OFF-HIGHWAY AND PUBLIC-USE GASOLINE CONSUMPTION ESTIMATION MODELS USED IN THE FEDERAL HIGHWAY ADMINISTRATION

Final Report for the 2014 Model Revisions and Recalibrations

Publication Number – FHWA-PL-17-012

June 2015

U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-PL-17-012		

4. Title and Subtitle	5. Report Date
OFF-HIGHWAY AND PUBLIC-USE GASOLINE CONSUMPTION ESTIMATION MODELS USED IN THE FEDERAL HIGHWAY ADMINISTRATION **Final Report for the 2014 Model Revisions and Recalibrations**	**March 1, 2015; revised June 1, 2015** 6. Performing Organization Code
7. Author(s) **Ho-Ling Hwang, Ph.D. Jianjiang Yang, Ph.D. Daniel Wilson Rob Taylor Shih-Miao C**	8. Performing Organization Report No. **ORNL/TM-2015/282**
9. Performing Organization Name and Address **DEPARTMENT OF ENERGY** **OAK RIDGE NATIONAL LABORATORY** **BUILDING 4500N MS-6269** **PO BOX 2008** **OAK RIDGE TN 37831-6269**	10. Work Unit No. (TRAIS) 11. Contract or Grant No. **IAA NO. DTFH61-13-X-30036**
12. Sponsoring Agency Name and Address **Federal Highway Administration** **Office of Policy and Government** **1200 New Jersey Avenue, SE** **Washington, DC 20590-0001**	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This research study was conducted by ORNL to revise and update the FHWA models used in estimating off-highway gasoline consumption. The previous FHWA off-highway motor fuel consumption estimation models contained outdated assumptions and data (mainly from the 2002 VIUS), as well as relied on obsolete regression equations in several of its modules. FHWA determined that there is an urgent need for recalibration and reformulation of these models. The models were recalibrated to utilize more updated data, or reformulated in the cases where the data source used is no longer available, or where new data source becomes available. Models were recalibrated or reformulated for the following sectors:

- **Agriculture,**
- **Aviation,**
- **Industrial and commercial,**
- **Construction,**
- **Recreational boating,**
- **Off-road recreational vehicles,**
  Lawn and garden equipment,
- **State, County, and Municipal governments use for on-highway, and**
- **Federal civilian agencies on-highway use.**

17. Key Words	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	**UNCLASSIFIED**	**127**	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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ACRONYMS

ACSA	American Council of Snowmobile Associations
ATV	All-Terrain Vehicle
BSFC	Break Specific Fuel Consumption
CalHEAT	California hybrid, Efficient and Advanced Truck Research Center
CBP	County Business Patterns
CNG	Compressed Natural Gas
CPSC	Consumer Product Safety Commission
DMV	Department of Motor Vehicles
DOE	Department of Energy
DOT	Department of Transportation
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
GPH	Gallons Per Hour
GSA	General Services Administration
HTF	Highway Trust Fund
ISMA	International Snowmobile Association
LPG	Liquefied Petroleum Gases
MAP-21	Moving Ahead for Progress in the 21st Century Act
MIC	Motorcycle Industry Council
MOVES	Motor Vehicle Emission Simulator
MPG	Miles per Gallon
NASS	National Agricultural Statistics Services
NIH	National Institute of Health
NSRE	National Survey on Recreation and the Environment
NVPP	National Vehicle Population Profile
OHV	Off-Highway Vehicles
ORNL	Oak Ridge National Laboratory

PADD	Petroleum Administration for Defense Districts
PWC	Personal Watercraft
RTP	Recreational Trails Program
SCM	State, County, and Municipal
TIP	Trucking Industry Profile
TIUS	Truck Inventory and Use Survey
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
VIN	Vehicle Identification Number
VIO	Vehicles in Operation
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle Miles Traveled

1. INTRODUCTION

1.1 BACKGROUND

Each year, highway users pay billions of dollars in highway excise taxes, which end up in the federal Highway Trust Fund (HTF). Federal legislation requires, generally, that funds paid into the HTF be returned to the states for various highway program areas in accordance with legislatively established allocation processes[1]. In general, the allocations to states are based on state-reported motor fuel data and the results of the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) HTF attribution process.

Prior to the Moving Ahead for Progress in the 21st Century Act (MAP-21) of 2012, each apportioned program had its own formula for distribution, and the total amount of Federal assistance a state received was the sum of the amounts it received for each program. During the annual attribution process, the FHWA determined a state's share of the overall on-highway motor fuel consumption and estimated the amount of HTF receipts to be attributed to highway users in each state. This information was used to distribute funds through the apportionment process for different highway programs. Now MAP-21 provides a total apportionment for each State and then divides that State amount among individual apportioned programs.

As a part of the FHWA process, models are utilized to estimate portions of motor fuel use data. Specifically, estimation models are used in producing state-level consumption estimates for (a) off-highway use of gasoline and (b) federal, state, county, and municipal governments (SCM) (i.e., public sector) use of gasoline. These models, which were built using mathematical/statistical formulas and supplemental information from other information sources, are used to aid FHWA program analysts to complete the attribution process.

The FHWA has to use models to achieve uniformity and accuracy across the states for two main reasons: (1) state-submitted data are not sufficient for the FHWA to distribute HTF funds accurately; and (2) states historically have been unable to provide actual and reliable data in certain motor fuel uses (e.g., off-highway gasoline uses). Note that prior to 2005, a gasohol model was also used by FHWA during the HTF attribution process to estimate state-level gasohol consumption in three blends. This model was discontinued after the federal tax rate for gasohol was changed to the same rate as for gasoline in 2005.

The Center for Transportation Analysis at the Oak Ridge National Laboratory (ORNL) developed models for the FHWA in the 1990's to estimate off-highway fuel consumption. A non-technical report [2] describing the methodologies and data sources of all these models was summarized by ORNL in early 2002. During that year, ORNL assisted the FHWA in conducting a Motor Fuel Modeling Workshop in Alexandria, Virginia, to communicate FHWA's attribution process to the states. The purposes of that workshop were to provide state and FHWA field staff

with an understanding of the various models that affected state's data and HTF attribution, and to obtain state input on these models and potential alternative data sources. Based on the outcomes from that workshop, the models used to estimate off-highway gasoline consumption were streamlined and updated by ORNL. The updated models were later built into an integrated system in September 2002 by ORNL and used by the FHWA in the attribution process for several years thereafter.

1.2 2008 MODEL UPDATES

In 2008, ORNL conducted another modernization effort on the 2002-developed integrated non-highway gasoline consumption estimation system for the FHWA[3]. This 2008 review updated the 1997-based Vehicle Inventory and Use Survey (VIUS) estimates with then the latest 2002 VIUS data [4]. This update process also revised the methodology applied under the "agricultural gasoline uses by equipment" module to resolve certain issues caused by availability changes in the data source that occurred after the 2002 system was developed. An update on the SCM populations and their forecasts used in the public sector models was also implemented.

In addition, the 2008 study also devoted effort in investigating the potential use of estimates based on the U.S. Environmental Protection Agency (EPA) NONROAD2005 model[1]. Comparisons between estimates generated from FHWA's models and the NONROAD2005 model were performed on comparable economic sectors; pros and cons of those EPA NONROAD2005 model-based estimates were also addressed. Based on the 2008 review, FHWA decided that further in-depth examinations of the EPA NONROAD model were necessary before they can be accepted and integrated into the processes of estimating non-highway gasoline consumption. Thus, FHWA continued to use the 2008-updated "Non-highway Gasoline Consumption Estimation Models" during its HTF allocation process.

1.3 CURRENT STUDY

Prior to 2007, Census collected VIUS data in 5-year intervals, following the same schedule as the Economic Census. The anticipated 2007 VIUS data collection effort, unfortunately, was discontinued by Census, making 2002 VIUS the last available data of the series. The loss of updated VIUS data means a prolonged use of the 2002 VIUS data beyond its "normal lifecycle" of 5-6 years after its release. This inevitably raised many concerns about data qualities in estimates generated using the now outdated 2002 VIUS data; including FHWA's motor fuel consumption estimation models. Although an effort being led by the FHWA/USDOT to bring back a VIUS-like data program is currently ongoing, the release of products from such a data collection effort is likely to take several years. There is an immediate need to find alternative

[1] Currently, the release of the model is for NONROAD2008a Model, for information see: http://www.epa.gov/otaq/nonrdmdl.htm

data sources and/or methods so that weaknesses in current FHWA non-highway motor fuel consumption estimation models can be addressed, specifically those for the industrial/commercial and construction sectors.

Recently, FHWA implemented a method utilizing changes in state gross domestic product as an interim quick-fix adjustment factor to generate estimates for non-highway gasoline use in some sectors, without using the 2002 VIUS data. Unfortunately, this method has begun to show questionable outputs, further prompting the need for additional reviews of the motor fuel estimation models. Because of that, FHWA determined that the existing models should be recalibrated utilizing more current data, or reformulated in cases where their currently used data sources are no longer available.

There are eight sector modules in FHWA's current Gasoline Consumption Estimation Models:

- Aviation,
- Recreational boating,
- Agricultural non-highway use,
- Industrial/Commercial non-highway use,
- Construction non-highway use,
- Federal civilian on-highway use,
- SCM government on-highway use, and
- SCM government non-highway use.

In addition, FHWA has used a model in the past to estimate the amount of gasoline used by non-highway recreational vehicles, including all-terrain vehicles (ATV), off-highway motorcycles, off-highway light trucks and snowmobiles. Although this model was not linked with the non-highway estimation system, results from this particular model historically have been used as a factor in making state allocations of funds from the Recreational Trails Program (RTP). This off-road recreational vehicle model was last updated in 2004. FHWA requested that this model be updated along with other sector-models under this study.

1.4 REPORT ORGANIZATIONS

This report describes efforts conducted to revise and update the current FHWA models used in estimating gasoline consumption during 2014-2015. An overview of the integrated off-highway and public uses of motor fuel estimation system, currently used by the FHWA (i.e., the status quo), is presented in Section 2 of this report. A major part of this Section describes all models as updated in 2008; including their methodologies and associated data sources. Since these models and data sources were generally not changed since 2008, these discussions largely resemble what was presented in the 2009 ORNL Technical Memorandum [3].

Section 3 of this report addresses the major challenges faced in developing updated models. Two options of using alternative sources to replace the roles played by VIUS are discussed in this section, including the use of an EPA model and an evaluation of truck registration data from Polk (now a part of the IHS Automotive). Revised Non-highway Gasoline Consumption Estimation Models, as developed under this current study, are discussed in several subsequent sections: including Section 4 for the Aviation model, Section 5 on the Recreational Boating model, Section 6 for the Agricultural sector, Section 7 for the Industrial/Commercial and Construction sectors, and Section 8 on the Public Use model. The Off-road Recreational Vehicle model is presented in Section 9, followed by a brief discussion of gasoline consumption by major equipment categories not currently addressed by the FHWA in Section 10. Finally, a summary is presented in Section 11.

2. CURRENT FHWA MODELS – THE STATUS QUO

2.1 OVERVIEW OF THE MOTOR FUEL ESTIMATION MODELS

As mentioned, methodologies implemented in the current FHWA Off-highway Gasoline Consumption Estimation Models are the same as those from the 2008 updates. As presented in Figure 2-1, FHWA's current Integrated Off-highway and Public Uses of Motor Fuel Estimation System includes two main components: one for the off-highway (i.e., non-highway) gasoline use estimation and another for estimating the public use of gasoline (both on and off-highway uses). Fundamentally, this integrated system was built as an easy-to-use Excel spreadsheet-based tool. Certain worksheets in the system contain cells that require annual inputs from FHWA analysts during the attribution process; while others would only need periodic updates (e.g., population and VIUS estimates).

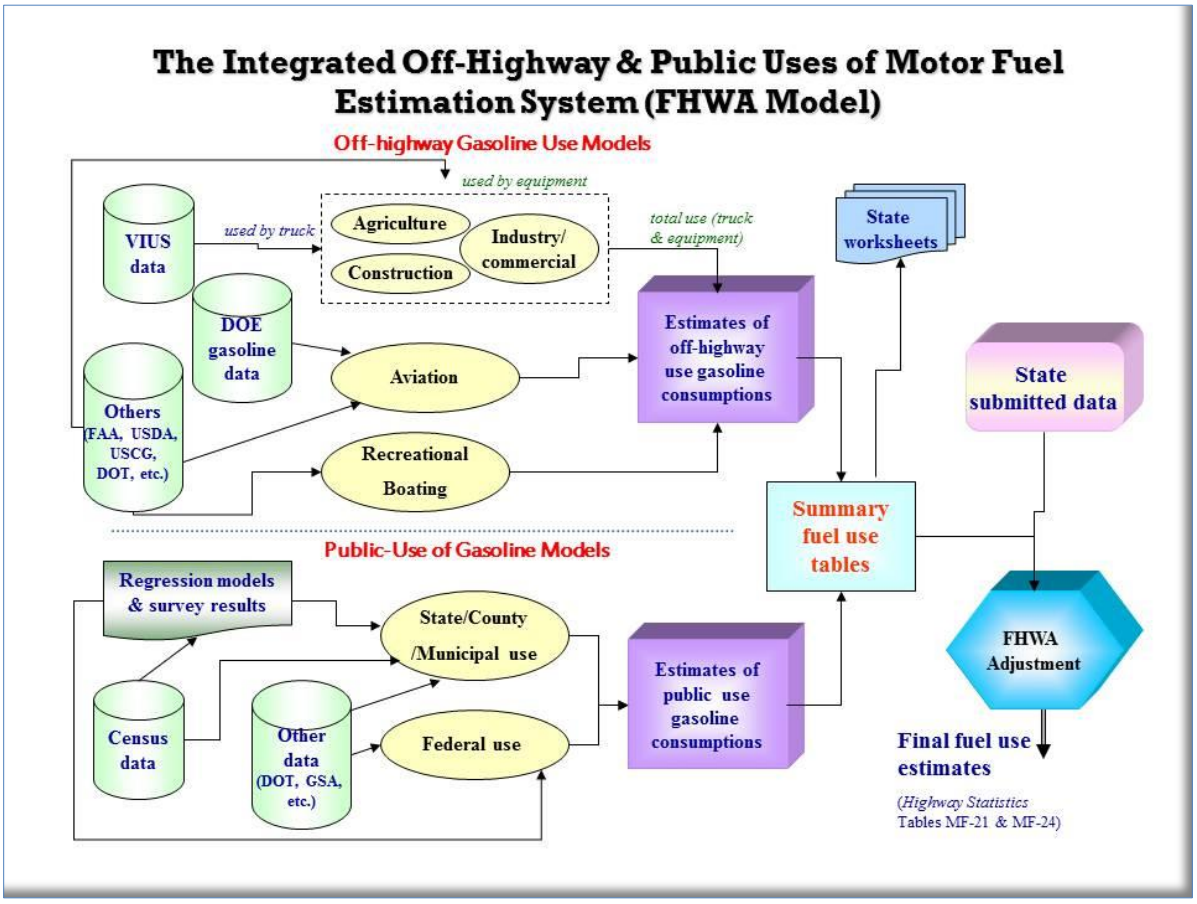

Figure 2-1. Current FHWA off-highway and public use of gasoline models.

Each of the two main components of the system involves more than one model. The component of **off-highway gasoline use models** cover five major sectors, including agriculture, construction, industrial/commercial, aviation, and recreational boating. There are two separate estimation models under the **public-sector gasoline use** component; one to estimate gasoline use

by the Federal government and another on SCM government uses. Estimates generated from each of the two components, shown with purple square boxes in Figure 2-1, are combined into one final fuel consumption table (i.e., a summary worksheet) for easy usage in later steps within the attribution process.

Descriptions on the data sources and estimation methodology applied within each of the sector-specific models are presented in more detail below in this section. Note that the model for estimating fuel use by off-road recreational vehicles was not a part of FHWA's Integrated System in the past. This off-road recreational vehicle fuel use model is described separately in Section 5 of this report. Incorporation of this off-road recreational vehicle model (or an updated version of this model) into the current FHWA Integrated Off-highway and Public Use of Motor Fuel Estimation System was not anticipated by the FHWA at the current time.

Although the data portions of the eight estimation models (i.e., components of the Integrated System) have been updated twice (in 2002 and 2008), their underlying model formulations have not been changed since they were developed nearly two decades ago. Readers interested in more detail on those model formulations are referred to a previous document prepared by ORNL under the 2002 update study, which was later incorporated into Chapter 2 of the FHWA report entitled "*Fuel Tax Attribution Process Review and Documentation*" [2]. To avoid unnecessary duplications, only brief descriptions of these methodologies are provided here.

2.2 OFF-HIGHWAY GASOLINE CONSUMPTION MODELS

The main system component associated with the Off-highway Gasoline Use Models, as shown in Figure 2-2, includes five economic sectors (oval-shape boxes). These sectors are agricultural, industrial/commercial, construction, aviation, and recreational boating. Obviously, sectors such as agriculture, industry/commerce, and construction can involve both trucks (used for off-highway purposes) and other types of equipment (e.g., wheel tractors, forklifts) in their off-highway operations. Thus, total motor fuel consumption estimates for each of these sectors should consider gasoline usages from two areas: (1) trucks operating off-highway and (2) equipment utilized in the given sector. Aviation and marine components, on the other hand, consider aircraft and recreational boats, respectively. Fuel consumed by aviation and recreational boating sectors does not include fuel used by trucks; which means that gasoline consumption estimates for these two sectors are generated from the fuel usage of equipment (non-vehicle) only.

Due to data limitations, the current FHWA models do not cover equipment used in industrial, commercial, or construction sectors. That is, only the agricultural sector module contains fuel used by both truck and equipment components. The following subsections address each of the five sector-based models individually.

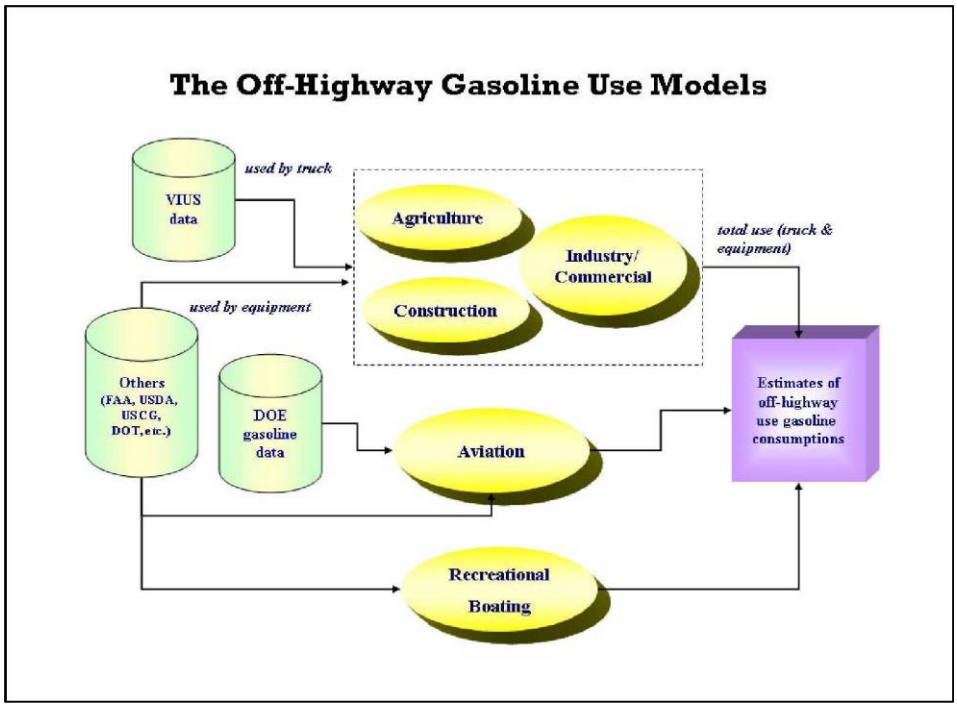

Figure 2-2. Off-highway Gasoline Consumption Estimation Models.

2.2.1 Aviation

2.2.1.1 Data sources

Two major sources of data are used in estimating aviation gasoline consumption: the *Prime Supplier Sales Volumes* [5] gathered by Energy Information Administration (EIA) and the *General Aviation and Part 135 Activity Survey[6] conducted by* the Federal Aviation Administration (FAA). Specifically, data on aviation gasoline (in gallons) is obtained from an EIA published table based on data collected on a monthly basis from all firms identified as suppliers who made the first sales of the products. Similarly statistics on the estimated "*total hours flown by general aviation*" for each state are obtained from the annual FAA *General Aviation and Part 135 Activity Survey* published tables. The latest available data and statistics for this survey are for calendar year 2013.

2.2.1.2 Estimation method

The estimation procedure for non-highway gasoline consumption in the aviation sector is relatively straightforward. For most states, annual totals from EIA aviation gasoline consumption as published in the *Prime Supplier Sales Volumes* are used directly. Due to confidentiality concerns, however, data for some states and Washington, D.C. were not disclosed by EIA. These missing data (i.e., those withheld by EIA) have to be estimated mathematically by the FHWA. A statistical regression model was used to estimate gasoline consumption for states that are either missing or not disclosed by the EIA. This regression model was built on a

relationship established between existing EIA data on "*aviation gasoline consumption*" and FAA data on "*hours flown by general aviation*" by state.

Total aviation gasoline consumption and total hours flown published in the *FAA Aerospace Forecasts[7]* are used to compute average gasoline consumption per hour flown. This average is then multiplied by the sum of the total number of hours flown for the 50 states and Washington, D.C. to generate a "*control total*" for aviation gasoline. Regression-estimated aviation gasoline consumption results, on states with missing or undisclosed EIA numbers, are then adjusted by their shares of the difference between the "*control total*" and the sum of those fully-reported states (i.e., with known values). Each state's share was determined by dividing its estimated amount (from the regression equation) with the sum of all regression-estimates for states with missing data.

It is worth reemphasizing that this modeling effort is only applied to estimating unreported values in the EIA dataset. Typically, a state would withhold certain data to avoid disclosure issues. Other unreported reasons might include a state not having a complete data set (i.e., missing information) or having concerns on the quality of certain data elements.

2.2.2 Recreational Boating

Since nearly all commercial vessels are powered by diesel fuel, the marine sector of interest for FHWA is limited to recreational boating involving motors. The fundamental issue here is to determine the number of powered boats in each state and the average amount of gasoline each boat uses for recreational purposes.

2.2.2.1 Data sources

The primary data source used in estimating gasoline consumption by recreational boating use in the current FHWA model is based on statistics provided from the *National Recreational Boating Survey (NRBS)[8] Program.* This is a major survey of boating sponsored by the Boating Safety Division of the U.S. Coast Guard (USCG), which was conducted once in 2002 and most recently during 2011-2013. The latest available survey dataset is from the 2011/*2012 NRBS*. Additional data sources used in this recreational boating module also include: *Boating Statistics[9]* published annually by USCG; *Statistical Abstract of the United States[10]*; and *State Median Income* data[11] from the U.S. Census Bureau.

2.2.2.2 Estimation process in current FHWA model

The current FHWA recreational boating consumption estimation model uses the year 2002 as the base-year mainly because data on the latest number of powered boats by state was taken from the *2002 NRBS data.* Specifically, data extracted from the annual *Boating Statistics* on the number of registered boats by state for the base-year and the latest year are used to

compute growth rates for the number of registered boats between these two years for each state. These growth rates are then applied to the base-year data to derive the estimated number of powered boats in the analysis year by state.

Information on median household income data by state, as obtained from the Census, for both 2002 and the latest year is used to compute growth rates of the household income for each state. These state-level growth rates are further corrected using the Consumer Price Index , taken from the *Statistical Abstract of the United States*, to adjust for inflation during the time period. These adjusted growth rates are then applied to the 1991 "average annual gallons used per boat" (i.e., average fuel efficiency per boat) to produce estimates for the target year. Note that 1991 fuel efficiency data was used because information for this data item was not available from the 2002 NRBS data.

The estimated "average gallons used per boat" was then multiplied by the number of powered boats for each corresponding state to obtain the estimates of total fuel consumption in recreational boating by state. These estimates are adjusted one more time to account for boats that are powered by fuels other than gasoline (i.e., diesel). This adjustment was made using information on the gasoline/diesel split, obtained from the 2002 *National Recreational Boating Survey.*

2.2.3 Agricultural Sector

2.2.3.1 Gasoline consumption by truck

Fundamentally, the data sources and estimation methods for gasoline consumption by truck that are used for off-highway purposes in the agricultural, industrial/commercial, and construction sectors are the same. Essentially, the VIUS-based (i.e., truck use) estimation methodology being applied in the current FHWA models (as described in this section) is not sector-specific.

Data Sources

In the current model, the major data source used in estimating off-highway uses of gasoline by trucks is the VIUS data collected by the U.S. Census Bureau. The VIUS contains information such as annual Vehicle Miles Traveled (VMT), average fuel efficiency or miles-per-gallon (MPG), and the percent of off-road travel by trucks with gasoline engines. The 2002 VIUS[4], which was the last of this data series, is still used in the current FHWA models.

Additional data sources used in estimating the VIUS-based off-highway gasoline consumption by truck include statistics published in: *Ward's Motor Vehicle Facts and Figures[12]* and FHWA's *Highway Statistics[13]*. These data sources are mainly used to adjust VIUS-based estimates from the base-year (i.e., 2002) to the targeted-year (i.e., attribution year). Naturally, these data need to be updated on an annual basis. Furthermore, a major data source used

specifically for estimating off-highway gasoline consumption in the construction sector is the annual *Statistical Abstract of the United States[10]*. This report is published annually by the Census Bureau.

Note that, due to budgetary concerns, the Census Bureau terminated the collection and compilation of data for the *Statistical Abstract of the United States* as of October 1, 2011. As a result, the Census Bureau unit that published the Statistical Abstract was eliminated in November 2011. ProQuest has now taken on responsibility of updating and releasing this publication, the most used statistical reference tool in U.S. libraries [14]. ProQuest brings its 35 years of experience in acquiring, abstracting, and indexing Federal Government statistical publications and tables to this new task of producing the *Statistical Abstract of the United States*.

Determining Major-Use of Trucks

The truck component of the current FHWA estimation process for off-highway gasoline consumption begins with an identification of the truck population for each sector of interest (in this case, agricultural sector). The VIUS categories on the major-use of truck (variable "Business") were regrouped to identify records belonging in the given sector uses. Specifically, a truck is assigned into the agricultural sector if its VIUS major-use falls under the "Agriculture, forestry, fishing, or hunting" category.

Note that, under the VIUS program, survey respondents were asked to report the "most often used" business category when a vehicle is being used for multiple business types during the reporting period. Thus, if a vehicle was operated in two or more different types of business with nearly equal percentages of uses, it would be at the survey respondent's discretion to report a specific type of use. Consequently, certain ambiguity in the "assignment" of sectors (agricultural, industrial, commercial, construction, etc.) might exist.

Estimating Fuel Efficiency

Two pieces of information are needed in order to calculate non-highway usage of motor fuel. They are: (1) fuel efficiency of the truck being used for non-highway purposes and (2) the share of non-highway operations for the given truck, on an annual mile basis, within a given state. Note that VIUS data was not used directly in estimating off-highway fuel consumption because it does not provide the required details, such as separation of on- and off-highway fuel efficiency or the percentage of off-road travel occurring within each state. Instead, VIUS data was analyzed to derive ratios of on-highway over off-highway MPG for each economic sector and truck type. Furthermore, "state of registration" information obtained from VIUS records were assumed as where the off-road travel took place for the given truck, although in reality this "state of registration" might not necessarily reflect where the truck actually operated. This is a limitation of VIUS data.

The MPG ratios derived from VIUS were used in computing off-highway gasoline consumption by state. Because VIUS is a survey of vehicles selected based on a statistical sampling method, each record (which represents a vehicle in the survey) also includes an expansion factor that can be used to "inflate" the sample to its national representation. As mentioned, the current Integrated Off-highway and Public Use Motor Fuel Consumption Estimation System was initially developed in 2002 with the 1997 VIUS data; the system updates conducted in 2008 replaced that with information derived from the 2002 VIUS.

Estimation of Adjustment and Growth Rate

Since the base-year for the most current VIUS data is 2002, off-highway consumption estimates generated from the process discussed above need to be adjusted to provide estimates for non-VIUS years. This adjustment is necessary so that changes that may have occurred since the VIUS-year can be properly captured and accounted for. To make these adjustments, additional data sources are used to compute a growth factor for non-VIUS years. As stated earlier in this section, these include *Ward's Motor Vehicle Facts and Figures* and the annual *Highway Statistics* series published by FHWA.

The estimated gasoline-use growth factor is basically a combined-rate calculated based on three growth rates: (1) the number of trucks in operation, (2) average VMT per truck, and (3) average MPG for trucks. These growth rates and the final gasoline consumption growth factor are automatically calculated in the current Integrated Non-highway System, using annually updated data entered by FHWA analysts.

2.2.3.2 Gasoline consumption by agricultural equipment

In addition to farm-use trucks, farm equipment such as wheel tractors and cotton pickers also consume gasoline. The estimation procedure for off-highway gasoline consumption by farm equipment is slightly more complicated than in the other sectors. Due to changes in published United States Department of Agriculture (USDA) data that occurred several years after the development of the original FHWA Integrated System in 2002, the model for estimating gasoline consumption by agricultural equipment was significantly revised under the 2008 update study. That revised model is the version contained in the current FHWA integrated off-highway consumption estimation system. Only a brief description of the agricultural-equipment consumption estimation model is presented here; readers are referred to the 2008 study report [3] for more details. Note that for the purpose of simplicity, the FHWA agriculture model assumes that farm equipment is used solely for off-highway purposes.

Data Source

The main data source used in estimating off-highway gasoline consumption by farm equipment (other than trucks) in the agriculture sector was obtained from the USDA. Specifically, data

collected under the *Census of Agriculture* [15]and the annual *Farm Production Expenditures*[16] which are published by USDA's National Agricultural Statistics Services (NASS). Additional data applied in the agricultural estimation model also includes information published in the *Petroleum Marketing Monthly*[17] by EIA, and *Highway Taxes and Fees* [18] published by the FHWA. Note that the *Census of Agriculture* is a five-year data collection cycle. The current FHWA consumption estimation model uses the data from *2007 Census of Agriculture.*

Estimation Method

As stated earlier, a few changes made in the USDA publications prior to 2008 have affected the original FHWA model significantly. The original model relied on gasoline expenditures by state data obtained from the *Census of Agriculture* publications. In later releases of the *Census of Agriculture*, however, USDA changed how it publishes this data. Instead of releasing separate **gasoline** expenditures by state data, the USDA publishes **total fuel** expenditures by state for the Census-year. In addition to the change of fuel expenditure details, the USDA also changed its number of Farm Production Regions from ten to five in 2004. Because of these more geographically aggregated and fewer fuel-type detail changes, an alternate method was developed under the 2008-update effort. Specifically, the 2008-revised model is no longer relying on gasoline-to-total fuel ratios computed from the *Census of Agriculture* data. The formulas for estimating shares of fuel expenditures by state within USDA regions were reconstructed in the 2008-revised agricultural estimation model.

Not all USDA publication changes influenced the FHWA applications in a negative way, however. Instead of publishing total fuel expenditure data only at regional levels as in the past, USDA began publishing total fuel expenditure data for each of the 15 *"Leading Cash Receipts"* states since the *Farm Production Expenditures 2004 Summary report* (published July 2005). Regional level statistics were provided for other non-published states. Although not at the same level of detail, the USDA also publishes total gasoline expenditures at the regional level in the *Farm Production Expenditures Annual Report*.

Figure 2-3, taken from the 2008 project report, shows the general process used to compute the farm-equipment consumption in the off-highway agricultural gasoline consumption model. These processes are briefly described step-by-step below.

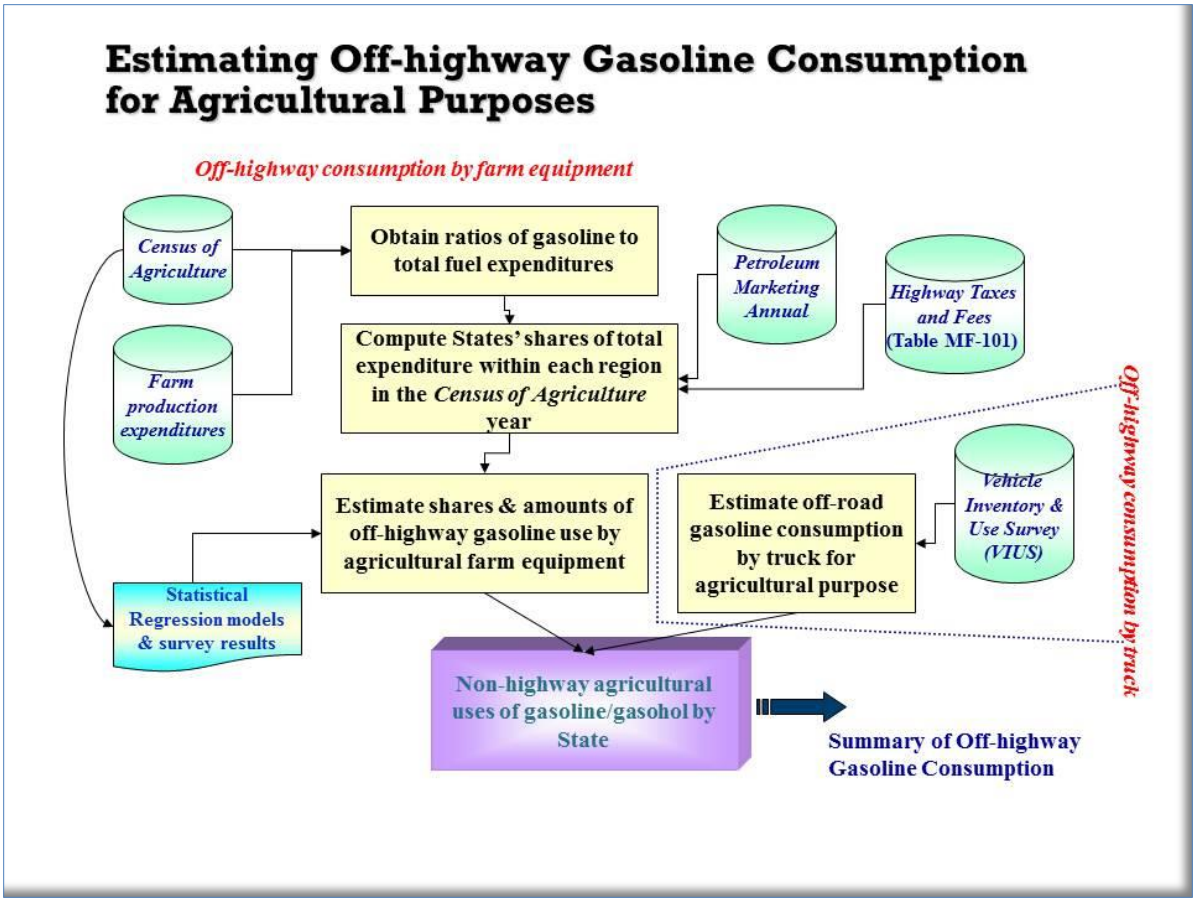

Figure 2-3. Off-highway farm equipment gasoline consumption estimation model.

Step 1: Estimating total fuel expenditure by State in analysis-year

The current farm-equipment consumption model began with the estimation of annual state total fuel expenditure in agricultural operations during the analysis year. Because total fuel expenditures in each of the top-15 states is readily available from the *Farm Production Expenditures Report* of the analysis-year (thus "known"), FHWA only needs to estimate total fuel expenditures for the 35 non-published states and Washington, D.C. The share for each non-published state within its corresponding region can be calculated using detailed state-level total fuel expenditures data from the Census-year (i.e., *2007 Census of Agriculture*). Assuming these shares remain the same in the analysis-year, the regional total from those non-published states (i.e., regional fuel expenditure total subtracts those from "known" states within the given region) can then be distributed accordingly to estimate fuel expenditures by those states.

Note that statistics reported in the *Farm Production Expenditures Annual Report* excluded the states of Alaska and Hawaii, although geographically these two states could be included in the West Region. Thus, the method described above was not applicable to estimate fuel expenditures for these two states. Instead, a simple supplemental method was applied to

generate estimates for Alaska and Hawaii. By assuming changes between the Census-year and the analysis-year for these two states are at the same rate as that in the lower-48 states, total fuel expenditures for Alaska (or Hawaii) can be estimated for the analysis-year. This was done by multiplying Alaska (or Hawaii) fuel expenditure data from the Census-year by a factor computed using the value resulting from the total fuel expenditures reported in the *Farm Production Expenditure Summary* for the analysis year divided by the same information for the Census-year.

Step 2: Generating total gasoline gallons in a Census-year

As noted above, gasoline expenditures at the state level were not available from the 2007 *Census of Agriculture* publication. To derive state-level gasoline expenditure estimates, total fuel expenditure data from the *Census of Agriculture* was supplemented with information on regional gasoline shares extracted from the *Farm Production Expenditures Summary* report for the Census-year. Due to the lack of better available data, a simple assumption was applied in estimating state-level gasoline expenditures in the Census-year. By assuming all states within a given region have the same gasoline-to-total-fuel expenditure share (from *Farm Production Expenditures*), state-level estimates of gasoline expenditures can be computed. These expenditures by state estimates, as generated from the abovementioned process, are then converted to gallons using the gasoline price obtained from the *Petroleum Marketing Monthly* (published by EIA) and the gasoline tax information from the *Highway Taxes and Fees* (published by the FHWA) for the Census-year.

Step 3: Estimating the ratio of off-highway use gasoline gallons in a Census-year

The methodology for estimating off-highway use gasoline gallons has not changed, the same method used originally was kept in the 2008-updated FHWA Integrated System. State-level off-highway gasoline use by agricultural farm equipment ina Census-year was based on a statistical regression model (developed by ORNL under the original 1994 study). This regression model was developed using information gathered from the *Census of Agriculture*, which established a relationship between the off-highway agricultural gasoline use and the number of farm equipment units used within each state during the Census-year. The ratio of off-highway use gasoline gallons for a given state, in the given Census-year, was computed by dividing its regression-estimated off-highway gasoline gallons by the corresponding total gallons estimated from Step 2.

Step 4: Generating total gasoline gallons in analysis-year

Similar to Step 2, the total gasoline expenditures by state in the analysis-year can be estimated using results from Step 1 and regional gasoline shares extracted from the *Farm Production Expenditures Summary* report for the analysis-year. That is, by applying the same simple assumption that states within a given region all have the same gasoline-to-total-

fuel expenditure share, estimates of gasoline expenditures by state can be computed. The resulting state-level expenditures are then converted to gallons using the gasoline price obtained from EIA and FHWA's gasoline tax information for the analysis year.

Step 5: Estimating off-highway gasoline consumption by farm equipment

By assuming the ratios of off-highway use gasoline from Step 3 remain the same in the analysis year, the off-highway agricultural gasoline consumption by farm equipment in each state were generated. Total consumption estimated for farm trucks and for farm equipment were then combined; thus completing the processes of estimating the off-highway agricultural consumption of gasoline by state.

At this point in the process, the resulting state-level estimates from the agricultural equipment consumption model and their corresponding off-highway gasoline consumption by truck used in the agricultural sector are combined. This completes the process of generating state totals for off-highway gasoline consumption by the agricultural sector.

2.2.4 Industrial/Commercial

As mentioned in the Agricultural Sector section above, the VIUS-based estimation methodology being applied in the current FHWA models is not sector-specific. Thus the exact same process applied for off-highway use of truck in agricultural sector, discussed in Section 2.2.3, can be used to estimate off-highway fuel consumption by truck for industrial and commercial purposes. For industrial/commercial use, truck records are selected based on VIUS major-use of "For-hire transportation or warehousing," "Vehicle leasing or rental," "Mining," "Utilities," "Manufacturing," "Wholesale trade," "Retail trade," "Information service," "Waste management, landscaping, or administrative/support service," "Arts, entertainment, or recreation service," "Accommodation or food services," or "Other services." The same limitation for potential ambiguity in assignment of sectors, as pointed out in the agricultural sector discussions, is still a caution here.

Note that industrial and commercial equipment, which includes forklifts, sweepers, scrubbers, material-handling equipment, generators, pumps, welding equipment, etc., can also consume gasoline. Due to lack of available data on gasoline consumption by engines of the above-mentioned equipment, the current FHWA Off-highway Gasoline Consumption Estimation Models only consider gasoline consumption by trucks operating off-road in industrial and commercial sectors.

Although fuel use by equipment (engines) information is available from the EPA NONROAD model, due to compatibility issues identified in ORNL's 2008 review [3], it was not considered in the current FHWA models. A more detailed discussion of the EPA NONROAD

model, including the pros and cons of using its estimates for the motor fuel program purposes, is provided in Section 3 of this report.

2.2.5 Construction

Similarly, motor fuel can be consumed by both equipment and vehicles used off-highway for construction purposes. The majority of vehicles used for off-highway construction purposes are expected to be trucks and vans, particularly single-unit heavy trucks. Most construction equipment, which includes surfacing equipment, loaders, excavators, etc., however, are not licensed for highway use and generally powered by diesel fuel. Since FHWA motor fuel reporting currently does not include off-highway diesel usage, the 1994-model development team determined that equipment for construction uses does not need to be included.

2.2.5.1 National-Level Gasoline Used by Truck in Construction Sector

The process applied for off-highway use of trucks in the agricultural sector can be used to estimate fuel consumption by trucks used for off-highway construction purposes. Under this process, "major use" is based on truck records specifying "Construction" as their category of "Business." Again, the same potential ambiguity in assignment of sectors, as pointed out in the agricultural sector discussions, remains.

Estimates generated for off-highway gasoline consumption by truck in the construction sector were treated differently, however. Rather than using the state-level consumption estimates directly as in agricultural and industrial/commercial sectors, the VIUS-based national total gasoline consumption estimates for trucks operating in the construction sector was retained only as a control total. The reason for handling the construction sector differently was due to a concern that VIUS data does not provide sufficient timely information to reflect current construction activities within each state.

2.2.5.2 State-Level Gasoline Used by Truck in Construction Sector

Instead of using the state-by-state estimates of construction consumption, dollar-values of non-residential construction contracts in each state are obtained from the "*Construction Contracts*" table of the latest edition of *Statistical Abstract of the United States* and are used to calculate state shares (i.e., measured as the percent of contracts in a given state). These state-shares are then applied to distribute the VIUS-estimated U.S. total to each state. This approach was based on a rationale that data on non-residential construction contracts as published in the *Statistical Abstract of the United States* is more up-to-date than what can be derived from the VIUS data. This approach is expected to generate estimates that can better reflect construction activities that occurred within the state.

2.2.6 Public Uses

The FHWA estimates motor fuel usage by the public sector for the same reasons that it estimates off-highway gasoline consumption. Because taxation policies in some states treat public use of motor fuel differently from others, using state submitted data without adjustment would create inconsistent and incompatible results that could not be used to distribute federal funds fairly to the states. The public sector includes federal and SCM governments. On the federal level, only civilian use of motor fuel is taken into consideration. Federal military motor fuel use is exempted from tax liability.

As shown in Figure 2-4, the FHWA estimation model for gasoline consumption by the public sector contains two components: (a) gasoline consumed by federal civilians and (b) gasoline consumed by SCM governments. These two classes of governments are estimated separately with different approaches that are discussed below. Note that both public sector models in the current FHWA Integrated Motor Fuel Consumption Estimation System have not been changed from earlier years. The methodologies used in these current FHWA models are the same as those originally developed in 1994; although data in these models has been updated over the years.

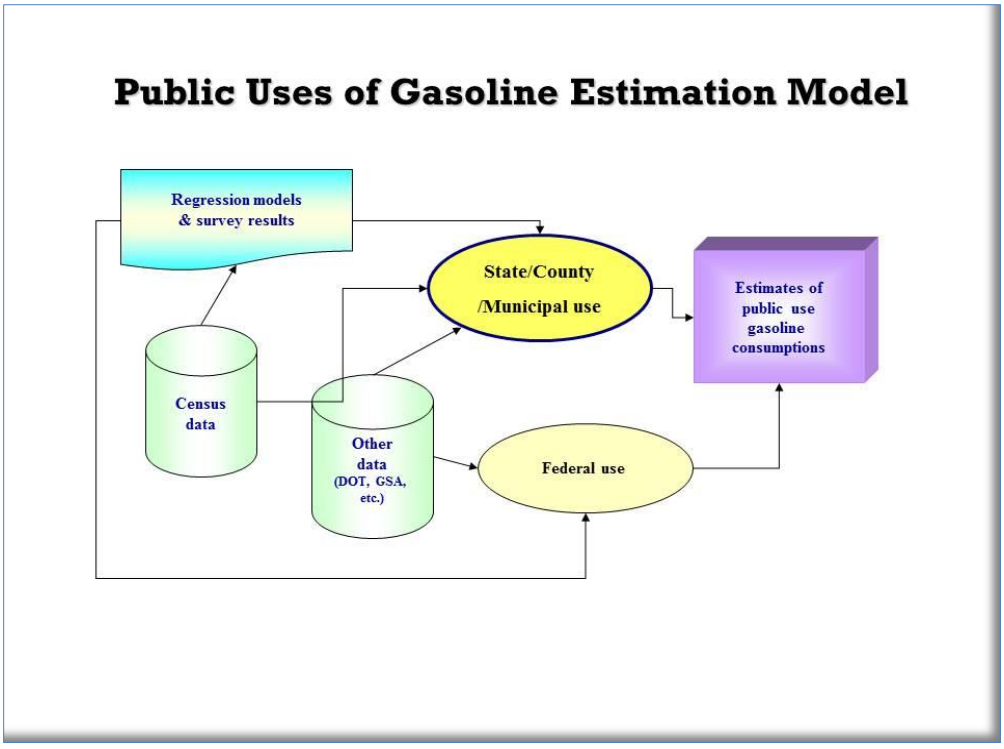

Figure 2-4. Public uses of gasoline consumption estimation model.

2.2.6.1 Federal civilian gasoline consumption estimation model

Data Sources

Data used for estimating federal civilian fuel consumption was compiled using various information sources, including publications produced by federal and private organizations. The number of federally owned vehicles that are operated by civilian departments and used in each state is obtained from the *Highway Statistics* Table MV-7 [19] .

Note that there is typically a one-year lag on this publication; data used in the analysis year is therefore one year behind. Data for the annual estimates of "gallons used per vehicle" are obtained from the annual *Transportation Energy Data Book [20]* produced by ORNL.

Information regarding fuel consumption and vehicle inventory for various vehicle types by federal agency is available from the *Federal Fleet Report* [21] published by the U.S. General Services Administration (GSA) annually. This GSA data was previously used as a data source in the Integrated System developed by ORNL. A modification done by FHWA in recent years changed the source of data to a table published in the *Transportation Energy Data Book* instead. Information from this *Transportation Energy Data Book* table actually was taken directly from GSA's *Federal Fleet Report*.

Estimation Method

As stated previously, the current methodology used in estimating Federal Civilian highway use of gasoline for all states was originally developed by ORNL in 1994 [22]. This methodology was based on a simple concept of multiplying the number of vehicles by the average gallons consumed per vehicle to derive the total amount of fuel used. The estimation process in this model is presented in Figure 2-5. Unlike the off-highway gasoline consumption estimation models discussed in the earlier part of Section 2, the process of estimating the federal-use gasoline consumption is rather straightforward.

The current FHWA estimation process begins with extracting data from Table MV-7 of the latest year's *Highway Statistics* to update the associated input cells contained in the FHWA Integrated System. Data of interest in this case is the number of federally owned cars/vans, buses, trucks, and motorcycles that are operated by civilian departments and used in each state. The next step of the process considers data on fuel consumption and average in-use vehicle inventory by vehicle types by different federal agencies, originally obtained from the GSA *Federal Fleet Report*. As mentioned above, the current version of the FHWA model uses information obtained from the *Transportation Energy Data Book* instead.

To generate the desired level of detail for FHWA uses, several parameters (or "coefficients") needed for distributing fuel consumption into different fuel types, as well as breaking fuel usage

into on and off-highway uses are obtained from the SCM module (discussed below). The estimation process then continues with further disaggregation of fuel types by state and breakouts of on-highway and off-highway fuel consumption by vehicle type and state.

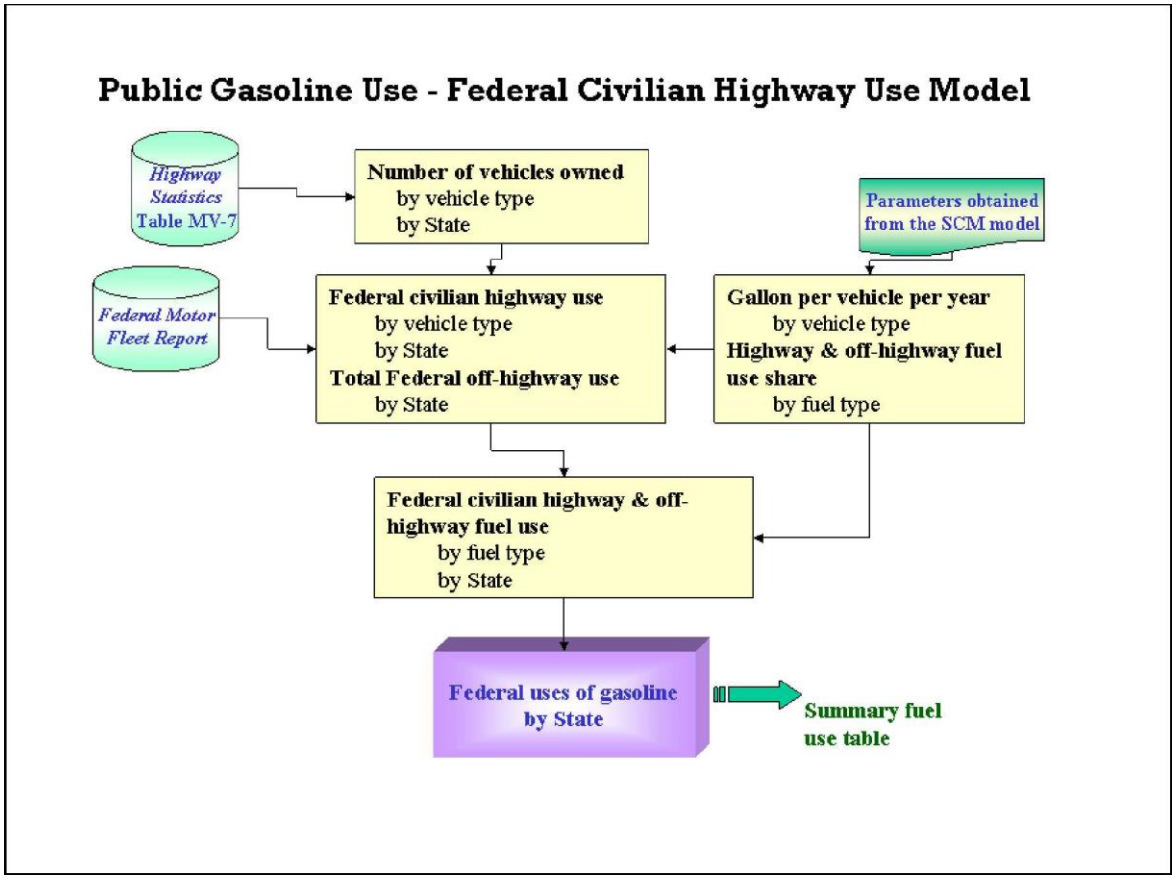

Figure 2-5. Process flow of the federal component of the Public Use model.

2.2.6.2 State, county, and municipal government uses

Data Sources

The original method for estimating motor fuel consumption by SCM governments for all states was based on results from a study conducted by ORNL for FHWA in 1994[22]. This model uses population and land area of a region (e.g., state, county, or city) to estimate fuel used in that region. These regional population and land-area data are obtained from the U.S. Census Bureau. In addition to the Census data, data from a statistical sampling survey of SCM governments in the U.S. conducted as a part of the 1994 study is also used in the current SCM model. That survey's results were used to develop the basic estimation equations used in this SCM module.

Estimation Method

Basically, the core of this model is a log-linear regression that associated SCM government gasoline uses in the states with their populations and land areas. This equation was developed during the 1994 study, and the same formulation has been used to estimate total gasoline consumption (including on- and off-highway uses) by state since then. The share of highway and non-highway fuel use, originally obtained from the 1994 survey of SCM, is applied to separate state total gasoline consumption into highway and non-highway shares.

2.2.7 Off-road Recreational Vehicles

The Recreational Trails Program, or RTP, provides funds to the states to develop and maintain recreational trails and trail-related facilities for both motorized and non-motorized recreational trail uses. This includes, hiking, bicycling, skiing, snowmobiling, off-road motorcycling, etc. The U.S. Congress authorized $60 million dollars for RTP in fiscal year (FY) 2005, and its annual funding steadily increased to $85 million dollars in FY 2009. The FY 2010 authorization extended the FY 2009 apportionment level of $85 million. The same authorization was extended in FY 2011, but with an additional distribution to apportioned programs from other fund allocations. This resulted in over $97 million dollars for the RTP in FY 2011.

The MAP-21 provided nearly $80 million dollars for FY 2012 and reauthorized the RTP through FY 2013 and 2014 as a set-aside from the Transportation Alternatives Program. The amount set aside is equal to the state's FY 2009 RTP apportionment. Previously (FY 1993 through FY 2012), the RTP funds were distributed to states by legislative formula; half are distributed equally among all states, and half are distributed in proportion to the estimated amount of off-road recreational fuel use in each state.

The current FHWA model that estimates the amount of motor fuel used by off-road recreational vehicles, at the state level by different vehicle types, was originally developed by ORNL in 1993. This off-road model was later updated and revised by ORNL in 1999 [23]; and as a result, an Excel spreadsheet-based tool was developed and provided for FHWA use since 1999. Vehicle populations considered in this off-road model include ATVs, off-highway motorcycles, off-highway light trucks, and snowmobiles. Results from this model historically have been used as a factor in making state allocations of funds from the RTP.

This off-road recreational vehicle model, however, has not been examined under the last two reviews of models used in the FHWA Motor Fuel Program (i.e., 2002 and 2008 reviews). Consequently, this model is not included under the FHWA Integrated Non-highway and Public-use Gasoline Consumption System. Since this model also relies on now-discontinued VIUS data, the off-road recreational vehicle model is also in need of alternate data sources and/or an updated estimation method. Note that off-road recreational fuel is defined as federally taxed gasoline, gasohol, diesel fuel, or special fuel used in recreational motorized vehicles on

recreational trails or backcountry terrain. This is different from all other sectors discussed under previous sections, where only gasoline is the motor fuel of concern.

2.2.7.1 Data sources

Generally, fuel use estimates in this model rely on the population of vehicles within a state and estimation of the average annual fuel used per vehicle, although the proportion of off-road recreational fuel use and average annual fuel usage per vehicle for different types were estimated slightly different. Once the estimate of total off-road recreational fuel use was determined, the state shares were adjusted by a rural land factor in the state. The adjustment was used to address the misleading problem with vehicle registration data as vehicles can travel beyond their registered state. A brief discussion of the data sources and estimation procedures are discussed below, readers should reference the 1999 report [23] for more detailed discussions.

Several tables from the *Highway Statistics* publication provide light truck-related data for this off-road model, including Table MV-9, Table MV-1, and Table PS-1. The off-road recreational vehicle model also relies on VIUS data, which was Truck Inventory and Use Survey (TIUS) prior to 1997, specifically those variables that can be used to estimate "percentage of trucks used for off-road recreational purposes." Note that this model was originally developed using 1992 TIUS data since 1997 VIUS data was not available then.

In addition to data sources used for light-truck related fuel uses for recreational purposes, motorcycle and ATV information and statistics are based on estimates produced by the Motorcycle Industry Council (MIC) and published in the *Motorcycle Statistical Annual.* Certain information from the Department of Motor Vehicles (DMV) in several states is also used to derive the ATV fuel usage by state produced from the 1999 study. For snowmobiles, this model uses registration data obtained from International Snowmobile Manufacturers Association(ISMA), American Council of Snowmobile Associations(ACSA), and other state agency (e.g., DMVs).

2.2.7.2 Estimation model

As stated above, data sources utilized in this off-road model vary among vehicle types. Thus, different estimation procedures are applied to obtain vehicle type specific fuel consumption estimates. A detailed description of this off-road recreational use fuel model can be found in the 1999 study report. Below is a brief summary of the estimation method.

Light truck

The total number light trucks for each state is obtained from Table MV-9 of *Highway Statistics* based on the reported total number of pickup trucks and sports utility vehicles by state. The estimation procedure assumed that all light trucks are registered. The share of light trucks used

for off-road recreational purposes is determined using TIUS/VIUS data, with certain assumptions applied (see [23]). Using these two pieces of information, the total number of off-road recreational-use light trucks can be estimated for each state.

The fuel consumption by light trucks for off-road recreational purposes can be estimated using the number of off-road recreational use light trucks, estimated from the above step, with information about the fuel economy (i.e., MPG) and the average annual miles traveled (i.e., VMT) per truck. For this estimation model, both MPG and VMT information are based on statistics published in the annual *Highway Statistics* Table VM-1. Using the estimated annual gallons of fuel used per truck in each state and multiplying it by the total number of off-road recreational light trucks for the given state, estimates of fuel use for light-trucks used in off-road recreation by state can be produced.

Motorcycles

The MIC represents manufactures and distributors of motorcycles, scooters, and ATVs as well as members of allied trades. The MIC conducts periodic surveys of equipment owners to determine usage characteristics. Information collected from the MIC survey is proprietary and the results are confidential. However, the MIC publishes an annual statistical report, the *Motorcycle Statistical Annual*, which contains key motorcycle industry statistics and proprietary information. Information provided in the current *Motorcycle Statistical Annual* report, for example, includes motorcycle population by model type, population by state, total registrations, sales volume, etc. The latest available *Statistical Annual* report was published in 2014, which contains statistics for the years of 2012 and 2013.

The current FHWA Off-road Recreational Vehicle model relies on annual estimates of the number of motorcycles published in the *Motorcycle Statistical Annual* and the proportion of motorcycles used for off-road estimated by MIC to produce the estimated number of off-road recreational motorcycles. As stated in the 1999 study [23], ORNL derived low, medium, and high values for average annual fuel use per motorcycle from that research effort. It was recommended, based on that study, the 'medium' estimate of 59 gallons per motorcycle per year should be used in estimating off-road recreational motorcycle fuel use for each state, until more precise data on average annual fuel use of off-road motorcycles are collected.

All-terrain Vehicles

An ATV is a three or four-wheeled motorized vehicle designed for off-road use. As pointed out previously, MIC also includes ATVs in some of its survey data collection. This inclusion of ATVs in MIC surveys, however, appears to be only periodical. The current FHWA off-road model assumes the numbers of ATVs by state as provided by the MIC are all used off-road.

Based on MIC estimate procedures, the number of ATVs was computed from the annual retailer sales in conjunction with the vehicle scrappage rates.

The current model uses percent of recreational uses of these ATVs estimated based on information from the U.S. Consumer Product Safety Commission (CPSC), which indicated about 74% of ATV drivers use ATVs for at least one non-recreational activity in 1997 (e.g., farming or ranching). Similar to motorcycles, the 'medium' estimate of 55.5 gallons per ATV per year was used to estimate off-road recreational ATV fuel consumption by state.

Snowmobiles

Snowmobiling is a popular recreational activity in the United States. According to ISMA, more than half of the total of approximately 145,000 snowmobiles sold worldwide in 2013 were sold in the U.S. (nearly 46,000) and Canada (about 44,000). The ISMA statistics show that there are 1.4 million registered snowmobiles in the U.S. and about 591,000 in Canada, with approximately 230,000 miles of groomed and marked snowmobile trails in North America [24]. However, the total number of registered snowmobiles in the U.S. currently reported on the ACSA's website is higher (1.65 million), but no reference on what year the registration information represents was provided [25].

The estimation for population of snowmobiles in the current FHWA off-road model is rather complicated. For most states, the numbers of registered snowmobiles are obtained from the ISMA. However, ACSA and ISMA only gather data for states that have snowmobile associations participating in international events, thus some states (e.g., Connecticut, Delaware, Maryland, New Jersey, New Mexico and Rhode Island) are not included. The numbers of snowmobiles for these states are obtained from other data source such as state DMVs. In addition, the number of snowmobiles for Arizona and Nevada used in the current FHWA model was estimated based on state survey data and associated estimates of growth rates. Furthermore, the number of snowmobiles in Alaska estimation followed guidelines provided by ISMA. According to ISMA, the number of unregistered, usable snowmobiles in the U.S. is no more than 5% of the total number of snowmobiles in any state that has registration data. Thus, the number of snowmobiles in each state (except for Alaska and Arizona) is increased by 5% to adjust for unregistered usable snowmobiles. As snowmobiles can only travel when there is snow on the ground, a snow factor categorizing temperature and snowfall are also used to adjust the number of snowmobiles in each state.

During the process to estimate fuel consumption by snowmobiles, it was assumed that all snowmobiles are used exclusively off-road. According to the ISMA, snowmobiles are used 80% of the time for 'typical' recreation, about 15% for ice fishing and about 5% for work purposes. In the current FHWA model, off-road recreational fuel consumption includes fuel used for 'typical' recreation and ice fishing. For the annual fuel usage, ISMA estimates that the average

snowmobiler uses about 101 gallons annually for ‘typical’ off-road recreational purposes and 13.3 gallons annually for ice fishing. By multiplying the number of snowmobiles for each state by the percentage use of time and its corresponding annual fuel usage, statewide annual fuel use for ‘typical’ recreational purposes and ice fishing can be generated. The total snowmobile off-road recreational fuel use is the sum of these two estimates.

Final Adjustment of Estimates

Since the availability of rural land is a proxy for opportunity to participate in off-road recreational activities, the above estimated fuel usage for each state was adjusted by this rural land factor to finalize the results produced from the FHWA model.

3. CHALLENGES AND OPTIONS FOR VIUS-BASED MODEL UPDATES

3.1 OUTDATED DATA AND PARAMETERS IN CURRENT MODELS

3.1.1 Concerns with VIUS Data

Again, VIUS was terminated prior to the scheduled update of 2007; making the 2002 VIUS release the latest available dataset from the series. Without a reliable equivalent data source to serve as a replacement, the current FHWA models are still utilizing information derived from the 2002 VIUS data. This causes data quality concerns, since the now over ten-year old VIUS cannot accurately represent characteristics or behaviors of trucks operating within today's business sectors. Consequently, the need for alternative data sources and the development of new methods to ensure accuracy in FHWA motor fuel estimates are urgent issues.

Restoring the VIUS is of critical importance to federal agencies, as well as state DOTs, metropolitan planning organizations, academic institutions, and private consulting agencies, as they currently have little alternative but to use the outdated 2002 VIUS for their research data needs. Although the USDOT is currently working with other government agencies (e.g., DOE, EPA, USDA) in an effort to bring back a VIUS-like data program, the planning phase of this effort is not expected to be completed until late 2015, at which time an assessment will be made regarding advancing the VIUS to the pre-test and survey phases. Therefore, even if the survey was successfully fielded, it would still be several years before such a data product could be released.

As pointed out in Section 2 of this report, a major issue in the current FHWA Integrated System, and the current off-road recreational fuel use model, is its use of the aging 2002 VIUS data, mainly for their truck-use components. To find a proxy data source for VIUS and/or to identify an alternate estimation method has been an urgent need for FHWA in recent years. Two specific data sources were considered in this study, one being the EPA Motor Vehicle Emission Simulator (MOVES) model and the other is the R.L. Polk dataset. Each of these is discussed further in the latter part of this Section (sections 3.2 and 3.3).

3.1.2 Obsolete Factors/Parameters in Current FHWA Models

Several of the current models relied on factors or parameters from regressions that were produced during the original model developments conducted in early 1990's. Specifically, this occurred in estimation models for the agricultural sector, recreational boating, aviation, as well as the public sector. Brief descriptions on selected examples of obsolete factors or parameters in the current FHWA models are presented below.

3.1.2.1 Agricultural estimation equation

In the current FHWA model, the process of estimating the off-highway gasoline consumption by agricultural farm equipment continued to be based on a statistical regression equation developed under the original 1994 study. This regression model, which was developed using information from the *1992 Census of Agriculture*, established a relationship between the off-highway agricultural gasoline consumption and the number of farm equipment units in the state. This equation is now over twenty years old; even if the established relationship remains the same, a recalibration of that regression equation (i.e., to generate new parameters) would be required.

3.1.2.2 Aviation model

As stated in the methodology section of the current aviation model (Section 2.2.1), a statistical regression model was used to estimate gasoline consumption for "missing" cells in the EIA data. The reason for "missing" data could include incomplete reporting of certain data by states, as well as withheld-values by the EIA due to non-disclosure or other reasons. The regression equation associated the EIA-published "aviation gasoline consumption" with FAA-reported "hours flown by general aviation" at the state level. Total gasoline consumption for states with missing values was then estimated by applying this regression equation. As in the agricultural model, this regression equation was built using data over twenty years old. This certainly is a weakness for this otherwise straightforward method of estimating aviation gasoline consumption by state.

3.1.2.3 Recreational boating estimation equation

The current FHWA recreational boating consumption estimation model also utilized a regression approach that was developed during the original study in 1994. This regression equation established the median household income information from Census data with the "average annual gallons used per boat" data from the 1991 USCG boating survey. This equation clearly is outdated and desperately in need of improvement from new estimation procedures. Furthermore, there is a concern on the association of boating usage with the median household income in a region. The revised model developed under this study, discussed later in this report (Section 5), attempts to address these issues as well as to produce a more reasonable and updated approach for estimating gasoline consumption by recreational boats in each state.

3.1.2.4 Public use gasoline consumption estimation process

The major weakness of the current FHWA model for estimating public-use gasoline consumption is in its use of several outdated survey results from a survey conducted as a part of the 1994 study. Specifically, share of fuel type (gasoline, gasohol, and diesel), average share of off-highway fuel use, and average fuel consumption per vehicle (by vehicle type) were all estimated based on information collected from this now twenty year old survey. In addition, the

current FHWA SCM model also relied on a regression equation that associated state population and land-area to its fuel consumption, which was developed in 1994 as well. Although conducting a new survey to collect more up-to-date SCM information is not possible at this time, the use of data from such an outdated survey should be minimized, if not avoided totally. This is indeed the aim of this research project.

3.1.3 Issues Associated with Off-road Recreational Vehicle Models

Moreover, the current method for fuel usage estimates by motorcycles and ATVs might be further reviewed and revised with a slightly more advanced procedure to better capture differences among states. Specifically, a 2008 report from the Forest Service at the USDA [26] provides statistics describing off-highway vehicle recreational use and their users in the U.S. The source of data for this report is the *National Survey on Recreation and the Environment* (NSRE), which is a general population survey that collected data regarding the use of off-highway vehicles (OHVs) for recreation within the past year. The data was collected between 1999 and 2007. The NSRE defines "off-highway" use to capture a broad range of motorized land-based uses including backcountry roads, trails, and cross-country riding. The OHVs considered in the NSRE surveys, focusing only on recreational uses of these vehicles, are:

- 4-wheel drive vehicles (jeeps, automobiles, pickups, or sport utility vehicles);
- Motorcycles (especially those designed for cross-country use);
- ATVs; and
- Other specially designed or modified off-road motor vehicles used in a wide variety of ways.

Note that snowmobiles are not included as OHVs in the NSRE report.

Furthermore, the U.S. Consumer Product Safety Comission (CPSC) publishes statistics on ATV-related deaths and injuries [27] on an annual basis, with the latest statistics being published in February 2013 for 2011 data. Researchers at the U.S. National Institutes of Health (NIH) also conducted several studies on ATV safety based on certain ATV injury surveillance database (2002 to 2009) that they have [28]. These information sources (i.e., NSRE, CPSC, and NIH) should be further investigated to evaluate any potential for fulfilling FHWA modeling needs in the area of estimating fuel consumption by off-road recreation vehicles.

3.2 EVALUATION OF EPA NONROAD MODEL ESTIMATES

3.2.1 Overview of EPA NONROAD Model

The NONROAD is a tool developed by EPA to predict emissions from non-road engines. It is essentially an emission inventory model for mobile sources involving equipment. Over the years, since its first draft release in 1998, the NONROAD model has went through many improvements; and recent NONROAD releases were designed to operate on computers with

Windows 98 and later versions of operating systems. The latest version of this EPA model is the NONROAD2008; which updated the previous NONROAD2005 model to include non-road emission standards promulgated in 2008 associated with small gasoline engines and pleasure-craft. The primary use of NONROAD2008 model is for estimation of air pollution inventories by professional mobile source modelers, e.g., air quality officials in states and their consultants.

To calculate emission factors, EPA relied on information about the break-specific fuel consumption (BSFC) along with other factors for the given set of equipment and the population of the equipment (i.e., inventory). With each model run, NONROAD2008 produces a set of output summary reports by the user-specified geographic level (nation, state, or county). One of these reports provides estimates on equipment populations and fuel consumption (gallons) by sector category as selected by the user.

Note that the NONROAD model does not include data for locomotives, aircraft, or commercial marine vessels. The EPA specified that NONROAD2008 must be used if equipment populations or fuel consumption estimates are required, or if output by model year is required. Under the Clean Air Act, EPA is required to update its mobile source emission models regularly. The EPA continuously collects data and measures vehicle emissions to make sure that it has the best possible understanding of mobile source emissions [29]. As a result, EPA has developed the Motor Vehicle Emission Simulator (MOVES) to estimate emissions for mobile sources at the national, state, county, and project level, which cover a broad range of pollutants and allows multiple scale analysis. Initially, mobile sources covered under the MOVES included on-road use vehicles only, mainly due to its MOBILE model root. MOBILE is an EPA model for estimating pollution from highway vehicles. It has been superseded by the MOVES since 2010.

MOVES2014 is the latest release and a major revision to EPA's mobile source emission model. It allows users to benefit from the most up-to-date regulations, incorporated new and updated emissions data, and improved functionality of the tool. In addition, EPA also added the capability to model non-highway mobile sources by incorporating its NONROAD2008 model into the MOVES2014 platform. Although there is no difference between the non-road model included in MOVES2014 and the "standalone" version of NONROAD2008, EPA recommends using MOVES2014 for users having problems installing or using NONROAD2008 on newer operating systems.

The MOVES2014 system, along with its documents, is available for download from EPA's web site at http://www.epa.gov/otaq/models/moves/. The system needs to be installed on a computer before it can be used. When MOVES2014 is executed, an opening screen of the MOVES2014 (as shown in Figure 3-1) is displayed. The user can click on the "Scale" option on the left bar of the screen and select the "Nonroad" option to initiate the NONROAD2008 model. As an example, Figure 3-2 shows the selection menus for fuel types and equipment sectors within the NONROAD module. The EPA provides several detailed online documents to guide users in

working with, and understanding the design and process of, the MOVES2014. Specifically, a step-by-step description of how to run the NONROAD model is provided in the *MOVES2014 User Guide [30]*.

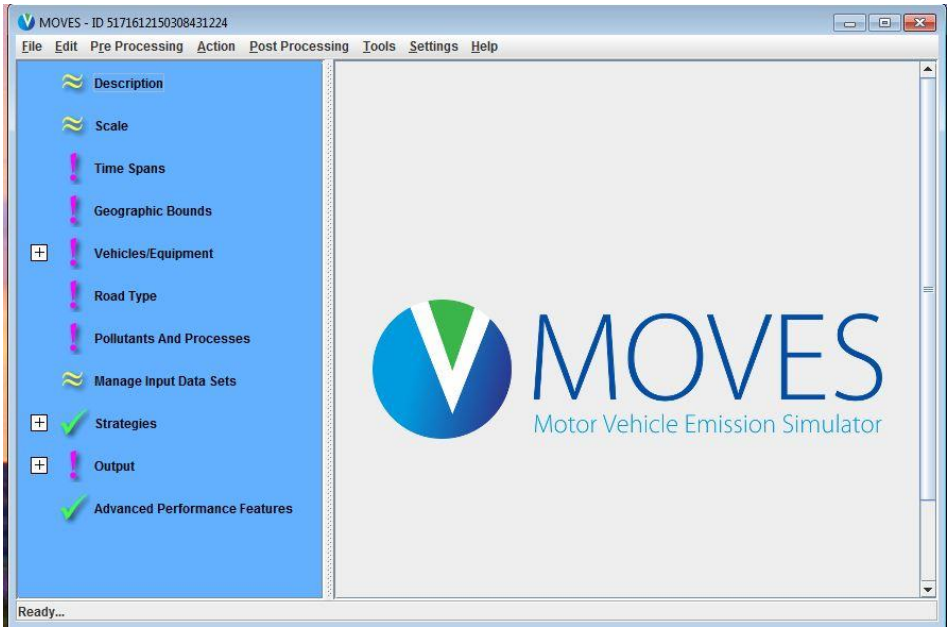

Figure 3-1. Opening screen of the MOVES2014.

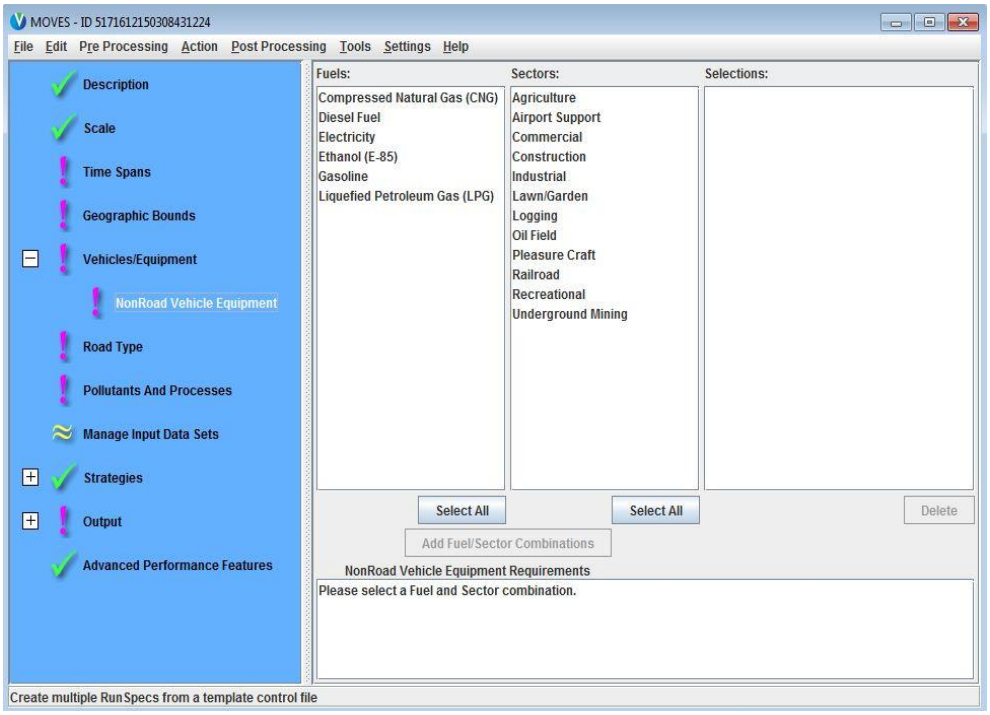

Figure 3-2. Example of menu options within the NONROAD portion of MOVES2014.

3.2.2 Equipment Coverages in EPA MOVES2014/NONROAD2008

It is important to understand that there are differences in equipment coverage between the current FHWA models and the EPA MOVES2014 (or NONROAD2008) model in each equivalent sector (e.g., agriculture, industrial, etc.). The following sections address the equipment coverage in the EPA MOVES2014/NONROAD2008 model by sector.

3.2.2.1 Agricultural equipment

The current FHWA agricultural model produces an estimate on fuel used by trucks that may be registered for on-road use, but are operating off-road for agricultural purposes (VIUS-based component). It also includes a separate estimate on fuel used by farm equipment, which was based on a statistical regression approach associating the number of wheel tractors with the amount of off-highway agricultural gasoline use (*Census of Agriculture*-based component). This regression modeling approach was intended to capture gasoline consumption by all farm-based equipment. A review of the USDA Agriculture Census data revealed that the process of matching equipment covered under the USDA Census and the EPA NONROAD model is rather difficult, mainly due to differences in data collection methods. Each agency employed the methodology to collect information that can best serve its intended purpose. That is, Agriculture Census collects data by surveying farmers/farm-operators while EPA gathers its data based on manufacturer sales and engine productions.

Specifically, Agriculture Census data on machinery and equipment used in farm or ranch businesses was collected for the following items:

- Trucks (including pickups);
- Tractors less than 40-horsepower (excluding garden tractors);
- Tractors 40-99 horsepower;
- Tractors 100 horsepower or more;
- Grain and bean combines (self-propelled);
- Cotton pickers and strippers (self-propelled);
- Forage harvesters (self-propelled); and
- Hay balers.

Note that there is no "other machinery or equipment" category in the Agriculture Census survey form to capture information on items outside that specific equipment. Therefore, it is possible that the actual number of machinery and equipment used in farm operations is higher than that reported by the survey respondents (i.e., in-scope machinery and equipment from the Census). Most of the listed farm machinery and equipment, especially those with larger horsepower ones, are likely non-gasoline powered, however.

On the other hand, the NONROAD2008 model covers all types of agricultural equipment, but not farm-based trucks. Under the EPA NONROAD2008 model, agricultural equipment includes the following types:

- Two-wheel tractors including walk-behind 2-wheeled tractors for use in edible produce or other intensive farming;
- Agricultural tractors, including large and small agricultural tractors, most prevalent farm equipment type;
- Combines including self-propelled combined harvesting and cleaning equipment;
- Baler equipment that bales from loose or windrowed hay or other forage mowed crop
- Agricultural mower equipment for mowing, not intended for later baling or harvesting;
- Sprayers including small (backpack) and large (self-propelled) powered equipment designed specifically for spraying;
- Tillers >6 HP, primarily small tillers similar to those used on lawn and garden applications intended to be used in edible produce or other intensive farming;
- Swather equipment designed to cut crops for later baling or harvesting including windrowers;
- Other agricultural equipment which includes other various cultivation equipment types, include harvesters or other special cultivating equipment; and
- Irrigation sets that include agricultural pumps and pivot wheel irrigation equipment to distribute water to fields or livestock.

The EPA NONROAD2008 model seems to have covered a wider range of equipment than the USDA Agriculture Census. Based on the *2012 Agriculture Census*, the total number of farm machinery and equipment (excluding trucks) used for farm operations in the United States was approximately 5,347 thousand units for all fuel types, although the majority of these is expected to be non-gasoline powered. Based on the NONROAD2008 estimate, the national number of agricultural equipment in 2012 amount to about 3,751 thousand units, which is significantly different from USDA's estimated number (about 30% less in the number of units). This discrepancy, however, is mainly due to reporting requirements of the USDA survey; i.e., what to include in the reporting of "machinery and equipment used in farm operations."

The *Census of Agriculture* survey asked its respondents to report "total number of machinery and equipment used in 2011 or 2012 that were in operation on December 31, 2012." Because of this, equipment used in 2011 farm operations but idled during 2012 would also be included. Besides, in addition to using their own machinery and equipment in farm operations, farm operators or owners could also rent or lease machinery and equipment from others in these operations. Since this survey asked farm operators to include all machinery and equipment used for their farm operations in answering the questionnaire, this created a possibility of double counting in the total number of units. Therefore, the difference in the number of units estimated from the two

different sources (USDA and EPA) might not be as significant as it seems. For easy reference, Appendix A at the end of this report provides a list of definitions for several categories of machinery and equipment. The list was extracted from the USDA published *Report Form Guide* for the 2012 Census of Agriculture.

3.2.2.2 Construction equipment

The current FHWA model for estimating gasoline use in off-highway construction purposes only accounts for fuel consumed by trucks used in off-road construction. No other construction equipment is included in the estimates. On the contrary, the EPA MOVES2014 (or NONROAD2008) model does not include trucks. Instead, it includes a large set of different equipment for construction and mining purposes (see Table 3–1). There are no overlaps in the data provided by these two models. Consequently, by considering both sets of data together, one could expect to obtain a more complete coverage of gasoline usage by off-highway construction sector. Note that the current FHWA model includes mining within its "industrial" category, while mining was combined with construction in the NONROAD2008.

Table 3-1. Construction Equipment Coverage

FHWA Model	NONROAD2008
Registered trucks used for off-road construction	Bore/Drill Rigs
	Cement & Mortar Mixers
	Concrete/Industrial Saws
	Cranes
	Crushing/Proc. Equipment
	Dumpers/Tenders
	Pavers
	Paving Equipment
	Plate Compactors
	Rollers
	Rough Terrain Forklifts
	Rubber Tire Loaders
	Signal Boards/Light Plants
	Skid Steer Loaders
	Surfacing Equipment
	Tampers/Rammers
	Tractors/Loaders/Backhoes
	Trenchers
	Other Construction Equipment

3.2.2.3 Industrial/commercial equipment

The current FHWA model estimated the off-highway industrial and commercial gasoline use by trucks only. No industrial and commercial equipment were considered in the FHWA

consumption estimation model. On the other hand, the NONROAD2008 (or MOVES2014) model does not include trucks, but covers many different types of industrial, commercial, and logging equipment. There is no overlap in terms of coverage in these two models, therefore an opportunity exists for FHWA to consider both sets of estimates together with the goal to improve coverage. Again, instead of including mining under the "industrial" sector as in the current FHWA model, NONROAD2008 combined mining with the construction sector. Table 3–2 lists all equipment types included under the NONROAD2008 model.

Table 3-2. Industrial and Commercial Equipment Coverage

FHWA Model	NONROAD2008
Registered trucks used for off-road industrial and commercial purposes	Air Compressors
	Generator Sets
	Hydro Power Units
	Pressure Washers
	Pumps
	Welders
	AC/Refrigeration
	Aerial Lifts
	Forklifts
	Other General Industrial Equipment
	Other Material Handling Equipment
	Sweepers/Scrubbers
	Terminal Tractors
	Chain Saws > 6 HP
	Forest Equipment - Feller/Bunch/Skidder
	Shredders > 6 HP

3.2.2.4 Recreational boating

Gasoline consumption in recreational boating is currently estimated by the FHWA model. All recreational powerboats registered with the states are considered in the FHWA model. Most states require registration for all watercraft with a motor, though some states exempt certain small vessels. The MOVES2014 (or NONROAD2008) model also estimates fuel use for similar recreational boats, including personal watercraft (i.e., Jet Ski).

3.2.2.5 Airport ground use

Aviation gasoline used by general aviation airplanes is included in the current FHWA model. On the other hand, equipment used for airport ground support is the only aviation-related equipment included in the MOVES2014/NONROAD2008 model. This includes cargo or baggage tractors, cargo loaders, aircraft tractors, etc. There is no overlap in estimates provided

by these two models (i.e., FHWA model and EPA NONROAD). Technically, figures from the two models should be added together to provide a better gasoline usage estimation that covers not only aircrafts but also their associated ground support activities. Further discussions related to this are included in later sections of this report.

3.2.2.6 Lawn and garden equipment

A "Miscellaneous" category is published in Table MF-24 which is used by the FHWA to capture state-reported off-highway consumption that was not represented in other categories, as determined by the FHWA. No similar miscellaneous category is included under EPA MOVES2014 (or NONROAD2008), however. There are additional categories of non-road equipment covered in the NONROAD model but not currently accounted for by the FHWA model. Some of these additional equipment categories are substantial users of gasoline, specifically the commercial and residential lawn and garden equipment listed in Table 3–3 below. More details on this sector are included in Section 10 of this report.

Table 3-3. Lawn and Garden Equipment in the EPA Model

Commercial Lawn and Garden	Residential Lawn and Garden
Chain Saws < 6 HP	Chain Saws < 6 HP
Chippers/Stump Grinders	Lawn & Garden Tractors
Commercial Turf Equipment	Lawn mowers
Front Mowers	Leaf blowers/Vacuums
Lawn & Garden Tractors	Rear Engine Riding Mowers
Lawn mowers	Rotary Tillers < 6 HP
Leaf blowers/Vacuums	Snow blowers
Rear Engine Riding Mowers	Trimmers/Edgers/Brush Cutter
Rotary Tillers < 6 HP	Other Lawn & Garden Equipment
Shredders < 6 HP	
Snow blowers	
Trimmers/Edgers/Brush Cutter	
Other Lawn & Garden Equipment	

3.2.2.7 Off-road recreational use equipment

The current FHWA Off-road Recreational Vehicle model discussed in Section 2 covers fuel uses by light truck, motorcycle, snowmobile, and ATV. The EPA NONROAD model is similar but also includes more types of equipment as shown in Table 3–4. Specifically, golf carts and specialty vehicles/carts are included in EPA NONROAD2008 but not by the FHWA model.

Clearly, light truck (included in the FHWA model) is not in the EPA NONROAD2008 equipment inventory.

Recall that the FHWA Off-road Recreational Vehicle model is a standalone tool, which estimates total fuel consumption, i.e., not gasoline specific. Traditionally, the FHWA ran this model as a separate activity, i.e., not associated with the FHWA Non-highway Gasoline Consumption Estimation Model. Although this study also updated the off-road recreational vehicle model, the FHWA has no plans to integrate it with other forms of non-highway use models.

Table 3-4. Off-road Recreational Equipment in EPA Model

ATVs
Golf Carts
Motorcycles: Off-Road
Snowmobiles
Specialty Vehicles/Carts

3.2.3 A Brief Overview of the Fuel Consumption Estimation Process in NONROAD

As mentioned above, the EPA NONROAD model was designed to estimate emissions generated from equipment engine uses in various sectors (agriculture, construction, etc.). This EPA model uses the engine population, an average number of hours per year that the engine is active, a fuel factor or BSFC rate (e.g., *pounds/*horsepower-hour, or gallon/horsepower-hour), and other information about the engine to derive fuel emission estimates. For example, the CO_2 exhaust emission[2] is calculated based on the following formula:

CO_2 = (*BSFC* * conversion factor – hydrocarbon emissions) *
(Carbon mass fraction of diesel) * (ratio of CO_2 mass to carbon mass)

Because the BSFC rate is used by EPA to produce emission estimates, this allows for a certain level of credence to this factor. Consequently, it provides a degree of confidence to fuel consumption generated using the same factor in a similar formulation:

*Fuel Consumption = Pop * Power * LF * A * BSFC*

Where Pop = Engine Population
Power = Average Power (horsepower)
LF = Load Factor (fraction of available power)
A = Activity (hours per year)
BSFC = Fuel Factor (in gallons per horsepower-hour)

[2] *Exhaust Emission Factors for NONROAD Engine Modelling – Spark Ignition*, EPA NONROAD2008 report NR-010f.

The NONROAD2008 also used other parameters (e.g., growth and scrappage rates for population, seasonal adjustment for activity) in its model to fine-tune the estimates. In order to estimate the growth of the engine populations, in most cases, EPA extrapolates from a simple linear regression of the historical population by market sector and fuel type. In the case of off-road motorcycles and ATVs, growth projections supplied by the MIC were used; while snowmobile growth projections are calculated based on information supplied by the ISMA. Furthermore, the fuel factor also changes over time to reflect the increased fuel efficiency of newer engines entering the population.

Note that NONROAD2008 is a simulation model. The EPA programmed the NONROAD2008 model to allow back casting and forecasting of emissions; the model can be used to produce estimates for years between 1970 and 2050. As with any model, however, the reliability declines as estimates are made further from the base year. As mentioned previously, EPA has integrated the NONROAD2008 model into the latest MOVES2014; which allows the users to estimate emissions for both on-road and off-road mobile sources.

3.2.4 Summary of EPA NONROAD Gasoline Consumption Estimates by State

Using EPA NONROAD2008 estimated total gasoline consumption for 2013, as the example, Figure 3-3 shows the distribution of gasoline uses by sector category at the national level. Gasoline consumption from equipment used in sectors of lawn and garden (both commercial and residential), off-road recreational vehicles, recreational boating, and commercial are visibly higher than other categories.

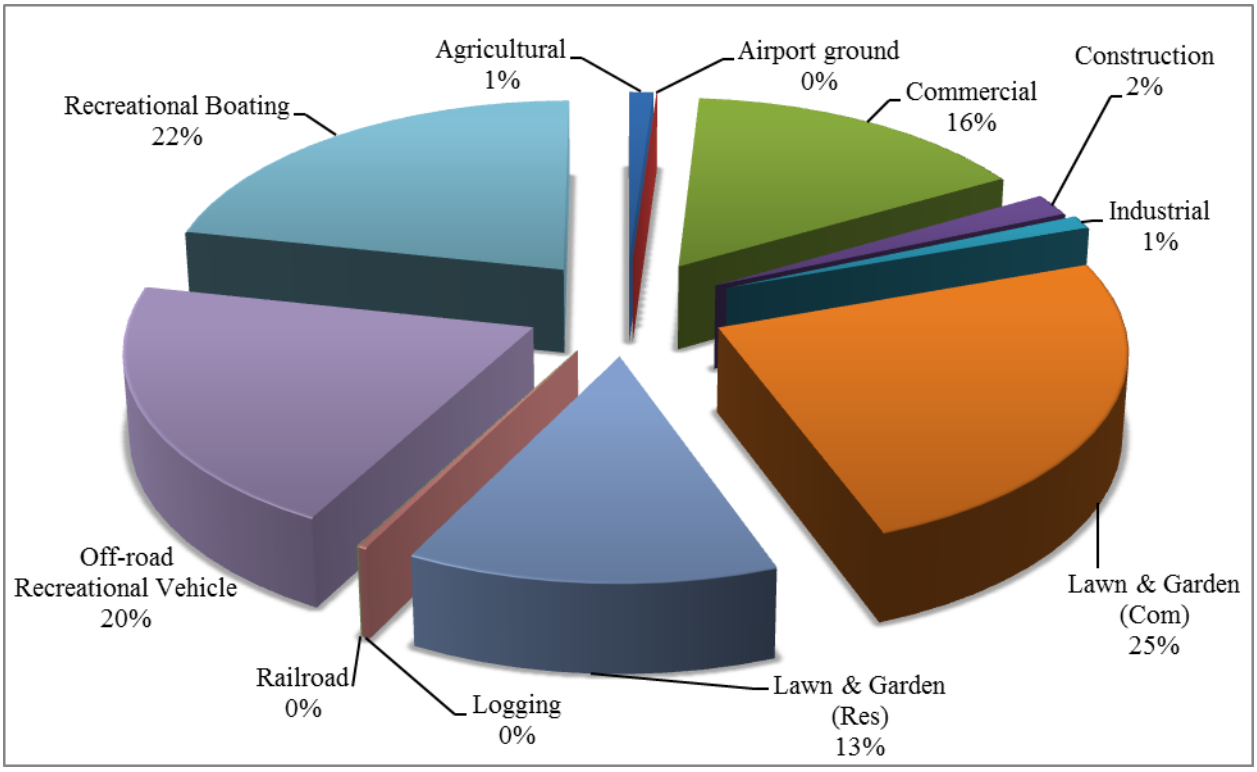

Figure 3-3. Share of 2013 gasoline consumption by sector covered in EPA NONROAD2008 model.

In fact, when examining this EPA NONRPAD2008 database by sector population size, it revealed that about two-third of all equipment inventories in 2013 are residential lawn and garden equipment (see Figure 3-4). Based on EPA estimates, average annual gasoline consumption on a residential lawn and garden equipment is around 8 gallons in the U.S.; while commercial lawn and garden equipment consumes about 147 gallons gasoline annually on the national average. Table 3–5 presents a summary of EPA NONROAD2008 estimates on equipment populations (inventory) and total gasoline consumption by sector for 2013. Average per-unit consumption calculated from these estimates are also included in this table. Due to large inventories of equipment used in lawn and garden, off-road recreational, boating, and commercial (see Table 3–5) sectors, their estimated share of emissions are also significantly higher. Figures 3-5 and 3-6 display two examples: one for CO_2 and the other for total hydrocarbon.

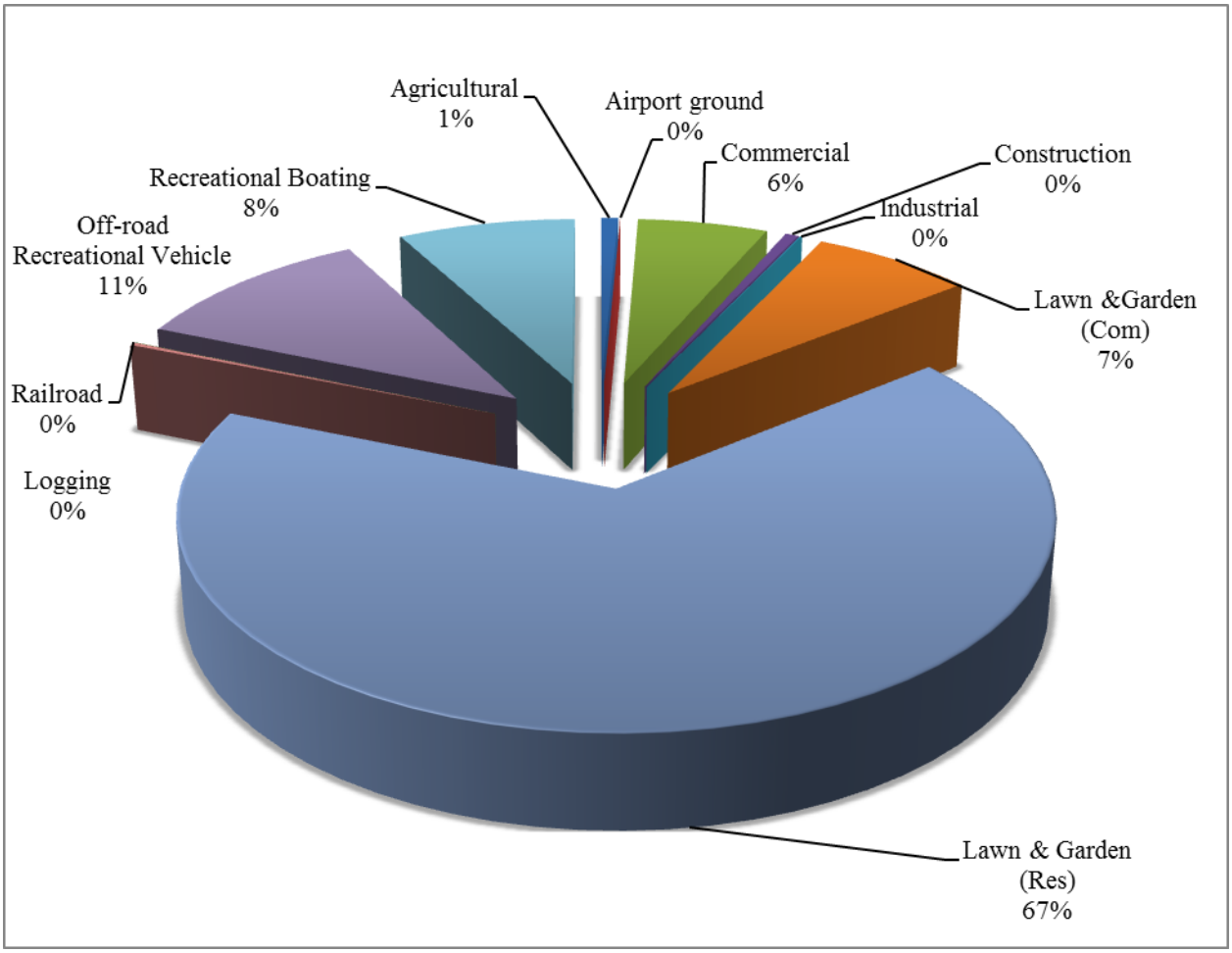

Figure 3-4. Share of 2013 EPA NONROAD2008 equipment inventory by sector.

Table 3-5. NONROAD2008 estimates of 2013 equipment inventory and gasoline consumption by sector

Sector	Gasoline consumption (gallons)	Equipment population (units)	Average consumption (gallon/unit)
Agricultural	77,702,049	1,245,382	62
Airport ground	2,142,083	2,087	1,026
Commercial	1,124,356,375	9,803,389	115
Industrial	78,681,298	78,426	1,003
Construction and Mining	132,493,781	1,013,646	131
Lawn and Garden (Com)	1,797,008,546	12,256,374	147
Lawn and Garden (Res)	954,713,691	114,397,313	8
Logging	21,877,414	390,698	56
Railroad	1,348,038	14,582	92
Off-road Recreational Vehicle	1,469,609,488	18,395,996	80
Recreational Boating	1,562,434,350	13,393,603	117
Grand Total	7,222,367,113	170,991,497	42

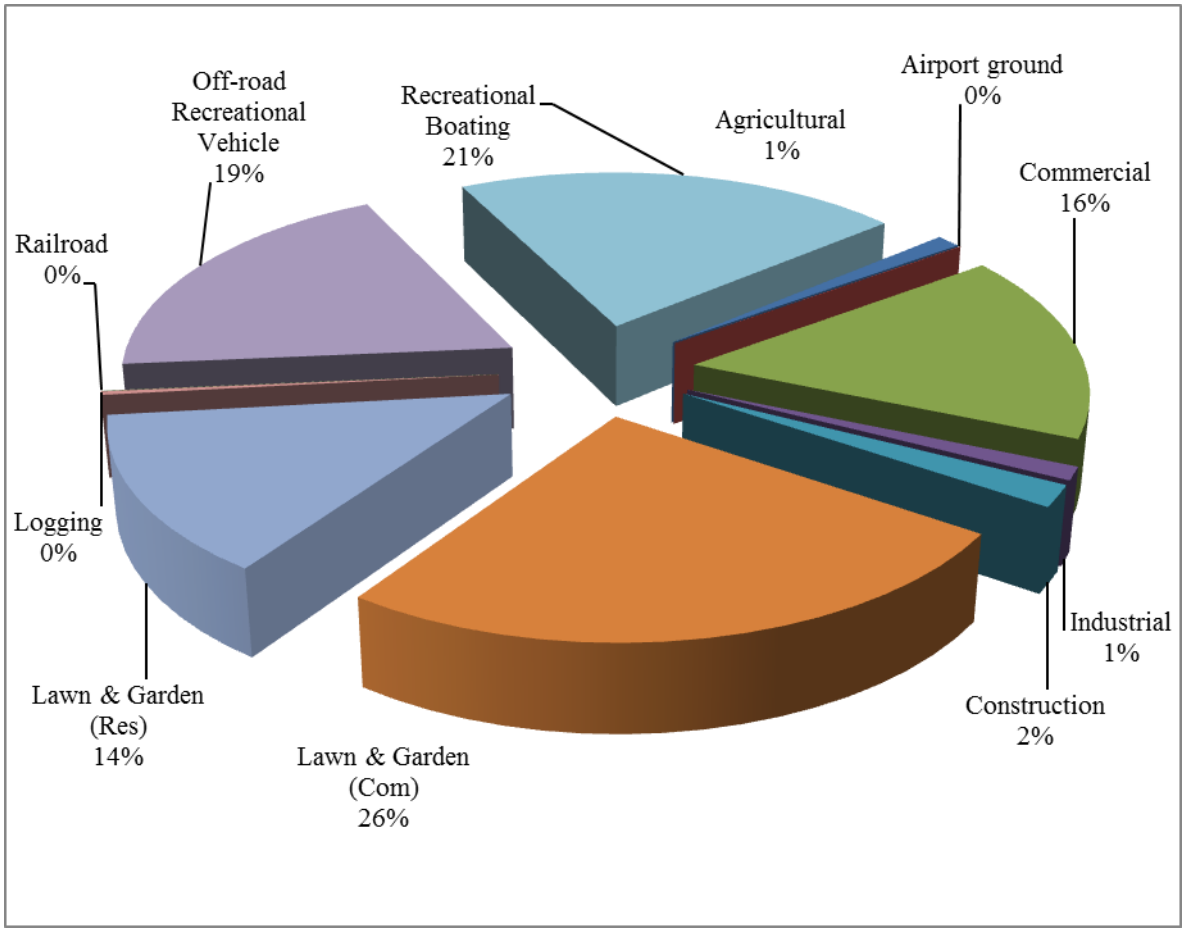

Figure 3-5. Share of 2013 EPA NONROAD2008 estimated CO_2 exhaust emissions.

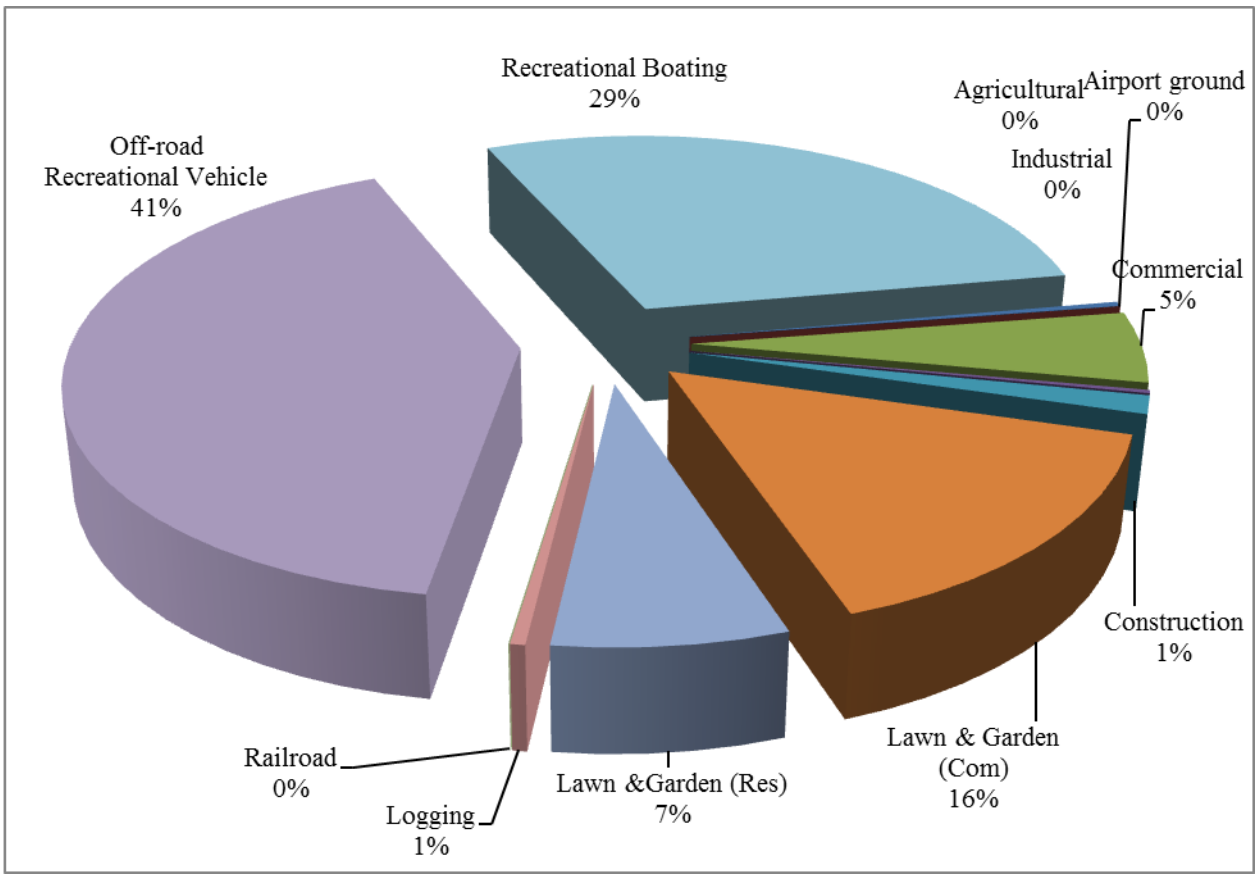

Figure 3-6. Share of 2013 NONROAD2008 estimated emissions on total hydrocarbon.

Table 3–6 presents a summary for 2013 gasoline consumption for off-road activities by state, as produced from the EPA NONROAD2008 tool (a part of MOVES2014), including some sectors that are not included in the current FHWA models.

Table 3-6. NONROAD2008 Estimates of 2013 Gasoline Use by Equipment (thousand gallons)

State	Agricultural	Construction	Commercial	Industrial	Boating
Alabama	512	1,935	14,809	1,143	37,306
Alaska	8	329	1,912	465	5,097
Arizona	228	4,350	16,966	699	18,852
Arkansas	1,913	1,015	9,038	939	20,319
California	2,172	14,303	150,080	6,527	111,534
Colorado	1,115	2,849	19,068	1,658	8,419
Connecticut	34	1,167	12,262	792	21,753
Delaware	111	394	2,437	160	11,268
District of Columbia	0	449	864	28	676
Florida	594	12,591	78,642	1,428	180,438
Georgia	833	4,990	34,815	1,464	35,319
Hawaii	28	446	4,674	42	4,606
Idaho	1,107	748	5,055	216	9,394
Illinois	5,788	4,899	52,661	2,886	39,420
Indiana	3,062	3,214	21,576	2,071	16,677
Iowa	6,155	1,599	12,791	761	15,009
Kansas	4,868	1,118	12,065	1,319	7,205
Kentucky	1,277	1,786	12,050	1,112	23,041
Louisiana	855	1,634	15,251	3,989	50,668
Maine	101	498	4,362	230	12,997
Maryland	329	2,327	15,397	540	30,774
Massachusetts	41	2,068	24,133	1,206	34,119
Michigan	1,752	3,586	33,378	2,769	84,067
Minnesota	4,976	2,630	23,435	1,230	55,499
Mississippi	1,062	932	7,586	1,056	25,599
Missouri	3,370	2,361	22,243	1,130	39,250
Montana	2,243	240	4,004	246	4,150
Nebraska	4,447	865	7,599	364	5,995
Nevada	141	2,387	6,612	169	7,474
New Hampshire	25	537	5,228	324	12,928
New Jersey	114	2,880	42,306	1,281	53,174
New Mexico	220	790	5,341	1,241	5,199
New York	987	5,122	91,091	2,350	88,935
North Carolina	1,105	4,741	30,860	1,994	47,770
North Dakota	5,107	275	3,879	392	3,796
Ohio	2,576	4,084	41,424	3,444	52,050
Oklahoma	1,977	1,293	12,362	3,183	22,492
Oregon	800	1,755	14,867	657	20,647
Pennsylvania	1,046	3,732	41,603	2,963	34,206
Rhode Island	5	285	3,787	217	4,953
South Carolina	353	2,445	12,628	977	33,278
South Dakota	3,461	301	3,431	136	4,363
Tennessee	1,120	2,636	19,464	1,461	34,435
Texas	4,554	11,357	81,493	14,474	79,179
Utah	247	1,260	8,555	757	10,054
Vermont	117	219	2,222	158	3,508
Virginia	673	3,775	19,521	1,151	35,531
Washington	1,256	2,999	24,726	1,006	37,060
West Virginia	166	433	4,364	750	6,432
Wisconsin	2,290	2,561	19,942	1,767	40,117
Wyoming	333	255	2,130	1,047	3,045
Grand Total	77,652	131,443	1,116,985	78,370	1,550,075

Table 3–6. NONROAD (continued, in thousand gallons)

State	Lawn & Garden (Com)	Lawn & Garden (Res)	Logging	Recreational	Airport Support	Railroad
Alabama	23,537	15,598	1,565	22,299	10	26
Alaska	1,228	2,129	184	32,128	35	3
Arizona	52,105	18,096	19	17,804	64	31
Arkansas	9,814	9,306	1,030	22,431	6	33
California	291,893	97,241	901	71,807	261	81
Colorado	40,634	15,501	64	23,801	55	20
Connecticut	24,272	11,272	36	6,657	11	16
Delaware	6,524	2,726	15	1,762	0	0
District of Columbia	163	2,191	0	133	0	1
Florida	151,759	59,036	709	28,330	180	17
Georgia	63,558	27,005	1,729	28,043	96	40
Hawaii	8,459	3,643	0	445	51	0
Idaho	7,755	4,437	371	24,990	6	15
Illinois	59,625	40,023	130	47,701	124	74
Indiana	35,040	20,961	179	26,921	20	33
Iowa	11,024	10,105	69	24,900	7	32
Kansas	13,557	9,286	33	7,616	4	46
Kentucky	14,170	14,186	424	19,991	37	31
Louisiana	13,579	14,563	1,184	22,380	19	23
Maine	5,929	5,341	827	41,923	6	6
Maryland	48,864	17,611	132	9,018	32	10
Massachusetts	33,469	21,287	127	15,703	41	3
Michigan	44,103	34,881	506	163,227	52	12
Minnesota	20,691	17,138	535	137,478	35	29
Mississippi	7,436	9,253	1,429	18,302	4	19
Missouri	31,354	19,999	353	21,869	66	58
Montana	2,254	3,352	243	12,990	7	64
Nebraska	7,259	5,938	25	7,834	10	76
Nevada	26,145	7,045	4	6,004	52	11
New Hampshire	7,422	4,510	267	19,961	6	6
New Jersey	56,748	27,029	93	13,992	56	2
New Mexico	8,430	6,409	26	6,043	13	41
New York	55,952	62,382	329	78,206	128	21
North Carolina	60,552	28,810	1,183	28,789	64	16
North Dakota	1,215	2,364	4	10,259	4	25
Ohio	80,386	39,189	191	43,669	36	47
Oklahoma	21,769	11,939	197	11,552	13	28
Oregon	22,244	12,019	1,045	20,779	20	12
Pennsylvania	66,689	42,818	404	56,097	78	27
Rhode Island	4,166	3,566	10	1,407	8	0
South Carolina	29,950	14,134	866	12,910	7	14
South Dakota	1,904	2,671	35	9,233	4	5
Tennessee	30,144	19,654	492	25,003	51	32
Texas	123,766	65,858	942	44,629	202	115
Utah	9,638	6,498	20	23,780	22	13
Vermont	2,554	2,407	155	14,279	1	3
Virginia	61,836	23,765	799	15,827	55	43
Washington	36,293	20,307	1,048	28,734	45	23
West Virginia	6,408	6,848	300	15,444	4	17
Wisconsin	24,019	19,181	617	106,473	17	16
Wyoming	1,536	1,832	32	12,305	1	33
Grand Total	1,769,817	943,342	21,877	1,463,856	2,126	1,348

3.3 EXPLORING POTENTIAL USE OF POLK VEHICLE REGISTRATION DATA

3.3.1 Overview of Polk Data

Based on data obtained from state DMVs, a vehicle registration database maintained by R. L. Polk lists every vehicle registered in the state along with their information. Specifically, the Polk database contains registration data for both automobile and all classes of trucks (Class 1 through Class 8). On the automobile side, the Polk National Vehicle Population Profile (NVPP) database contains over 263 million registered passenger cars and light Vehicles in Operation (VIO) in the U.S. (including Puerto Rico) and Canada. Note that VIO is a snapshot of registered VINs at a designated point in time; where each snapshot includes all of the registered vehicles on the road. This dataset also captures vehicle attributes (e.g., make, model, model year, engine type, etc.) for each registered vehicle. As a part of the NVPP, Polk also maintains a separate dataset for motorcycles (including ATVs) registered in the U.S.

For trucks, Polk has a Trucking Industry Profile (TIP) database that contains vehicle information for Classes I through VIII trucks (i.e., gross vehicle weight of 6,000 pounds and over). Information from state truck registration records, including the VIN, owner (name and address), and various truck characteristics, is compiled regularly by Polk into this TIP database. To ensure data accuracy in its databases, Polk indicated that multiple tests are routinely conducted to validate registration records, and multiple sources are used to verify owner and VIN data . Note that, in 2013, Polk became a part of the IHS Automotive, which is a service provider of global market, industry and technical expertise and information.

3.3.2 Potentially Useful VIUS-like Information in Polk Data

Because the main purpose of examining the Polk data is to determine whether it could fill the role that VIUS has played in the FHWA models, only the TIP truck database is of concern in this study. Some specific Polk data elements of interest (in the TIP database) for this motor fuel project include:

- Vocation
  This is the registered business type of the owner, which might give clues as to how a truck is used. This variable bears certain similarities with the "Use" variable in the VIUS.
- Vehicle type (truck type)
  Classes 1 and 2, which include pickup truck, minivan, and sport utility vehicles are of particular interest for this project.
- Make, Series, Model, & Model-year
  These are data fields that provide potential clues for determining fuel efficiency (i.e., MPG) that is needed to estimate fuel consumption (i.e., total gallons). Model-year can also be used to determine the age of a vehicle.

- Fuel type

  This variable allows one to separate records on gasoline-fueled vehicles from all other types of vehicles included in the Polk database.
- Registered state

  Similar to VIUS, this data element is used to assign the trucks to a state. Note that a registered state (where the vehicle is registered) is not necessarily the same as the location where the registered truck operates. Due to data limitations, as in the VIUS, registered state is used as a proxy for the state of operation for the given truck.
- Register year

  This data element reflects the year of vehicle registration.
- Mileage reading at time of registration

  Because data collected for truck is based on registration records, owner-reported odometer readings at the time of vehicle registrations are available, although not in all records. Most states require reporting the mileage during the initial registration of a vehicle by its owner, but do not necessarily require this reading in its subsequent annual renewals. Thus, multiple mileage readings on a vehicle might be possible but it is not expected to be consistently available for all vehicles.

In fact, the idea of utilizing Polk data in estimating truck inventory and use is not new. In 2011, California Hybrid, Efficient and Advanced Truck Research Center (CalHEAT) conducted a California Truck Inventory and Impact Study, which used Polk data as one of its primary resources. The goal of that study was, as stated in a report released by CalHEAT [31], "to better understand the various types of trucks used in California, their relative populations, and how they are used." The focus of that specific study was on classes 2 to 8 trucks. In addition to Polk data, major information sources for the CalHEAT study included 2002 VIUS data, and a couple of other state (California) reports. No technical procedure or estimation process was specifically described in this CalHEAT report, however. In the final report of an associated CalHEAT project, entitled *Research and Market Transformation Roadmap for Medium- and Heavy-Duty Trucks*[3], the authors stated that:

> *"… secondary research on the average VMT, fuel consumption, and emissions per mile for each of the truck categories to define the average fuel used and NOx and CO2e emission levels. These averages were then multiplied by the vehicle populations derived in the truck population inventory to develop baseline fuel consumption… "*

This points to the possible use of 2002 VIUS data for obtaining average VMT and fuel consumption, since the 2002 VIUS was specified in the CalHEAT report as one of its

[3] CalHeat Truck Research Center, Feb. 2013. http://www.calstart.org/Libraries/CalHEAT_2013_Documents_Presentations/CalHEAT_Roadmap_Final_Draft_Publication_Rev_6.sflb.ashx.

information sources and Polk data does not contain annual mileage information on the registered vehicle.

Rather than purchasing the Polk data, a recent effort was conducted to produce a California Vehicle Inventory and Use Survey (Cal-VIUS 2014) [32] which utilized registration data directly obtained from the California DMV and the International Registration Plan. The design of this study was patterned after the 2002 VIUS questionnaire to ensure consistency between them. This survey was launched by the Institute of Transportation Studies at the University of California- Irvine on December 26, 2014. For additional information on this Cal-VIUS 2014 study, readers are referred to the project website at: http://freight.its.uci.edu/calvius/.

3.3.3 Evaluation of TIP Data for Potential Use in the FHWA Motor Fuel Program

The Office of Policy Information in the FHWA has an annual subscription of Polk data, mainly for generating statistics needed in the *Highway Statistics* (e.g., Table VM1). In order to evaluate its potential usefulness in supporting the Motor Fuel Program, the ORNL research team contacted the Federal Business Manager at Polk to discuss information needs and acquired a sample dataset of the TIP file.

3.3.3.1 Description of the TIP sample data file

The sample dataset provided by Polk contains records extracted from the TIP VIO database for the March 2014 reporting month. To limit the size of this sample file, Polk included only those VIO that met the following criteria:

- Reporting state is Tennessee,
- Each registration name has 10 or more units registered, and
- Must have mileage of at least 5,000 miles per year of age.

Note that "age" referred to above is calculated based on model year of the registered vehicle and the reporting year (i.e., 2014). The "mileage" is the reported odometer reading at the time of registration. Specifically, the sample file provided for this evaluation contains 53,465 records, representing 53,518 Class 1 to Class 8 vehicles registered in Tennessee in March 2014. The data elements (variables) provided for each record are discussed below, along with some results produced from reviews of this sample dataset.

Reg_Vocation

As mentioned previously, this is the business type reported by the registered vehicle owner. Table 3–6 provides a list of vocations as found in the sample TIP VIO sample dataset. The counts are provided as a reference for Tennessee, since distributions of businesses in an individual state are likely to be different due to variations among regions. Clearly, as seen in Table 3–7, some of the vocations might be out of scope for this motor fuel study purpose; e.g.,

"bus transportation" and "individual." Furthermore, government vehicles are categorized under the Public Use, thus the vocation of "government/miscellaneous" might be considered as out-of-scope for the non-highway use share of this motor fuel study. Note that, some effort would be needed to categorize these vocations into use-groups (e.g., industrial/commercial), if Polk data is determined to be a suitable alternative source for the motor fuel project.

Table 3-7. Vehicle counts by registered vocation in March 2014 TIP VIO sample data for Tennessee

(Vehicle with at least 5,000 mile per year usage)

Registered Vocation	Vehicle Counts
Agriculture/Farm	463
Beverage Processing & Distribution	256
Bus Transportation	2,136
Construction	6,217
Dealer	1,663
Emergency Vehicles	476
Food Processing & Distribution	815
Forestry/Lumber Products	82
General Freight	2,648
General Freight/Hazardous Materials	104
Government/Miscellaneous	2,099
Hazardous Materials	28
Individual	1,632
Landscaping/Horticulture	1,014
Lease/Finance	13,724
Lease/Manufacturer Sponsored	165
Lease/Rental	2,516
Manufacturing	2,431
Mining/Quarrying	64
Miscellaneous	311
Moving And Storage	108
Petroleum	555
Road/Highway Maintenance	509
Sanitation/Hazardous Material	3
Sanitation/Refuse	311
Services	7,176
Specialized/Heavy Hauling	341
Unclassified	788
Utility Services	1,730
Wholesale/Retail	3,153
All	53,518

MAKE, SERIES, AND MODEL

These variables, along with the Model Year below, provide information that allows one to "look-up" EPA provided data and determine vehicle fuel efficiency (i.e., MPG) for each truck.

Although EPA publishes MPG information for all types of vehicles annually, due to variations in spelling or "short-hand" titles in reporting (registration record), item-to-item data matching between two different sets of records (EPA and Polk files) is likely to be very time consuming. Use of average MPGs by vehicle type would be relatively easy; however, there is no guarantee that the resulting fuel volume estimates (i.e., total gasoline used by vehicles) would have acceptable qualities. If Polk data is to be used for the motor fuel program, it might be necessary to take a specific hybrid approach so that acceptable quality results could be produced within a reasonable processing time.

YR_MDL

This variable provides information on the model year of the reported vehicle, which also reflects the "age" of the given vehicle. Using the Tennessee sample set of the March 2014 TIP VIO file provided by Polk, a distribution of vehicle model year is displayed in Figure 3-7.

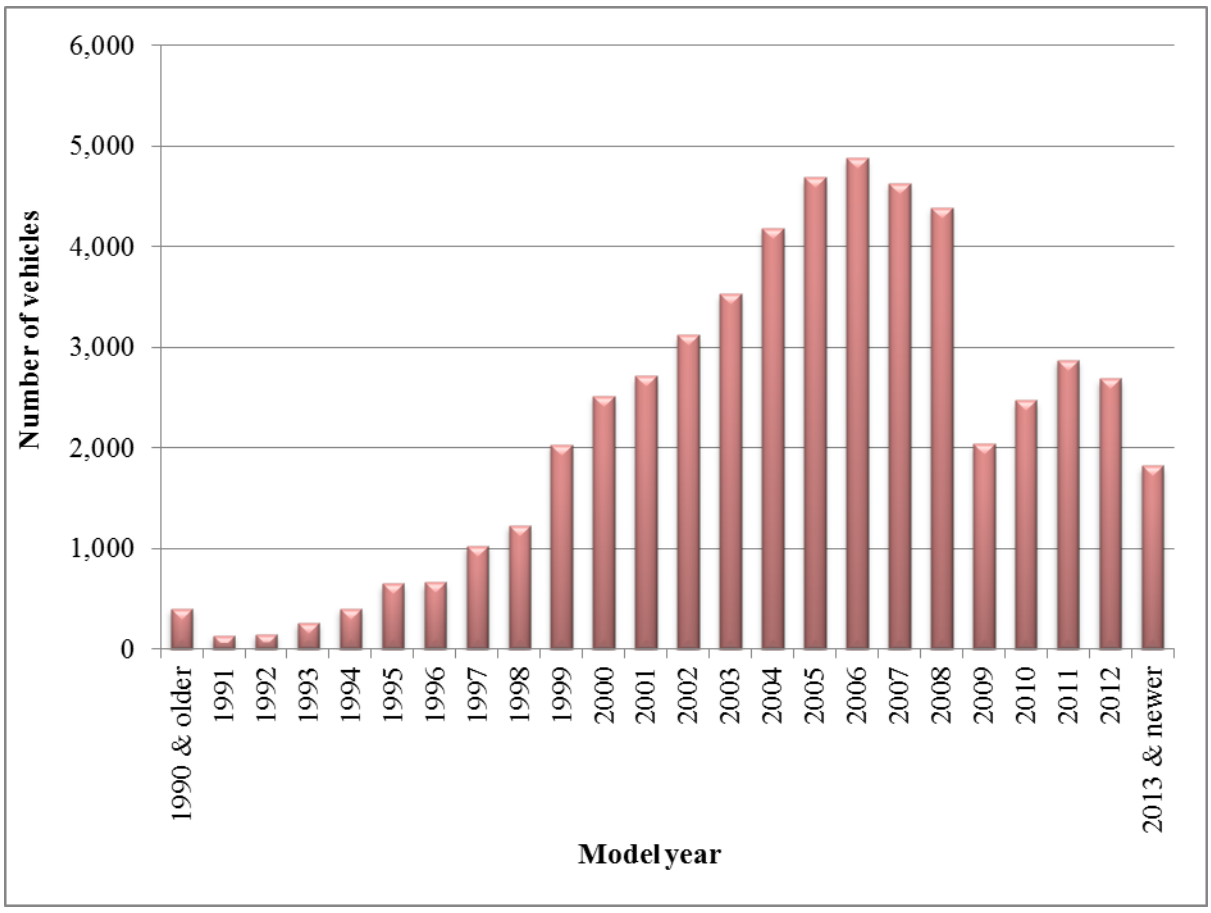

Figure 3-7. Distribution of vehicle model year based on Polk Tip VIO sample set for TN (vehicles with 5,000 or more miles per year).

A significant drop on the number of vehicles with model years 2009 and later is clearly visible in the figure. It is suspected that the 2008-2009 economic downturns might have some effects on

new truck purchases in the state. Evidence of this decline in truck sales at the national level was pointed out in a *Transport Topics Online* report dated April 22, 2013[4]; the Newspaper of Trucking and Freight Transportation publishes this online report.

VIN_GVW

This variable contains the Gross Vehicle Weight (GVW) class of the reported truck, not the actual vehicle weight. Table 3–8 provides a list of FHWA vehicle classes with their associated vehicle weight ratings (in pounds) and categories. The share of vehicle weight classes, using the sample Polk TIP VIO data for Tennessee is given in Table 3–9.

Table 3-8. FHWA Definition of Vehicle Weight Classes

Vehicle Class	Gross Vehicle Weight Rating (lbs)	Gross Vehicle Weight Category
1	<6,000	Light Duty (<10,000 lbs)
2	6,001 – 10,000	Light Duty (<10,000 lbs)
3	10,001 – 14,000	Medium Duty (10,000-26,000 lbs)
4	14,001 – 16,000	Medium Duty (10,000-26,000 lbs)
5	16,001 – 19,500	Medium Duty (10,000-26,000 lbs)
6	19,501 – 26,000	Medium Duty (10,000-26,000 lbs)
7	26,001 – 33,000	Heavy Duty (>26,000 lbs)
8	> 33,001	Heavy Duty (>26,000 lbs)

[4] A new article enti4tled “Truck Sales Decline 24.3%”, Transport Topics Online, Trucking, Freight Transportation and Logistics News,5 April 22, 2013. See http://www.ttnews.com/articles/printopt.aspx?storyid=31790.

Table 3-9. Share O\of Vehicle Weight Classes using March 2014 TIP VIO Sample Data for Tennessee (Vehicle with at least 5,000 mile per year usage)

Vehicle Weight Class	Share (%)
1	34.50
2	48.91
3	4.61
4	2.49
5	1.53
6	2.23
7	2.18
8	3.55
All	100.00

Not surprisingly, light duty vehicles (i.e., those under 10,000 pounds) accounted for the majority of the truck inventory. Specifically, over 83% of the vehicles included in this Polk Tennessee-sample dataset are light duty trucks. This is consistent with the share estimate based on Table VM-1 of the *2013 Highway Statistics*, considering the total number of motor vehicles registered for light duty (long wheelbase), single-unit, and combination trucks. Note that, vehicle classes 1 and 2 (possibly 3 as well) are of the most interest to this motor fuel study, since heavier trucks are generally fueled by special fuels (non-gasoline). A further review on fuel type and vehicle class is presented in the "Fuel Type" section below.

VEH_TYPE

This variable contains information on body type of the reported vehicle. Most pickup trucks, sport utility vehicles, and vans fall into the light duty truck category. Therefore, the number of these light duty trucks (shown in Table 3–10) as calculated from the Polk TIP VIO Tennessee sample dataset also added up to a similar level of total share (~80%).

Table 3-10. Vehicle types covered in the March 2014 TIP VIO sample database for Tennessee (Classes 1 to 8 trucks with at least 5,000 mile per year usage)

Vehicle Type	Total # of Trucks	Share (%)
Pickup	17,852	33.36
Sport Utility Vehicle	13,727	25.65
Van Passenger	6,641	12.41
Van Cargo	5,323	9.95
Straight Truck	3,039	5.68
Cab Chassis	2,637	4.93
Cutaway	1,278	2.39
Tractor Truck	1,200	2.24
Incomplete Pickup	893	1.67
Bus School	544	1.02
Incomplete (Strip Chassis)	138	0.26
Bus Non School	89	0.17
Step Van	68	0.13
Sport Utility Truck	44	0.08
Motor Home	33	0.06
Fire Truck	3	0.01
Gliders	3	0.01
Unknown	6	0.01
All types	53,518	100.00

FUEL_TYPE

Categories of fuel types specified in the March 2014 Polk TIP VIO Tennessee sample dataset include gas, diesel, flexible, electric and gas hybrid, propane, convertible, CNG, and unknown. As seen in Table 3–11, , gasoline-fueled vehicles accounted for nearly 70% of all trucks captured in this Tennessee sample dataset. Since most light duty vehicles are fueled with gasoline, this is clearly a result of the sheer number of light duty vehicles in the truck inventory. This conclusion also is reflected in Figure 3-8, which is based on the same dataset, where gasoline-fueled trucks accounted for the majority of Tennessee vehicles within Classes 1 and 2 categories.

Table 3-11. Share of Fuel Types Based on March 2014 TIP VIO Sample Data for Tennessee (Classes 1 to 8 trucks with at least 5,000 mile per year usage)

Fuel Type	Share by number of trucks (%)
Gasoline (include electric & gas hybrid)	69.17
Diesel	17.50
Flexible	13.29
All other fuels	0.18
Unknown	0.03
All fuel types	100.00

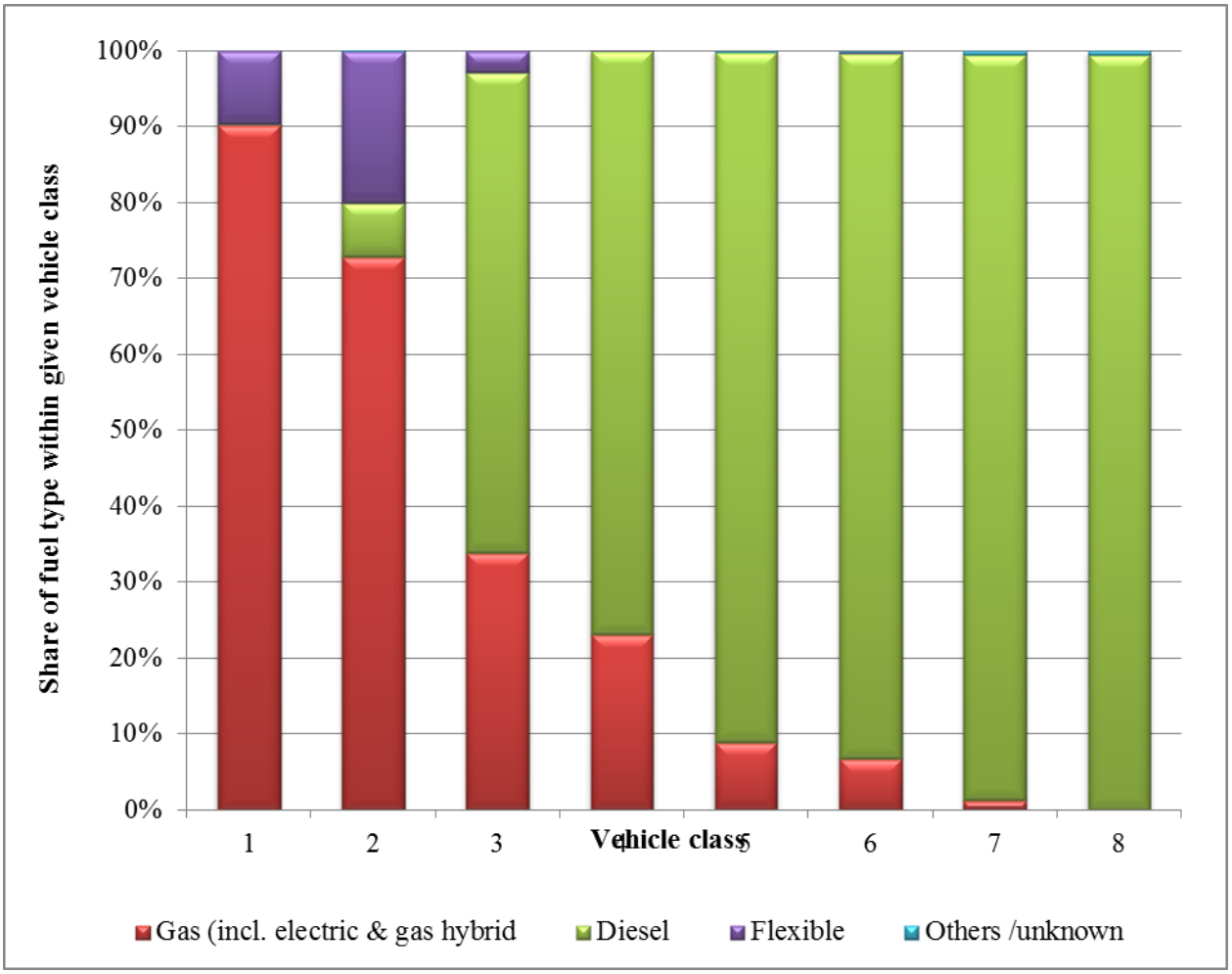

Figure 3-8. Vehicle count distribution by fuel type and vehicle class; based on March 2014 Polk TIP VIO Tennessee sample dataset (vehicles with 5,000 mile or more per year only).

MILEAGE

The mileage field in this Polk sample dataset gives the odometer reading of vehicles at the reporting time (March 2014). Using the model year discussed above and the reporting year of 2014 in this case, vehicle age can be easily estimated. Using the mileage provided in Polk's TIP VIO Tennessee sample dataset, along with its corresponding vehicle age, an "annual average miles driven" by each truck in the sample set can be calculated. The distribution of these annual average miles is summarized in Figure 3-9.

When taking into consideration the vehicle classes, Figure 3-10 shows that on average, vehicles in all classes are driven within 10 to 15 thousand miles annually, except for Class 8 vehicles that booked over 30,000 miles a year. Figure 3-10 also includes medium annual mile estimates for these vehicle classes. All values of averages are higher than their mediums, signifying an influence from certain larger values in each group, most not extreme with the exception of the

Class 8 group. A closer look at the data records found that one model-year 2014 Class 8 truck reported a mileage of 532,358 miles, which is in not realistic. The medium value is more robust to such an extreme value than the average.

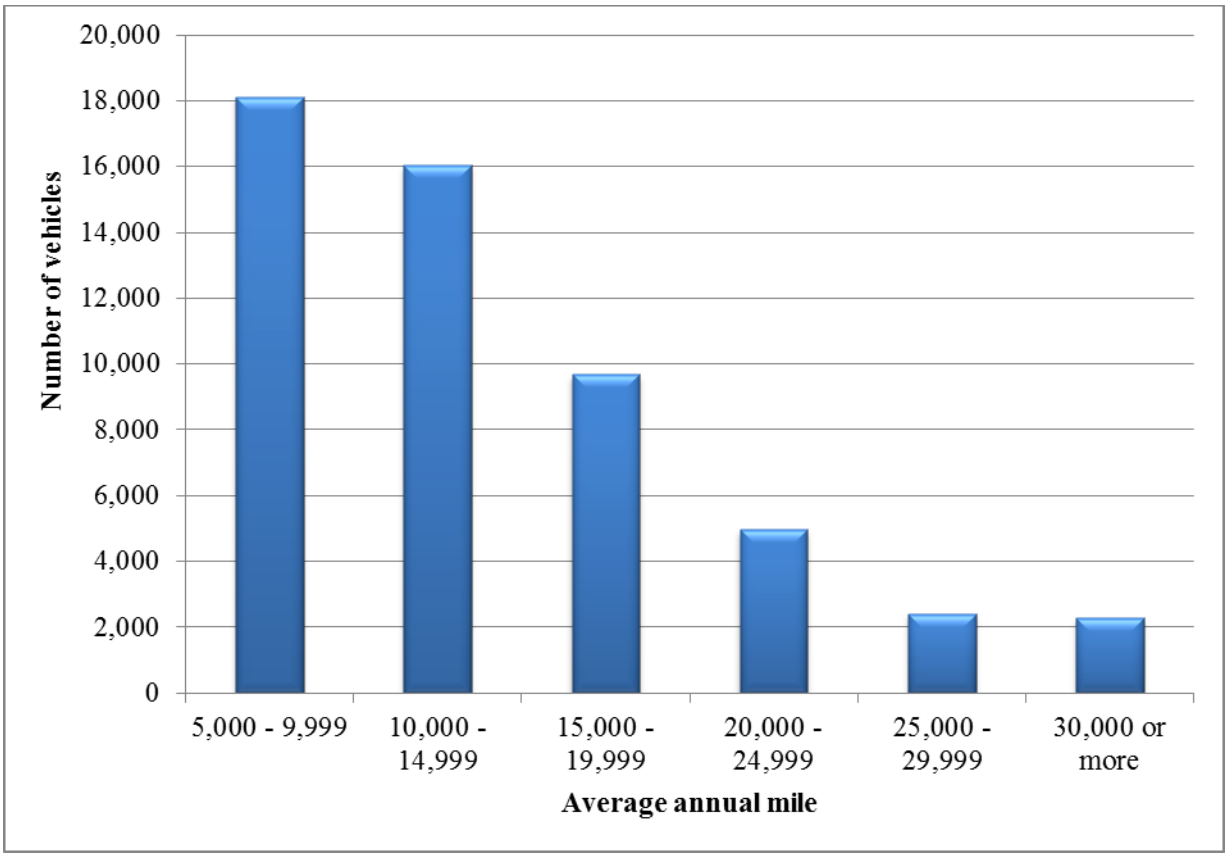

Figure 3-9. Annual average mile distribution for vehicles in the March 2014 Tennessee TIP VIO sample dataset (includes only vehicle with a minimum of 5,000 mile per year).

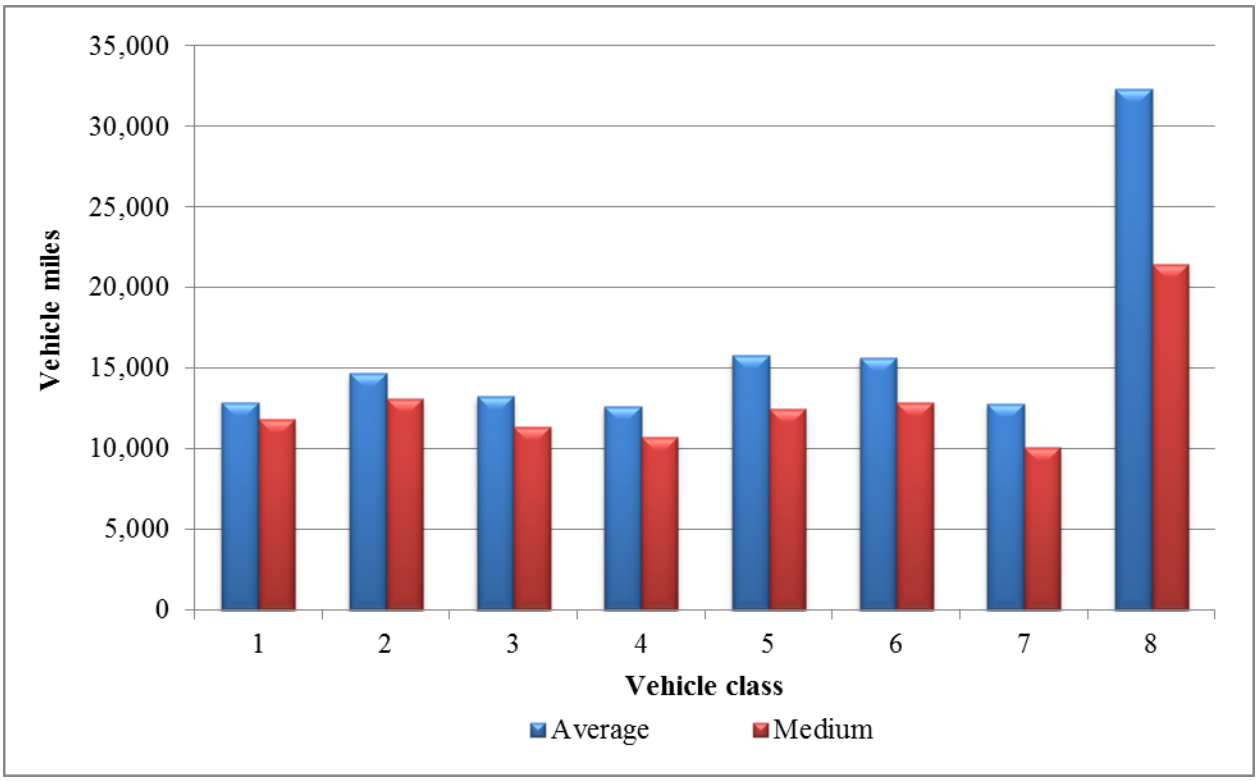

Figure 3-10. Average and medium vehicle miles by vehicle class; based on Polk TIP VIO Tennessee sample dataset (vehicles with 5,000 miles or more per year only).

STD_COUNT

This is a count variable for each "unique" combination of given truck characteristics. In a way, this provides an "expansion factor" to bring the total number of records in the dataset to the number of trucks that they represent. All statistics presented in this section utilized this variable so that the results are representative to the population (i.e., Tennessee trucks in operation as of March 2014 that have traveled at least 5,000 miles per year).

3.3.3.2 Potential estimation procedure if used for motor fuel purpose

In order to use Polk data as a potential "substitute" for the role that VIUS played, several processing steps have to be taken. First, a crosswalk between Polk's "vocation" and VIUS "business" has to be established. As mentioned earlier, some of the vocations (e.g., individual, government) might be "out of scope" for this motor fuel study so they can be dropped. This matching process is not necessarily trivial given some vocations are rather ambiguous (e.g., unclassified, miscellaneous).

Next, to obtain MPG information for each of the trucks, some matching effort between the Polk TIP file and the EPA fuel efficiency dataset is necessary. The EPA fuel efficiency file includes detailed vehicle make, series, model, model year, and many other vehicle characteristics. The extent of such a "matching" effort greatly depends on the level of accuracy in terms of vehicle-

specific MPG information that is desired. The higher the accuracy level is, the more the variables will need to be matched, which clearly could be very time consuming. Since only gasoline vehicles are of concern, all non-gasoline vehicles in this Polk dataset are eliminated from the process.

Once the above two processes are done, total gasoline use by truck in each sector can be estimated. Note that these sector totals include both on-highway and off-highway uses of their corresponding vehicles. Because the Polk TIP data does not contain any information regarding a vehicle's off-highway usage, VIUS 2002 based estimates of "percent off-road" would still be needed in order to separate out the non-highway gasoline consumption by sector.

3.3.3.3 Limitations and Challenges of Using Polk Data

As stated at the beginning of Section 3.3.3, FHWA has an annual subscription of Polk data, mainly for generating statistics needed in the *Highway Statistics*. This FHWA subscription includes data items from the NVPP as well as the TIP VIO. As pointed out previously, TIP data elements are more in line with the motor fuel program needs. The FHWA-subscribed TIP dataset, however, does not contain a "mileage" variable (odometer reading) and is limited to Class 3 and higher trucks. That is, in order to extend the TIP data to cover motor fuel program needs, additional records (Classes 1 and 2) and variables (odometer reading, and the year of reading if possible) would need to be purchased from Polk which would incur additional expenses for the FHWA.

Even if FHWA purchases the additional records and data elements, the odometer reading is not always reported by all trucks at the time of vehicle registration. The Polk representative for FHWA stated that the majority of the TIP VIO records do contain this information and many have multiple readings. In that case, ideally, one could take readings from two different reporting years (the most recent two, if multiple readings are available) to get an estimated annual mileage (average over the period – assuming they do not change patterns over years). By doing so, one could expect a better estimate of annual miles traveled (i.e., VMT) for the vehicle than relying on one odometer reading and average over vehicle's age.

For the Tennessee sample dataset, Polk filtered out vehicles with an average of less than 5,000 miles per year when the sample dataset was created, partly to reduce the file size. This constraint could be easily removed or modified to allow more truck records to be included in the analysis. As a part of evaluating Polk's potential role of providing "critical" data variables for the motor fuel program needs (i.e., annual VMT, MPG, percent off-highway), results generated from the sample dataset were compared with published values from the *Highway Statistics*.

Based on Table VM-1 of the *2013 Highway Statistics*, FHWA estimated that light duty trucks (long wheelbase) traveled an average of 11,722 miles per vehicle, single-unit trucks traveled 13,116 miles per vehicle, and combination trucks (heavy trucks) had an annual average of 68,155

miles, nationally. As compared to results from the Tennessee sample presented in Figure 3-8, clearly, the TIP-based estimate of annual average miles traveled by Tennessee Class 8 trucks is significantly lower (i.e., 32,000miles versus 68,000 miles). Since the sample set is limited to Tennessee trucks, the reason for this large difference is difficult to pinpoint. However, this does raise certain concerns on the accuracy of using odometer readings reported at registration to estimate annual VMT for trucks.

As noted, Polk does not have any information on the percent of VMT being used off-road (non-highway). If Polk data were to be used for the motor fuel program, one would have to rely on the 2002 VIUS to provide this percentage to separate out non-highway gasoline consumption from the total consumption amount.

4. UPDATED AVIATION GASOLINE USE MODEL

4.1 CHALLENGES IN THE CURRENT AVIATION MODEL

Note that there have not been any updates on the regression equation used in estimating aviation gasoline consumption since its original development in 1994. A recommendation made in the 2008 study suggested that, at the minimum, a recalibration of the model should be performed to obtain updated parameters for this application. Furthermore, by design, the current FHWA aviation model is in some ways over-"penalizing" states with missing EIA data. Under the current method, regardless of the extent of missing data (e.g., missing 1 month or missing all 12 months), the known values of all involved states are ignored and replaced by their regression-estimated amounts, which are then readjusted with a portion of the "left over" control total. Although this is a reasonable approach in general, states with only one or two missing monthly data tend to be overly adjusted under this method. This section discusses a revised method developed by the ORNL research team to eliminate the weakness in the FHWA current model and to improve the accuracy of the resulting estimates.

4.2 DATA SOURCE

In the current FHWA aviation model, the main data source used in this revised model is EIA published annual "aviation gasoline sales volume data" from the *Prime Supplier Sales Volumes*. The major difference here is that, instead of state-level monthly volumes (used in the current model), this revised model relies on annual state-level average daily gallons when available and utilizes regional totals as supplemental information if an estimation is necessary for some states. Data from *General Aviation and Part 135 Activity Surveys* by FAA is also used in the revised aviation model when necessary. The usage of these data sources is described in more detail in the methodology section.

4.3 ESTIMATION METHOD

The Aviation Gasoline Consumption Model is probably the least complicated model among all non-highway gasoline use models covered in this study. State-level aviation gasoline consumption, for the most part, is available from the annual EIA publication *Prime Supplier Sales Volumes* for the analysis year. As an example, out of the 51 regions (states and DC), all but 12 have EIA-reported aviation gasoline volumes in 2012. Moreover, only 5 regions did not have EIA-reported aviation gasoline volumes in 2013.

4.3.1 States with EIA Reported Volume

For states with EIA-published aviation gasoline information, which are presented in thousand gallons per day, their annual consumption can be calculated directly by multiplying the daily

volumes by either 365 or 366 (e.g., 2012), depending on the specific year. Therefore, no estimation procedure is needed for these states.

4.3.2 States Where the Volumes Are Missing/Withheld from EIA Reporting

In addition to state-level statistics, EIA also publishes regional totals by Petroleum Administration for Defense Districts (PADD), which is a geographic aggregation of the states and Washington D.C. into five Districts. The PADD 1 is further divided into three sub-districts, as shown in Figure 4-1. Not shown in the map are the states of Alaska and Hawaii, both are included in the West Coast District, which is PADD 5.

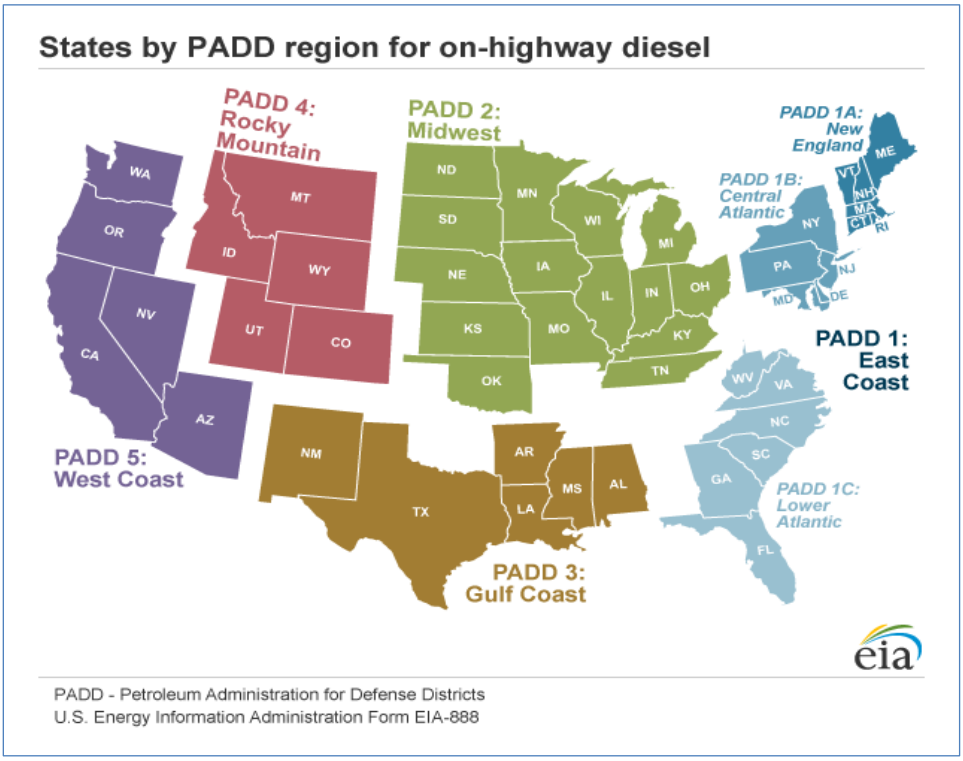

Figure 4-1. States by PADD region.

These regional-level totals are always available even though some state-level data within a district might be withheld from publication in the EIA report. Using the total volume of a given district and sum of those with known state-level data within the district, one can obtain a "residual" volume that should equal to the sum of volumes from those "missing" states. Or mathematically speaking,

$$\sum_{state\ in\ district} (\boldsymbol{missing\ volume\ state}) = \boldsymbol{District\ vloume} - \sum_{state\ in\ district} (\boldsymbol{volume\ of\ known\ state})$$

Now, the remaining question is how to "share" this "residual" volume reasonably among the missing states within the given district. To do so, the state-level total hours flown statistics from

the FAA publication, *General Aviation and Part 135 Activity Surveys*, are used to calculate these shares. The rationale is that aviation gasoline use by a state should be proportionally associated with the usage of aircrafts (thus, the hours flown) in the state. The shares are calculated directly based on the hours flown statistics, no regression equation as in the current FHWA is used.

To illustrate this process, Table 4–1 below shows an example with state data for the New England region (PADD 1A). Here, two states (RI and VT) are missing EIA data. Based on the regional total (i.e., 24.7) and the known volumes from CT, MA, NH, and ME it is obvious the total daily volumes for two "missing volume" states should be summed to 2.0 thousand gallons (i.e., 24.7-3.0-3.8-12.3-3.6 = 2.0). These two states had flown a combined total of 35,127 hours (i.e., sum of the hours: 21,209+13,918).

Table 4-1. Example of Aviation Data from EIA and FAA for States of PADD 1A

State	Aviation Gasoline (Thousand Gallons per Day)	Hours Flown
Connecticut	3.0	771,689
Maine	3.8	140,994
Massachusetts	12.3	955,537
New Hampshire	3.6	66,282
Rhode Island	NA	21,209
Vermont	NA	13,918
New England (PADD 1A)	24.7	1,969,629

Using their individual state-level hours flown statistics from the two unknown states, one can easily obtain their "shares" as 60.4% (21,209 / 35,127 = 0.604) and 39.6% (13,918/35,127=0.396) for RI and VT, respectively. Applying these shares to the above "residual" volume of 2.0 thousand gallons per day, their daily aviation consumption is calculated as 1.2 and 0.8 thousand gallons, for RI and VT respectively.

4.4 RESULTS

The estimation process for aviation gasoline consumption is straightforward. Table 4–2 presents a summary of estimated aviation gasoline consumption for 2012 and 2013 using the revised model discussed in this section. When comparing "totals" from the new model against EIA-published national totals (bottom row in Table 5–2), all differences were within rounding error of +/- 0.04%. For reference, published statistics in MF-24 of the 2012 and 2013 *Highway Statistics* are also listed in Table 4–2. Note that shaded cells highlight states without EIA-reported values which required estimates. Only five states were missing from the EIA data and needed estimations in 2013; while 12 missing states required estimations in 2012. The ORNL research team recommends the use of this newly developed model, instead of the current FHWA model for aviation gasoline estimation.

Table 4-2. Estimated Gasoline (Thousand Gallons) Consumption by Aviation for 2012-2013

STATE	*New model 2012*	*MF-24 2012*	*New model 2013*	*MF-24 2013*
Alabama	2,665	2,819	2,774	2,442
Alaska	6,735	2,870	997	6,692
Arizona	7,081	8,452	7,811	6,700
Arkansas	2,187	1,521	1,424	3,382
California	21,316	16,754	26,645	16,449
Colorado	4,818	5,054	3,322	3,597
Connecticut	1,606	1,211	1,095	3,151
Delaware	574	7,606	475	2,047
District of Columbia	290	284	37	32
Florida	26,609	18,672	20,550	21,964
Georgia	6,753	5,001	4,964	5,606
Hawaii	1,966	424	208	1,296
Idaho	1,241	1,842	1,679	2,769
Illinois	4,745	4,243	3,468	4,047
Indiana	1,935	2,942	2,482	3,555
Iowa	2,884	1,698	2,300	2,321
Kansas	2,482	6,317	2,336	3,028
Kentucky	10,147	1,601	2,008	1,238
Louisiana	8,030	2,685	2,701	4,289
Maine	998	2,192	1,387	747
Maryland	742	1,963	1,716	1,645
Massachusetts	4,452	1,622	4,490	2,068
Michigan	4,380	2,128	3,504	4,455
Minnesota	4,234	3,387	3,468	4,082
Mississippi	1,791	1,753	2,884	3,003
Missouri	5,293	2,814	2,884	3,801
Montana	1,825	1,951	1,716	1,783
Nebraska	12,556	1,770	1,460	1,664
Nevada	3,089	1,870	1,387	2,542
New Hampshire	1,278	1,030	1,314	1,046
New Jersey	3,942	2,490	2,008	2,884
New Mexico	1,643	1,683	1,862	1,776
New York	5,439	2,098	3,395	1,769
North Carolina	6,278	4,621	4,490	5,906
North Dakota	2,008	1,057	2,154	989
Ohio	3,979	3,333	4,198	5,344
Oklahoma	2,300	5,001	2,044	6,319
Oregon	4,088	3,175	3,760	4,833
Pennsylvania	5,658	3,358	6,315	5,118
Rhode Island	332	185	484	180
South Carolina	1,205	2,904	2,263	1,791
South Dakota	1,278	3,946	1,241	1,399
Tennessee	16,352	-	3,030	3,015
Texas	36,829	19,467	24,565	31,407
Utah	6,132	2,817	2,774	2,349
Vermont	276	338	246	314
Virginia	2,446	2,861	2,555	3,506
Washington	8,213	3,614	5,694	7,898
West Virginia	657	804	621	899
Wisconsin	2,957	2,998	2,884	2,501
Wyoming	767	11,726	657	1,031
Total	**267,472**	**192,952**	**190,713**	**212,669**
EIA Total	**267,509**	**267,509**	**190,749**	**190,749**

5. REVISED RECREATIONAL BOATING GASOLINE USE MODEL

5.1 BACKGROUND

The main limitation of the current FHWA recreational boating model is on its outdated data source, the current FHWA model is still using information gathered from the 1991 boating survey. Although a private source of *Boating Registration Statistics*, published by the National Marine Manufacturers Association[18], was mentioned under the 2008 study as a potential data source to supplement FHWA models, the proprietary nature of that data ultimately limited its usefulness to the FHWA.

Fortunately, databases produced from a more recent USCG survey (i.e., *2011 and 2012 NRBS*) allows for a superior approach for estimating fuel use by recreational boat to be developed. The *2011 NRBS* survey collected detailed information such as: boat ownership rate per household by boat type on regional and state levels, days and hours of recreational boats' use by boat type on regional level, boat fuel type, and boat hull composition etc.

Under this current model review effort, a brief examination of the newly available USCG survey data (i.e., *2011 NRBS* and *2012 NRBS*) was conducted initially to determine whether these data could be used to improve the FHWA model for gasoline consumption by recreational boating use. Based on this examination, along with considerations of outdated data being used in the current FHWA model, the ORNL team determined that it is essential to develop a new approach for estimating gasoline consumption by recreational boats. Specifically, to take advantage of more recently available data sources and to eliminate the use of old parameters inherited from the original model so that fuel consumption by recreational boating could be more accurately estimated.

5.2 DATA SOURCE

The main data source for this boating model was obtained from the 2011 and 2012 NRBS data. The USCG conducted its *2011 NRBS* from August through December of 2011, by mail as well as by telephone, which targeted U.S. households owning a recreational boat that is registered in the state where it is most often used. The mail survey sample was selected from state's boat registries, while the telephone survey population was the U.S. households owning a recreational boat, or having a member who participated in recreational boating in 2011 [33]. The *2011 NRBS* provided information on boat population and their characteristics. A "Trip Survey" using a panel sample, which is referred as the 2012 NRBS, supplements the "Boat Survey" conducted in 2011. The ICF Macro, Inc. conducted this trip portion of the NRBS on behalf of the USCG, where data was collected monthly during 2012 [34]. This Trip Survey collected exposure information such

as hours that boats and boaters are on the water, which is crucial in estimating fuel consumption for this current motor fuel study.

Other data sources used in this model include the *Consumer Price Index* from the Bureau of Labor Statistics, total number of registered boats from the annual *Recreational Boating Statistics* published by USCG, and *Disposable Personal Income* available from the *Statistical Abstract*.

5.3 ESTIMATION METHOD

5.3.1 Gasoline-Powered Boat Population

The latest version of *Recreational Boating Statistics* is for 2013, which was released by USCG in May 2014. Recreational vessel registration data by state, along with the scope of the state's registration program, is published in this report for 2012 and 2013. Table 5–1 shows the top five states by their registered number of recreational boats in 2013. Boats registered in these five states accounted for nearly one-third of the total U.S. boat registrations. Note that boat registration regulations vary among states. Table 5–1 also listed the scope of boat registration for the top five states, as an example of showing their variations.

Table 5-1. Top Five States by the Number of Recreational Boat Registrations in 2013

State	Registration	Scope of current boat registration system
Florida	870,749	All motorboats
California	820,490	All motorboats; sailboats over 8 feet
Minnesota	808,744	All watercraft, exclude non-motorized boats 9 feet or less, duck-boats and rice-boats during season, and seaplanes
Michigan	795,875	All watercraft, exclude manually propelled boats 16 feet or less and non-motorized rafts, canoes, and kayaks
Wisconsin	613,516	All motorboats; sailboats over 12 feet
U.S. total	11,993,067	Including 28,835 from U.S. territories

The focus of this research is on estimating gasoline consumption of recreational boats, therefore only a subset of gasoline-powered boats is of concern. Using survey data collected from the *2011 NRBS*, the percent of gasoline-powered boats at the state-level was derived. Assuming this share stays the same in the subsequent years (until the next survey is conducted), the total number of gasoline-powered boats in a given state (during the analysis year) can be estimated by multiplying the share to its corresponding number of registered boats in the year.

5.3.2 Hours of Boat Engine Use

Logically, the frequency and duration of making a boat trip (for recreational purpose) could depend on location, season, and many other factors. Even when a boat is used, many times the

engine might be turned off thus consuming no fuel. In order to estimate gasoline consumption from boating accurately, one needs to consider the hours that the boat engine is indeed operating, instead of counting the hours a boat is "in use." Specifically, the *2012 NRBS* questionnaire of the Participant Survey included two questions designed to gather this information: (1) Were the boat's motors or engines operated during this trip? (2) Approximately how many hours did you operate the motors or engines on this trip? Using the *2012 NRBS* data, average engine-hours per boat on a boat day and average boating days in the year, by state and boat type (e.g., power boat, sail boat), can be generated.

5.3.3 Fuel Efficiency of Recreational Boats

Instead of MPG, the fuel efficiency of boats is typically measured in gallons per hour (GPH) of boat engine use. In this study, the *2012 NRBS* data was also used to derive estimates of GPH by boat type by state. Specifically, the survey asked participants about amount of fuel expenses for their boat trips. Using this fuel cost information, along with EIA data on average gasoline price for some states and at all PADD regions, the GPH for each reporting boat can be estimated. Table 5–2 lists the average fuel efficiency for gasoline-powered boats that operated in 2001/2012, based on data collected from the 2012 NRBS at the national level.

Table 5-2. National average of fuel efficiency for gasoline-powered boats (Derived from *2012 NRBS* survey data)

Boat Type	Average fuel efficiency (GPH)	Number of reported boats
Powerboat	2.10	8,733
Personal watercraft (PWC)	2.31	897
Pontoon	1.68	1,503
Sail boat	0.88	724

The average fuel efficiency of a boat at the state level varies as expected. Figure 5-1 shows estimates generated using the *2011/2012 NRBS* data. Average fuel efficiency for gasoline-powered boats operating in the majority of states (37 out of 51) are within the range of 1.0 to 3.0 GPH for powerboats; while 39 of the 51 states are within a slightly wider range between 1.0 and 4.0 GPH on the PWCs.

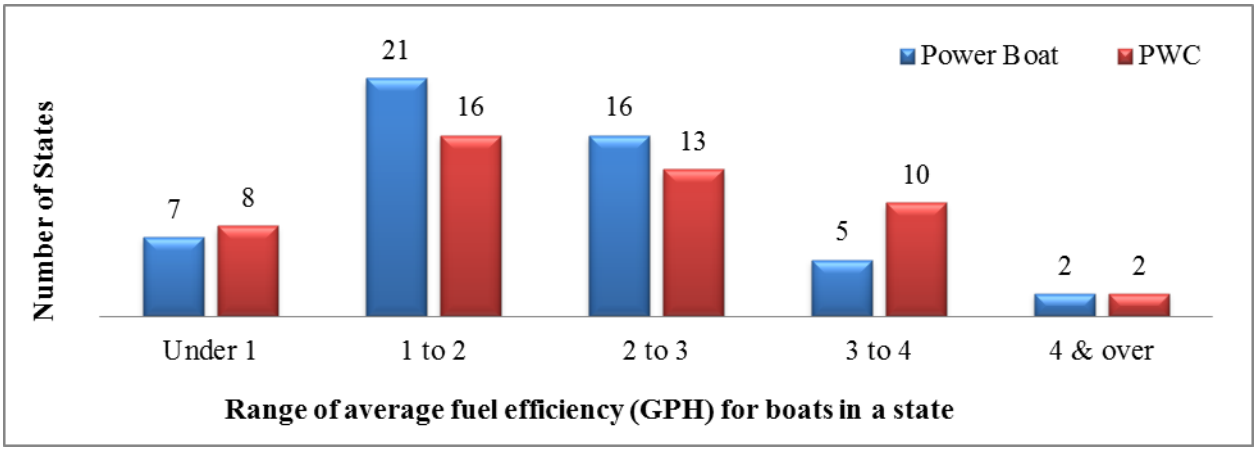

Figure 5-1. Distribution of state-level average fuel efficiency (GPH) for gasoline-powered boats (2012 NRBS data).

5.3.4 Total Gasoline Consumption by Recreational Boats

Based on the above estimates of population size of gasoline powered boats, number of engine hours used per boat, and average fuel efficiency (GPH), a total for gasoline consumption by recreational boats for each state in the "base year" (which is the survey data year of 2011/2012) can be estimated.

To produce estimates for consumption in non-base year (i.e., analysis year), USCG boat registration data for each state in the analysis year is used. By adjusting the base-year number of engine hours in a state with factors calculated as the ratio of Census Deposable Personal Income between the analysis year and base year; and the ratio of their corresponding annual average gasoline prices, the analysis-year number of boat engine hours for the given state can be estimated. Note that these ratios took into consideration of inflation, i.e., "real-dollars" for deposable personal income, and gasoline prices.

The growth adjustment was based on a simple assumption that a higher deposable personal income could mean a higher usage of the boats; on the other hand, higher gasoline prices would reduce boat usages. By assuming the analysis-year average state-level fuel efficiency remains the same as in the base year, the total gasoline consumption by boats in the analysis-year for a given state is estimated by multiplying all three parts together (i.e., gasoline-powered boat population, engine hours per boat, and GPH per boat). Note that this new method is relatively straightforward, and there is no regression equation involved as in the current FHWA model.

5.4 RESULTS

Using the boating model described above, estimates of gasoline consumption at the state level are presented in Table 5–3. At the national level, there is a visible decline pattern in consumption from 2011 to 2013. A comparison of the results between this new boating model

and those reported in MF-24 of the 2013 *Highway Statistics* is showed in Table 5–4. On average, the new model estimated about 21.7% higher fuel consumption than MF-24 for boating activities in 2013. Because several outdated data and factors are used in the current model (e.g., 1991 and 2002 NRBS), which MF-24 estimates were based on, the new model that relied largely on data collected under the 2011/2012 USCG survey is recommended.

Table 5-3. Gasoline Consumption in Recreational Boating, Estimated by the New Model

(Thousand Gallons)

State	2011	2012	2013
Alabama	47,707	48,684	46,256
Alaska	5,881	5,788	6,047
Arizona	10,870	10,459	10,705
Arkansas	23,747	24,139	29,950
California	68,639	61,144	67,588
Colorado	4,644	4,573	4,491
Connecticut	11,618	11,410	11,526
Delaware	10,256	10,315	10,855
Dc	350	247	311
Florida	177,469	174,079	178,344
Georgia	38,547	38,790	39,728
Hawaii	831	860	862
Idaho	4,650	4,754	4,942
Illinois	33,452	33,553	29,357
Indiana	14,888	15,084	15,642
Iowa	9,822	10,205	9,204
Kansas	4,394	4,274	4,310
Kentucky	20,122	20,704	21,293
Louisiana	41,932	43,042	45,105
Maine	13,661	13,859	14,254
Maryland	19,355	18,810	18,906
Massachusetts	15,066	14,894	15,194
Michigan	88,265	89,202	91,887
Minnesota	43,671	45,634	46,337
Mississippi	19,948	17,472	17,995
Missouri	37,090	37,100	38,065
Montana	2,001	2,601	3,107
Nebraska	4,828	4,966	5,214
Nevada	4,947	4,821	4,665
New Hampshire	14,207	14,354	14,744
New Jersey	20,753	19,876	19,804
New Mexico	3,285	3,254	3,208
New York	56,620	55,402	56,169
North Carolina	45,944	46,438	47,223
North Dakota	3,152	4,744	5,537
Ohio	40,186	41,146	43,591
Oklahoma	27,846	28,603	28,861
Oregon	9,729	9,529	9,974
Pennsylvania	27,981	27,754	28,589
Rhode Island	4,364	4,278	4,357
South Carolina	56,589	58,193	60,612
South Dakota	3,798	3,874	3,874
Tennessee	37,076	37,810	38,888
Texas	75,131	76,797	79,328
Utah	9,607	9,936	9,681
Vermont	3,709	3,746	4,052
Virginia	34,122	33,775	34,196
Washington	15,307	15,103	15,996
West Virginia	4,487	5,007	5,613
Wisconsin	54,606	54,778	56,191
Wyoming	2,965	3,014	3,017
Total	**1,330,115**	**1,328,875**	**1,365,646**

Table 5-4. Comparison of Gasoline Consumption in Recreational Boating in 2013

State	New Boating model	MF-24
Alabama	46,256	25,661
Alaska	6,047	7,122
Arizona	10,705	14,875
Arkansas	29,950	16,682
California	67,588	61,200
Colorado	4,491	6,382
Connecticut	11,526	13,341
Delaware	10,855	13,240
District of Columbia	311	508
Florida	178,344	153,514
Georgia	39,728	24,187
Hawaii	862	2,360
Idaho	4,942	7,324
Illinois	29,357	28,265
Indiana	15,642	17,400
Iowa	9,204	12,458
Kansas	4,310	4,241
Kentucky	21,293	16,641
Louisiana	45,105	32,553
Maine	14,254	6,710
Maryland	18,906	21,776
Massachusetts	15,194	15,925
Michigan	91,887	59,010
Minnesota	46,337	39,839
Mississippi	17,995	14,589
Missouri	38,065	24,515
Montana	3,107	4,712
Nebraska	5,214	4,812
Nevada	4,665	4,918
New Hampshire	14,744	7,938
New Jersey	19,804	30,623
New Mexico	3,208	2,980
New York	56,169	56,053
North Carolina	47,223	42,153
North Dakota	5,537	3,201
Ohio	43,591	41,907
Oklahoma	28,861	19,943
Oregon	9,974	12,694
Pennsylvania	28,589	27,628
Rhode Island	4,357	4,254
South Carolina	60,612	41,476
South Dakota	3,874	3,154
Tennessee	38,888	22,224
Texas	79,328	51,252
Utah	9,681	7,857
Vermont	4,052	1,632
Virginia	34,196	26,678
Washington	15,996	25,918
West Virginia	5,613	4,312
Wisconsin	56,191	29,656
Wyoming	3,017	4,230
Grand Total	**1,365,646**	**1,122,523**

6. REVISED METHOD FOR ESTIMATING GASOLINE CONSUMPTION IN THE AGRICULTURAL SECTOR

As discussed in Section 2 of this report, the current FHWA agricultural model estimated non-highway gasoline consumption by the agricultural sector in two separate components, truck and farm-equipment. Two major concerns on the current agricultural model are: the use of outdated VIUS 2002 data as its primary source for the truck component and the utilization of a regression equation developed nearly two decades ago in the equipment component.

6.1 DATA SOURCE

As in the current FHWA agricultural model, the main data source used in estimating off-highway gasoline consumption by farm equipment in the agriculture sector is based on data obtained from the USDA. Specifically, data collected under the *Census of Agriculture* and the *Annual Farm Production Expenditures* which are published by NASS. Additional data applied in the agricultural estimation model includes information published in the *Petroleum Marketing Monthly* by EIA, and *Highway Taxes and Fees* published by the FHWA.

Note that the *Census of Agriculture* is under a five-year data collection cycle. The current FHWA consumption estimation model used the data from *2007 Census of Agriculture.* The latest 2012 Census report with state- and county-level data was released in May 2014. The most current *Farm Production Expenditures Annual Summary* publication has 2013 data which was released in August 2014. Note that the states of Alaska and Hawaii are excluded from these production expenditure tables.

6.2 ESTIMATION METHOD

The state-level estimation method for gasoline consumption in the agricultural sector stays relatively unchanged. Simply speaking, farm-based gasoline expenditure by individual state in the Census year is estimated using available USDA sources first. Using gasoline price information by state from EIA, the expenditures data are then converted into gallons. The following sections briefly describe the estimation procedures used in the revised model.

6.2.1 Total Fuel Expenditures and Shares of Gasoline Expenditure

Based on data published in the *Farm Production Expenditures* for the Census year (i.e., 2012) and the latest year (generally a year behind the analysis year), total fuel expenditures for the top fifteen U.S. states and the five Farm Production Expenditure Regions (Atlantic, South, Midwest, Plans, and West; see Figure 6-1) can be directly obtained. Furthermore, gasoline-specific expenditures at the regional level are also published in the same USDA report, which allows one to estimate the share of gasoline expenditures by region. In other words, gasoline share of

expenditures at the regional level for each individual year (Census year as well as analysis year) can be calculated using data published in the *Farm Production Expenditures* of its corresponding year. Table 6–1 shows these expenditures information, along with estimated gasoline share of expenditures, by region in the USDA Census year of 2012. The same set of gasoline share of expenditures for the analysis year can also be generated using information obtained from the corresponding annual *Farm Production Expenditures* report.

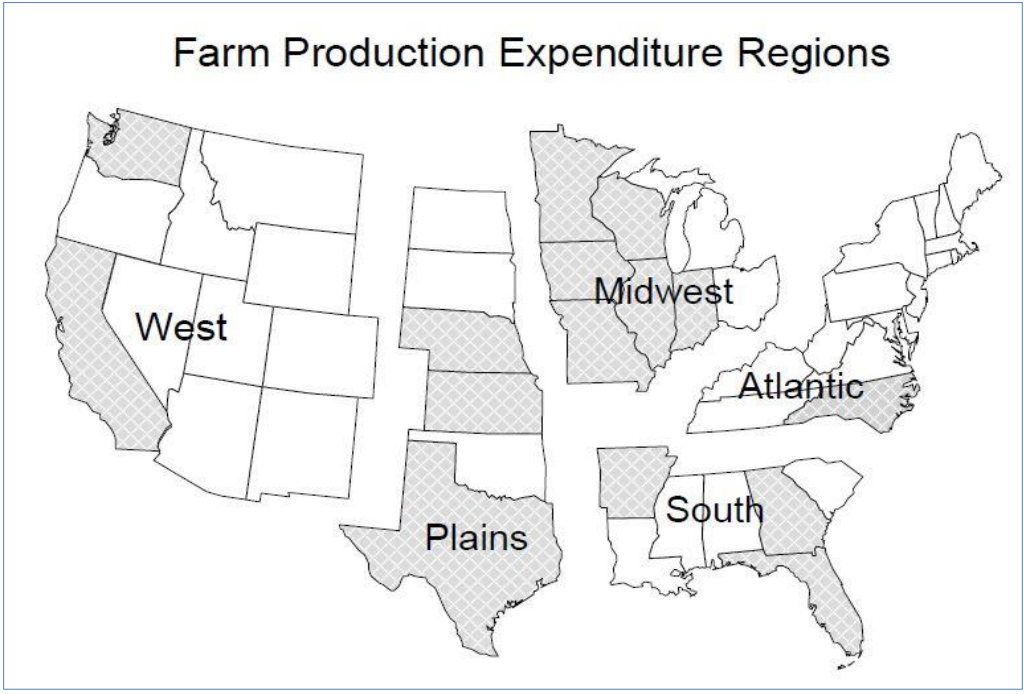

Figure 6-1. Farm production region (top 15 production states are shaded).

Table 6-1. Base year (2012) fuel expenditures data by Farm Production Expenditure Region (Source: *Farm Production Expenditures* for 2012)

Region	Fuels expenditures (thousand $)	Gasoline expenditures (thousand $)	Percent Gasoline expenditures
Atlantic	2,040,000	460,000	22.5%
South	1,900,000	350,000	18.4%
Midwest	4,580,000	770,000	16.8%
Plains	3,900,000	780,000	20.0%
West	2,980,000	740,000	24.8%
U.S. Total	15,400,000	3,100,000	20.1%

6.2.2 Gasoline Expenditures by State in Analysis Year

As pointed out previously, information on total fuel expenditures in the analysis year is available at the regional level and for the top 15 states. In order to estimate analysis-year fuel expenditures

for states other than the 15 known ones, the regional-level "residual" fuel expenditures for the analysis-year need to be distributed among unknown states within its corresponding region. This step requires the use of additional information for the Census year. The *2012 Census of Agriculture* published total fuel expenses (including gasoline, fuels, and oil) by farm for **all** states in Table 3 of this Census report. This data allows one to calculate the share of expenditures for states within each region, specifically for states outside the fifteen that were reported in the *Farm Production Expenditures* for the Census year.

To illustrate this process, an example using the South region is presented here. The state-level expenditures data as published in Table 3 of the *2012 Census of Agriculture* report, and their reporting status in the *Farm Production Expenditures* report, are extracted and presented in Table 6–2 in this example. The shares of fuel expenditures, calculated based on the Census reported fuel expenditures, for states that were aggregated in the "other states" category (in *Farm Production Expenditures*) are also provided in Table 6–2.

Table 6-2. An example on South region data to illustrate procedures used in model (*2012 Agriculture Census* data)

State	Fuel expenditures in 2012 Census ($1,000)	*Farm Production Expenditures* reporting status	Share of expenditures for other states
Arkansas	510,909	Reported/known	
Florida	325,053	Reported/known	
Georgia	346,738	Reported/known	
Alabama	179,640	Included in "Other States" total	21.4%
Louisiana	235,089	Included in "Other States" total	28.1%
Mississippi	288,348	Included in "Other States" total	34.4%
South Carolina	134,969	Included in "Other States" total	16.1%
Regional total	2,020,746		

Using these Census-year based shares, and assuming this distribution remains in the analysis-year, the total analysis-year fuel expenditures for "other states" as reported in the *Farm Production Expenditures* for that year can be distributed to obtain state level expenditure information. Once total fuel expenditures in all states are estimated, the regional gasoline expenditure shares as discussed in Section 6.2.1 can be applied to generate gasoline-specific expenditures for each state. Note that states of Alaska and Hawaii are excluded from the *Farm Production Expenditures* reporting. Thus, the gasoline share of fuel expenditures at the national level (i.e., 20.1% in 2012) is used to generate these two states' gasoline-specific expenditures estimates.

6.2.3 Gasoline Consumption Estimates by State

The next step is to convert these gasoline-specific expenditures data into total gallons of gasoline used by farm equipment and vehicles. This process is calculated by dividing the gasoline-specific expenditures data for each state with its corresponding state-level average gasoline price in the analysis year, similar to that in the recreational boating model.

6.2.4 Estimating Non-Highway Gasoline Consumption by State

The total gasoline consumption estimated so far includes gasoline used by all farm equipment and vehicles. Typically, farm equipment is not permitted to operate on highways, thus gasoline consumption by farm equipment should be considered as non-highway use. Farm vehicles on the other hand might be used for both on- and off-highway. Because of this, the gasoline consumption estimated so far needs to be adjusted to remove the on-highway gasoline use of farm vehicles.

To do so, first, the EPA NONROAD2008 estimated gasoline consumption by agricultural equipment in each state is subtracted from its corresponding state total gasoline consumption obtain above. The remaining vehicle share of state gasoline gallon is then divided into highway and non-highway consumption by applying the state's non-highway agricultural use share calculated from 2002 VIUS. This last step is the only step that relies on the old VIUS data--a limitation due to lack of other alternatives.

6.3 RESULTS

As described above, this revised agricultural gasoline consumption estimation model utilizes, for the most part, the USDA published data. The EPA NONROAD2008 model estimated gasoline usage by agricultural equipment was used in order to separate out vehicle (truck) involved gasoline consumption. This model revision eliminated many drawbacks found in the existing FHWA model, such as the use of an obsolete regression equation and a completely VIUS-based estimation process on fuel consumption by truck. Until better data on the percent of off-highway use by truck for agricultural purposes could be found, this model has no choice but to continue to apply the same off-highway share (of gasoline consumption by truck) calculated from the 2002 VIUS data.

Table 6-3 presents results generated using this new estimation model for non-highway gasoline consumption by agricultural sector in each state annually during 2011-2013. The 2013 estimates published in Table MF-24 of *Highway Statistics* were also included in the same table for easy reference. As seen in Table 6–3, estimates from the new agriculture model are much smaller than the estimates published in MF-24. Further investigation indicated that state-level agricultural fuel consumption published in MF-24 appear to be overestimated, however.

As a quick illustration, the *2012 Census of Agriculture* report showed $3,100 million as the total gasoline expenditure in the nation. For ease of calculation, if one assumes gasoline price of $3.0 per gallon, this expenditure could be translated into a little over 1 billion gallons of gasoline, which accounts for both on-highway and non-highway use in the agricultural sector (including both equipment and vehicles used in farm operations). The MF-24 reported over 870 million gallons for non-highway agricultural use in 2012 (*Highway Statistics 2012*), which accounted for over 85% of the above reference "control total" of 1 billion gallons in 2012. This share of non-highway usage of gasoline is clearly unrealistic. A similar process using 2013 USDA data compared with 2013 MF-24 estimates resulted in a significantly lower but still unreasonably high (60%) for the non-highway share of gasoline usage. Most of this unreasonably high volume in MF-24 estimates may have been attributed to its use of the outdated regression-based approach in the current FHWA agricultural sector model. The revised estimation method developed under this research clearly eliminated that issue.

Furthermore, the MF-24 method used adjustment factors calculated from growths in annual truck VMTs, number of truck registrations, and total fuel consumption by truck might also have certain weaknesses. This is because non-highway activities do not necessarily follow the same economic patterns as those in the on-highway sectors. The factors considered in the MF-24 calculation of growth, as stated above, relied on measures that were dominated by on-highway activities.

Using the "control total" of 1 billion gallon gasoline in the above illustration, the new model's estimate of nearly 132 million gallons in 2012 (bottom row of Table 6–3) would result in about 14%, as the share for non-highway use in the agricultural sector, which seems a lot more reasonable. Because of this, the research team recommended the use of this new model to estimate gasoline consumption by the agricultural sector.

Table 6-3. Non-highway Gasoline Consumption in Agricultural Sector (thousand gallons)

State	New model 2011	New model 2012	New model 2013	2013 MF-24
Alabama	1,306	1,387	1,465	7,435
Alaska	27	28	29	1,199
Arizona	1,328	1,422	1,456	11,201
Arkansas	4,097	4,485	4,250	19,987
California	5,596	6,121	5,896	57,071
Colorado	1,974	2,068	2,080	11,839
Connecticut	41	42	43	3,144
Delaware	122	123	126	3,530
District of Columbia	0	0	0	0
Florida	680	681	698	17,533
Georgia	933	927	926	14,250
Hawaii	112	117	123	677
Idaho	2,169	2,283	2,298	17,843
Illinois	6,339	6,393	6,413	20,801
Indiana	4,309	4,570	4,507	19,375
Iowa	7,524	7,754	7,820	24,543
Kansas	7,822	7,912	7,633	9,816
Kentucky	1,475	1,501	1,534	10,506
Louisiana	2,382	2,539	2,688	12,965
Maine	106	107	109	7,413
Maryland	592	619	645	8,109
Massachusetts	52	53	55	6,977
Michigan	1,888	1,913	1,934	13,588
Minnesota	5,338	5,413	5,461	29,087
Mississippi	4,449	4,798	5,117	14,847
Missouri	4,588	5,068	4,882	1,200
Montana	4,139	4,361	4,390	8,361
Nebraska	5,830	6,305	6,068	13,955
Nevada	617	660	675	1,535
New Hampshire	26	26	26	2,056
New Jersey	431	462	488	6,855
New Mexico	347	361	366	7,865
New York	1,768	1,848	1,922	21,236
North Carolina	2,063	2,261	2,213	22,770
North Dakota	8,784	9,205	9,619	7,884
Ohio	2,571	2,575	2,608	16,078
Oklahoma	5,392	5,743	6,065	18,465
Oregon	1,011	1,030	1,047	8,045
Pennsylvania	2,693	2,857	3,006	31,502
Rhode Island	5	5	5	947
South Carolina	408	414	423	4,100
South Dakota	5,247	5,444	5,653	9,760
Tennessee	1,218	1,231	1,255	8,827
Texas	6,955	6,963	7,200	73,383
Utah	1,092	1,180	1,184	2,508
Vermont	154	158	162	3,411
Virginia	1,018	1,059	1,094	7,579
Washington	4,195	4,504	4,243	13,685
West Virginia	358	381	398	996
Wisconsin	2,586	2,674	2,651	15,547
Wyoming	1,797	1,952	1,958	2,276
Grand Total	**125,953**	**131,981**	**132,908**	**654,562**

7. NEW METHODS FOR ESTIMATING GASOLINE CONSUMPTION IN INDUSTRIAL, COMMERCIAL, AND CONSTRUCTION SECTORS

As discussed in Section 3, the EPA MOVES2014 (NONROAD2008) model includes non-road use of equipment but not trucks, while Polk TIP VIO truck data lacks more precise measures on annual VMT for each truck or information on its off-road uses. Furthermore, Polk data is a proprietary dataset and there are costs involved to add data items needed for the motor fuel program. For these reasons, a method that utilizes information from published data series was developed by the research team as another option for estimating non-highway gasoline consumption by industry sectors (specifically, industrial, commercial and construction).

7.1 CONSIDERATION OF SUPPLEMENTING VIUS WITH VMT DATA

7.1.1 Data Sources And General Method

Rather than a totally VIUS-based approach as in the existing FHWA model, this new estimation model attempted to utilize information from FHWA published *Highway Statistics* data series, particularly Tables VM-1 and VM-2. Table VM-2 provides VMT information at the state level and represents on-highway uses by all vehicles, while Table VM-1 provides fuel efficiency estimates (i.e., MPG) at the national level. Unfortunately, some information from the 2002 VIUS is still used in this new modeling approach, mainly due to lack of alternative data sources.

7.1.1.1 State level VMT

This new approach starts with the calculation of a simple ratio between 2002 VM-2 data and VIUS2002-based non-highway used VMT by state. Mathematically speaking, this can be expressed as, for each given state,

Non-highway ratio (2002) = non-highway VMT2002 / 2002 VM-2

This state-level ratio is then used to multiply with the given state's VMT amount published in Table VM-2 of the analysis-year to produce an estimate of the total non-highway VMT in the analysis-year for the given state. That is, for each given state,

*Non-highway VMT (analysis year) = VM-2 VMT (analysis year) * Non-highway ratio (2002)*

7.1.1.2 VMT shares by industry sector

To separate the total non-highway VMT estimated above into industry sectors, two methods were examined. The first method used the 2002 VIUS data to calculate sector-shares of non-highway VMT for construction and industrial/commercial. The second method considered in this research was using Census employment data from the annual *County Business Patterns*

(CBP) to compute the industry shares (based on employment counts or payrolls). Although using employment or payroll data for dividing VMT into industry sector (the second method) might not be a desirable approach, the continued use of outdated VIUS data could be a major drawback for the first method. Both methods were carried out initially as options in estimating non-highway consumption under this effort. Because business data such as sales, employment, and payroll are generally not sensitive to non-highway activities, the CBP-based approach was later dropped as recommendations to the FHWA.

7.1.1.3 Non-highway consumption estimates by industry sector

The final step is to divide each sector-specific non-highway VMT estimated from above by its corresponding average MPG, also produced using 2002 VIUS data, to obtain gallon estimates by sector (construction and industrial/commercial) by state. Estimates from these steps are presented below. Note that the VMT-based non-highway gasoline consumption estimates produced here is an attempt to produce VIUS-equivalent consumption estimates, which means that its coverage is for truck only.

7.2 CONSTRUCTION

The 2013 VMT-based estimates for non-highway gasoline use in the construction sector are listed in Table 7–1. Three different sets of VMT-based estimates are provided and vary only in how the industry shares were estimated. The "VIUS-based" means sector shares are calculated using 2002 VIUS data; while the CBP-employment and CBP-payroll use CBP data on employment or payroll, respectively, to estimate the sector shares. While EPA NONROAD2008 model estimates for the same year are also provided in this table, they are for reference purposes only. This is because that EPA model covers equipment only (see Table 3–1 in Section 3) and the VMT-based model (as in VIUS) only includes trucks resulting in these measures becoming incomparable. To have a more complete view of non-highway gasoline uses in the construction sector, consumption from both equipment and vehicle should be considered. Therefore the research team recommends the FHWA consider combining gasoline consumption results from both equipment and non-highway use of vehicles for the construction sector.

Table 7-1. Non-highway gasoline use by construction sector in 2013 (thousand gallons)

State	VMT-Based	CBP-Employment	CBP-Payroll	EPA NONROAD
Alabama	2,352	7,395	8,499	1,935
Alaska	359	1,613	2,947	329
Arizona	10,970	10,905	12,534	4,350
Arkansas	6,079	4,809	5,769	1,015
California	24,612	19,318	20,136	14,303
Colorado	10,199	7,734	9,806	2,849
Connecticut	308	195	210	1,167
Delaware	717	857	887	394
District of Columbia	29	11	10	449
Florida	29,244	20,242	20,143	12,591
Georgia	2,172	2,200	2,314	4,990
Hawaii	2,330	1,882	3,031	446
Idaho	4,693	5,635	6,887	748
Illinois	4,630	3,089	3,950	4,899
Indiana	3,622	4,788	6,413	3,214
Iowa	1,988	2,194	2,943	1,599
Kansas	3,769	5,266	6,491	1,118
Kentucky	1,457	1,929	2,481	1,786
Louisiana	3,600	10,232	14,582	1,634
Maine	1,060	1,027	1,213	498
Maryland	1,515	1,599	1,741	2,327
Massachusetts	1,381	704	818	2,068
Michigan	10,408	6,360	8,323	3,586
Minnesota	8,767	4,927	6,853	2,630
Mississippi	2,097	2,543	3,335	932
Missouri	3,703	3,062	3,770	2,361
Montana	2,808	5,292	8,258	240
Nebraska	5,095	4,179	4,845	865
Nevada	2,795	4,335	6,231	2,387
New Hampshire	345	563	692	537
New Jersey	1,222	1,221	1,388	2,880
New Mexico	6,326	9,192	12,574	790
New York	3,120	3,819	3,979	5,122
North Carolina	5,064	3,925	3,958	4,741
North Dakota	3,415	6,264	10,700	275
Ohio	6,857	4,630	5,876	4,084
Oklahoma	4,832	12,743	18,943	1,293
Oregon	2,156	3,124	3,694	1,755
Pennsylvania	4,326	4,217	5,259	3,732
Rhode Island	201	186	240	285
South Carolina	2,850	2,459	2,708	2,445
South Dakota	1,096	1,376	1,774	301
Tennessee	9,265	6,037	6,725	2,636
Texas	11,259	21,570	28,323	11,357
Utah	1,820	3,842	4,628	1,260
Vermont	275	242	311	219
Virginia	1,926	1,750	1,742	3,775
Washington	3,273	5,330	6,033	2,999
West Virginia	2,123	5,753	9,516	433
Wisconsin	5,872	3,785	5,457	2,561
Wyoming	2,426	9,308	14,170	255
US	**232,807**	**255,660**	**324,109**	**131,443**

7.3 INDUSTRIAL/COMMERCIAL

Similarly, Table 7–2 presents 2013 VMT-based estimates for non-highway gasoline use in industrial and commercial sectors. The EPA NONROAD2008 model produced results for equipment (see Table 3–2) are also listed as a reference. Similar to the construction sector, consumption from both equipment and vehicle should be considered in order to have a complete picture of non-highway gasoline uses in the industrial and commercial sectors. The research team thus recommends the FHWA consider combining gasoline consumption results from both equipment and non-highway use of vehicles for the industrial/commercial sector.

Table 7–3 provides a comparison between MF-24 2013 estimates and those from the new model for 2013, by construct and industrial/commercial sectors. The MF-24 estimates for California and Texas were very high, likely due to their shares of non-residential construction contracts (9.4% and 8.2%, respectively) which was the main factor used in the MF-24 method to distribute national gasoline consumption to the state level. As in agricultural sector model, MF-24 used growth factors produced from the number of vehicle registration, truck MPGs, and CPI to adjust 2002-VIUS based estimates. By doing this, it was assumed that non-highway activities in construction and industrial/commercial sectors behaved the same as their counterparts within the on-highway sectors. Thus, the estimates could possibly be biased on the high side.

Table 7-2. Non-highway Gasoline Use by Industrial/Commercial in 2013 (thousand gallons)

State	VMT-Based	CBP-Employment	CBP-Payroll	EPA NONROAD
Alabama	12,462	51,137	56,556	15,951
Alaska	924	4,915	4,935	2,378
Arizona	35,014	86,857	97,272	17,665
Arkansas	9,035	42,046	47,173	9,977
California	32,667	159,649	186,501	156,606
Colorado	10,646	49,577	58,283	20,726
Connecticut	456	2,123	2,615	13,054
Delaware	1,492	6,408	7,466	2,596
District of Columbia	118	329	442	893
Florida	52,129	195,435	218,510	80,070
Georgia	3,726	23,117	26,350	36,279
Hawaii	3,741	12,992	13,642	4,715
Idaho	8,686	37,376	41,537	5,270
Illinois	6,987	33,569	39,035	55,547
Indiana	6,677	33,334	37,737	23,647
Iowa	2,690	16,903	19,199	13,552
Kansas	10,101	34,657	39,499	13,385
Kentucky	3,345	14,027	15,574	13,162
Louisiana	4,749	33,281	37,612	19,240
Maine	2,793	7,630	8,377	4,591
Maryland	1,918	10,969	12,644	15,937
Massachusetts	1,776	7,579	9,340	25,339
Michigan	10,824	72,875	83,022	36,147
Minnesota	5,954	50,707	59,605	24,665
Mississippi	2,105	18,695	20,071	8,642
Missouri	5,119	24,308	27,916	23,374
Montana	5,424	20,113	21,923	4,250
Nebraska	6,134	36,788	41,331	7,962
Nevada	5,842	24,103	25,720	6,781
New Hampshire	766	4,742	5,349	5,553
New Jersey	2,599	12,692	15,065	43,587
New Mexico	8,677	32,155	35,820	6,582
New York	7,152	33,073	41,284	93,441
North Carolina	6,051	31,061	35,956	32,854
North Dakota	4,969	26,358	27,577	4,270
Ohio	6,207	42,403	48,682	44,868
Oklahoma	12,254	51,847	56,804	15,545
Oregon	4,942	20,679	23,711	15,524
Pennsylvania	6,019	28,839	33,667	44,566
Rhode Island	376	1,627	1,904	4,003
South Carolina	4,470	23,173	26,516	13,605
South Dakota	2,912	8,837	9,759	3,567
Tennessee	12,318	57,339	63,763	20,925
Texas	21,642	112,142	128,849	95,967
Utah	3,698	21,384	23,310	9,311
Vermont	327	1,717	1,955	2,380
Virginia	2,700	12,863	15,299	20,672
Washington	5,367	35,238	42,184	25,732
West Virginia	3,755	20,490	21,332	5,115
Wisconsin	8,111	39,547	44,662	21,709
Wyoming	3,217	13,334	13,274	3,177
US	**382,064**	**1,743,039**	**1,976,610**	**1,195,355**

Table 7-3. Comparison of New Model and MF-24 Estimates by Construction and Industrial/Commercial in 2013 (thousand gallons).

State	New Industry/ Commercial	MF-24 Industry/ Commercial	New Construction	MF-24 Construction
Alabama	12,462	7,532	2,352	6,331
Alaska	924	2,143	359	6,229
Arizona	35,014	14,488	10,970	15,150
Arkansas	9,035	4,128	6,079	7,697
California	32,667	68,718	24,612	136,665
Colorado	10,646	9,967	10,199	13,744
Connecticut	456	6,479	308	11,043
Delaware	1,492	1,710	717	1,880
District of Columbia	118	959	29	502
Florida	52,129	36,865	29,244	31,036
Georgia	3,726	18,243	2,172	24,785
Hawaii	3,741	3,345	2,330	1,770
Idaho	8,686	2,925	4,693	3,569
Illinois	6,987	23,897	4,630	39,762
Indiana	6,677	9,993	3,622	27,751
Iowa	2,690	4,614	1,988	11,554
Kansas	10,101	3,936	3,769	8,873
Kentucky	3,345	5,729	1,457	13,002
Louisiana	4,749	10,301	3,600	25,458
Maine	2,793	2,020	1,060	2,763
Maryland	1,918	13,688	1,515	11,203
Massachusetts	1,776	12,880	1,381	20,232
Michigan	10,824	13,717	10,408	30,785
Minnesota	5,954	11,598	8,767	19,891
Mississippi	2,105	4,773	2,097	7,485
Missouri	5,119	7,985	3,703	14,895
Montana	5,424	1,987	2,808	1,820
Nebraska	6,134	3,215	5,095	5,923
Nevada	5,842	7,101	2,795	3,980
New Hampshire	766	2,142	345	3,750
New Jersey	2,599	14,934	1,222	24,451
New Mexico	8,677	3,460	6,326	5,214
New York	7,152	34,457	3,120	39,367
North Carolina	6,051	16,139	5,064	30,713
North Dakota	4,969	1,669	3,415	2,912
Ohio	6,207	13,487	6,857	38,068
Oklahoma	12,254	6,313	4,832	13,893
Oregon	4,942	6,824	2,156	21,545
Pennsylvania	6,019	21,147	4,326	36,851
Rhode Island	376	2,102	201	2,022
South Carolina	4,470	7,923	2,850	11,065
South Dakota	2,912	1,499	1,096	2,012
Tennessee	12,318	8,694	9,265	21,121
Texas	21,642	60,271	11,259	122,183
Utah	3,698	5,404	1,820	8,564
Vermont	327	981	275	1,004
Virginia	2,700	16,869	1,926	17,547
Washington	5,367	15,114	3,273	18,978
West Virginia	3,755	2,895	2,123	4,424
Wisconsin	8,111	8,511	5,872	18,654
Wyoming	3,217	1,801	2,426	4,847
Grand Total	**382,063**	**567,572**	**232,808**	**954,963**

8. UPDATES ON PUBLIC USE MODELS

Essentially, the current FHWA models for estimating gasoline consumption by the public sectors, which includes Federal civilian and SCM governments, were not changed, except for data updates. This is mainly due to data limitations, particularly on the fractions of off-highway versus on-highway uses and the share of fuel consumption by vehicle type. Furthermore, information on distribution of fuel type (gasoline vs. diesel) used in these pubic use models were generated from a survey conducted during the original model development in 1994. No such survey has been conducted to gather updated information since then, unfortunately.

8.1 FEDERAL USE OF GASOLINE MODELS

8.1.1 Data Source

The current FHWA model uses information regarding the number of federally owned vehicles, which are operated by civilian departments and used in each state, from Table MV-7 of the *Highway Statistics* series. It also used information from the *Transportation Energy Data Book* associated with fuel consumption by federal vehicles, as pointed out in Section 2 of this report. Note that federal fleet information published in the *Transportation Energy Data Book*, was in fact obtained from the *Federal Fleet Report*. The research team determined the direct use of *Federal Fleet Report* information is preferred because of the ability to access more up-to-date data than what is published in the *Transportation Energy Data Book*. For example, the latest *Federal Fleet Report* was published by GSA in 2014, which includes 2013 annual data; while the latest *Transportation Energy Data Book* (Edition 33 published in July 2014) includes information based on 2012 *Federal Fleet Report*. Furthermore, *Federal Fleet Report* provides additional information that was included in the *Transportation Energy Data Book* , which could be of interest to this FHWA modeling effort.

8.1.2 Estimation Method

Although not by state, information on total vehicle inventory by vehicle type is available from the *Federal Fleet Report* data. Table MV-7 published state-level data (a year before the *Federal Fleet Report* data) could be used to generate state shares so that the total vehicle inventory obtained from the latest *Federal Fleet Report* (Table 2–3) can be distributed into state level by vehicle type. By doing so, however, one assumes that a state-share of federal vehicle fleet (by vehicle type) in the current year remains at the same level as year before.

8.1.2.1 The initial simple method for total gasoline consumption by state

The GSA *Federal Fleet Report* Table 5–1 published annual total fuel consumption by fuel type at the agency level, including vehicles used by federal agencies located in foreign countries. That is, aggregated data on the annual gasoline consumption by the federal fleet is readily

available. Using vehicle inventory data presented in the *Federal Fleet Report* Table 2-3 to calculate the domestic share of vehicles by agency and then applied to information obtained from Table 5-1 of the same report, total domestic use of gasoline gallons at the national level was estimated. With this national total and the state shares generated from Table MV-7 from the *Highway Statistics*, gasoline consumption by the federal fleet by state can then be produced.

This is a rather simple and straightforward calculation, the use of vehicle numbers to split domestic and foreign gasoline consumption might be a weakness for this approach, however. This method does not consider how the vehicles were used.as some vehicles might be driven a lot while others might not.

8.1.2.2 A modified method for total gasoline consumption by state

Instead of the simple method described above, the modified method took into consideration data from several additional GSA *Federal Fleet Report* tables. Using GSA *Federal Fleet Report* data on annual fuel consumption by fuel type (Table 5-1) and vehicle inventory by fuel type (Table 5-3), estimates of annual gasoline consumption per-vehicle was calculated. Because these two tables include vehicles used by federal agencies located in foreign countries with domestic vehicles, , some adjustments on the fuel consumption and vehicle inventory values were performed first. This separation of domestic and foreign fuel use was done by utilizing VMT information from the *Federal Fleet Report* Table 4-3 (which is by vehicle type). By applying the resulting per-vehicle gasoline consumption estimate to the state-level vehicle inventory as estimated above (MV-7 based, thus is by vehicle type), the **total** gasoline consumption estimates by vehicle type for each state can then be estimated.

8.1.2.3 Estimating on- and off-highway gasoline consumption by state

Now that the state-level total gasoline consumption by vehicle type were estimated, the remaining challenge then was how to separate on- and off-highway uses of gasoline for each state. The only piece of information available for on- and off-highway separation of VMT, unfortunately, was based on the original SCM survey collected data, which indicated that 5% of truck VMT and 3% of auto (passenger car) VMT were for off-highway use. Using these factors, the total state-level gasoline consumption by federal fleet can be broken down into federal on-highway and federal off-highway gasoline consumption.

8.2 GASOLINE CONSUMPTION BY SCM GOVERNMENTS

8.2.1 Data Source for A New SCM Approach

The FHWA published annual *Highway Statistics* series is the main data source for this model. Specifically, this revised method for estimating gasoline consumption by SCM governments for each state is based on data obtained from several of the *Highway Statistics* tables. Similar to that

in the Federal module, state level SCM-owned number of vehicles by vehicle type can be obtained from Table MV-7 of the annual *Highway Statistics*. Furthermore, information obtained from Table MF-27 can be utilized to separate fuel usage into gasoline and other fuels. Data from the *Federal Fleet Report*, as discussed in Section 8.1, is also used for this SCM model.

8.2.2 The Experimental SCM Estimation Method

The current FHWA model used a population-based approach and involved the use of a regression equation developed in early 1990's. Under this current model revision, the research team decided to avoid using such a regression equation and opted for a more empirical approach for estimating the desired gasoline consumption, when possible. Instead of using regression, the research team utilized the total number of SCM vehicles by state (as published in Table MV-7) and applied a simple and straightforward way to obtain the desired estimates of on- and off-highway gasoline consumption for each state. The non-highway gasoline use by SCM governments is then computed as the product of vehicle population, average gasoline use per vehicle, and percent of the non-highway use. Figure 8–1 shows the process of this simple experimental SCM model. Due to data limitation, this model assumed that state fleet vehicle use was similar to the federal fleet, i.e., the average VMT per vehicle, by vehicle type, estimated from data obtained from the *Federal Fleet Report*, specifically Tables 4–3 and 2–3.

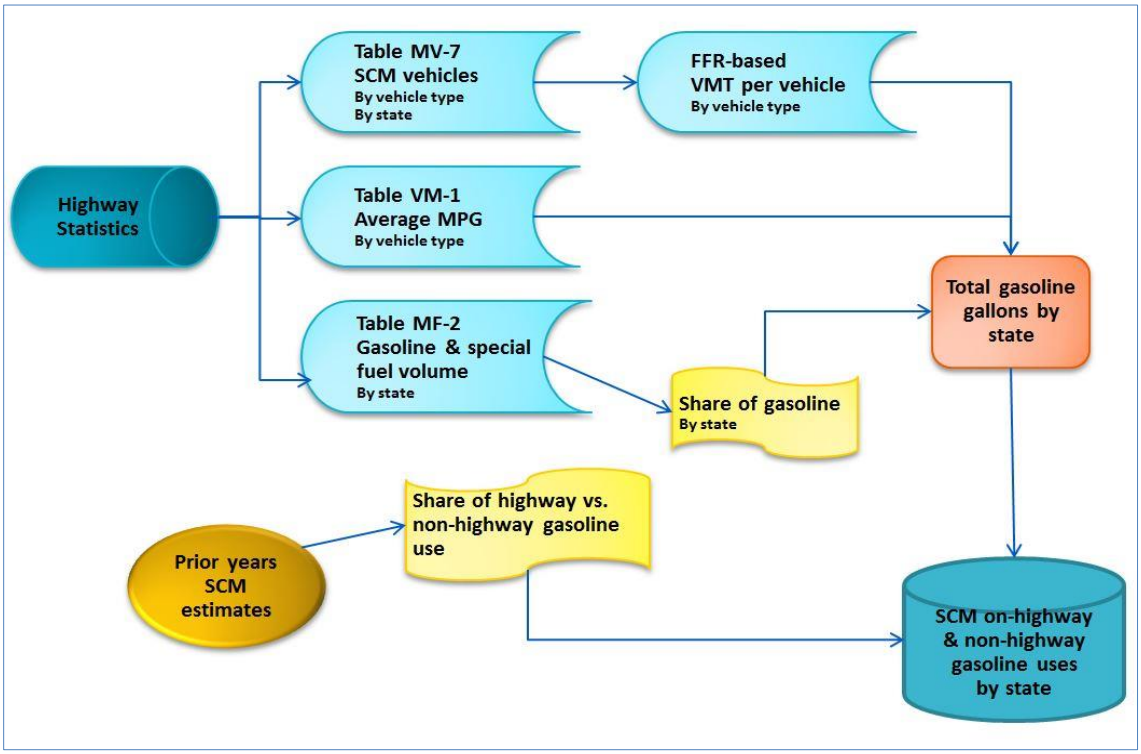

Figure 8-1. Revised SCM estimation model process.

As mentioned, the vehicle population (i.e., number of vehicles by state and vehicle type) was taken from *Highway Statistics* Table MV-7. Along with average VMT per vehicle (by vehicle

type) calculated from the *Federal Fleet Report* and the fuel efficiency by vehicle type data from Table VM-1, the estimates of total fuel consumption volume for each state can be obtained. Table MF-2 was used again to split gasoline and other fuels to obtain the total gasoline consumption by state. Due to lack of a good data source, the separation of on- and off-highway gallons was done by utilizing historical estimates (i.e., prior years of SCM results) to obtain an average of on- and off-highway fuel use ratio. Although this method is simple and straightforward, it unfortunately had to rely on certain assumptions. The use of *Federal Fleet Report* based average gasoline consumption per vehicle implied that a SCM vehicle was used in the same manner as a federal vehicle.

8.3 RESULTS FROM PUBLIC USE MODELS

Estimates for federal civilian on-highway gasoline use are listed in Table 8–1 below. The annual U.S. totals for federal civilian gasoline consumption presented in this table were in line with the total gasoline consumption reported in Table 5–1 of the *Federal Fleet Report* (which includes a small portion of foreign fleets). A decreasing trend in gasoline consumption over time is visible from Table 8–1. This pattern was expected since federal fleets are increasingly moving toward the use of more energy-efficient alternative fuels. As a comparison to the current FHWA model, along with results from the new model, the 2013 estimates from Table MF-21 of the 2013 *Highway Statistics* were also included in Table 8–1. Besides using factors and the regression model from 1994, the current Table MF-21 model used the same Table MV-7-based approach as in the new model. The new model, however, also used GSA consumption data by vehicle type as control totals at the national level.

Figure 8–2 presents the estimates produced from the new Federal Use model compared to those published in Table MF-21 (based on current FHWA model). For reference, the secondary axis was used to overlay the number of federally-owned vehicles (from Table MV-7) onto the consumption estimates (in thousand gallons) in the same figure. Since both models utilized Table MV-7 data for disaggregation to the state, the generally consistent patterns seen among the states were expected. Note that, the current FHWA model used factors and parameters from a regression model developed in 1994. Furthermore, instead of using the latest GSA *Federal Fleet Report* as its data source, the current FHWA model took that information from the *Transportation Energy Data Book*, which is a year older than the original GSA source. Thus, the research team is recommending the use of this updated model for estimating federal on-highway gasoline consumption by state.

Table 8-1. Estimates of Federal Civilian On-highway Use of Gasoline (thousand gallons)

STATE	New Model for Federal On-highway Use 2011	New Model for Federal On-highway Use 2012	New Model for Federal On-highway Use 2013	MF-21 2013
Alabama	3,232	3,202	3,011	2,777
Alaska	2,024	1,900	1,900	416
Arizona	7,880	7,510	7,349	3,155
Arkansas	1,975	1,831	1,824	1,504
California	28,296	27,211	27,004	16,341
Colorado	4,875	4,754	4,742	2,434
Connecticut	2,198	2,043	2,103	1,556
Delaware	620	622	609	450
District of Columbia	3,453	3,204	3,529	520
Florida	12,448	11,934	11,977	8,841
Georgia	7,285	6,794	6,573	5,165
Hawaii	2,505	2,439	2,438	611
Idaho	2,510	2,364	2,324	832
Illinois	7,398	6,874	6,877	5,038
Indiana	3,483	3,233	3,207	3,130
Iowa	1,715	1,649	1,626	1,596
Kansas	2,192	2,014	1,969	1,360
Kentucky	2,823	2,632	2,523	2,320
Louisiana	3,293	2,886	2,844	2,391
Maine	929	881	924	703
Maryland	6,543	6,094	5,966	3,161
Massachusetts	4,114	3,759	3,818	3,010
Michigan	5,333	5,155	5,207	4,735
Minnesota	2,992	3,007	3,018	2,646
Mississippi	2,558	2,309	2,199	1,789
Missouri	4,117	4,197	4,003	3,337
Montana	2,405	2,195	2,136	651
Nebraska	1,427	1,474	1,457	918
Nevada	2,849	2,759	2,690	1,274
New Hampshire	702	810	707	740
New Jersey	5,747	5,361	5,521	4,376
New Mexico	5,028	4,718	4,582	1,327
New York	9,480	9,081	9,024	6,035
North Carolina	5,600	5,347	5,384	4,536
North Dakota	1,376	1,081	1,050	509
Ohio	6,200	5,966	6,020	5,255
Oklahoma	3,144	2,743	2,638	2,070
Oregon	3,536	3,557	3,510	1,682
Pennsylvania	6,794	6,574	6,520	5,412
Rhode Island	827	761	819	410
South Carolina	3,281	3,071	3,071	2,822
South Dakota	1,298	1,221	1,129	534
Tennessee	4,598	4,502	4,587	3,434
Texas	17,800	16,807	16,678	13,557
Utah	3,021	2,740	2,725	1,243
Vermont	411	240	399	334
Virginia	9,498	9,088	8,729	4,664
Washington	6,992	6,595	6,590	3,114
West Virginia	1,271	2,736	1,276	1,000
Wisconsin	2,928	1,274	2,813	2,522
Wyoming	1,557	1,262	1,206	430
US	**234,563**	**222,461**	**220,830**	**148,667**

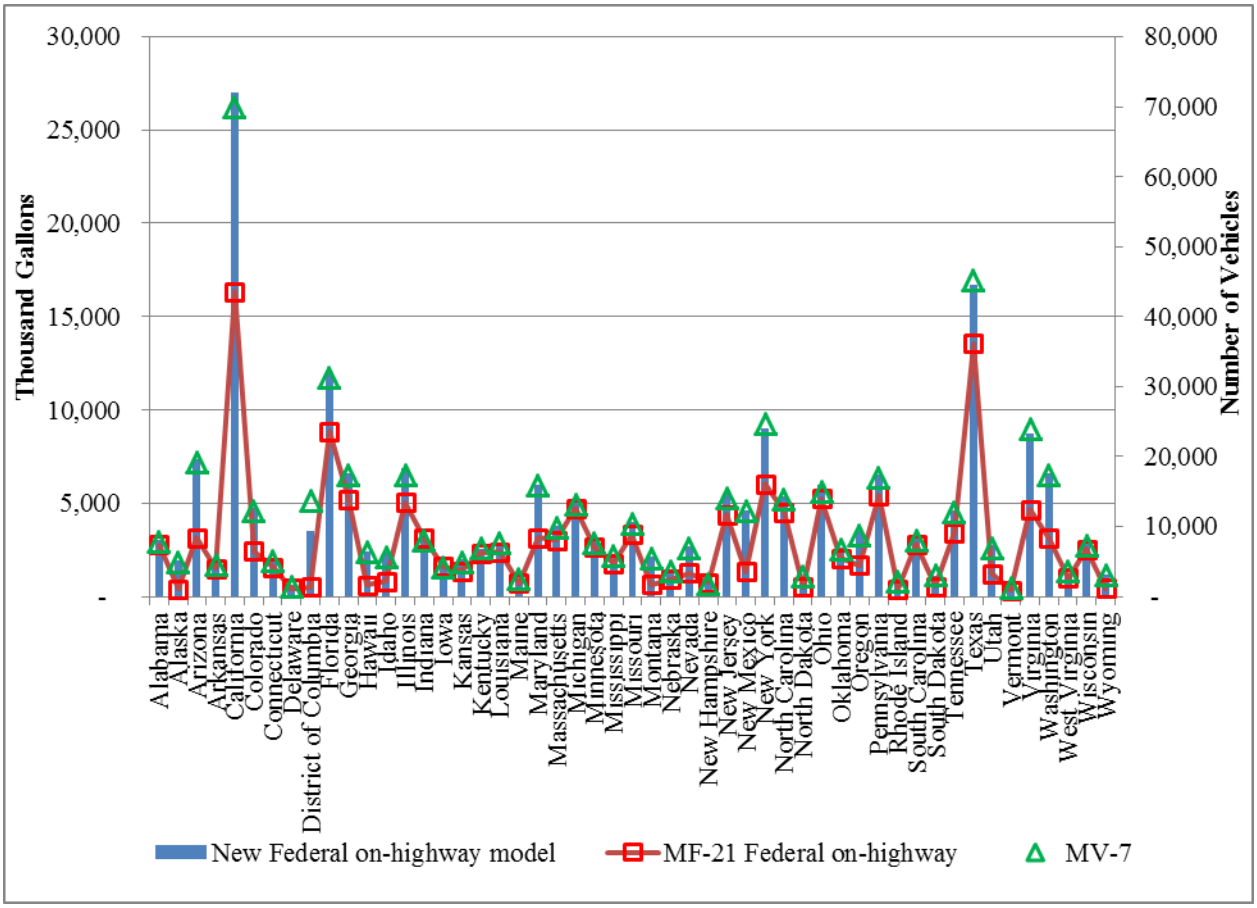

Figure 8-2. Comparison of on-highway Federal use gasoline estimates and number of federally owned vehicles in 2013

As mentioned, without alternate data sources to allow generation of better estimates for total gasoline consumption by SCM governments, the estimates produced from the experimental modeling approach discussed above might not be as accurate as desired. On the other hand, the current FHWA SCM model (published in Table MF-21 of the *Highway Statistics*) was using data from a twenty-year old survey, as well as an obsolete regression equation that is mainly based on population and land size. Continued usage of such an outdated model is problematic. Thus, a revised approach was adopted by the research team and results based on the updated SCM models are listed in Table 8–2 for 2011-2013.

For comparison with results from the current FHWA model, as published in Table MF-21, SCM 2013 estimates from the new model were listed with Table MF-21 data obtained from the 2013 *Highway Statistics* in Table 8–3. Note that results shown in the Table MF-21 were produced using a model that relied on factors and parameters from a regression equation developed from 1994 study.

Table 8-2. Estimates of SCM On-/non-highway Uses of Gasoline (thousand gallons)

STATE	2011	2011	2012	2012	2013	2013
	Non-highway	On-highway	Non-highway	On-highway	Non-highway	On-highway
Alabama	1,626	30,629	1,352	25,469	1,196	22,524
Alaska	213	4,100	439	8,449	394	7,575
Arizona	1,480	28,368	1,784	34,198	1,617	30,998
Arkansas	685	13,060	1,368	26,077	1,499	28,578
California	7,154	137,078	20,661	395,869	19,231	368,468
Colorado	1,535	29,236	1,462	27,842	1,408	26,824
Connecticut	719	13,778	1,338	25,649	1,667	31,946
Delaware	228	5,225	305	6,995	180	4,122
District of Columbia	272	6,112	262	5,875	236	5,289
Florida	4,040	85,060	4,098	86,292	7,447	156,791
Georgia	3,210	61,529	3,187	61,084	3,171	60,770
Hawaii	400	7,634	621	11,853	528	10,074
Idaho	486	9,262	481	9,174	107	2,036
Illinois	2,924	56,012	3,796	72,719	3,784	72,480
Indiana	1,733	33,059	1,516	28,915	172	3,274
Iowa	977	18,636	1,329	25,344	1,164	22,213
Kansas	788	15,023	1,065	20,298	916	17,455
Kentucky	1,347	25,797	1,277	24,454	1,204	23,063
Louisiana	1,482	26,156	1,289	22,751	2,538	44,787
Maine	516	9,871	408	7,805	355	6,794
Maryland	1,579	30,266	1,737	33,306	1,685	32,302
Massachusetts	1,357	25,992	1,785	34,198	1,526	29,223
Michigan	2,637	50,604	2,448	46,972	2,107	40,433
Minnesota	1,492	28,481	1,664	31,763	1,545	29,498
Mississippi	999	19,022	998	19,010	426	8,111
Missouri	1,539	29,335	1,534	29,229	1,322	25,198
Montana	298	5,702	297	5,675	37	717
Nebraska	492	9,413	1,031	19,740	970	18,567
Nevada	560	10,728	684	13,121	630	12,085
New Hampshire	426	8,161	485	9,299	322	6,168
New Jersey	2,102	40,296	2,537	48,628	1,924	36,868
New Mexico	500	9,582	678	13,000	624	11,968
New York	5,069	97,129	5,402	103,512	4,784	91,666
North Carolina	2,220	51,816	2,614	61,016	2,059	48,066
North Dakota	219	4,186	219	4,177	341	6,514
Ohio	3,077	58,702	2,520	48,076	4,154	79,240
Oklahoma	1,012	19,378	929	17,797	684	13,094
Oregon	867	16,582	1,086	20,774	924	17,675
Pennsylvania	2,282	47,006	4,160	85,706	2,994	61,672
Rhode Island	223	4,554	474	9,698	443	9,062
South Carolina	1,292	24,024	1,584	29,440	2,884	53,610
South Dakota	258	4,897	537	10,212	667	12,674
Tennessee	1,420	28,842	1,616	32,825	4,511	91,650
Texas	6,850	131,070	17,599	336,739	15,450	295,616
Utah	801	15,289	733	13,983	332	6,329
Vermont	237	4,525	259	4,955	234	4,471
Virginia	2,615	50,135	2,629	50,403	3,419	65,552
Washington	1,525	34,722	1,727	39,338	1,613	36,742
West Virginia	632	12,099	960	18,393	891	17,061
Wisconsin	1,415	26,998	3,638	69,386	3,322	63,366
Wyoming	223	4,219	231	4,353	19	360
US	**78,032**	**1,519,381**	**112,834**	**2,191,837**	**111,654**	**2,171,621**

Table 8-3. Comparisons of SCM On-/non-highway Uses of Gasoline in 2013 (1,000 gallons)

	On-highway Use	On-highway Use	Non-highway Use	Non-highway Use
State	New model	MF-21	New model	MF-21
Alabama	22,524	36,358	1,196	1,913
Alaska	7,575	7,219	394	376
Arizona	30,998	36,120	1,617	1,896
Arkansas	28,578	25,466	1,499	1,354
California	368,468	208,955	19,231	10,977
Colorado	26,824	35,135	1,408	1,873
Connecticut	31,946	19,856	1,667	1,042
Delaware	4,122	6,487	180	278
District of Columbia	5,289	5,708	236	308
Florida	156,791	94,865	7,447	5,138
Georgia	60,770	58,049	3,171	3,047
Hawaii	10,074	9,912	528	525
Idaho	2,036	13,267	107	705
Illinois	72,480	89,363	3,784	4,698
Indiana	3,274	48,735	172	2,589
Iowa	22,213	29,882	1,164	1,587
Kansas	17,455	27,751	916	1,477
Kentucky	23,063	34,939	1,204	1,837
Louisiana	44,787	34,869	2,538	1,856
Maine	6,794	9,775	355	515
Maryland	32,302	27,575	1,685	1,446
Massachusetts	29,223	35,136	1,526	1,848
Michigan	40,433	64,835	2,107	3,393
Minnesota	29,498	44,073	1,545	2,337
Mississippi	8,111	25,968	426	1,384
Missouri	25,198	46,594	1,322	2,480
Montana	717	10,275	37	542
Nebraska	18,567	18,193	970	958
Nevada	12,085	13,962	630	732
New Hampshire	6,168	9,297	322	488
New Jersey	36,868	50,015	1,924	2,625
New Mexico	11,968	16,735	624	878
New York	91,666	103,166	4,784	5,420
North Carolina	48,066	56,603	2,059	3,019
North Dakota	6,514	8,303	341	439
Ohio	79,240	80,436	4,154	4,272
Oklahoma	13,094	32,920	684	1,731
Oregon	17,675	26,195	924	1,383
Pennsylvania	61,672	73,507	2,994	3,854
Rhode Island	9,062	8,071	443	423
South Carolina	53,610	24,487	2,884	1,490
South Dakota	12,674	9,614	667	515
Tennessee	91,650	44,777	4,511	2,383
Texas	295,616	158,303	15,450	8,344
Utah	6,329	20,787	332	1,104
Vermont	4,471	5,576	234	294
Virginia	65,552	51,472	3,419	2,700
Washington	36,742	37,913	1,613	1,994
West Virginia	17,061	16,243	891	854
Wisconsin	63,366	44,447	3,322	2,361
Wyoming	360	6,628	19	361
Grand Total	**2,171,627**	**2,004,817**	**111,654**	**106,043**

9. INTEGRATING THE ESTIMATION MODEL FOR GASOLINE CONSUMPTION BY OFF-ROAD RECREATIONAL VEHICLES

The fundamental structure of the off-road recreational vehicle model stays relatively the same as in the current FHWA model (discussed in Section 2.2.7 of this report). Basically, the same data sources are used for each vehicle type considered, except the latest releases of data are used to the extent possible. Unfortunately, the light trucks that were used for off-road recreational purposes has the same data issue of associated with the discontinuation of VIUS.

Note that this off-road recreational vehicle module is currently operated as a separate function outside the FHWA motor fuel estimation operations with Integrated Non-highway Gasoline Consumption System. Under this research study, the off-road recreational vehicle module is being integrated with all other modules into one system. The following is a brief discussion focused on the data updating efforts.

9.1 DATA UPDATE FOR MOTORCYCLE AND ATV

9.1.1 Motorcycle

As discussed in section 2.2.7 of this report, the motorcycle share of the off-road recreational vehicle module relies heavily on the MIC *Statistical Annual.* The most recent edition of this publication is for the year 2014 and contains data from 2012 and 2013. The existing module was updated with state off-road motorcycle statistics from table "U.S. Motorcycle Usage by Model Type and State: 2012." This table yields a population of motorcycles by state that were used off-highway at some point, from which an estimate of the total number of off-highway motorcycles can be derived.

Due to the lack of better information, this module continues to rely on the existing 'medium' estimate of 59 gallons per motorcycle per year for estimating off-road recreational motorcycle fuel use.

9.1.2 ATV

In updating the ATV population by state for this module, information from the MIC was used. Specifically, the *2012 Annual Report of ATV Related Deaths and Injuries*[5] published by the Consumer Product Safety Commission (CPSC), which listed the total U.S. population of ATVs in 2012 at approximately 10.7 million. The MIC representative also provided statistics that were previously obtained from FHWA on populations by state for ATVs in 2008. In the absence of more recent state shares of the total ATV population, the 2008 state shares of ATVs were

[5] Report provided by from Ms. Pam Amette of the Motorcycle Industry Council in 2015.

calculated from the CPSC report and FHWA's 2008 report. These shares (as a percentage) were then applied to the 2012 CPSC ATV population to yield an estimated population by state. Similar to the motorcycle module, this ATV module also continues to rely on the existing 'medium' estimate of 55.5 gallons per ATV per year for estimating off-road recreational ATV fuel consumption by state.

It is important to note that in recent years a new market of side-by-side, or utility terrain vehicles, has begun to grow quickly in the off-road recreational sector. These are similar to ATVs in definition; however, their population statistics are not collected by the abovementioned research efforts and, therefore, are not included within these ATV population statistics. As the population of this new vehicle type continues to grow, a need for its inclusion into the model will likely rise in the near future.

9.2 DATA UPDATE FOR SNOWMOBILES

The snowmobile population statistics by state were updated with numbers from the ISMA for 2014. As mentioned in section 2.2.7, the existing model for snowmobile population estimation is rather complicated, as snowmobiles have an additional geographic limitation as many states in the Southern and Southwestern U.S. do not have any significant populations. In addition, the reporting of state registration statistics to ISMA varies by state, depending on the presence of snowmobile associations participating in international events.

For this update, no new data was collected from individual state DMVs or state surveys, however, existing ISMA guidelines for the Alaskan snowmobile estimation as well as the existing snow factor categorizing temperature and snowfall were used to adjust the number of snowmobiles in each state.

9.3 DATA UPDATE FOR LIGHT TRUCK

Outside the option to continue relying on the 2002 VIUS-based results, there was no alternate data source available for updating the light truck for recreational use component. Note that the EPA NONROAD2008 model does not include trucks used for off-road recreational, although it does include "specialty vehicle or carts" (utility vehicles).

9.4 RESULTS

Results from all sections from above are added into a total of fuel consumption for the off-road recreational vehicles in each state. These results are then adjusted, the same way as in the current FHWA model, by using each state's rural factor (based on Table PS-1 of *Highway Statistics*). The resulting estimates of non-highway fuel consumption by off-road recreational

vehicles are presented in Table 9–1. Note that, the majority of these recreational vehicles (i.e., light truck, motorcycle, ATV, and snowmobile) are expected to be gasoline powered.

In addition to the off-road model estimates, EPA NONROAD2008 estimates of gasoline consumption by recreational equipment (from Table 3–5) are also listed alongside for reference. As mentioned in Section 3, the EPA NONROAD model covers a slightly different set of equipment than the FHWA off-road recreational vehicle model. While motorcycles, ATVs, and snowmobiles are covered in both models, the FHWA model also includes light trucks which is not in scope with the EPA model. On the other hand, the EPA model considers golf carts and specialty vehicles or carts that were excluded from the FHWA model. As seen in Table 9–1, national estimates from the two models are quite similar, only about 5% difference in total gallon consumption, while state-level gallon estimates differ in varying degrees, however.

Table 9-1. 2013 Non-highway Fuel Uses by Off-road Recreational Vehicles (in gallons)

State	Off-road model	EPA NONROAD2008
Alabama	29,629,348	22,298,905
Alaska	21,748,804	32,127,730
Arizona	42,292,972	17,803,630
Arkansas	27,208,032	22,431,467
California	151,322,300	71,806,823
Colorado	41,231,950	23,800,737
Connecticut	4,148,379	6,656,830
Delaware	2,838,721	1,762,045
District of Columbia	0	133,170
Florida	64,193,418	28,330,251
Georgia	31,934,954	28,042,912
Hawaii	6,079,286	444,735
Idaho	30,473,370	24,990,401
Illinois	24,296,516	47,701,137
Indiana	20,091,259	26,920,735
Iowa	19,210,921	24,900,270
Kansas	18,429,122	7,616,004
Kentucky	24,641,867	19,990,930
Louisiana	25,544,668	22,380,275
Maine	17,577,193	41,922,703
Maryland	9,183,705	9,018,427
Massachusetts	11,185,712	15,703,265
Michigan	49,094,495	163,227,326
Minnesota	53,910,770	137,478,275
Mississippi	21,963,992	18,302,221
Missouri	32,140,091	21,868,883
Montana	31,572,283	12,990,335
Nebraska	14,010,392	7,833,591
Nevada	25,772,251	6,003,834
New Hampshire	13,026,840	19,960,616
New Jersey	13,880,287	13,991,655
New Mexico	22,316,347	6,043,395
New York	53,967,263	78,206,362
North Carolina	32,264,134	28,788,530
North Dakota	10,191,991	10,258,871
Ohio	28,717,256	43,669,102
Oklahoma	32,487,414	11,551,609
Oregon	27,835,436	20,778,911
Pennsylvania	43,299,236	56,096,979
Rhode Island	1,292,932	1,406,597
South Carolina	14,880,811	12,909,561
South Dakota	12,034,200	9,232,908
Tennessee	31,354,860	25,002,719
Texas	115,275,561	44,629,397
Utah	22,362,301	23,779,988
Vermont	5,046,380	14,279,227
Virginia	27,904,988	15,826,856
Washington	35,501,764	28,733,507
West Virginia	19,218,221	15,443,852
Wisconsin	47,938,339	106,472,725
Wyoming	22,756,696	12,304,829
Grand Total	**1,485,280,028**	**1,463,856,044**

10. CONSIDERATION OF GASOLINE CONSUMPTION BY OTHER EQUIPMENT

As stated in Section3.2, where data from EPA NONROAD2008 model was discussed, several equipment types covered under the EPA model, but not in the existing FHWA models, also used significant amounts of gasoline. This includes equipment for commercial and residential lawn and garden maintenance purposes, airport ground support, and railway maintenance. Specifically, as seen in Table 10–1, the significant number of lawn and garden equipment in use also translate into a large quantity of gasoline being used by this sector. This area deserves further investigation by the FHWA.

Table 10-1. Fuel Consumption and Equipment Inventory by Sector in EPA NONROAD2008 Model

Sector	Gasoline consumption (gallons)	Equipment population (units)	Average annual consumption (gallon/unit)
Agricultural	77,652,256	1,244,584	62
Airport ground	2,125,686	2,071	1,026
Commercial	1,116,985,349	9,739,120	115
Industrial	78,369,766	78,047	1,004
Construction/Mining	131,442,893	1,005,606	131
Recreational Boating	1,550,075,213	13,287,657	117
Lawn and Garden (Commercial)	1,769,817,074	12,078,700	147
Lawn and Garden (Residential)	943,341,850	113,088,922	8
Logging	21,877,414	390,698	56
Railroad	1,348,038	14,582	92
Off-road Recreational Vehicle	1,463,856,044	18,278,247	80
Grand Total	7,156,891,585	169,208,235	42

10.1 LAWN AND GARDEN EQUIPMENT COVERAGE

The gasoline-fueled lawn and garden equipment covered under the EPA NONROAD2008 model was listed previously in Section 3 of this report. They are presented again in Table 10–2 for ease of reference. Since lawn and garden equipment is usually not centrally fueled, they tend to be operated on the more readily available fuel, which is gasoline. Based on NONROAD2008 model estimated 2013 fuel consumption presented in Figure 10-1, gasoline-powered lawn and garden equipment used more than 2,600 million gallons, which accounted for 38% of total gasoline consumption by all equipment sectors.

Table 10-2. Lawn and Garden Equipment Covered under EPA NONROAD2008 Model

(a) Commercial Lawn and Garden Equipment	(b) Residential Lawn and Garden Equipment
Chain Saws < 6 HP	Chain Saws < 6 HP
Chippers/Stump Grinders	Lawn & Garden Tractors
Commercial Turf Equipment	Lawn mowers
Front Mowers	Leaf blowers/Vacuums
Lawn & Garden Tractors	Rear Engine Riding Mowers
Lawn mowers	Rotary Tillers < 6 HP
Leaf blowers/Vacuums	Snow blowers
Rear Engine Riding Mowers	Trimmers/Edgers/Brush Cutter
Rotary Tillers < 6 HP	Other Lawn & Garden Equipment
Shredders < 6 HP	
Snow blowers	
Trimmers/Edgers/Brush Cutter	
Other Lawn & Garden Equipment	

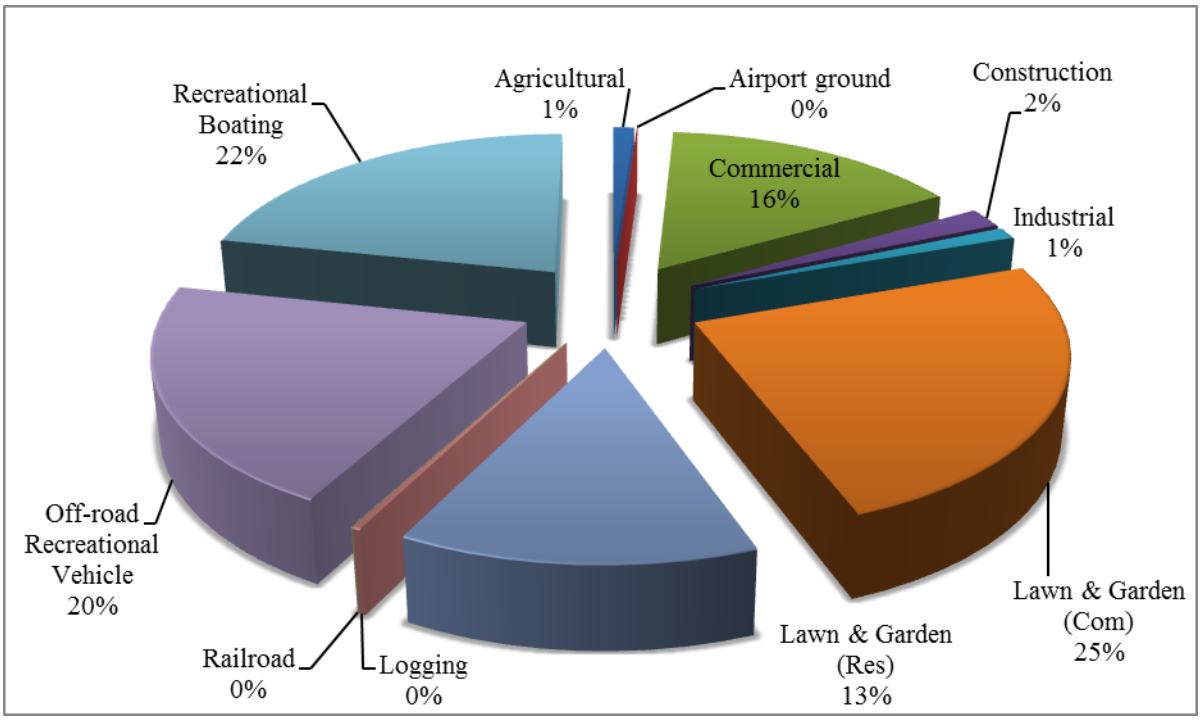

Figure 10-1. EPA NONROAD2008 estimates gas consumption in 2013 by sector.

10.2 AIRPORT GROUND EQUIPMENT COVERAGE

The current FHWA model includes aviation gasoline used by general aviation airplanes. However, gasoline consumption in equipment used for airport ground support activities are not estimated by the FHWA model. Airport ground equipment includes powered as well as non-

powered equipment; only gasoline-powered equipment would be interest to this study. This type of equipment can generally be found on the ramp and in servicing areas of an airport, e.g., aircraft tractors, baggage or cargo tractors, cargo loaders, etc.

The EPA NONROAD2008 model covers equipment populations in gasoline, LPG, as well as diesel powered airport service and support equipment. Based on NONROAD2008 estimates, airport gasoline consumption at the top five states (California, Texas, Florida, New York, and Illinois) accounted for over 42% of total 2013 gasoline consumption by airport ground equipment in the nation. Note that the NONOROAD2008 methodology assumes 50% of the terminal tractor and aircraft support equipment populations are operated on LPG/CNG [35]. The total gasoline consumption by equipment of airport ground services is quite small when compared with other equipment.

10.3 EPA NONROAD2008 ESTIMATED GASOLINE CONSUMPTION BY STATE

Table 10–3 provides EPA state-level estimates of gasoline consumption by lawn and garden equipment, including both commercial and residential uses. Together, they represent a significantly large amount of gasoline consumption as compared to consumption by other industry sectors. On the other hand, Table 10–4 shows that airport ground support consumes a relatively small amount of gasoline in the U.S., totaled only slightly above 2 million gallons per year.

Table 10-3. NONROAD Estimates for Gasoline Use by Lawn and Garden Equipment

(thousand gallons)

	2012	2012	2012	2013	2013	2013
State	**Commercial**	**Residential**	**Total**	**Commercial**	**Residential**	**Total**
Alabama	23,167	15,368	38,536	23,537	15,598	39,135
Alaska	1,208	2,097	3,306	1,228	2,129	3,357
Arizona	51,288	17,829	69,117	52,105	18,096	70,202
Arkansas	9,660	9,169	18,829	9,814	9,306	19,120
California	287,312	95,806	383,118	291,893	97,241	389,134
Colorado	39,994	15,271	55,265	40,634	15,501	56,135
Connecticut	23,889	11,105	34,994	24,272	11,272	35,543
Delaware	6,421	2,686	9,107	6,524	2,726	9,249
District of Columbia	160	2,158	2,318	163	2,191	2,353
Florida	149,378	58,165	207,543	151,759	59,036	210,795
Georgia	62,561	26,607	89,167	63,558	27,005	90,563
Hawaii	8,327	3,589	11,916	8,459	3,643	12,103
Idaho	7,633	4,371	12,004	7,755	4,437	12,192
Illinois	58,686	39,429	98,114	59,625	40,023	99,647
Indiana	34,489	20,650	55,139	35,040	20,961	56,002
Iowa	10,850	9,955	20,805	11,024	10,105	21,129
Kansas	13,343	9,148	22,491	13,557	9,286	22,842
Kentucky	13,948	13,977	27,924	14,170	14,186	28,357
Louisiana	13,366	14,348	27,714	13,579	14,563	28,142
Maine	5,835	5,262	11,097	5,929	5,341	11,270
Maryland	48,094	17,349	65,444	48,864	17,611	66,474
Massachusetts	32,941	20,972	53,913	33,469	21,287	54,756
Michigan	43,408	34,363	77,772	44,103	34,881	78,984
Minnesota	20,365	16,884	37,249	20,691	17,138	37,829
Mississippi	7,320	9,117	16,436	7,436	9,253	16,689
Missouri	30,860	19,703	50,563	31,354	19,999	51,353
Montana	2,219	3,302	5,521	2,254	3,352	5,606
Nebraska	7,145	5,850	12,995	7,259	5,938	13,197
Nevada	25,735	6,941	32,675	26,145	7,045	33,190
New Hampshire	7,305	4,443	11,748	7,422	4,510	11,931
New Jersey	55,854	26,628	82,482	56,748	27,029	83,777
New Mexico	8,297	6,314	14,611	8,430	6,409	14,839
New York	55,071	61,457	116,527	55,952	62,382	118,334
North Carolina	59,602	28,384	87,986	60,552	28,810	89,362
North Dakota	1,196	2,329	3,525	1,215	2,364	3,579
Ohio	79,120	38,608	117,728	80,386	39,189	119,576
Oklahoma	21,428	11,763	33,191	21,769	11,939	33,709
Oregon	21,894	11,840	33,734	22,244	12,019	34,263
Pennsylvania	65,639	42,183	107,821	66,689	42,818	109,507
Rhode Island	4,101	3,513	7,614	4,166	3,566	7,733
South Carolina	29,480	13,926	43,406	29,950	14,134	44,084
South Dakota	1,874	2,631	4,505	1,904	2,671	4,574
Tennessee	29,671	19,364	49,035	30,144	19,654	49,798
Texas	121,824	64,886	186,710	123,766	65,858	189,623
Utah	9,486	6,402	15,888	9,638	6,498	16,136
Vermont	2,514	2,372	4,885	2,554	2,407	4,961
Virginia	60,863	23,413	84,276	61,836	23,765	85,600
Washington	35,721	20,005	55,727	36,293	20,307	56,599
West Virginia	6,307	6,746	13,053	6,408	6,848	13,256
Wisconsin	23,641	18,896	42,537	24,019	19,181	43,200
Wyoming	1,511	1,804	3,316	1,536	1,832	3,367
Total US	**1,741,999**	**929,377**	**2,671,376**	**1,769,817**	**943,342**	**2,713,159**

Table 10-4. EPA Estimated Gasoline Use by Airport Ground Support (thousand gallons)

State	2012	2013
Alabama	10	10
Alaska	34	35
Arizona	63	64
Arkansas	6	6
California	259	261
Colorado	55	55
Connecticut	11	11
Delaware	0	0
District of Columbia	0	0
Florida	179	180
Georgia	95	96
Hawaii	51	51
Idaho	6	6
Illinois	123	124
Indiana	20	20
Iowa	7	7
Kansas	4	4
Kentucky	36	37
Louisiana	19	19
Maine	6	6
Maryland	32	32
Massachusetts	40	41
Michigan	52	52
Minnesota	34	35
Mississippi	4	4
Missouri	65	66
Montana	7	7
Nebraska	10	10
Nevada	52	52
New Hampshire	6	6
New Jersey	56	56
New Mexico	13	13
New York	128	128
North Carolina	63	64
North Dakota	4	4
Ohio	35	36
Oklahoma	13	13
Oregon	20	20
Pennsylvania	77	78
Rhode Island	8	8
South Carolina	7	7
South Dakota	4	4
Tennessee	51	51
Texas	201	202
Utah	22	22
Vermont	1	1
Virginia	54	55
Washington	44	45
West Virginia	4	4
Wisconsin	17	17
Wyoming	1	1
U.S.	**2,113**	**2,126**

11. SUMMARY

11.1 OVERVIEW

This research study was conducted by ORNL to revise and update the current FHWA models used in estimating non-highway gasoline consumption. The existing FHWA non-highway motor fuel consumption estimation models contained outdated assumptions and data (mainly from the 2002 VIUS), as well as relied on obsolete regression equations in several of its modules. The FHWA determined that there is an urgent need for recalibration and reformulation of these models. .

All of the nine sector models were examined in this study. In all cases, information used in the model was updated with the latest available data where feasible. As mentioned earlier in this report, empirical approaches were used with the models when possible to avoid the use of previously developed old regression equations. For example, rather than generating state-level aviation gasoline consumption from a regression equation, shares based statistics for hours-flown in unreported states were used to distribute aviation gasoline totals to states within each given region. Similarly, instead of a regression equation that associated median household incomes to fuel use by boat, the revised method relies only on information derived from the empirical data collected in the *2011/2012 NRBS*. Several other regression equations, such as those used in the agricultural sector and the public use sector, were also eliminated and replaced by more empirically derived estimates.

Methodologies used in all sector approaches were revised, except for the off-road recreational model. There was no mathematical "modeling" (i.e., equations) applied in the current FHWA off-road recreational model; it simply relies on summarizing data obtained directly from each data source. All data elements used in this off-road recreational model were updated with the latest available information, with the exception of light trucks that were used for off-road recreational purposes. The off-road recreational use of light trucks relied on data from the VIUS, which has had no updates since the 2002 data release.

11.2 CHALLENGES REMAIN

The issue of 2002 VIUS data is still lingering around some modules, specifically, the light truck portion of the off-road recreational vehicle model mentioned above and the construction and industrial/commercial sectors. In the current FHWA models, the industrial/commercial and construction sectors were generated totally based on VIUS data (i.e., truck only). Under this study, alternate data sets from the EPA NONROAD2008 model and Polk data were considered and evaluated. The use of the EPA NONROAD model results are straightforward (no modeling involved) and no specific annual input of data is required. This, however, would be a significant change from the current "truck only" approach to one that considers all "equipment" but no

trucks. In the construction and industrial/commercial cases, specifically, the EPA equipment-based estimates are significantly different from the VIUS truck-based gasoline consumption volumes by state. If EPA estimates were to be used for generating the non-highway gasoline consumption for these sectors for the new analysis year, they would likely cause some compatibility issues with estimates from previous years.

On the other hand, the Polk data is based on truck registration data similar to VIUS, with a much lesser degree of detail on truck-specific characteristics or its operations, however. The major deficiency of Polk data for use in the motor fuel application includes its lack of annual mileage data and no information on percent of off-road use by a truck. Although odometer reading in most cases could be obtained from registration data, there is an important constraint. Unless multiple readings were obtained for the "not so distant" years on a given truck (so that a reasonably accurate average annual mileage could be estimated for the truck), the quality of average annual VMT as estimated by dividing the odometer reading value over the period between the registration year and the model-year of the truck cannot be assured. Furthermore, Polk is a private dataset, which could raise certain cost concerns as well. Thus, at this current time, the research team does not consider the Polk data being used as a feasible option for the motor fuel program.

11.3 RECOMMENDATIONS

This research revised and improved the FHWA Non-highway Gasoline Consumption Estimation models for all sectors. The integrated Excel spreadsheet-based tool, namely the *Integrated Non-highway Gasoline Consumption Estimation System*, was updated accordingly to reflect improvements made to each model. One exception in the current version is on the estimation procedures for the industrial/commercial and construction sectors. Two procedure options of estimation were provided for these sectors for further testing by FHWA analysts; the EPA NONROAD2008-based model and the new *Highway Statistics* VMT-based model. The research team opted to provide both methods to the FHWA so that their impacts on the bottom-line (i.e., end results of FHWA's annual motor fuel data processing) could be better reviewed. The selected method will then be integrated with the rest of the system into one complete tool.

As mentioned in the report, the research team recommended the inclusion of consumption by gasoline-powered equipment with several vehicle-based sectors (e.g., construction, industrial, and commercial). Furthermore, the team suggested FHWA take into consideration incorporating consumption from other equipment provided by the EPA NONROAD database, but not traditionally measured by the FHWA, specifically consumption by lawn and garden equipment in commercial and residential segments. Implications of including additional sectors on current programs that use results from the FHWA models will need to be further investigated, because including more sectors could significantly change consumption figures at the state level, which could cause changes in programs that utilize those for policy decisions. Table 11–1 gives a

summary of total 2013 gasoline consumption estimated by the three models discussed in this study (namely, current model as published in Table MF-24, the new model developed in this study, and the EPA NONROAD model), by individual sector covered. The "combined vehicle & equipment" column represents totals where consumption from vehicle and equipment were considered to be – the "complete picture" scenario as recommended. Detailed state-level 2013 estimates from Table MF-24 and from the new models were included in Appendix B at the end of this report. Consumption estimates for the combined vehicle and equipment in all sectors were also listed in this appendix.

Table 11-1. Summary of Gasoline Consumption by Sector by Model

2013 estimates (million gallons)	Table MF-24	New models	EPA NONROAD	Combined vehicle & equipment
Aviation	213	191	2	193
Boating	1,123	1,366	1,550	1,366
Agricultural	655	133	78	132
Construction	955	233	131	364
Industrial / commercial	568	382	1,195	1,577
Off-road recreational		1,485	1,464	1,464
Lawn & garden (commercial)			1,770	1,770
Lawn & garden (residential)			943	943
Misc. (rail & logging)			22	22

In addition, regarding the SCM model, the revised model relies on an assumption that miles traveled per SCM vehicle, by vehicle type, is the same as their corresponding federal fleets. Certainly, this could be refined in the future if additional data becomes available. Furthermore, if funding resources become available, FHWA may want to consider conducting a data collection effort similar to the 1994 SCM model development study to obtain more precise and up-to-date information for future motor fuel program uses.

11.4 REMARKS ON THE ONGOING VIUS RESTORATION EFFORT

As mentioned in the report, the FHWA Office of Freight Operations is currently leading a multi-agency (including DOT, DOE, EIA, EPA, USDA, etc.) effort to restore the VIUS. This study aims to design and scope a new VIUS, possibly utilizing new forms of survey technologies. The project is currently in the planning phase, which includes outreach to public and private stakeholders, review of previous and similar studies, and definition of the scope for a pretest and full survey [36]. The planning phase of this VIUS restoration effort is expected to be complete by late 2015, at which time an assessment will be made regarding advancing the VIUS to its pre-test and survey phases. So if all goes well and a new VIUS is to be conducted, the earliest date that a VIUS dataset could be available for use would likely be around 2018-2019.

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APPENDIX A

DEFINITIONS OF "MACHINERY AND EQUIPMENT" AS IN SECTION 29 OF *2012 CENSUS OF AGRICULTURE REPORT FORM GUIDE*[6]

For the items listed in this section, report the total number usually kept on this operation on December 31, 2012 in the first column and of these, report the number that were manufactured in the last 5 years from 2008 through 2012 in the second column. Include the number of leased machines used for farm activities and on this operation on December 31, 2012. Mark the "none" box when appropriate. Do not include obsolete or abandoned equipment.

Item 1a – Trucks, including pickups - Report the number of trucks, including pickups, used in 2011 or 2012 that were on this operation on December 31, 2012.

Item 1b - Tractors less than 40 horsepower (PTO) - Report the number of tractors with less than 40 horsepower (PTO) used in 2011 or 2012 that were on this operation on December 31, 2012. Exclude garden tractors.

Item 1c - Tractors with 40 to 99 horsepower (PTO) - Report the number of tractors with 40 to 99 horsepower (PTO) used in 2011 or 2012 that were on this operation on December 31, 2012.

Item 1d - Tractors with 100 horsepower (PTO) or more - Report the number of tractors with 100 horsepower (PTO) or more used in 2011 or 2012 that were on this operation on December 31, 2012.

Item 1e - Grain and bean combines, self-propelled - Report the number of self-propelled grain and bean combines (used for harvesting and threshing operations) used in 2011 or 2012 that were on this operation on December 31, 2012. Include all grain combines equipped with picking head attachments for corn or grain harvest. Report self-propelled silage and forage harvesters in item1g (1f for Hawaii). Exclude all pull-type grain and bean combines.

Item 1f - Cotton pickers and strippers, self-propelled (Not applicable for Hawaii) - Report the number self-propelled cotton pickers and strippers used in 2011 or 2012 that were on this operation on December 31, 2012.

Item 1g - Forage harvesters, self-propelled (item 1f for Hawaii) - Report the number of self-propelled forage harvesters used in 2011 or 2012 that were on this operation on December 31, 2012.

[6] "2012 Census of Agriculture Report Form Guide" issued by National Agricultural Statistics Service, U.S. Department of Agriculture, November 2012.

Item 1h - Hay balers (item 1g for Hawaii) - Report the number of hay balers used in 2011 or 2012 that were on this operation on December 31, 2012. Include pull type and self-propelled hay balers.

APPENDIX B

SUMMARY OF 2013 ESTIMATES ON NON-HIGHWAY USE OF GASOLINE BY SECTOR

Table B.1 Private and Commercial Non-highway Use of Gasoline – 2013 Table MF-24

Table B.2 Non-highway Use of Gasoline Estimates from the New Model - 2013

Table B.3 Combined Non-highway Use of Gasoline by Vehicle and Equipment – 2013

Table B.1 Private and Commercial Non-highway Use of Gasoline – 2013 MF-24

STATE (Thousand gallons)	AGRICULTURE	AVIATION	INDUSTRIAL AND COMMERCIAL	CONSTRUCTION	MARINE
Alabama	7,435	2,442	7,532	6,331	25,661
Alaska	1,199	6,692	2,143	6,229	7,122
Arizona	11,201	6,700	14,488	15,150	14,875
Arkansas	19,987	3,382	4,128	7,697	16,682
California	57,071	16,449	68,718	136,665	61,200
Colorado	11,839	3,597	9,967	13,744	6,382
Connecticut	3,144	3,151	6,479	11,043	13,341
Delaware	3,530	2,047	1,710	1,880	13,240
District of Columbia	0	32	959	502	508
Florida	17,533	21,964	36,865	31,036	153,514
Georgia	14,250	5,606	18,243	24,785	24,187
Hawaii	677	1,296	3,345	1,770	2,360
Idaho	17,843	2,769	2,925	3,569	7,324
Illinois	20,801	4,047	23,897	39,762	28,265
Indiana	19,375	3,555	9,993	27,751	17,400
Iowa	24,543	2,321	4,614	11,554	12,458
Kansas	9,816	3,028	3,936	8,873	4,241
Kentucky	10,506	1,238	5,729	13,002	16,641
Louisiana	12,965	4,289	10,301	25,458	32,553
Maine	7,413	747	2,020	2,763	6,710
Maryland	8,109	1,645	13,688	11,203	21,776
Massachusetts	6,977	2,068	12,880	20,232	15,925
Michigan	13,588	4,455	13,717	30,785	59,010
Minnesota	29,087	4,082	11,598	19,891	39,839
Mississippi	14,847	3,003	4,773	7,485	14,589
Missouri	1,200	3,801	7,985	14,895	24,515
Montana	8,361	1,783	1,987	1,820	4,712
Nebraska	13,955	1,664	3,215	5,923	4,812
Nevada	1,535	2,542	7,101	3,980	4,918
New Hampshire	2,056	1,046	2,142	3,750	7,938
New Jersey	6,855	2,884	14,934	24,451	30,623
New Mexico	7,865	1,776	3,460	5,214	2,980
New York	21,236	1,769	34,457	39,367	56,053
North Carolina	22,770	5,906	16,139	30,713	42,153
North Dakota	7,884	989	1,669	2,912	3,201
Ohio	16,078	5,344	13,487	38,068	41,907
Oklahoma	18,465	6,319	6,313	13,893	19,943
Oregon	8,045	4,833	6,824	21,545	12,694
Pennsylvania	31,502	5,118	21,147	36,851	27,628
Rhode Island	947	180	2,102	2,022	4,254
South Carolina	4,100	1,791	7,923	11,065	41,476
South Dakota	9,760	1,399	1,499	2,012	3,154
Tennessee	8,827	3,015	8,694	21,121	22,224
Texas	73,383	31,407	60,271	122,183	51,252
Utah	2,508	2,349	5,404	8,564	7,857
Vermont	3,411	314	981	1,004	1,632
Virginia	7,579	3,506	16,869	17,547	26,678
Washington	13,685	7,898	15,114	18,978	25,918
West Virginia	996	899	2,895	4,424	4,312
Wisconsin	15,547	2,501	8,511	18,654	29,656
Wyoming	2,276	1,031	1,801	4,847	4,230
Total	**654,562**	**212,669**	**567,572**	**954,963**	**1,122,523**

Table B.2 Non-highway Use of Gasoline Estimates from the New Model - 2013

STATE (Thousand gallons)	AGRICULTURE	AVIATION	INDUSTRIAL AND COMMERCIAL	CONSTRUCTION	MARINE
Alabama	1,465	2,774	12,462	2,352	48,692
Alaska	29	1,102	1,136	359	13,599
Arizona	1,456	7,811	27,769	10,970	11,794
Arkansas	4,250	1,424	12,132	6,079	32,337
California	5,896	26,645	97,733	24,612	78,276
Colorado	2,080	3,322	9,275	10,199	4,980
Connecticut	43	1,095	8,887	308	12,854
Delaware	126	475	4,037	717	12,924
District of Columbia	0	37	268	29	474
Florida	698	20,550	99,172	29,244	219,038
Georgia	926	4,964	32,600	2,172	60,261
Hawaii	123	230	6,533	2,330	1,086
Idaho	2,298	1,679	4,902	4,693	5,545
Illinois	6,413	3,468	12,719	4,630	36,698
Indiana	4,507	2,482	65,595	3,622	23,581
Iowa	7,820	2,300	5,338	1,988	20,067
Kansas	7,633	2,336	7,641	3,769	4,759
Kentucky	1,534	2,008	9,928	1,457	23,838
Louisiana	2,688	2,701	9,458	3,600	47,699
Maine	109	1,387	3,976	1,060	15,389
Maryland	645	1,716	24,315	1,515	22,306
Massachusetts	55	4,490	17,988	1,381	17,259
Michigan	1,934	3,504	11,024	10,408	100,989
Minnesota	5,461	3,468	3,644	8,767	61,006
Mississippi	5,117	2,884	2,972	2,097	19,747
Missouri	4,882	2,884	4,301	3,703	41,414
Montana	4,390	1,716	3,797	2,808	3,362
Nebraska	6,068	1,460	1,450	5,095	5,859
Nevada	675	1,387	3,009	2,795	4,794
New Hampshire	26	1,314	3,119	345	15,931
New Jersey	488	2,008	26,666	1,222	21,627
New Mexico	366	1,862	11,829	6,326	3,746
New York	1,922	3,395	30,349	3,120	62,156
North Carolina	2,213	4,490	18,962	5,064	112,907
North Dakota	9,619	2,154	2,419	3,415	5,797
Ohio	2,608	4,198	20,001	6,857	66,852
Oklahoma	6,065	2,044	18,395	4,832	34,488
Oregon	1,047	3,760	16,753	2,156	10,715
Pennsylvania	3,006	6,315	3,947	4,326	36,442
Rhode Island	5	484	4,164	201	5,225
South Carolina	423	2,263	11,905	2,850	65,674
South Dakota	5,653	1,241	3,430	1,096	4,487
Tennessee	1,255	3,030	36,142	9,265	40,884
Texas	7,200	24,565	80,963	11,259	85,237
Utah	1,184	2,774	7,818	1,820	10,009
Vermont	162	246	2,013	275	4,398
Virginia	1,094	2,555	12,417	1,926	38,984
Washington	4,243	5,694	1,604	3,273	17,823
West Virginia	398	621	5,655	2,123	6,895
Wisconsin	2,651	2,884	7,941	5,872	61,197
Wyoming	1,958	657	3,603	2,426	3,268
Total	**132,908**	**190,840**	**834,153**	**232,807**	**1,665,371**

Table B.3 Combined Non-highway Use of Gasoline by Vehicle and Equipment – 2013

STATE	AGRICULTURE	AVIATION	INDUSTRIAL AND COMMERCIAL	CONSTRUCTION	MARINE
Alabama	1,465	2,784	28,413	4,287	48,692
Alaska	29	1,137	3,514	687	13,599
Arizona	1,456	7,875	45,434	15,319	11,794
Arkansas	4,250	1,430	22,109	7,094	32,337
California	5,896	26,906	254,339	38,915	78,276
Colorado	2,080	3,377	30,001	13,048	4,980
Connecticut	43	1,106	21,941	1,475	12,854
Delaware	126	475	6,633	1,110	12,924
District of Columbia	0	37	1,160	478	474
Florida	698	20,730	179,242	41,835	219,038
Georgia	926	5,060	68,879	7,161	60,261
Hawaii	123	281	11,248	2,776	1,086
Idaho	2,298	1,685	10,172	5,441	5,545
Illinois	6,413	3,592	68,266	9,530	36,698
Indiana	4,507	2,502	89,242	6,836	23,581
Iowa	7,820	2,307	18,891	3,587	20,067
Kansas	7,633	2,340	21,026	4,887	4,759
Kentucky	1,534	2,044	23,090	3,243	23,838
Louisiana	2,688	2,720	28,698	5,234	47,699
Maine	109	1,393	8,568	1,558	15,389
Maryland	645	1,747	40,252	3,842	22,306
Massachusetts	55	4,530	43,327	3,448	17,259
Michigan	1,934	3,556	47,170	13,994	100,989
Minnesota	5,461	3,502	28,309	11,396	61,006
Mississippi	5,117	2,888	11,613	3,029	19,747
Missouri	4,882	2,949	27,675	6,064	41,414
Montana	4,390	1,723	8,047	3,049	3,362
Nebraska	6,068	1,470	9,412	5,960	5,859
Nevada	675	1,439	9,790	5,182	4,794
New Hampshire	26	1,320	8,672	882	15,931
New Jersey	488	2,063	70,253	4,103	21,627
New Mexico	366	1,874	18,411	7,116	3,746
New York	1,922	3,523	123,790	8,242	62,156
North Carolina	2,213	4,553	51,816	9,805	112,907
North Dakota	9,619	2,157	6,690	3,689	5,797
Ohio	2,608	4,233	64,869	10,941	66,852
Oklahoma	6,065	2,057	33,940	6,125	34,488
Oregon	1,047	3,780	32,277	3,911	10,715
Pennsylvania	3,006	6,392	48,513	8,059	36,442
Rhode Island	5	492	8,168	486	5,225
South Carolina	423	2,270	25,509	5,295	65,674
South Dakota	5,653	1,245	6,996	1,397	4,487
Tennessee	1,255	3,081	57,067	11,901	40,884
Texas	7,200	24,767	176,931	22,616	85,237
Utah	1,184	2,796	17,130	3,080	10,009
Vermont	162	247	4,393	493	4,398
Virginia	1,094	2,610	33,089	5,701	38,984
Washington	4,243	5,739	27,337	6,272	17,823
West Virginia	398	624	10,770	2,556	6,895
Wisconsin	2,651	2,900	29,650	8,434	61,197
Wyoming	1,958	658	6,780	2,682	3,268
Total	**132,908**	**192,966**	**2,029,508**	**364,250**	**1,665,371**

Table B.3 Combined Non-highway Use of Gasoline by Vehicle and Equipment – 2013 (cont.)

STATE	Off-road recreational	Lawn & garden (com)	Lawn & garden (res)	Misc. (rail & logging)	All Sectors
Alabama	29,629	23,537	15,598	1,591	155,996
Alaska	21,749	1,228	2,129	187	44,259
Arizona	42,293	52,105	18,096	50	194,422
Arkansas	27,208	9,814	9,306	1,062	114,611
California	151,322	291,893	97,241	982	945,771
Colorado	41,232	40,634	15,501	84	150,937
Connecticut	4,148	24,272	11,272	53	77,163
Delaware	2,839	6,524	2,726	15	33,371
District of Columbia	297	163	2,191	1	4,800
Florida	64,193	151,759	59,036	725	737,257
Georgia	31,935	63,558	27,005	1,768	266,554
Hawaii	6,079	8,459	3,643	0	33,696
Idaho	30,473	7,755	4,437	386	68,193
Illinois	24,297	59,625	40,023	204	248,647
Indiana	20,091	35,040	20,961	212	202,973
Iowa	19,211	11,024	10,105	101	93,112
Kansas	18,429	13,557	9,286	78	81,994
Kentucky	24,642	14,170	14,186	454	107,203
Louisiana	25,545	13,579	14,563	1,207	141,933
Maine	17,577	5,929	5,341	833	56,697
Maryland	9,184	48,864	17,611	142	144,592
Massachusetts	11,186	33,469	21,287	130	134,692
Michigan	49,094	44,103	34,881	518	296,239
Minnesota	53,911	20,691	17,138	564	201,979
Mississippi	21,964	7,436	9,253	1,448	82,495
Missouri	32,140	31,354	19,999	411	166,889
Montana	31,572	2,254	3,352	307	58,055
Nebraska	14,010	7,259	5,938	100	56,077
Nevada	25,772	26,145	7,045	16	80,857
New Hampshire	13,027	7,422	4,510	273	52,063
New Jersey	13,880	56,748	27,029	96	196,286
New Mexico	22,316	8,430	6,409	67	68,736
New York	53,967	55,952	62,382	350	372,284
North Carolina	32,264	60,552	28,810	1,200	304,119
North Dakota	10,192	1,215	2,364	30	41,753
Ohio	28,717	80,386	39,189	237	298,035
Oklahoma	32,487	21,769	11,939	226	149,097
Oregon	27,835	22,244	12,019	1,058	114,886
Pennsylvania	43,299	66,689	42,818	431	255,649
Rhode Island	1,293	4,166	3,566	10	23,412
South Carolina	14,881	29,950	14,134	880	159,015
South Dakota	12,034	1,904	2,671	40	36,426
Tennessee	31,355	30,144	19,654	523	195,865
Texas	115,276	123,766	65,858	1,057	622,706
Utah	22,362	9,638	6,498	33	72,730
Vermont	5,046	2,554	2,407	158	19,859
Virginia	27,905	61,836	23,765	842	195,824
Washington	35,502	36,293	20,307	1,071	154,586
West Virginia	19,218	6,408	6,848	316	54,033
Wisconsin	47,938	24,019	19,181	633	196,604
Wyoming	22,757	1,536	1,832	65	41,534
Total	**1,485,577**	**1,769,817**	**943,342**	**23,225**	**8,606,964**