes in MOBILE6.

Of the values in Table 15-3, only the estimates for Transit Buses (HDDBT), School Buses (HDDBS) and Motorcycles (MC) were needed for MOVES. These same estimates were used for every hour of all days.

Table 15-2. MOBILE6 Vehicle Classifications

Index	*Class*	*Description*
1	LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-Duty Gasoline Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
3	LDGT2	Light-Duty Gasoline Trucks 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
4	LDGT3	Light-Duty Gasoline Trucks 3 (6,001-8500 lbs. GVWR, 0-3750 lbs. LVW)
5	LDGT4	Light-Duty Gasoline Trucks 4 (6,001-8500 lbs. GVWR, 3751-5750 lbs. LVW)
6	HDGV2B	Class 2b Heavy-Duty Gasoline Vehicles (8501-10,000 lbs. GVWR)
7	HDGV3	Class 3 Heavy-Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
8	HDGV4	Class 4 Heavy-Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
9	HDGV5	Class 5 Heavy-Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
10	HDGV6	Class 6 Heavy-Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
11	HDGV7	Class 7 Heavy-Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
12	HDGV8A	Class 8a Heavy-Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
13	HDGV8B	Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14	LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
15	LDDT12	Light-Duty Diesel Trucks 1 (0-6,000 lbs. GVWR)
16	HDDV2B	Class 2b Heavy-Duty Diesel Vehicles (8501-10,000 lbs. GVWR)
17	HDDV3	Class 3 Heavy-Duty Diesel Vehicles (10,001-14,000 lbs. GVWR)
18	HDDV4	Class 4 Heavy-Duty Diesel Vehicles (14,001-16,000 lbs. GVWR)
19	HDDV5	Class 5 Heavy-Duty Diesel Vehicles (16,001-19,500 lbs. GVWR)
20	HDDV6	Class 6 Heavy-Duty Diesel Vehicles (19,501-26,000 lbs. GVWR)
21	HDDV7	Class 7 Heavy-Duty Diesel Vehicles (26,001-33,000 lbs. GVWR)
22	HDDV8A	Class 8a Heavy-Duty Diesel Vehicles (33,001-60,000 lbs. GVWR)
23	HDDV8B	Class 8b Heavy-Duty Diesel Vehicles (>60,000 lbs. GVWR)
24	MC	Motorcycles (Gasoline)
25	HDGB	Gasoline Busses (School, Transit and Urban)
26	HDDBT	Diesel Transit and Transit busses
27	HDDBS	Diesel School Busses
28	LDDT34	Light-Duty Diesel Trucks 1 (6,001-8500 lbs. GVWR)

Table 15-3. MOBILE6 Starts Per Day, Miles Driven Per Day and Average Speed And Calculated Starts Per Source Hour Operating

Index	*Class*	Starts/day Weekday	Starts/day Weekend	CY2000 Miles/day	Average Speed	Calculated SHO	Weekday Starts/SHO
1	LDGV	7.28	5.41	29.4755	27.6	1.067953	6.817
2	LDGT1	8.06	5.68	35.2916	27.6	1.278681	6.303
3	LDGT2	8.06	5.68	35.2916	27.6	1.278681	6.303
4	LDGT3	8.06	5.68	34.0771	27.6	1.234678	6.528
5	LDGT4	8.06	5.68	34.0771	27.6	1.234678	6.528
6	HDGV2B	6.88	6.88	35.6267	27.6	1.290822	5.330
7	HDGV3	6.88	6.88	30.9094	27.6	1.119906	6.143
8	HDGV4	6.88	6.88	20.3003	27.6	0.735518	9.354
9	HDGV5	6.88	6.88	27.6105	27.6	1.00038	6.877
10	HDGV6	6.88	6.88	26.9164	27.6	0.975232	7.055
11	HDGV7	6.88	6.88	22.8339	27.6	0.827315	8.316
12	HDGV8A	6.88	6.88	21.3321	27.6	0.772902	8.902
13	HDGV8B	6.88	6.88	21.3321	27.6	0.772902	8.902
14	LDDV	7.28	5.41	19.4586	27.6	0.705022	10.326
15	LDDT12	8.06	5.68	10.7539	27.6	0.389634	20.686
16	HDDV2B	6.65	6.65	45.4056	27.6	1.64513	4.042
17	HDDV3	6.65	6.65	49.4674	27.6	1.792297	3.710
18	HDDV4	6.65	6.65	62.2014	27.6	2.253674	2.951
19	HDDV5	6.65	6.65	65.185	27.6	2.361775	2.816
20	HDDV6	6.65	6.65	65.0443	27.6	2.356678	2.822
21	HDDV7	6.65	6.65	61.6706	27.6	2.234442	2.976
22	HDDV8A	6.65	6.65	108.9881	27.6	3.948844	1.684
23	HDDV8B	6.65	6.65	168.0957	27.6	6.090424	1.092
24	MC	1.35	1.35	10.0204	27.6	0.363058	3.718
25	HDGB	6.88	6.88	27.2301	27.6	0.986598	6.973
26	HDDBT	6.65	6.65	97.6678	27.6	3.538688	1.879
27	HDDBS	6.65	6.65	27.2301	27.6	0.986598	6.740
28	LDDT34	8.06	5.68	43.8645	27.6	1.589293	5.071
Source Hours Operating = (Miles per Day) / (Miles per Hour) = SHO							

15.2. IdleSHOFactor

The IdleSHOFactor field stores the factor used to determine the number of hours of extended idling for each Source Type by day of the week and hour of the day. Extended idling, also referred to as "hoteling," is defined as any long period of discretionary idling that occurs during long distance deliveries by heavy-duty trucks.

No sources exist that directly measure extended idling in order to determine the total hours of extended idling estimated for heavy-duty trucks. However, hoteling mainly occurs among the largest (Class 8) trucks, which are now almost exclusively diesel. A paper by Lutsey, et al., [48] recently submitted to the Transportation Research Board, provides some insights on how truck hoteling relates to overall truck activity.

Federal law limits the number of hours which long haul truck drivers can operate each day. These regulations are described in the Federal Register.[49] Using the distribution of truck hoteling duration times (shown in Figure 1 of the Lutsey, et al. paper) and assuming that long haul truck drivers travel an average 10 hours a day when engaged in hoteling behavior, we can estimate the average duration of hoteling as 5.9 hours for every 10 hours of long-haul truck driving. However, for MOVES we need to know the fraction of hours spent hoteling versus hours of vehicle operation by time of day. This value can be derived from the known truck activity.

In particular, the report, "Roadway-Specific Driving Schedules for Heavy-Duty Vehicles,"[50] combines data from several instrumented truck studies. The data contains detailed information about truck driver behavior; however, none of the trucks in any of the studies was involved in long haul, interstate activity. We assumed that all long haul truck trips have the same hourly truck trip distribution as the heavy heavy-duty trucks in the instrumented studies and that all long haul trips are 10 hours long, and thus deduced an hourly distribution of long haul trip ends. The distribution of hoteling durations from the Lutsey report was applied to these trip-end distributions. From these calculations, we estimated the number of hours of truck operation and hours of truck hoteling. For MOVES, we then calculated the ratio of hoteling hours to truck operation hours for each hour of the day. Only weekday data was used.

In MOVES, only the long haul combination truck sourcetype is assumed to have hoteling activity. All other source use types have hoteling activity fractions set to zero.

16. ZoneYearRoadType

The **SHOAllocFactor** field stores the factor used to determine the hours of vehicle operation in each zone in each calendar year on each of the roadway types.

The spatial allocation of source hours operating distributes the domain-wide estimates of hours of operation to the zones. In the macro-scale implementation of the model, the domain is the nation and the zones are counties. The nationwide hours of operation are not known (measured). However, roadway vehicle miles traveled (VMT) information is available in detail. Since the allocation is by roadway type, it is reasonable to assume that the average speeds by roadway type are the same in every county, which would make the hours of operation directly proportional to the VMT on each roadway type. So, VMT will be used to determine the allocation of source hours operating to counties.

The estimate for the VMT by county comes from the 1999 National Emission Inventory (NEI) analysis documented by Pechan & Associates.[51] The NEI estimates are based on the Highway Performance Monitoring System (HPMS) data collected by the Federal Highway Administration[52] for use in transportation planning and vehicle type breakdowns from the EPA MOBILE6 Emission Factor model.[53] The NEI VMT estimates have been incorporated into the National Mobile Inventory Model (NMIM) county database.

The VMT estimates were obtained from the NMIM database. VMT estimates for each roadway type were determined for each county in each state and the allocation calculated using the following formula.

$$\text{CountyAllocation}(i) = (\ \text{CountyVMT}(i) / \text{Sum}(\text{CountyVMT}(i)\ )$$

The roadway types in the NMIM database match the roadway types used in MOVES2004. The county allocation values for each roadway type will sum to one for the nation. Although the data is from 1999 calendar year estimates, the same allocations will be used for all calendar years.

17. ZoneYear

ZoneYear consists of two fields: **StartAllocFactor** and **IdleAllocFactor.**

17.1. StartAllocFactor

The StartAllocFactor field stores the factor used to determine the number of starts in each zone in each calendar year.

The trip start allocation distributes the domain-wide estimates of the number of trip starts to the zones. In the macro-scale implementation of the model, the domain is the nation and the zones are counties. Nationally, the number of trip starts are not known (measured), but roadway vehicle miles traveled (VMT) is documented. Since the number of trips is roughly proportional to the VMT, VMT will be used to determine the allocation of trip starts to counties.

The estimate for the VMT by county comes from the 1999 National Emission Inventory (NEI) analysis.[54] The NEI estimates are based on the Highway Performance Monitoring System (HPMS) data collected by the Federal Highway Administration[55] for use in transportation planning and vehicle type breakdowns from the EPA MOBILE6 Emission Factor model.[56] The NEI VMT estimates have been incorporated into the National Mobile Inventory Model county database.

The VMT estimates were obtained from the NMIM database. VMT estimates for each county in each state and the allocation calculated using the following formula.

$$CountyAllocation(i) = (CountyVMT(i) / Sum(CountyVMT(i))$$

The county allocation values will sum to one for the nation. Although the data is from 1999 estimates, the same allocations will be used for all calendar years.

17.2. IdleAllocFactor

The IdleAllocFactor field stores the factor used to determine the hours of extended idling in each zone in each calendar year.

No sources exist that directly measure extended idling in order to allocate the hours of extended idling estimated for heavy-duty trucks. However, extended idling (or hoteling) occurs primarily on long-haul trips across multiple states, which suggests that travel on rural and urban interstates would best represent long-haul trips. Extended idling mainly occurs among the largest (Class 8) trucks, which are now almost exclusively diesel. Since we have estimates for the amount of rural and urban interstate VMT by Class 8 heavy-duty diesel trucks in each county of the nation, we can use this estimate to create a national allocation factor for extended idling hours.

The actual total demand for overnight parking by trucks has been estimated by the Federal Highway Administration on a state by state basis.[57] These estimates were used to determine the allocation to each State(i) using the following formula:

$$StateAllocation(i) = StateParkingDemand(i) / Sum(StateParkingDemand(i))$$

The State allocation values will sum to one for the entire country. This method results in no idling in Washington, D.C., Hawaii, Virgin Islands, or Puerto Rico, which make sense, since none of these areas have VMT associated with rural or urban interstates.

The estimate for the VMT from Class 8 heavy-duty diesel trucks by county comes from the 1999 National Emission Inventory (NEI) analysis.[58] The NEI estimates are based on the Highway Performance Monitoring System (HPMS) data collected by the Federal Highway Administration[59] for use in transportation planning and vehicle type breakdowns from the EPA MOBILE6 Emission Factor model.[60] The NEI VMT estimates have been incorporated into the National Mobile Inventory Model (NMIM) county database.

The VMT estimates were obtained from the NMIM database. VMT estimates for Class 8 heavy-duty diesel trucks on rural and urban interstates were determined for each county in each state and the allocation calculated using the following formula.

$$CountyAllocation(i) = StateAllocation * (CountyVMT(i) / Sum(CountyVMT(i))$$

The county allocation values will sum to one for the entire country. The sum of the county allocations for a given State will equal the State allocation for that State, as determined earlier.

18. SCCVTypeDistribution

For some uses, particularly the preparation of national inventories, modelers will need to produce output aggregated by EPA's Source Category Codes (SCC). The EPA's highway vehicle SCC were derived from MOBILE5 and MOBILE6 and do not directly correspond to the MOVES SourceTypes. For example, depending on its fuel and Gross Vehicle Weight (GVW) limits, a vehicle in the MOVES Passenger Truck category may be coded with one of eight SCCs—including the SCC for a Light-Duty Gasoline Truck 1, a Light-Duty Gasoline Truck 2, a Heavy-Duty Gasoline Truck, a Light-Duty Diesel Truck, or one of the four codes for Heavy-Duty Diesel Vehicle.

The MOVES model is designed to aggregate emissions to the user's choice of SourceType or SCC using the SCCVTypeDistribution table. For each combination of SourceType, Model Year and FuelType, the SCCVTypeDistribution table lists IDs for the possible SCC and the fraction of vehicles assigned to each SCC. The full SCC also includes a suffix that indicates roadway type. This is a simple mapping from the MOVES roadtype on which the emissions occur.

While the existing SCCs only identify gasoline and diesel-fueled vehicles, it was necessary to map alternatively-fueled vehicles to SCCs. All alternative-fuel vehicles were mapped to the **diesel** SCC, with the same distribution between light and heavy-duty categories as diesels in that model year. In the future, SCCs may be revised to explicitly handle alternative fuels.

For most SourceTypes, the mapping to SCC was straightforward. These mappings are summarized in Table 18-1. However, the trucks span a wide range of GVWs and, thus, a wide range of SCCs. We used VIUS97 values for GVW to determine the truck SCC fractions by model year. To separate Light-Duty Trucks 1 and Light-Duty Trucks 2, which are distinguished by Loaded Vehicle Weights, we used information from the Oak Ridge National Laboratory Light-Duty Vehicle database. And to separate Class 2a and 2b trucks, we used information from Davis and Truitt.[61] The resulting truck mappings are too complex to summarize here, but are available in the MOVES database.

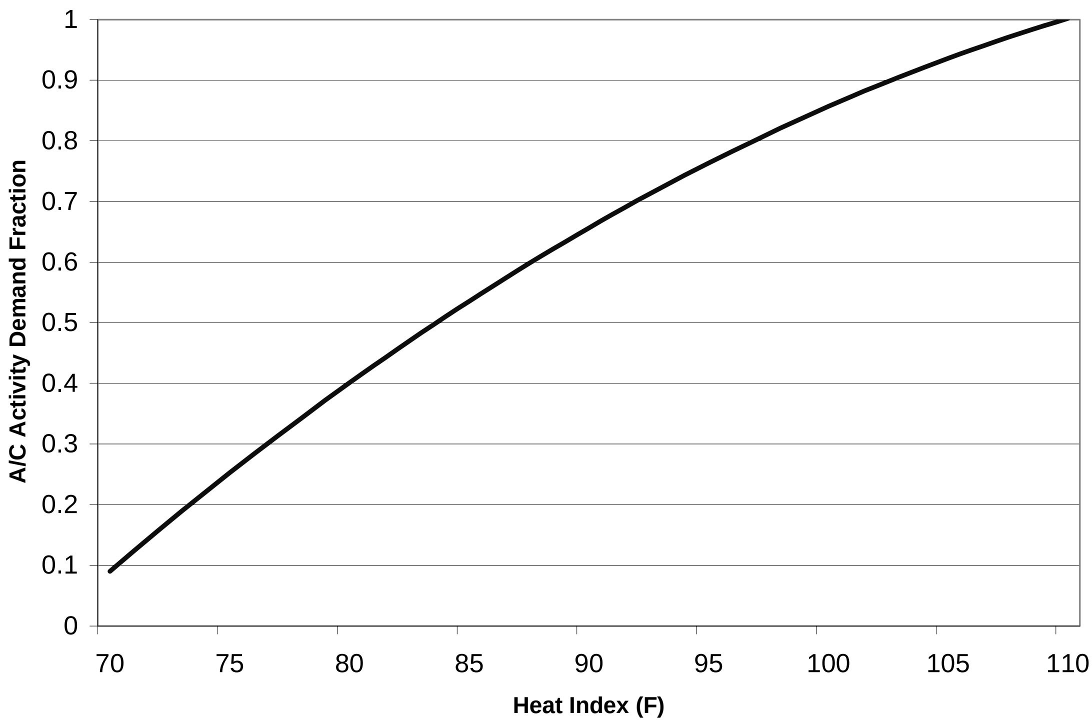
Table 18-1. SCC Mappings for Selected SourceTypes

Source Type ID	SourceType	Fuel Type	SCC-ID	SCC prefix	Abbreviated Description
11	Motorcycle	gasoline	5	2201080	Motorcycles
21	Passenger Car	gasoline	1	2201001	LDGV
21	Passenger Car	other	6	2230001	LDDV
41	Intercity Bus	gasoline	4	2201070	HDGV&B
41	Intercity Bus	other	12	2230075	HDDB
42	Transit Bus	gasoline	4	2201070	HDGV&B
42	Transit Bus	other	12	2230075	HDDB
43	School Bus	gasoline	4	2201070	HDGV&B
43	School Bus	other	12	2230075	HDDB
54	Motor Home	gasoline	4	2201070	HDGV&B
54	Motor Home	other	10	2230073	M-HDDV

19. MonthGroupHour

ACActivityTerms A, B and C are coefficients for a quadratic equation that calculates air conditioning activity demand as a function of the heat index. They are applied in the calculation of the A/C adjustment in the energy consumption calculator. The methodology and the terms themselves were originally derived for MOBILE6 and are documented in the report "Air Conditioning Activity Effects in MOBILE6."[62] They are based on analysis of air conditioning usage data collected in Phoenix, Arizona, in 1994. In MOVES, ACActivityTerms are allowed to vary by monthGroup and Hour, in order to provide the possibility of different A/C activity demand functions at a given heat index by season and time of day (this accounts for differences in solar loading observed in the original data). However, for MOVES2004, the default data uses one set of coefficients, to be applied across all MonthGroups and Hours. These default coefficients represent an average A/C activity demand function over the course of a full day. These coefficients are: -3.63 for A, 0.0725 for B, and -0.00028 for C. The A/C activity demand function that would result from these coefficients is shown in Figure 19-1. A value of 1 means the A/C compressor is engaged 100 percent of the time; a value of 0 means no A/C compressor engagement.

Figure 19-1: Air Conditioning Activity Demand as a Function of Heat Index



20. ZoneMonthHour

The ZoneMonthHour table contains environmental parameters that may affect energy consumption, such as temperature, relative humidity. This table also contains the heat index value, which is derived from the temperature and humidity. The heat index is used in the calculation of air conditioning usage.

Temperature and relative humidity are linked, since the value of relative humidity is in units of percent, which will vary, depending on the temperature. Values of temperature should not be changed, unless the corresponding relative humidity value can also be determined.

The MOVES model allows temperature and relative humidity to vary by month, hour and zone. In the macroscopic implementation of MOVES2004, Zone is defined as County. There is an average temperature value (in degrees Fahrenheit) and relative humidity value (in percent) for each hour of an average day for each month of the year for each county. The same temperatures and humidity values are used for all calendar years.

The temperature and humidity values in the ZoneMonthHour table were derived from data from the National Climatic Data Center (NCDC)[63]. The NCDC is the national and international depository for weather observations. As part of its many duties, the NCDC publishes and maintains many climatic data sets. Among these databases are historical and current daily and monthly average maximum and minimum temperatures and dew point measurements. However, it was necessary to obtain the daily maximum and minimum observations for all stations for all years of interest, and compute the long and short term averages from scratch in order to resolve missing monthly averages.

The daily maximum and minimum temperature data for all available stations were processed into monthly averages. These stations covered all classifications, including First-Order, Second-Order, (both Automated Surface Observing System (ASOS) and Automated Weather Observing System (AWOS)) and cooperative. Meteorologists and Climatologists routinely refer to the major National Weather Service (NWS) observation stations as "First Order" stations. These usually include large cities and metropolitan airports. Second Order generally means hourly airways observations are taken, but not in accordance with first order requirements. Most are FAA-operated stations. Smaller stations are referred to as "Co-Operative (Co-Op)" or "Third Order" stations. These stations are usually found in small towns, or rural areas, and number in the thousands in the U.S. Following NCDC guidelines, a month's averages were considered valid when no more than 5 days had missing data during that month. The data were then organized to determine if the station has enough valid data to be included in subsequent analyses. Using NCDC guidelines, a year of data is valid only if all of the months have data.

After these filters were applied, the average monthly maximum and minimum temperature data were adjusted to the common midnight-to-midnight observational period. This adjustment is necessary since many of the cooperative stations take their observations either early in the morning or late in the afternoon rather than at midnight. These observation times induce a bias into the monthly temperature averages. The contractor obtained the appropriate correction values from the NCDC and applied them to the monthly averages.

Population centroids (latitude and longitude) for each county were obtained from the 2000 United States Census. Population, rather than geographic, centroids were used to provide the best estimate of where the county's VMT would occur. From each county's centroid, the distance and direction to each weather station was calculated. The nearest site in each of the eight compass directions (an octal search) was used to identify the nearby measurements. The distance was computed using the standard great circle navigation method and the constant course direction was computed using the standard rhumb line method. A rhumb line is a line on a sphere that cuts all meridians at the same angle; for example, the path taken by a ship or plane that maintains a constant compass direction. For each octant, the stations were sorted by distance. The station closest to the centroid for each octant was chosen for further processing. If the closest station was more than 200 miles away, that octant was ignored. (Such situations occurred near the oceans and the along the Canadian and Mexican borders. The temperatures from these eight (or less) stations were then weighted together using inverse-distance weighting.

Relative humidity is a calculated value that depends on both temperature and dew point. Average hourly dew points were computed employing the same octal search, inverse-distance weighting scheme as used for temperature. The relative humidity was then computed from the resulting hourly temperature and dew point pairs.

21. Fuel Types

Energy consumption, expressed as fuel consumption, will vary depending on the fuel used. MOVES2004 expresses fuel as one of nine categories. These categories are shown in Table 21.1 below.

Table 21-1. Fuel Types

fuelTypeId	fuelTypeDesc
1	Gasoline
2	Diesel Fuel
3	Compressed Natural Gas (CNG)
4	Liquid Propane Gas (LPG)
5	Ethanol (E85 or E95)
6	Methanol (M85 or M95)
7	Gaseous Hydrogen
8	Liquid Hydrogen
9	Electricity

The fuel types are represented by fractions of each source use type and model year combination (SourceTypeModelYearID) in the FuelEngFraction table by the FuelEngFraction field. The sum of the FuelEngFraction values will be one for each SourceTypeModelYearID. Although the fractions of engines by fuel type is constant, the overall total number of engines of each fuel type will vary by calendar year depending on the number of engines of each source use type and model year in that calendar year.

21.1. FuelSubType

The properties of specific fuels in the broad FuelType categories can vary widely. These differences are captured as fuel subtypes. The FuelSubtypes used by MOVES2004 are shown in Table 21-2 below.

The fractions of vehicles which are use the various fuel subtypes are stored in the MarketShare field of the FuelSupply table. The MarketShare values for a FuelType will sum to one for each combination of CountyID, YearID and MonthGroupID. Market share values may vary by calendar year and month grouping for each county.

Table 21-2. Fuel SubTypes

fuelSubtypeID	fuelTypeID	fuelSubtypeDesc
10	1	Conventional Gasoline
11	1	Reformulated Gasoline (RFG)
12	1	Gasohol (E10)
20	2	Conventional Diesel Fuel
21	2	Biodiesel
22	2	Fischer-Tropsch Diesel
30	3	Compressed Natural Gas (CNG)
40	4	Liquid Propane Gas (LPG)
50	5	Ethanol (E85 or E95)
60	6	Methanol (M85 or M95)
70	7	Gaseous Hydrogen
80	8	Liquid Hydrogen
90	9	Electricity

21.2. FuelSupply

Each individual engine within a SourceType is assumed to be built to be powered by only one of the FuelTypes shown in Section 21.1. However, within a FuelType, an engine can be run on any of the FuelSubtypes within their FuelType shown in Section 21.2, depending on the availability of the alternatives and other motivational factors. As a result, the fuel consumption of each FuelSubtype may depend on the time and location, as well as the count and activity of the SourceTypes.

MOVES2004 allows the FuelSubtype to vary by time (calendar year and season) and the location (county). The distribution of fuel consumption between the various FuelSubtypes is stored in the FuelSupply table. Table 21-3 describes the fields in the FuelSupply table.

Table 21-3. FuelSupply Table Description

Field Name	Description
countyID	A political and territorial subdivision of a State (see definition of State) as defined by FIPS standard codes.
yearID	Calendar year (4 digit integer). The valid range is 1990-2050.
monthGroupID	Integer value which indicates a particular grouping of months. 1=Summer, 2=Fall, 3=Winter, 4=Spring.
fuelSubtypeID	Identifies a particular kind of fuel within a FuelType. e.g. Gasoline may be conventional, or Reformulated Gasoline (RFG), diesel may be conventional, biodiesel, Fischer-Troppes, etc.
marketShare	Decimal Fraction of the supply of this FuelType which this FuelSubtype constitutes. Defaults to 1.0 for the lowest numbered fuelSubtypeID, 0.0 for all others, if no record is present.

The MOVES2004 database contains default values for FuelSubtype market shares for each season (MonthGroupID) in each year (YearID) for each county (CountyID). These values were derived from a more detailed set of fuel descriptions developed for the National Mobile Inventory Model (NMIM) County database for the National Emission Inventory (NEI)[64].

The NMIM fuel parameters were derived from several surveys: U.S. EPA's reformulated gasoline (RFG) survey (U.S. EPA, 2000), the U.S. EPA Oxygenated Fuel Program Summary (U.S. EPA, 2001), the TRW (previously NIPER) fuel survey (TRW, 1999), and the Alliance of Automobile Manufacturers' (AAMA) North American Gasoline and Diesel Fuel Survey (AAMA, 1999). The TRW fuel survey reports the data in several tables, including Table 9 (Motor Gasoline Survey, Season [Summer/Winter], Year [1999/2000], and Average Data for Different Brands) and Table 10 (Motor Gasoline Survey, Season [Summer/Winter], Year [1999/2000], and Average Data for Different Brands Containing Alcohols). Data for the percent market share of oxygenated fuel sales were obtained from Oxygenate Type Analysis Tables (1995-2000) (U.S. EPA, 2001) and the Federal Highway Administration website (FHWA 1999).

The survey fuels were assigned to individual counties by region and many fuel parameters were combined to generate a single set of fuel parameters for each county. Separate fuels were derived for Summer, Winter and Spring/Fall. Future calendar years fuel properties were derived accounting for the phase-in of Phase 3 RFG in California, the Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements and other expected changes in fuel properties due to regulations. For MOVES2004, each fuel was assigned to one of the FuelSubtypes and market shares were derived from the market share field used in NMIM.

22. Peer Review

This section includes the complete comments received in November 2004 from the formal EPA peer review of the initial draft "MOVES2004 Highway Vehicle Population and Activity Data" report. EPA responses are in italics. The review was done by:

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General Comments

In general, EPA has developed the underlying vehicle population and activity databases by integrating a number of different data. The methods and assumptions used to combine external data sources and to populate the EPA databases reflect many of the same assumptions applied in MOBILE6. There are likely many reasonable approaches to assembling a complete census of vehicle population/activity, and thus, a variety of opinions about the assumptions applied or the ways in which the various source data are combined. That is, some assumptions are inevitable regardless of how the underlying databases are developed. Within the scope and time provided for reviewing the technical documentation, my overall assessment is that EPA has taken a reasonable approach to assembling the vehicle population/activity data required for the operation of MOVES. Within this assessment, however, I did have a number of questions which I elaborate on in this document.

The review begins with a brief comment on the technical documentation. This is the starting point of the discussion because I believe many of the questions in the subsequent section could be cleared up with additional detail in the technical documentation. The main questions in the second section are related to specific variables/databases and the way in which some assumptions about various databases are applied. The report concludes with a brief summary of longer term suggestions that might be useful for EPA to consider during the development period of the complete MOVES model.

Suggestions Related to the Documentation

As it stands the documentation could use significantly more references and/or details or appendices. This may in fact be EPA's longer term intent. The current documentation does not seem to provide enough details on how databases are combined or manipulated into their final form. For example, for the MOBILE6 emissions model, the EPA calculated future year vehicle populations by vehicle class and age by setting vehicle counts for the xth year equal to the sum of vehicle counts for (x-1)th year multiplied by (1-scrappage rate for the xth year) plus the new sales for xth year. That is, each year's vehicle population forecast is based on the vehicle population estimated from the previous year.

For MOBILE6, I believe the 1996 vehicle population was used as the baseline for 1997 and forward estimates and survival rates were based on the 1996 World Vehicle Forecasts and Strategies' Report (Pemberton, 1996). As I recall, EPA generally estimated scrappage rates as an increasing trend over time. For example, for the periods 1995-1999, 2000-2004, 2005-2009, 2010-2014, and 2015-2020, the scrappage rates (as of percentage of the total in-use fleet) are estimated as 5.77%, 5.7%, 6.01%, 6.34%, and 6.56%. Given that MOVES, in its current version, is being estimated for the 1999 baseline only, some of this is not applicable, however, some of it is, even to set the 1999 baseline. A simple reference would help to document whether MOBILE6 methods are being used (e.g., consider SurvivalRate[a] or SalesGrowthFactor, which seems to be computed in a slightly different manner from that applied in MOBILE6). Additional details, some of which I've tried to identify below, about the assumptions used to distill the main ingredients of most of the tables would be helpful, including identifying when the basic methods are similar to or diverge from MOBILE6.

EPA Response: *Additional text was added to Section 3.2 and 5.1 indicating how MOVES differs from MOBILE6.*

There is also somewhat of an incongruence that arises in the documentation. It is clear both from EPA's letter of request to review the documentation and from various statements in the report that the main emphasis of this particular version is on producing national estimates. However, there is also text (and some modeling capabilities) that suggests that MOVES is "ready" for more localized estimation (e.g., at the roadway level or for more resolved time periods). I personally would prefer the documentation to be consistent – either the model is acceptable in EPA's view for use at the local level or references to localized model capabilities should be taken out and perhaps summarized in a concluding chapter that identifies next steps.

EPA Response: *The design of the MOVES model was intended to accommodate both national (macroscale) and local (mesoscale) modeling. Modeling of local areas will require areas to provide detailed roadway specific information that will not be provided by EPA. This document only describes the information provided by EPA for the MOVES model for national modeling. Because of the design of the MOVES model, it is difficult to avoid discussing the model inputs in terms that exclude the local modeling input options. We will try to make clear the distinctions between national (EPA supplied) inputs and local (user supplied) inputs in this documentation.*

In general, the technical documentation feels hurried. In many places (again, I've tried to identify some of them below), the lack of detail on the methods, assumptions, and rationale for these assumptions in the documentation makes truly understanding the development of the databases a bit hard to discern. I would also suggest staying away from language used in the introduction referring to "accuracy." The number of assumptions and lack of independent

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[a] In SurvivalRate, the text is confusing and suggests that rates are based on 1990 baseline. Enough detail should be added to the technical documentation to make clear how each of the datasets are phased "up" to the 1999 baseline year. These kinds of details are directly related to the assembly of the databases themselves and might influence results in ways that users should be made aware of.

verification of the vehicle population and activity census makes it difficult to assess (or claim) accuracy.

Questions Related to Database Details

Pg. 10 Please clarify the statement: "Some of the values are available directly from other sources; other values were derived from the available data." **EPA Response:** *The statement was rewritten, "Some of the values are taken directly from the indicated sources; other values needed to be derived from available data and are not found explicitly in any of the data sources."*

Pg. 15 The discussion of the migration variable, which is set at 1 for this release, is an example where EPA seems to imply more localized modeling is acceptable. I would suggest gathering these kinds of statements into a final chapter on next releases. **EPA Response:** *The MOVES design includes migration rates. Discussion of migration is appropriate, even if the value for national modeling is set to one. No changes were made.*

Pg. 18 Provide the mapping from MOBILE6 to MOVES for the Relative MARs. Many of the regression equations are of squared and exponential forms, are these functional forms reasonable from an applied perspective? **EPA Response:** *The functional forms were chosen to best represent the form of the observed data. No changes were made.*

Pg. 27 Here is an example of where the report implicitly emphasizes use of MOVES for national estimates (or perhaps cautions against localized): "On a national scale…" **EPA Response:** *This is certainly an issue. Local areas will (hopefully) have a better idea of how flexible fueled vehicles are operated in their areas. However, this document is clearly not intended to be guidance on how local areas might change the assumptions used for the national averages. No changes were made.*

Pg. 45 Some underlying rationale for the decisions made with respect to splits derived for the data in AEO Table 45 should be provided. Why is splitting gas hybrids between moderate and full a reasonable assumption? **EPA Response:** *Text was added to Section 7.7 to better explain the need for the various engine technology categories shown in Table 7-20.*

Pg. 45 Why not use 2004 or 2005 size and weight distributions for future years instead of 1999? **EPA Response:** *The statement was rewritten, "The inputs for determining default SourceBinDistributions for model years 2000-and-later were generally based on fuel and engine technology projections from AEO2004 and on the 1999 calendar year regulatory class, size and weight distributions used in MOVES." Regulatory class, size and weight distributions for other calendar years are not yet available.*

Pg. 56 I would suggest adding at least a mention of the problems and constraints associated with using the (mostly) self-reported data in Highway Statistics. See Hendren and Niemeier[65] (2001) for some background. **EPA Response:** *Text was added to Section 9 to caution the reader.*

Pg. 57 Here is also where WIM data (discussed later) might be useful. **EPA Response:** *The statistical tools necessary to use the use weigh-in-motion data to supplement or replace vehicle census data have not yet been developed. No changes were made.*

Pg. 58 There are serious limitations to the data used to develop the speed distributions for MOBILE6. Suggest instead of just translating these data, EPA utilize the new California chase data that was collected as part of the CAMP effort. These data provide a much more robust sample in terms of sample size and representativeness. In the mapping on Table 10-1, where are collectors? **EPA Response:** *The California chase data was not yet available at the time the national average estimates for MOVES were developed. However, data from these studies is now becoming available and the average speed distributions for rural roadways from the California studies will now be used instead of the MOBILE6 estimates. All twelve of the HPMS roadway types are represented in Table 10-1, including collectors.*

Pg. 59 The BaseYearOffNetVMT seems to conflict with what is implied in Table 9-1, where all of the functional classes are included. Yet, most travel models don't include local roads, which (I think) would actually be captured in this parameter. When you look at Table 9-2, source type fractions appear for local roads (and there can be collectors not included in the travel networks as well). Need to clarify whether these fractions and types are used or not in the current version. **EPA Response:** *Text was added to Section 9 and 11.2 to clarify the meaning of "off network" VMT.*

Pg. 64 Please clarify the statement "The data does not vary by month or SourceType." Do the automatic counters give a breakdown by source type? "Do not vary" seems to imply there very little month to month variation. There have been studies through the years suggesting monthly variation between summer and winter for example. Perhaps provide a standard error to justify this statement? Also on pg. 64, there is a statement "The correct distribution for "off network" VMT…" that seems to conflict with the BaseYearOffNetVMT discussion? **EPA Response:** *The statement in Section 12.2 was rewritten, "The data obtained from the OHIM report is not disaggregated by month or SourceType. The same values will be used for every month and SourceType." The discussion in Section 12.2 was also rewritten to clarify that the urban day of the week distribution is applied to the off network VMT (if any).*

Pg. 64 Are the hourly VMT fractions computed in Table 12-3 to be applied across all roadway types (e.g., rural versus urban)? **EPA Response:** *No. There are separate hourly VMT fractions for urban and rural driving. Text was added to Section 12.3 to clarify the content of Table 12-3 (urban only).*

Pg. 67 VSP is typically applied on a second by second basis. How do the driving schedules combine with VSP? And if the drive cycle acceleration and speed are inputs to the VSP calculation, is this averaged over the drive cycle or calculated sec by sec? **EPA Response:** *Text has been added to Section 13 to discuss briefly how driving schedules are combined.*

Pg. 68 Table 14-1 seems to imply that freeway schedules are used for arterial and local roads? Is this correct? **EPA Response:** *That is correct. Text has been added to Section 14 to discuss this fact.*

Longer Term Considerations

There are some interesting longer-term fundamental issues related to the vehicle population/activity data required for MOVES that EPA could begin to assess. One main issue worth considering is the value of continuing to construct what is essentially a vehicle and activity census, which requires a great many assumptions and sometimes less than optimal use of less than optimal databases. The alternative would be to concentrate on the development of statistical sampling and modeling methods that would provide the ability to statistically produce a robust vehicle profile.

For example, in the case of mileage accrual, Miller et al (2001)[66] noted that, in contrast to that represented in MOBILE6, mileage accrual is nonlinearly related to vehicle age, and the distribution of mileage accruals for vehicles of the same age is likely to be normal. Miller et al. also argued that the reason such a discrepancy exists between MOBILE6 estimates and observed data is because vehicles with different odometer readings will likely have different scrappage rates. For example, a vehicle with a higher odometer reading is likely to have a higher scrappage rate than a vehicle with a lower odometer reading, even if they are of comparable age.

The way in which a vehicle population and activity census is developed necessarily involves many assumptions that might better be captured in a statistical model. Each time an update is required, a sampling protocol could be implemented and model parameters updated. This at least would provide the opportunity to assess issues related to variability and precision. The use of weigh-in-motion data would also provide a better linkage between vehicle types and activity for freeway related travel. WIM stations are usually located to provide reasonable representation of freeway activity, particularly for heavy duty vehicles. It might be useful to examine these data with respect to MOVES and the ability to define statistical relationships instead of relying on full development of a census.

EPA Response: *EPA is looking at weigh-in-motion data as a source of information about the distribution of vehicles on roadways and will incorporate the information into MOVES as it becomes available.*

EPA should consider developing a mapping scheme between travel models and the MOVES vehicle categories. Right now, not only is mapping done for the MOVES model (such as that shown in the technical documentation), but then two other steps of mapping are also performed. The first with the travel model, in which at best, there are only general categories of LDV, LDT and “goods movement,” and the second, when the emissions inventory is prepared for photochemistry. The result of all this series of mapping between vehicle sources is almost certainly a cause for error propagation.

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