Nonroad Engine Population Growth Estimates in MOVES2014b

United States Environmental Protection Agency

Nonroad Engine Population Growth Estimates in MOVES2014b

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

United States Environmental Protection Agency

EPA-420-R-18-010
July 2018

Table of Contents

1 Introduction

Computing accurate nonroad air pollution emissions inventories depends on estimations of emission factors and engine activity levels. Changes in nonroad emission factors are driven primarily by regulations and will not be discussed here (detailed discussions of nonroad emission factors used in MOVES2014b can be found in Technical Reports NR-009d[1] and NR-010f[2]). Changes in nonroad engine activity levels over years are the result of complex interactions between human population growth, changes in national and local economic factors, and changes in the markets for nonroad engines and products they produce. Because trends in nonroad engine activity levels are rarely directly measured, MOVES instead starts with base year engine populations and estimates growth in the populations of nonroad engines while applying constant annual activity values for every engine type (see Technical Report NR-005d[3] for a technical discussion of annual activity values). This report focuses on the methodology for estimating growth in nonroad engine populations in MOVES2014b.

2 Background

Previous versions of EPA's nonroad emissions inventory model – including NONROAD2008, which was added to the MOVES model in 2014 – based engine population growth projections on a time series analysis of historical (1989 through 1996) nonroad engine populations taken from the Power Systems Research (PSR) Parts Link database[4,5]. This database contains detailed information about each engine family sold in the United States and was used to segregate nonroad engines by market sector and fuel type. Total engine populations, segregated by fuel type, were calculated for each year from 1989 through 1996 for the following broad market sectors: Construction, Agriculture, Industrial, Lawn & Garden, Commercial, Logging, Railroad Support, Recreational, Recreational Marine, and Airport Service. Future engine populations were projected by extrapolating from a simple linear regression of historical populations.

Some adjustments were made to the PSR-based approach, including:

- Engine population growth in the Oil Field sector was based on the Department of Commerce's Bureau of Economic Analysis (BEA) estimates of gross state product from domestic oil production. This data source was preferred over the PSR database for this sector because the 1989-to-1996 decline in oil field equipment reflected in the PSR database would have resulted in all oil field equipment disappearing by 2006.
- Recreational equipment population growth rates derived from the PSR database were applied to the Recreational Marine equipment category, but pre-1996 back-casted populations of personal watercraft were modified to force a zero population in 1970, as it was assumed that personal watercraft were not available in significant numbers prior to 1970.
- Within the Recreational equipment sector, population growth rates for all-terrain vehicles and off-highway motorcycles were revised based on historical sales information and sales growth projections supplied by the Motorcycle Industry Council. Additionally, growth projections of snowmobiles were based on information provided by the International Snowmobile Manufacturers Association.

In addition to forming the basis of nonroad engine population growth rates in MOVES2014, PSR's engine population database also supplied the model's default base year national populations, which were used as a starting point to estimate future and past year engine populations. Population base years varied by engine type and are either 1996, 1998, 1999, or 2000 (see Technical Report NR-006e[6] for a technical discussion of the derivation of base year equipment population estimates). Geographic allocation factors derived from surrogate information sources (e.g., business activity data, human population data, geographic data) were used to allocate national engine populations to the county level (see Technical Report NR-014d[7] for a detailed discussion of geographic allocation factors).

MOVES2014b will continue to use the base-year engine populations and geographic allocation factors used in NONROAD2008,MOVES2014, and MOVES2014a. However, to address concerns that long-term national growth rates derived from seven years of engine population data limits the model's ability to accurately portray nonroad engine/emissions growth at the regional or state levels, EPA has developed a set of annual, state-level growth indices for projecting nonroad engine populations from the population base years.

3 Methodology

EPA considered four primary methods for projecting nonroad engine population growth trends (Table 3.1)[8]:

Table 3.1 Methods for projecting nonroad engine activity and population growth trends

Projection Methodology	Description
Equipment activity projections	Tend to focus on a narrow or specialized equipment sectors (e.g., the Federal Aviation Administration's *Terminal Area Forecasts* tool for projecting commercial aviation operations could be used to project airport service equipment activity)
Census population projections	Considered reliable because population demographics are well understood. Often used in nonpoint source emission inventory projections where activity is closely correlated with human population size and could be used in certain nonroad equipment sectors (e.g., recreational vehicles, residential lawn and garden).
Economic projections	Sometimes used as surrogates to approximate changes in emissions-generating activity. Examples of economic data include employment statistics, gross domestic product, and volumes of product output.
Energy use (fuel consumption) projections	Fuel consumption data and fuel consumption projections from specific economic sectors such as construction, agriculture, and mining can be adopted as surrogates for projecting future nonroad engine populations/emissions trends in those sectors. This methodology is appropriate for projecting nonroad engine activity and emissions because fuel consumed by nonroad engines is proportional to their use levels.

Because the model assigns constant hours-per-year activity rates to each piece of nonroad equipment, changes in emissions-generating activity levels are instead approximated by estimating changes in nonroad engine populations. Projections such as those described in Table 3.1 can be adopted as surrogates for projecting future nonroad engine populations.

EPA identified sets of projections to serve as surrogates for constructing annual growth indices from 2014 to 2040 for each nonroad equipment sector (see Section 3.1). The projections are independent of fuel type. The growth indices function as annual multipliers that are applied to base year nonroad engine populations in order to estimate the engine population for a given year. For example, a growth index of 2.0 for a particular year indicates that the engine population in that year is double that of the base year population. The model then linearly extrapolates, based on projected engine population estimates for 2039 and 2040, to project populations further into the future.

EPA also identified historical datasets to serve as surrogates for constructing annual, equipment sector-specific growth indices from the population base years (1996, 1998, 1999, or 2000) to 2014 (see Section 3.2). The selected historical datasets closely resemble the 2014-2040 projections with which they're mapped (e.g., fuel sales data are matched with fuel consumption projections; human population data are matched with human population projections).

EPA's methodology for applying annual, sector-specific growth indices to estimate nonroad engine populations beyond the population base years is summarized in Table 3.2.

Table 3.2 Methodology for applying nonroad engine population growth indices in MOVES2014b

Calendar Years	Method
Population base year (1996, 1998, 1999, 2000) through 2014	Apply annual historical growth indices to base year populations
2014 through 2040	Apply annual projection growth indices to estimated populations for 2014
2040 through 2060	Linearly extrapolate from the 2039 and 2040 population estimates

3.1 Surrogate Data for Projecting Future Nonroad Engine Populations

The equipment sector-specific sets of projections in Table 3.3 are largely derived from publicly available sources. While state-level projections are preferred, this level of spatial detail is not available for all equipment sectors.

State-level projections of gross domestic product (GDP) from Moody's Analytics[9] are used as growth surrogates for the Industrial and Commercial equipment sectors. Given that many of the equipment types (e.g., generator sets, forklifts, pumps) in the Industrial and Commercial equipment sectors are spread throughout the economy and not confined to a specific economic sector, a high-level economic indicator like GDP is assumed to be the best option for projecting growth in these equipment sectors.

The Lawn and Garden (residential and commercial) and Recreational Vehicles equipment sectors use state-level human population projections[10] as surrogates for engine population growth, as activity in these sectors is assumed to be closely tied to population size. State-level projections of commercial aviation operations from the Federal Aviation Administration (FAA)'s *Terminal Area Forecasts*[11] are used as growth surrogates for the Airport Service equipment sector.

National projections of revenue ton miles and recreational marine fuel consumption from the Energy Information Administration (EIA)'s *Annual Energy Outlook (AEO) 2016* are used for the Rail Maintenance[12] and Recreational Marine[13] sectors, respectively.

Finally, census region (Table 3.4) projections of energy consumption from the EIA's AEO2016 are applied to the Construction[14], Agriculture[15], Logging[16], Oil Field[17], and Underground Mining[18,19] equipment sectors. EIA furnishes unpublished energy consumption projections for specific economic sectors; these sectors are mapped to corresponding nonroad equipment sectors, as noted in Table 3.3.

Table 3.3 Surrogate data for projecting future (2014-2040) growth of nonroad engine populations[20]

Equipment Sector	Surrogate Data Source	Surrogate Data for Future Projections
Industrial	Moody's Analytics	GDP from warehousing sector
Commercial	Moody's Analytics	Economy-wide GDP
Lawn and Garden (residential and commercial)	U.S. Census Bureau	Human population
Recreational	U.S. Census Bureau	Human population
Airport Service	FAA TAF Model	Number of commercial aviation operations
Rail Maintenance	EIA AEO	Revenue ton miles
Recreational Marine	EIA AEO	Fuel consumption (recreational marine)
Construction	EIA AEO	Energy consumption (construction sector)
Agriculture	EIA AEO	Energy consumption (agriculture sector)
Logging	EIA AEO	Energy consumption (other agriculture sector)
Oil Field	EIA AEO	Energy consumption (oil and gas mining sector)
Underground Mining	EIA AEO	Energy consumption (sum of the coal sector and metallic & non-metallic mining sector)

Table 3.4 Census regions of the United States[21]

Census Region	States
West	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming
Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
South	Alabama, Arkansas, District of Columbia, Florida[a], Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia
Northeast	Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

Note:
[a] Growth indices developed for Florida are used to estimate growth in nonroad engine populations in Puerto Rico and the U.S. Virgin Islands.

3.2 Surrogate Data for Constructing Historical Nonroad Engine Populations

A second set of annual growth indices is required in order to project nonroad engine populations from the population base years (1996, 1998, 1999, or 2000) to 2014. EPA identified publicly available datasets (Table 3.5) to serve as surrogates to estimate historical engine populations, seeking to match the projection methodologies used for constructing historical populations with those used to project growth in engine populations beyond 2014. With the exception of the national-scale revenue ton miles dataset (Oak Ridge National Laboratory (ORNL)'s *Transportation Energy Data Book*[22]) used as growth surrogates for Rail Maintenance equipment, state-level data are used as historical growth surrogates for all equipment sectors.

Table 3.5 Surrogate data for projecting nonroad engine populations from the base years to 2014

Equipment Sector	Surrogate Data Source	Surrogate Data for Historical Projections
Industrial	Bureau of Economic Analysis	GDP from multiple economic sectors[a]
Commercial	Bureau of Economic Analysis	GDP from multiple economic sectors[a]
Lawn and Garden (residential)	U.S. Census Bureau	Human population
Lawn and Garden (commercial)	U.S. Census Bureau	Number of landscaping services establishments
Recreational	U.S. Census Bureau	Human population
Airport Service	FAA Terminal Area Forecasts	Number of commercial aviation operations
Rail Maintenance	ORLN Transportation Energy Data Book	Revenue ton miles
Recreational Marine	National Marine Manufacturers Association	Boat registrations
Construction	EIA Fuel Oil and Kerosene Sales	Fuel delivered to off-highway (construction) consumers
Agriculture	EIA Fuel Oil and Kerosene Sales	Fuel delivered to farm consumers
Logging	EIA Fuel Oil and Kerosene Sales	Fuel delivered to off-highway (non-construction) consumers
Oil Field	EIA Fuel Oil and Kerosene Sales	Fuel delivered to oil company consumers
Underground Mining	EIA Fuel Oil and Kerosene Sales	Fuel delivered to industrial consumers

Note:
[a] See Table 3.6 for a list of economic sectors used in the analysis.

For the Industrial and Commercial equipment sectors, GDP by state from several industries (Table 3.6) thought to utilize Industrial and Commercial equipment were obtained from the U.S. Department of Commerce Bureau of Economic Analysis[23]. GDP by state from the selected industries were summed to create the time series of state-level GDP which serve as surrogates for projecting Industrial and Commercial engine populations from the base years to 2014.

Table 3.6 North American Industry Classification System (NAICS)[24] economic sectors from which state-level GDP serve as surrogates for projecting Industrial and Commercial engine populations

NAICS Sector	NAICS Sector Description	Industrial Equipment	Commercial Equipment
11	Agriculture, Forestry, Fishing, and Hunting	X	X
21	Mining, Quarrying, and Oil and Gas Extraction	X	X
22	Utilities	X	X
23	Construction	X	X
31-33	Manufacturing	X	X
42	Wholesale Trade	X	X
44-45	Retail Trade	X	
48-49	Transportation and Warehousing	X	X
51	Information	X	
53	Real Estate and Rental and Leasing		X
56	Administrative and Support & Waste Management and Remediation Services	X	X

To maintain consistency with the surrogate data selected to project future Lawn and Garden (residential) and Recreational Vehicles equipment populations, state-level annual human population data sourced from the U.S. Census Bureau[25] are used as historical growth surrogates for these equipment categories. Similarly, the number of commercial aviation operations in each state from FAA's *Terminal Area Forecasts* model are used as growth surrogates for Airport Service equipment. The number of landscaping establishments for each state, as reported in the U.S. Census Bureau County Business Patterns Database (NAICS code 561730)[26], serve as historical growth surrogates for Commercial Lawn & Garden equipment.

State recreational boat registrations for the period 2004-2013, compiled by the National Marine Manufacturers Association[27], are used as historical growth surrogates for the Recreational Marine equipment category. A simple linear regression of 2004-2013 registrations is used to construct historical growth indices for the missing periods of 1996-2004 and 2013-2014.

Finally, EPA selected data from EIA's Fuel Oil and Kerosene Sales (FOKS) report[28] to serve as surrogates for projecting engine populations from the base years to 2014 for the Construction, Agriculture, Logging, Oil Field and Underground Mining equipment sectors. The Adjusted Distillate Fuel Oil and Kerosene Sales by End Use survey reports different grades of diesel and distillate fuels for various end use sectors in major economic sectors. EPA mapped FOKS end use sectors to nonroad equipment sectors and compiled state-level sales data for the reported fuel grades provided in Table 3.7.

Table 3.7 Fractions of reported fuel grades used to construct state-level historical trends, by FOKS end use sector and nonroad equipment sector

		Distillate Fuel Grade (Fraction)			
FOKS End Use Sector	**Nonroad Equipment Sector**	**Distillate Fuel Oil**	**No. 2 Distillate – High Sulfur Diesel**	**No. 2 Distillate – Low Sulfur Diesel**	**No. 1 Distillate**
Off-Highway: Construction	Construction	1.0			
Off-Highway: Non-Construction	Logging	1.0			
Industrial	Underground Mining		1.0	1.0	0.4
Oil Company	Oil Field	1.0			
Farm	Agriculture	1.0			

Due to the volatile behavior of the raw sales series, we elected not to use a value for a single year as the basis from which to forecast future fuels sales. Consequently, we performed aggregation of the raw series, using a technique common in econometric analysis.

As a first step in constructing historical sales trends for each state, the 5-point weighted-centered moving average (WCMA5) of the raw sales trend was calculated, with fuel sales expressed as thousands of gallons (1,000 gal). Five time points (years) were included, i.e. *t*-2, *t*-1, *t*, *t*+1 and *t*+2, with each weighted as 2, 3, 5, 3 and 2, respectively. To obtain the average, the weighted sales sum was divided by 15, or the total sum of the weights.

In the final year of the series (2014), at which point five time points are not available, the average was calculated as a 3-point trailing moving average that included points *t*-2, *t*-1 and *t* (weighted, respectively, as 2, 3 and 5), and with a reduced sum of weights of 10.

After calculating the WCMA5, the average sales were indexed to a population base year of 2000. However, in some cases, values in specific years were modified to avoid nonsensical or unreasonable results in some states in some sectors. Specifically, if the WCMA5 in any year and state in any of the target sectors was between zero and 1,000 gallons, the values were reset to 1,000 gallons.

4 Results

Annual, state-level growth indices for each equipment sector are applied to every equipment type within the sector, from their respective population base year to 2040. The resulting nrgrowthindex database contains over 55,000 entries, so in the interest of brevity, a sample of results are presented here. Figures 4.1- 4.13 show time series of annual growth indices corresponding to one state from each U.S. Census Region (Table 3.4). Although the model linearly extrapolates engine populations from 2039 and 2040 for years beyond 2040, for illustrative purposes, Figures 4.1- 4.13 include linearly extrapolated growth indices. Example states vary by sector to better illustrate the sector growth. The national average index across all states is also plotted.

Figure 4.1 shows the results from the Industrial equipment sector (1998 base year). Surrogate data for historical indices is GDP from multiple economic sectors; surrogate data for future projections is GDP from the warehousing sector (NAICS sector 48-49). Growth indices for Illinois (Midwest Census Region), Massachusetts (Northeast Census Region), Texas (South Census Region), and Arizona (West Census Region) are shown.

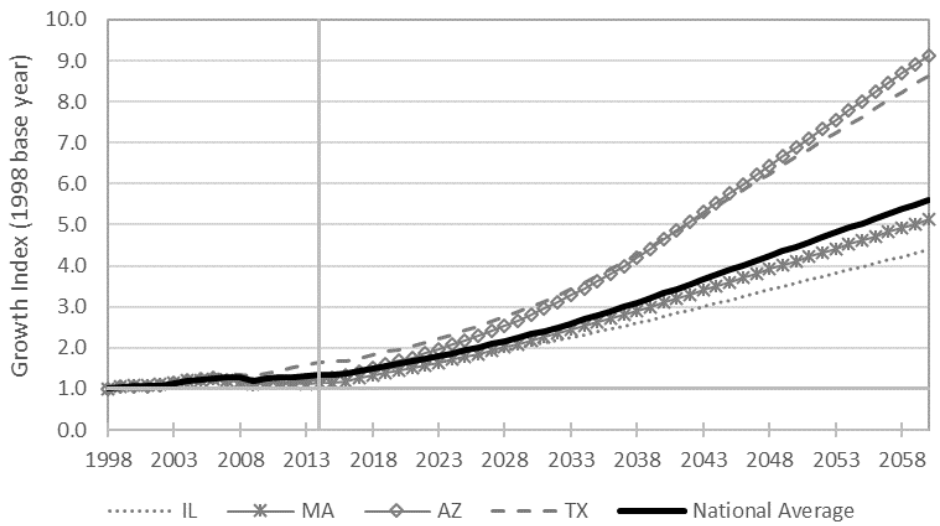

Figure 4.1 Annual growth indices from 1998 base year to 2060 for Industrial equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Results from the Commercial equipment sector (1998 base year) for Illinois, Massachusetts, Arizona, and Texas are shown in Figure 4.2. Surrogate data for historical indices is state-level GDP from multiple economic sectors; surrogate data for future projections is the economy-wide state GDP.

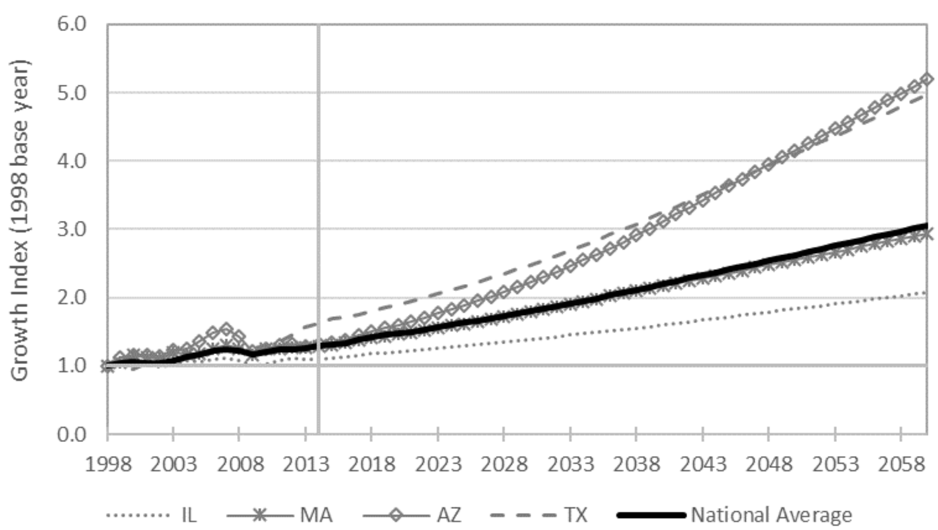

Figure 4.2 Annual growth indices from 1998 base year to 2060 for Commercial equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Example growth indices corresponding to the Lawn and Garden equipment sector are shown in Figure 4.3 (residential lawn and garden equipment) and Figure 4.4 (commercial lawn and garden equipment). Both plots assume a 1998 population base year and results from Illinois, Massachusetts, California, and Texas are highlighted. Human population projections are used as surrogates to project future populations of residential and commercial lawn and garden equipment. Historical growth indices for residential lawn and garden equipment populations are based on human population data; the number of landscaping services establishments is the basis for the historical indices used for commercial lawn and garden equipment.

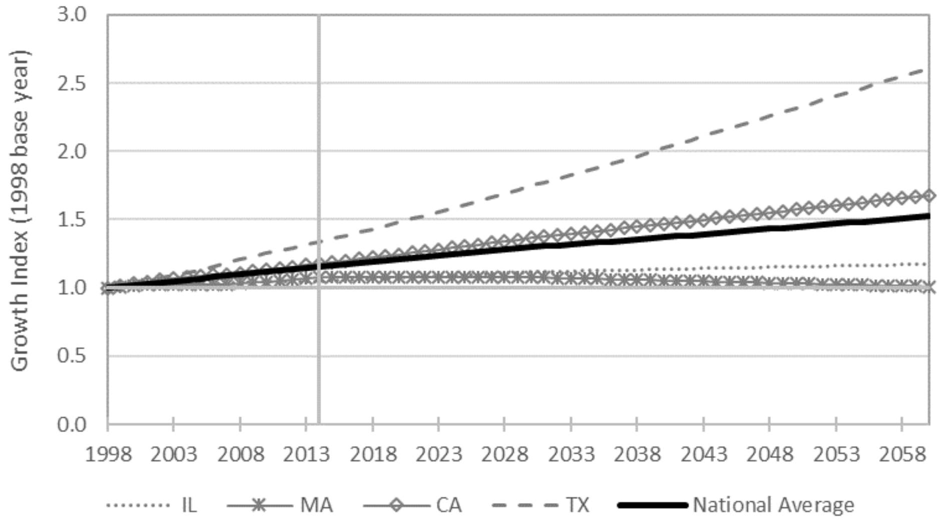

Figure 4.3 Annual growth indices from 1998 base year to 2060 for Residential Lawn and Garden equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

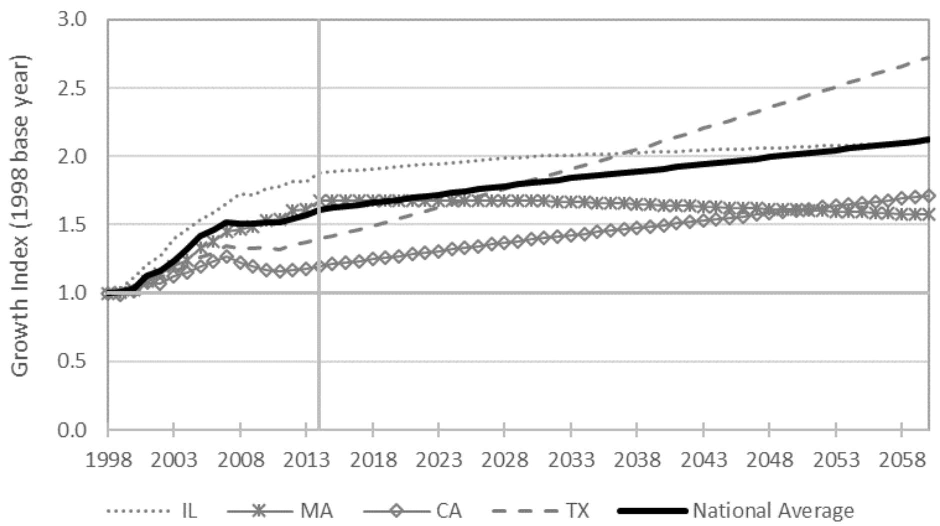

Figure 4.4 Annual growth indices from 1998 base year to 2060 for Commercial Lawn and Garden equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Equipment population growth indices for the Recreational equipment sector (1998 base year) for Minnesota, Massachusetts, Wyoming, and Texas are shown in Figure 4.5. Human population data and projections serve as surrogates for both historical and projected equipment populations.

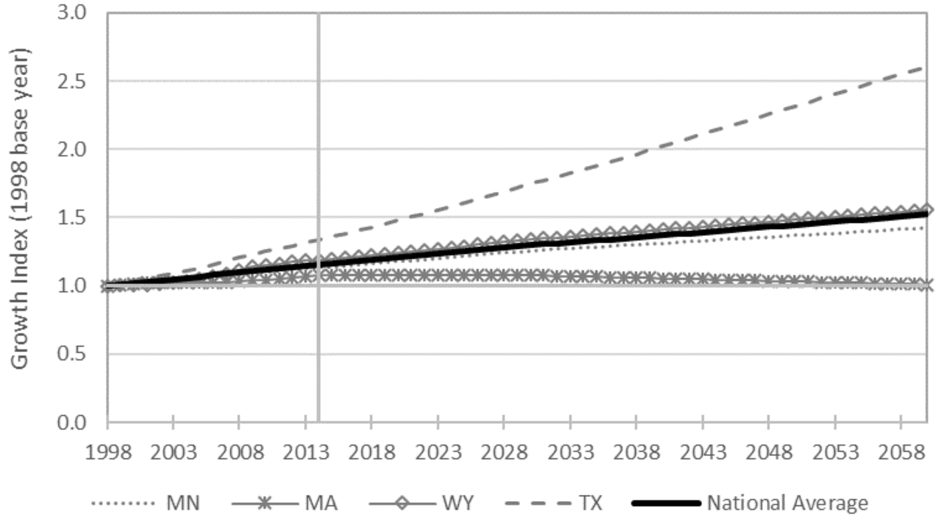

Figure 4.5 Annual growth indices from 1998 base year to 2060 for Recreational equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

State-level equipment population growth indices for the Airport Service equipment sector (1998 base year) for Illinois, New York, Arizona, and Texas are shown in Figure 4.6. Both the historical and future projections are based on the number of commercial aviation operations reported by FAA's TAF model.

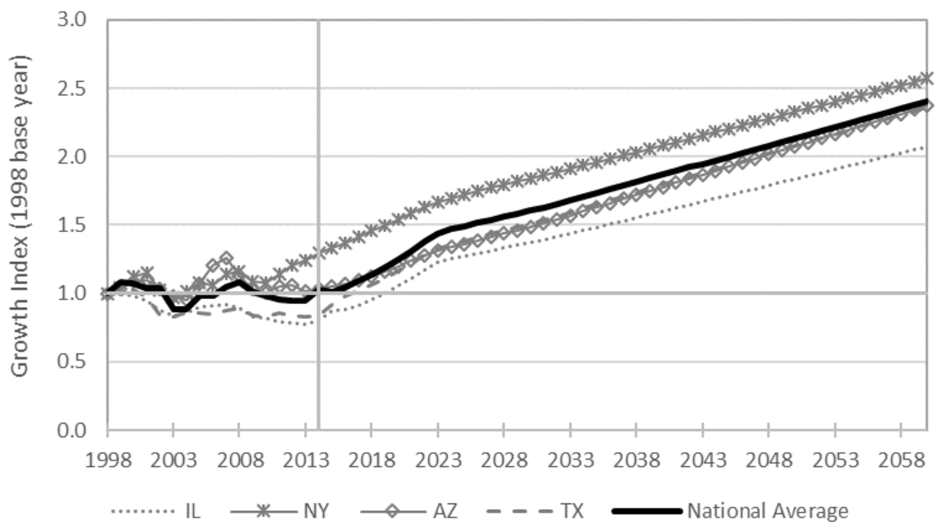

Figure 4.6 Annual growth indices from 1998 base year to 2060 for Airport Service equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

The national-scale growth indices for the Railway Maintenance equipment sector (1998 and 2000 base years) are shown in Figure 4.7. National revenue ton miles are the basis for both historical and future projections.

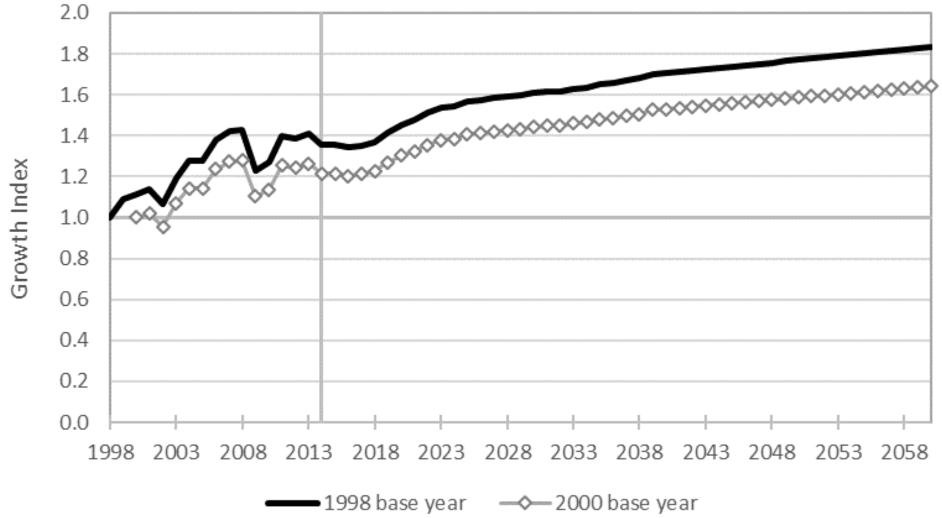

Figure 4.7 Annual growth indices from 1998 and 2000 base years to 2060 for Railway Maintenance equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Figure 4.8 shows the growth indices for the Recreational Marine equipment sector (1998 base year) for Minnesota, New York, Washington, and Florida. The pre-2014 historical indices are based on state-level boat registration data; human population projections are used to project future populations of Recreational Marine equipment.

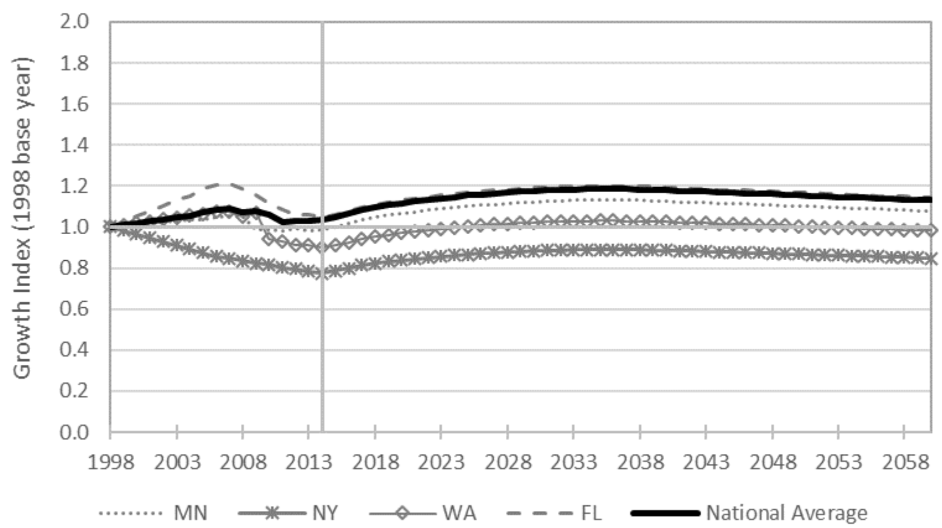

Figure 4.8 Annual growth indices from 1998 base year to 2060 for Recreational Marine equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Equipment population growth indices for the Construction equipment sector (2000 base year) for Illinois, New York, Arizona, and Texas are shown in Figure 4.9. Historical indices are based on sector-specific Fuel Oil and Kerosene Sales data, while the future growth indices are based on projected fuel consumption in the construction sector.

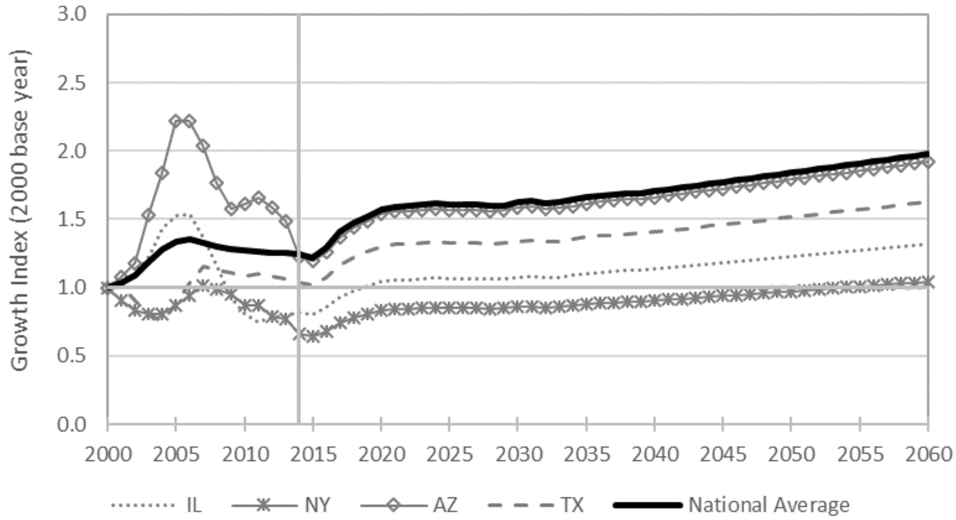

Figure 4.9 Annual growth indices from 2000 base year to 2060 for Construction equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Similar to the Construction equipment sector, the Agricultural equipment sector uses sector-specific fuel sales data and energy consumption projections are surrogates for historical and future growth indices. Results from Nebraska, Vermont, California, and North Carolina (2000 base year) are highlighted in Figure 4.10.

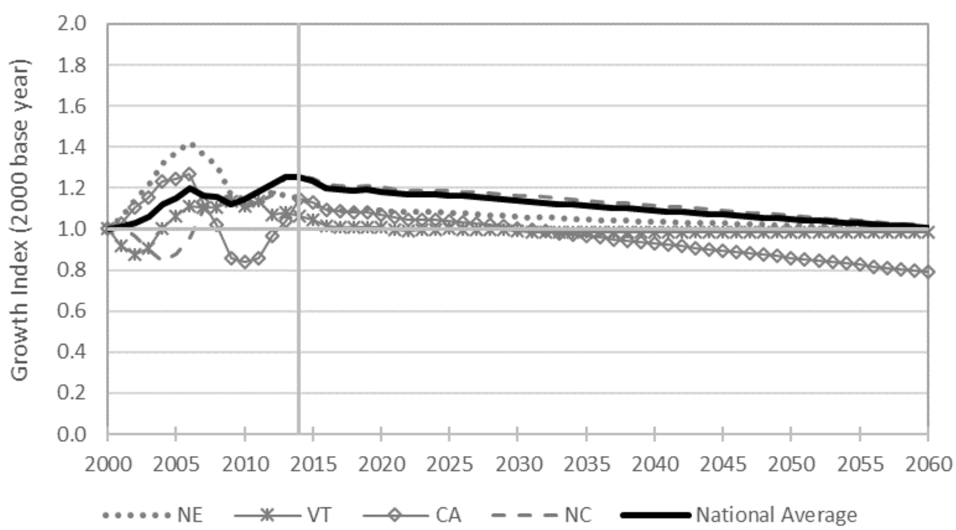

Figure 4.10 Annual growth indices from 2000 base year to 2060 for Agricultural equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Figure 4.11 shows the growth indices for the Logging equipment sector (2000 base year) for Minnesota, Vermont, Oregon, and Georgia. Historical indices are based on sales of fuel delivered to off-highway consumers, while the future projections are based on projected energy consumption in the "other agriculture" sector.

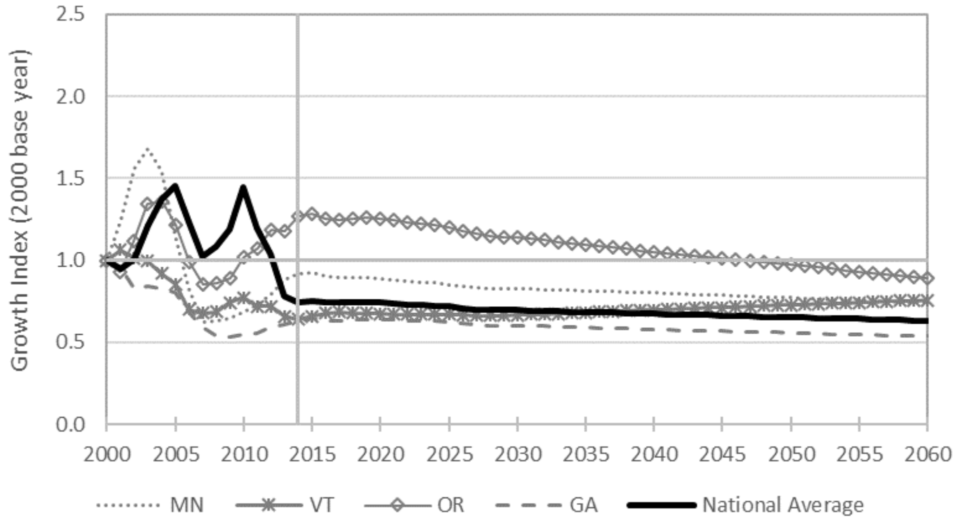

Figure 4.11 Annual growth indices from 2000 base year to 2060 for Logging equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Equipment population growth indices for the Oil Field equipment sector (2000 base year) for South Dakota, Pennsylvania, Alaska, and Texas are shown in Figure 4.12. Projections of energy consumption in the oil and gas mining sector serve as surrogates for future growth indices, and fuel sales to oil company consumers are used to construct historical growth indices.

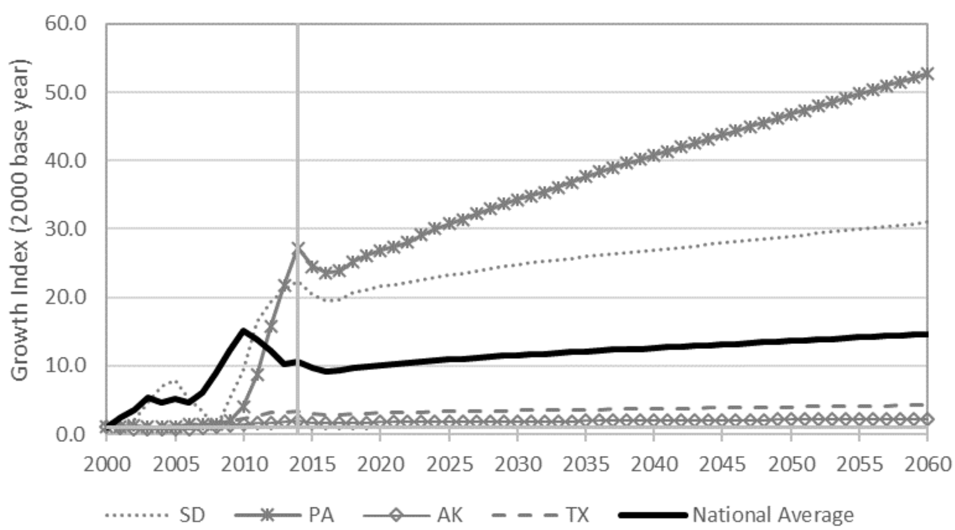

Figure 4.12 Annual growth indices from 2000 base year to 2060 for Oil Field equipment. The vertical line at 2014 indicates the transition between historical and projection indices.

Figure 4.13 shows the growth indices for the Underground Mining equipment sector (2000 base year) for Illinois, Pennsylvania, Wyoming, and West Virginia. Historical indices are based on sales of fuel delivered to industrial consumers, while the future projections are based on projected energy consumption in the coal sector and metallic & non-metallic mining sector.

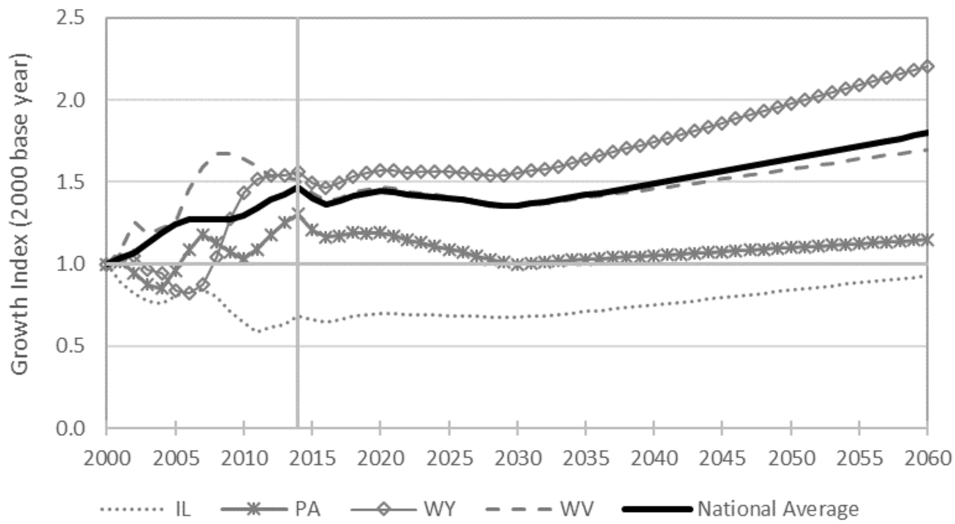

Figure 4.13 Annual growth indices from 2000 base year to 2060 for Underground Mining equipment. The vertical line at 2014 indicates the transition between historical and projection indices

5 Peer Review of Draft Report

This section contains comments on the draft report of *Nonroad Engine Population Growth Estimates in MOVES2014b* from two peer reviewers and EPA's responses to those comments. The reviewers were selected by a third-party contractor, ICF International, facilitating a peer review of MOVES technical reports. The submitted peer review comments are publicly available on the EPA Science Inventory database[29].

5.1 Overview of the Peer-Review

The two experts who reviewed the draft report of *Nonroad Engine Population Growth Estimates in MOVES2014b* were:

Robert F. Sawyer, Ph.D.
Partner
Sawyer Associates

Phil Lewis, Ph.D.
Associate Professor
Department of Construction Science
College of Architecture
Texas A&M University

The peer-reviewers were given the following charge:

We are submitting this material for you to review selected methods and underlying assumptions, their consistency with the current science as you understand it, and the clarity and completeness *of the presentation. For this review, no independent data analysis is required. Rather, we ask that you assess whether the information provided is representative of the state of current understanding, and whether incorporating the information into EPA's MOVES model will result in appropriate predictions and conclusions.*

We request you provide us comments on substantive content sequentially. These will be listed as an appendix to the final published report, along with EPA's responses. Comments on organization, formatting, and other minor issues are welcome, but should be provided separately.

Below are questions to define the scope of the review; we are not expecting individual responses to the questions, but would like them to help guide your response.

General Questions to Consider:

1. *Does the presentation describe the selected data sources sufficiently to allow the reader to form a general view of the quantity, quality and representativeness of data used in the analysis? Are you able to recommend alternate data sources that might better allow the model to estimate national or regional default values?*

2. *Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA while developing the model inputs? Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?*

3. *Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs? In making recommendations, please distinguish between instances involving reasonable disagreement in adoption of methods as opposed to instances where you conclude that current methods involve specific technical errors.*

4. *Where EPA has concluded that applicable data is meager or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions are appropriate and reasonable? If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.*

5. *Are the resulting model inputs appropriate and, to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in mobile source emissions, formation and control? Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?*

Specific Questions:

In addition to the general review, we request specific responses to the following questions:

1. *This report describes a method for aggregating Fuel Oil and Kerosene Sales (FOKS) data to generate growth indices for various nonroad equipment sectors. Are there better or alternative methods for aggregating time series data such as the FOKS dataset?*
2. *Are there data sources EPA selected to serve as surrogates for historical and future growth indices appropriate for the nonroad equipment sectors to which they are assigned?*

5.2 General Comments from Robert F. Sawyer

The methodology outlined to establish the baseline population is a reasonable, but unfortunate, compromise based on a lack of contemporary data. The database, now 22 years old, is valuable in that it contains a reasonably detailed breakdown nonroad engines by sector and fuel. It would appear that there is no provision for electricity as a fuel in any of the sectors. (Perhaps this will be accounted for in the emission factor part of the model.) In Table 3.1, the fourth projection methodology is unclear.

> ***RESPONSE:*** *MOVES does not currently account for the relatively small fraction of nonroad equipment powered by electricity. EPA recognizes that electricity as a fuel for nonroad mobile sources is growing in market share, and that this penetration will need to be addressed in future versions of MOVES.*
>
> *The description for adopting fuel consumption data and projections as surrogates for estimating growth in nonroad engine populations has been edited for clarity.*

The surrogate data for estimating nonroad engine population growth methodology outlined in Table 3.3 and Table 3.5 is reasonable. The use of fuel sales to develop population is an important check on projections based on historical trends, but appears, incorrectly, to assume that engine efficiencies are constant over time. Statistical methods for smoothing data are reasonable. Projections to 2060 are, of course, highly uncertain but this is not critical since the model and base data will certainly continue to be improved periodically. The methodology for developing state level nonroad engine populations is reasonable.

> ***RESPONSE:*** *We take the reviewer's point, and agree that the projections described here are not sophisticated enough to explicitly account for projected trends in fuel efficiency. However, developing this sophistication would require investment of significant effort to predict an additional uncertain parameter. Given the major uncertainties involved in long-term projections, it is not clear that these efforts would substantially improve the utility of the model..*

5.3 General Comments from Phil Lewis

General Comments:

In my opinion, the reports include an adequate presentation of the methods used to update the Nonroad model. As a user of previous versions of Nonroad, I frequently referred to the documents and reports to gain better insight to the application of the model. I believe these reports provide a sufficient explanation of the assumptions and data used in the updated Nonroad model. As a potential user of Nonroad in the future, I am satisfied with the explanations given for the assumptions and data sources provided in the reports. Furthermore, I have no recommendations for alternate data sources.

Description of the analytical methods are thorough enough for the reader to gain an understanding of the general approaches used to update the Nonroad model; however, it would be somewhat difficult to duplicate the methodologies in their entirety. In order to duplicate the methodologies, I believe more detail is needed, perhaps in the form of sample calculations. I do not believe, however, that duplication is the primary objective of the reports; therefore, I do not recommend adding unnecessary details. I also found the examples provided for tables and figures to be appropriate for their intended use.

I believe the methods and procedures are technically and scientifically sound. This is a reasonable approach to predict the future of nonroad equipment on a grand scale. I have no suggestions or recommendations for improving the approach.

When trying to predict the future, no one has a High Definition crystal ball; therefore, we are left with assumptions. I believe the assumptions chosen to fill in the gaps in data are sufficient enough to provide reasonable model outputs.

Unfortunately, I have limited expertise with the physical and chemical processes associated with the formation and speciation of emissions. I believe the model inputs are empirically consistent and adequate based on my limited knowledge.

Specific Comments:

I believe the FOKS methodology is the most direct approach to estimating growth indices for some nonroad equipment sectors. It may be possible to refine the approach in an attempt to gain a higher resolution estimate, although I am not sure the added benefits would justify the extra effort. Considering the Construction sector as an example, it may be possible to use population and GDP data (particularly in specific regions) to estimate the growth in market for construction which would result in the need for more nonroad equipment. Presumably, the FOKS methodology takes this into account but it is not apparent in the report. I believe for the intended use of Nonroad (and ultimately MOVES), the FOKS approach as presented in sufficient.

> ***RESPONSE:*** *As tailpipe emissions are created during fuel combustion, we considered fuel sales and projected consumption to be perhaps the most appropriate surrogate available to forecast equipment populations. Nonetheless, for future versions of MOVES, EPA is interested in exploring projection methodologies that utilize multiple data sets that might provide a more holistic view of nonroad engine activity and population growth.*

To the best of my knowledge, the surrogates are appropriate to the sectors they were assigned. As a general comment, I feel that the approach is rather clever and certainly provides some insight in an area where it is difficult to gain any at all.

Additional Overall Comments:

I have a minor qualm with the following phrase:
“Because trends in nonroad engine activity levels are never directly measured, …”

In my opinion, this phrase makes me think that the data has never been available nor will it ever be available. I agree that heretofore it has been very difficult to acquire real-world activity data from nonroad equipment; however, with the advent of telematics and portable activity measurement systems (PAMS), collecting large amounts of activity data is becoming more of a reality. I realize that future data collection cannot have an impact on this version of Nonroad but EPA should consider sponsoring large scale data collection, storage, management, and analysis efforts to gain this missing component. Real-world activity data will help fill the gaps and refine the assumptions that are inherent in this version of Nonroad.

> ***RESPONSE:*** *We agree that real-world activity data measured by portable activity and telematics measurement systems could serve to enhance the assumptions and refine the underlying data in MOVES. Whilst real-world activity data collection efforts in the nonroad sector are not yet as widespread as in the onroad sector, and require major and sustained research investments, EPA supports these efforts and intends to incorporate such datasets into future versions of the model. The opening paragraph has been modified to indicate that trends in nonroad engine activity are* ***rarely*** *directed measured.*

6 References

[1] U.S. Environmental Protection Agency (2018). *Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines.* EPA-420-R-18-009. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Ann Arbor, MI. July, 2018. https://www.epa.gov/moves/moves-technical-reports

[2] U.S. Environmental Protection Agency (2010). *Exhaust Emission Factors for Nonroad Engine Modeling – Spark-Ignition.* EPA-420-R-10-019. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Ann Arbor, MI. July, 2010. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081YF.pdf

[3] U.S. Environmental Protection Agency (2010). *Median Life, Annual Activity, and Load Factor Values for Nonroad Emissions Modeling.* EPA-420-R-10-016. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Ann Arbor, MI. July, 2010. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081RV.pdf

[4] Power Systems Research (1998). *US Parts Link Edition 6.2*. St. Paul, MN.

[5] U.S. Environmental Protection Agency (2004). *Nonroad Engine Growth Estimates.* EPA-420-P-04-008. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental

Protection Agency, Ann Arbor, MI. April, 2004. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10001W2.pdf

[6] U.S. Environmental Protection Agency (2010). *Nonroad Engine Population Estimates.* EPA-420-R-10-017. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Ann Arbor, MI. July, 2010. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081T6.pdf

[7] U.S. Environmental Protection Agency (2005). *Geographic Allocation of Nonroad Engine Population Data to the State and County Level.* EPA-420-R-05-021. Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency, Ann Arbor, MI. December, 2005. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1004LDX.pdf

[8] Wolf, M. and Baker, R. (2016). *Summary of Proposed Approaches for Generating Projections of Nonroad Population Growth Trends: Technical Memorandum*. EPA Contract No. EP-C-12-017, Work Assignment No. 4-14, Eastern Research Group (ERG), May 23, 2016.

[9] Moody's Analytics (2016). *Gross Domestic Product Forecasts.*

[10] University of Virginia Weldon Cooper Center for Public Service (2016). *Observed and Total Population for the U.S. and the States, 2010-2014; May 2016 Update.* http://demographics.coopercenter.org/national-population-projections/

[11] Federal Aviation Administration (2015). *Terminal Area Forecast (TAF) Model*. https://www.faa.gov/data_research/aviation/taf/

[12] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – Table 7 (Transportation Sector Key Indicators and Delivered Energy Consumption)*. September 15, 2016. https://www.eia.gov/outlooks/archive/aeo16/

[13] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – Table 37 (Transportation Sector Energy Use by Fuel Type Within a Mode)*. September 15, 2016. https://www.eia.gov/outlooks/archive/aeo16/

[14] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – unpublished data (INDUSA File – Table 6 [Energy and Macroeconomic Profile for Non-Manufacturing Industry – Construction])*. Files provided to ERG on July 5, 2016 for EPA Contract No. EP-C-12-017, Work Assignment No. 4-14.

[15] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – unpublished data (INDUSA File – Table 1 [Energy and Macroeconomic Profile for Non-Manufacturing Industry – Crop Agriculture])*. Files provided to ERG on July 5, 2016 for EPA Contract No. EP-C-12-017, Work Assignment No. 4-14.

[16] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – unpublished data (INDUSA File – Table 2 [Energy and Macroeconomic Profile for Non-Manufacturing Industry – Other Agriculture])*. Files provided to ERG on July 5, 2016 for EPA Contract No. EP-C-12-017, Work Assignment No. 4-14.

[17] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – unpublished data (INDUSA File – Table 4 [Energy and Macroeconomic Profile for Non-Manufacturing Industry – Oil &*

Gas Mining]). Files provided to ERG on July 5, 2016 for EPA Contract No. EP-C-12-017, Work Assignment No. 4-14.

[18] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – unpublished data (INDUSA File – Table 5 [Energy and Macroeconomic Profile for Non-Manufacturing Industry – Metallic & Non-metallic Mining]).* Files provided to ERG on July 5, 2016 for EPA Contract No. EP-C-12-017, Work Assignment No. 4-14.

[19] U.S. Energy Information Administration (2016). *Annual Energy Outlook 2016 – unpublished data (INDUSA File – Table 3 [Energy and Macroeconomic Profile for Non-Manufacturing Industry – Coal Mining]).* Files provided to ERG on July 5, 2016 for EPA Contract No. EP-C-12-017, Work Assignment No. 4-14.

[20] Wolf, M. and Baker, R. (2016). *Develop Final Population Growth Rates and Supporting Documentation: Technical Memorandum*. EPA Contract No. EP-C-12-017, Work Assignment No. 4-14, Eastern Research Group (ERG), November 15, 2016.

[21] U.S. Census Bureau (2010). *Geographic Terms and Concepts – Census Divisions and Census Regions*. https://www.census.gov/geo/reference/gtc/gtc_census_divreg.html

[22] Davis, S., Williams, S., and Boundy, R., Oak Ridge National Laboratory Center for Transportation Analysis (2016). *Transportation Energy Data Book: Edition 35*. Oak Ridge, TN, October 31, 2016. http://cta.ornl.gov/data/index.shtml

[23] U.S. Department of Commerce Bureau of Economic Analysis (2016). *Interactive Tables: Gross Domestic Product (GDP)*. https://www.bea.gov/regional/index.htm

[24] Office of Management and Budget (2017). *North American Industry Classification System*. Washington, D.C. https://www.census.gov/eos/www/naics/2017NAICS/2017_NAICS_Manual.pdf

[25] U.S. Census Bureau (2016). *Population and Housing Unit Estimates Datasets*. https://www.census.gov/programs-surveys/popest/data/data-sets.html

[26] U.S. Census Bureau (2016). *County Business Patterns Database*. https://www.census.gov/programs-surveys/cbp/data/datasets.html

[27] National Marine Manufacturers Association (2016). https://www.nmma.org/

[28] U.S. Energy Information Administration (2016). *Fuel Oil and Kerosene Sales*. https://www.eia.gov/petroleum/fueloilkerosene/

[29] U.S. Environmental Protection Agency (2018). *Science Inventory. Peer Review: Nonroad (NR) Updates to Population Growth, Compression Ignition (CI) Criteria, Toxic Emission Factors and Speciation Profiles*. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=339678