



# Updated NONROAD Equipment Population Growth Rates

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MOVES Review Work Group  
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# Overview

- NONROAD Equipment Populations
- Equipment Population Growth Rates in NONROAD
- Approaches for Developing Nonroad Equipment Growth Indices
- Surrogate Data for Updated Growth Indices
- Testing Results: Updated Equipment Populations
- Testing Results: Inventory Impacts (NO<sub>x</sub>, CO, PM<sub>2.5</sub>)



# NONROAD Equipment Populations

- EPA continues to work on updating NONROAD's underlying data inputs and model architecture
- In contrast to onroad sources, there is a scarcity of high-quality nonroad equipment population and activity data, so data updates require substantial effort. For example:
  - National equipment populations for a specified base year must be estimated with sales data and approximations of scrappage rates
  - National populations must be allocated to the county level using surrogate data
- Equipment populations for a specified base year are a snapshot; the year-to-year variability of equipment populations – a critical input for estimating nonroad emissions inventories – must be taken into account by the model
- NONROAD uses annual growth rates to determine equipment populations beyond the model base years (1996-2000)
- In lieu of updating NONROAD equipment populations for the next version of MOVES, EPA intends to update the **equipment population growth indices** that are applied to base year populations



# Current NONROAD Equipment Growth Estimates

- The model specifies annual national average growth rates by equipment category (e.g., construction, agriculture, lawn & garden, recreational) and fuel type
- Uses a simple linear regression of historical (1989-1996) engine populations from the Power Systems Research (PSR) database to estimate engine populations out to 2050
- Average annual growth rates derived from the PSR database of equipment population from 1989-1996 are significantly higher than economic (gross state product) measures from the Bureau of Economic Analysis (BEA) over the same time period

Sector	BEA	PSR Database				
		Total	Diesel	Gasoline	LPG	CNG
Construction	1.2%	2.3%	3.2%	0.2%		
Agriculture	2.0%	2.6%	3.0%	1.8%		-10.2%
Industrial	1.8%	2.7%	3.7%	-4.0%	3.8%	
Lawn & Garden	0.9%	2.4%	6.8%	2.4%		
Commercial	1.8%	4.0%	4.5%	3.8%	8.7%	4.2%
Logging	0.6%	4.5%	-1.0%	5.0%		
Railway	3.4%	2.6%	4.4%	1.4%		
Recreational <sup>1</sup>	0.9%	0.7%	3.3%	0.6%		

- General consensus that basing long-term growth estimates on seven years of population data limits the model's ability to accurately portray nonroad equipment/emissions growth at the regional or state levels

<sup>1</sup> These linear values are not used for off-road motorcycles, ATVs, or snowmobiles

Source: USEPA (2004). Nonroad Engine Growth Estimates. EPA420-P-04-008. Ann Arbor, MI. April 2004. <https://www.epa.gov/moves/nonroad-technical-reports>



# Updating NONROAD Growth Indices

- Approaches for projecting nonroad equipment population growth trends include:
  - **Extrapolation of Historical Data:** used if other projection methods are not feasible (current method)
  - **Activity Projections:** tend to focus on a narrower or specialized sector of equipment
  - **Census Population Projections:** often used in nonpoint source emission inventory projections for which activity is closely correlated with human population size
  - **Economic Projections:** sometimes used to approximate changes in emission-generating activity
  - **Energy Use Projections:** appropriate for projecting future nonroad emissions because nonroad equipment consume fuel in direct proportion to their use levels
- Projections of sector-specific energy use are a preferred surrogate data source, because nonroad fuel consumption tends to correlate to use levels
- Surrogate data from publicly-available data sources are preferred
- Projection data can be matched with corresponding historical data to “reconstruct” annual equipment populations in NONROAD



# Surrogate Data for Projecting Future (2014+) Growth

Equipment Sector	Projections Surrogate Data	Scale	Projections Surrogate Data Source
Construction	Energy consumption (construction)	Census Region	EIA Annual Energy Outlook <sup>1</sup>
Agriculture	Energy consumption (agriculture)	Census Region	EIA Annual Energy Outlook <sup>1</sup>
Logging	Energy consumption (other agriculture)	Census Region	EIA Annual Energy Outlook <sup>1</sup>
Oil Field	Energy consumption (oil & gas mining)	Census Region	EIA Annual Energy Outlook <sup>1</sup>
Rail Maintenance	Revenue ton miles	National	EIA Annual Energy Outlook
Underground Mining	Energy consumption (coal and metallic & non-metallic mining)	Census Region	EIA Annual Energy Outlook <sup>1</sup>
Industrial	GDP from warehousing sector	State	Moody's Analytics
Lawn & Garden	Human population	State	U.S. Census Bureau
Recreational Vehicles	Human population	State	U.S. Census Bureau
Commercial	Economy-wide GDP	State	Moody's Analytics
Airport Service	Number of commercial operations	State	FAA Terminal Area Forecast Model
Recreational Marine	Fuel consumption (recreational marine)	National	EIA Annual Energy Outlook

<sup>1</sup>Unpublished data (Energy and Macroeconomic Profile for Non-Manufacturing Industry) from the 2016 Annual Energy Outlook (EIA)



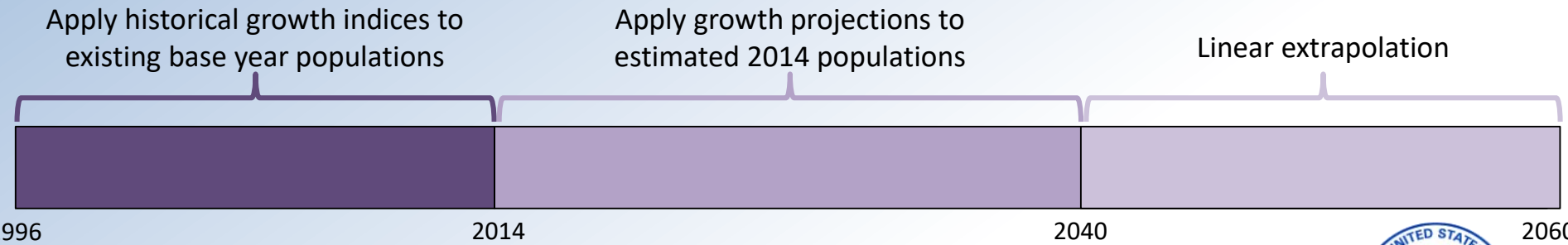
# Surrogate Data for Reconstructing Historical (1996-2014) Growth

Equipment Sector	Historical Surrogate Data	Scale	Historical Surrogate Data Source
Construction	Fuel delivered to off-highway consumers	State	EIA Fuel Oil and Kerosene Sales
Agriculture	Fuel delivered to farm consumers	State	EIA Fuel Oil and Kerosene Sales
Logging	Fuel delivered to off-highway consumers	State	EIA Fuel Oil and Kerosene Sales
Oil Field	Fuel delivered to oil company consumers	State	EIA Fuel Oil and Kerosene Sales
Rail Maintenance	Revenue ton miles	National	ORNL Trans. Energy Data Book
Underground Mining	Fuel delivered to industrial consumers	State	EIA Fuel Oil and Kerosene Sales
Industrial	GDP from multiple sectors	State	Bureau of Economic Analysis
Lawn & Garden	Human population	State	U.S. Census Bureau
Recreational Vehicles	Human population	State	U.S. Census Bureau
Commercial	GDP from multiple sectors	State	Bureau of Economic Analysis
Airport Service	Number of commercial operations	State	FAA Terminal Area Forecast Model
Recreational Marine	Boat registrations	State	National Marine Manufacturers Assoc.



# Constructing NONROAD Growth Indices

- State-level historical growth indices and future growth projections (both derived from surrogate data) are combined:
  - Apply historical growth indices to NONROAD’s base year (1996, 1998, 1999, 2000) populations, to estimate annual equipment populations through 2014
  - Apply growth projections to the reconstructed 2014 equipment populations, to estimate equipment populations through 2040. The model linearly extrapolates, from the 2039 and 2040 population estimates, to 2060.





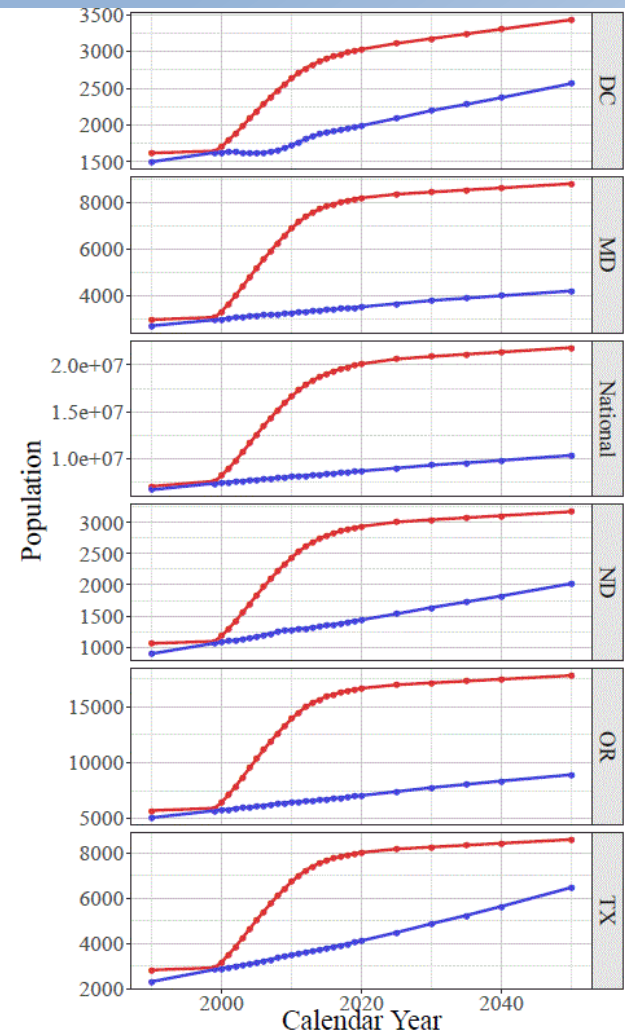
# Testing New Growth Indices

- Growth update requires modifications to model source code, to accommodate the ~55,000 annual, state-level indices (the model currently contains 564 growth index values)
- New growth indices were tested by running MOVES2014a-NONROAD with the FORTRAN changes and database update and comparing output against a MOVES2014a-NONROAD run with all default values
- Runspecs included:

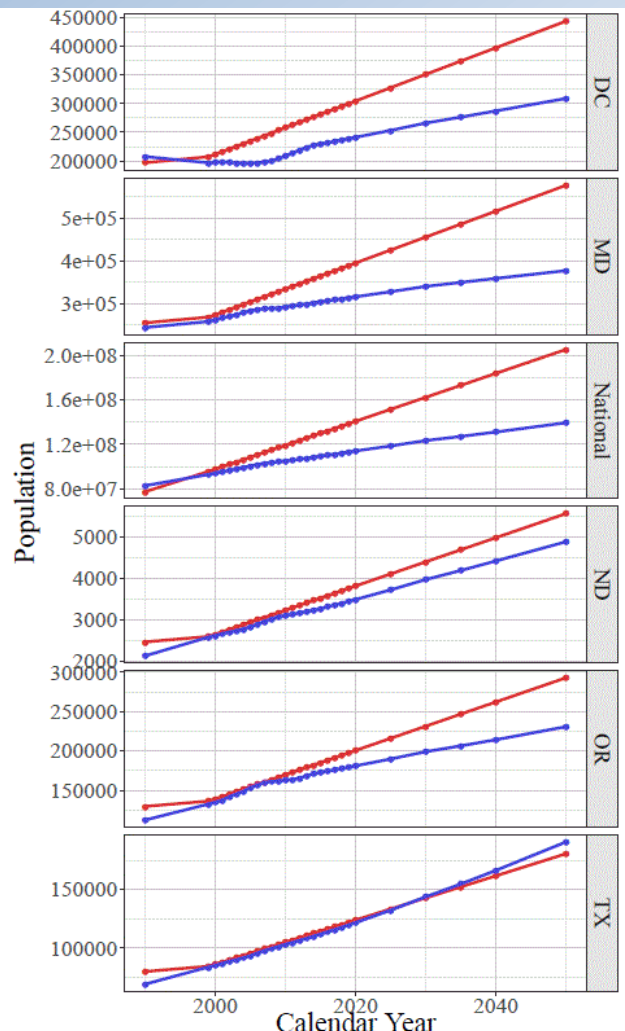
<b>Calendar Years</b>	1990, 1996-2020, 2025, 2030, 2035, 2040, 2045, 2050
<b>Months</b>	January, July (annual inventories estimated by scaling up the January and July inventories; assuming an average of 4.3 weekend-weekday combinations per month)
<b>Days</b>	Weekend and weekday
<b>Geographic Scope</b>	National, D.C., Galveston (TX), Prince George's (MD), Clackamas (OR), Mountrail (ND) Counties
<b>Equipment</b>	All SCCs
<b>Fuel Types</b>	All
<b>Pollutants</b>	CO <sub>2</sub> , CO, NO <sub>x</sub> , PM <sub>10</sub> , PM <sub>2.5</sub> , SO <sub>2</sub> , Brake-Specific Fuel Consumption

# Updated Equipment Populations (By Equipment Category; 1990-2050)

Recreational



Lawn & Garden



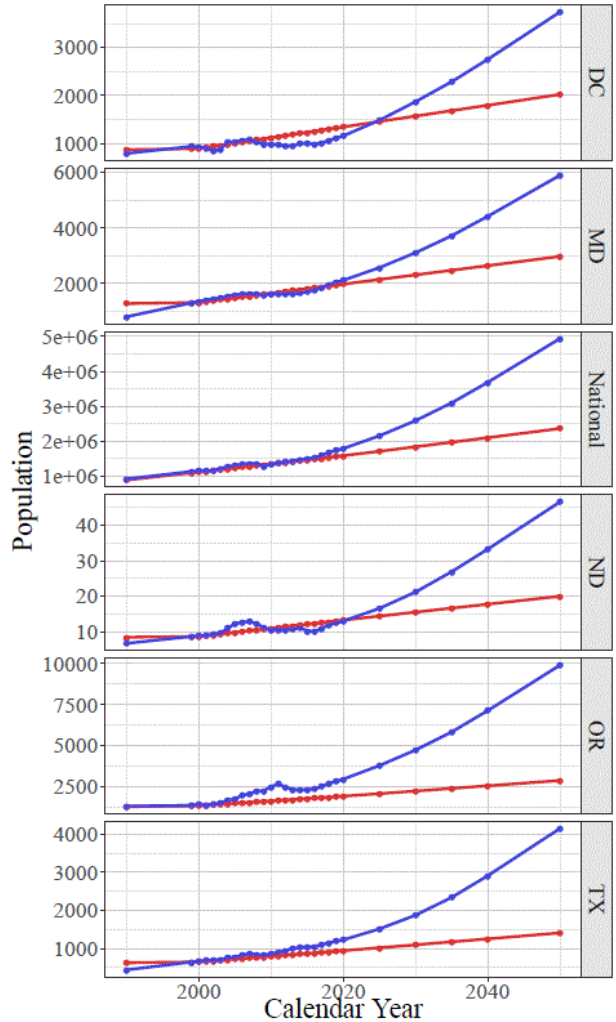
*State-level human population (actual and projected) used as the surrogate for growth*

**MOVES2014a**  
**Update**

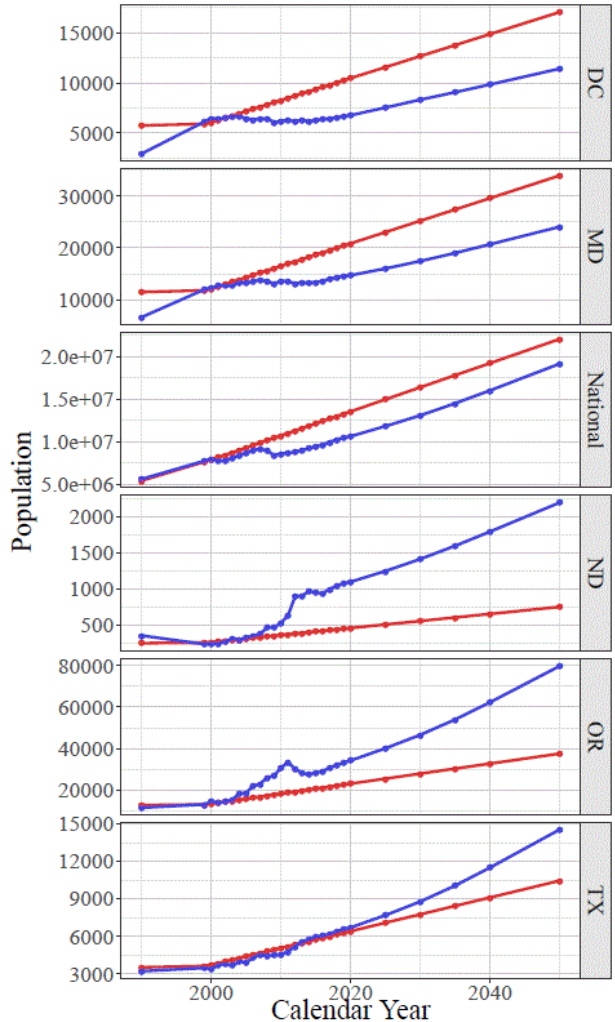


# Updated Equipment Populations (By Equipment Category; 1990-2050)

Industrial



Commercial



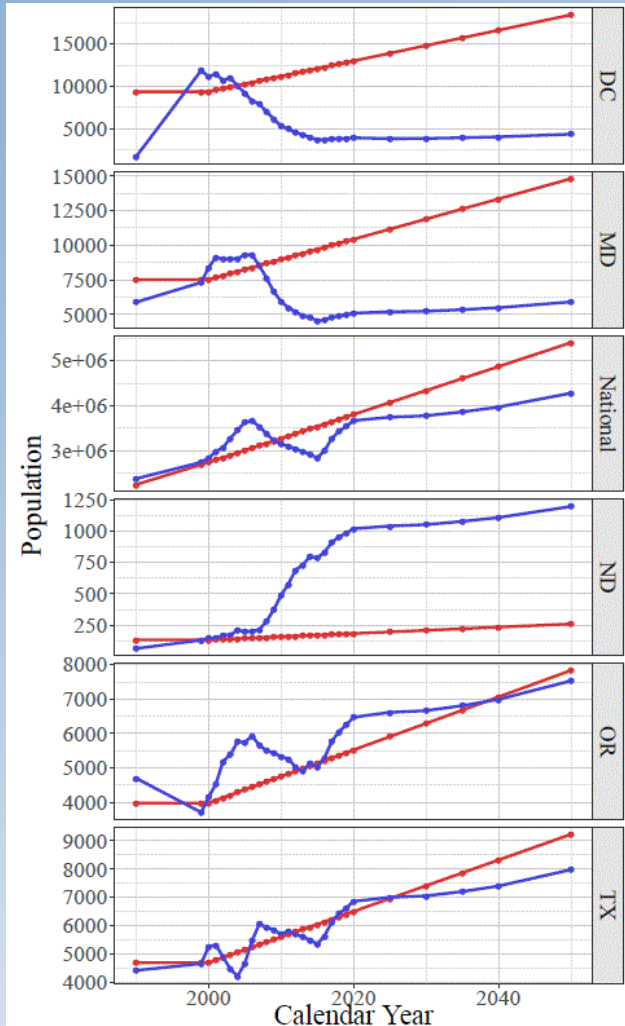
*State-level GDP (actual and projected) used as the surrogate for growth*

**MOVES2014a**  
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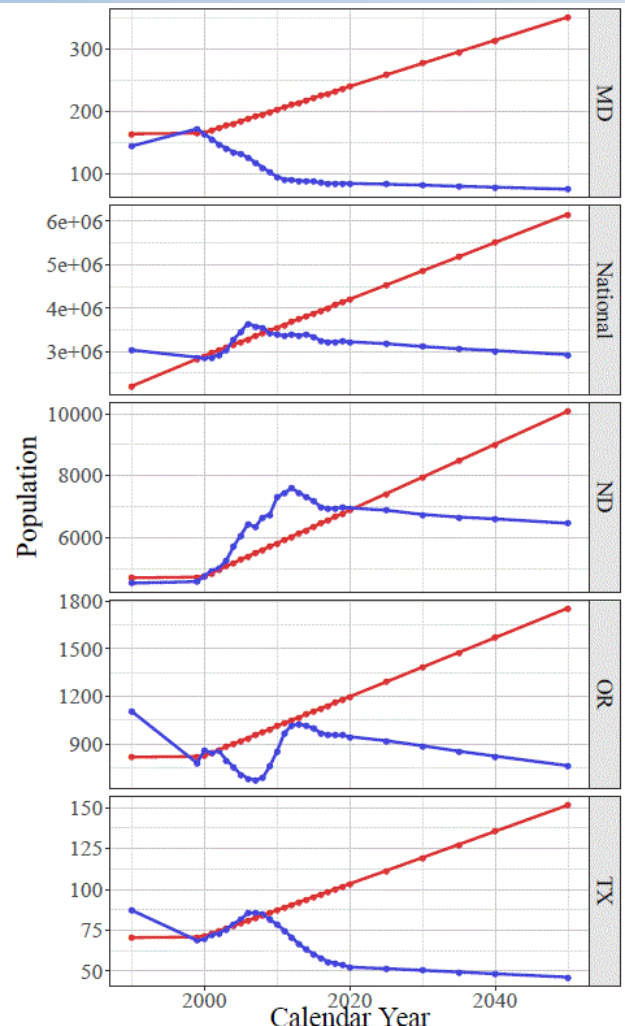


# Updated Equipment Populations (By Equipment Category; 1990-2050)

Construction



Agriculture



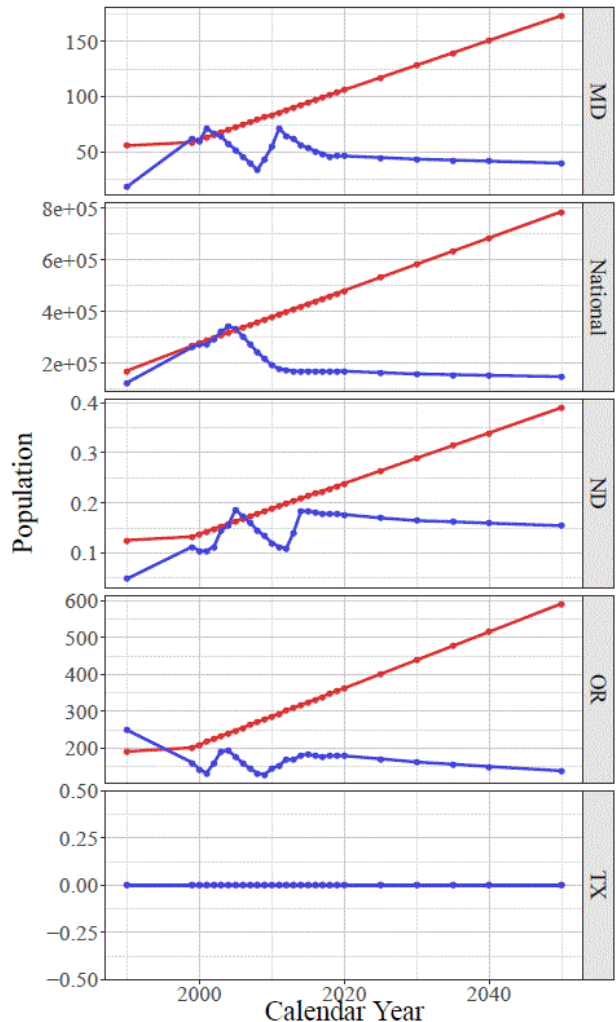
*State- and census region-level fuel consumption used as the surrogate for growth*

**MOVES2014a**  
**Update**

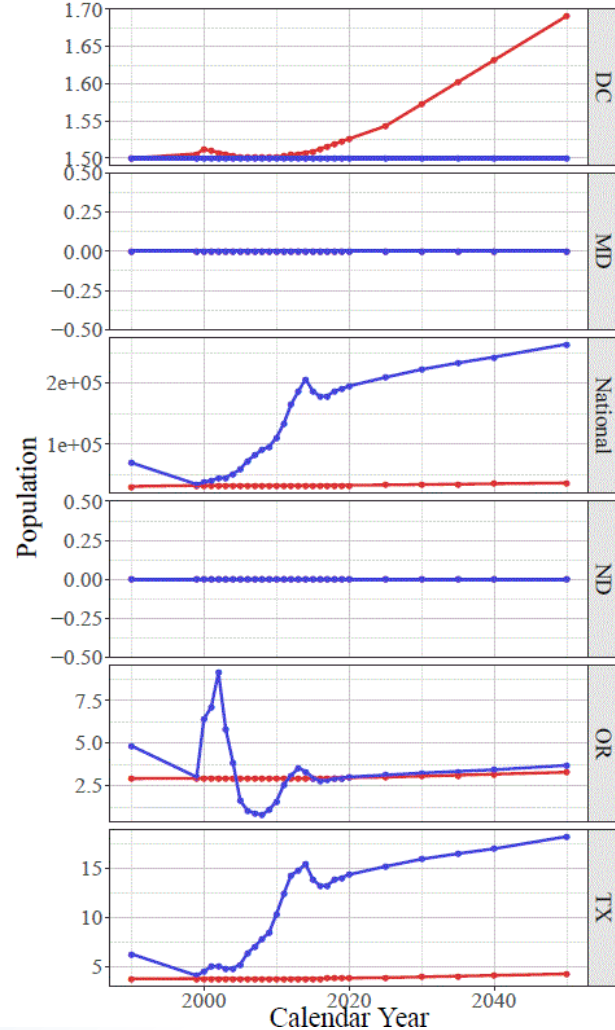


# Updated Equipment Populations (By Equipment Category; 1990-2050)

Logging



Oil Field



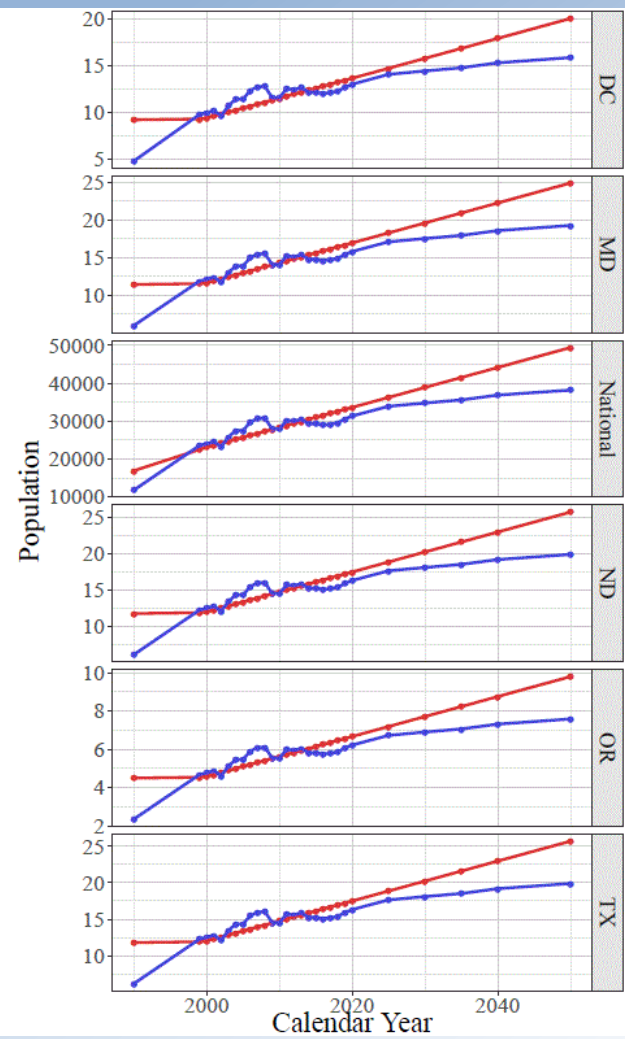
*State- and census region-level fuel consumption used as the surrogate for growth*

**MOVES2014a**  
**Update**

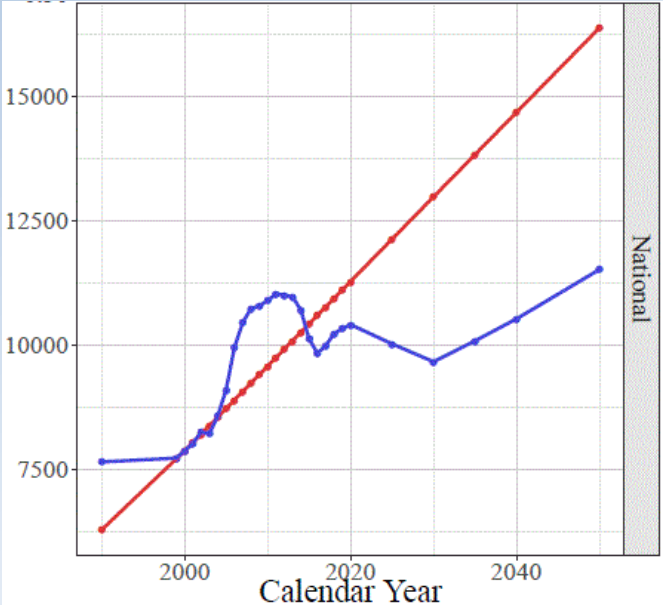


# Updated Equipment Populations (By Equipment Category; 1990-2050)

Railroad Support



Underground Mining



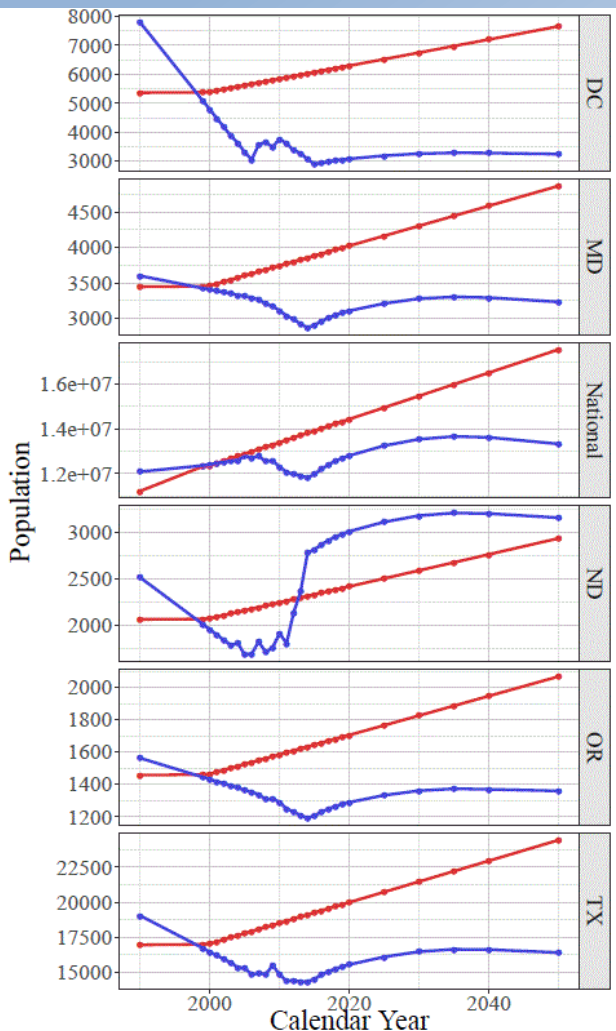
*State- and census region-level fuel consumption used as the surrogate for growth*

- MOVES2014a
- Update

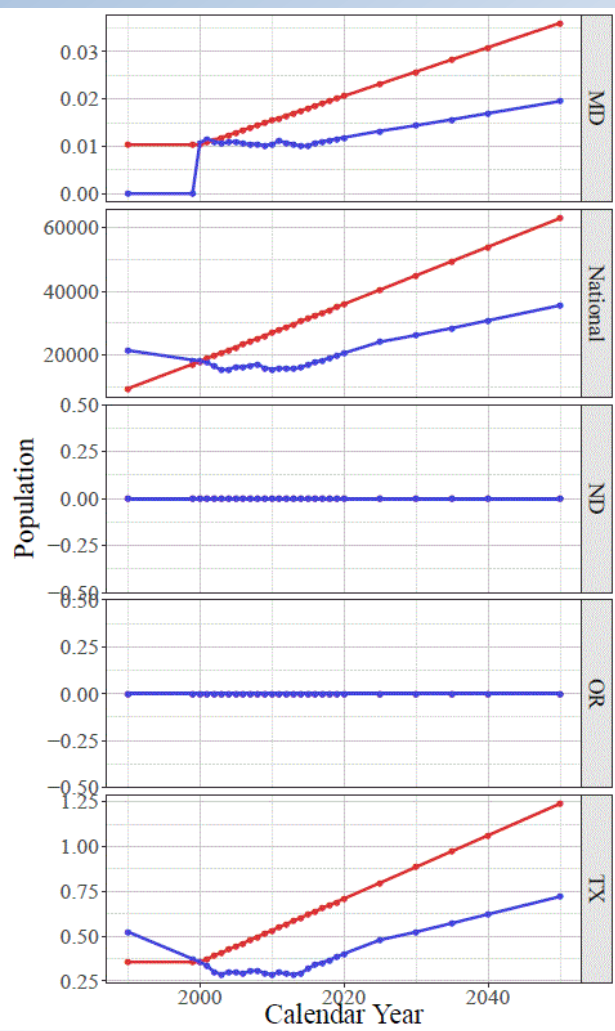


# Updated Equipment Populations (By Equipment Category; 1990-2050)

## Recreational Marine



## Airport Support



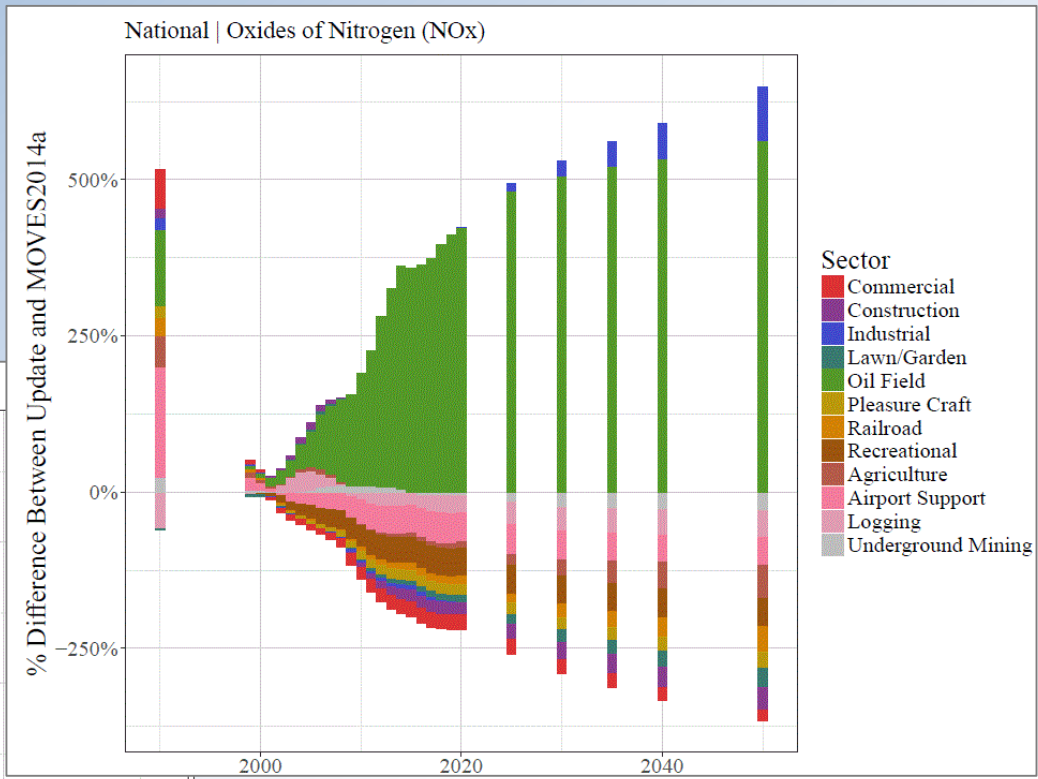
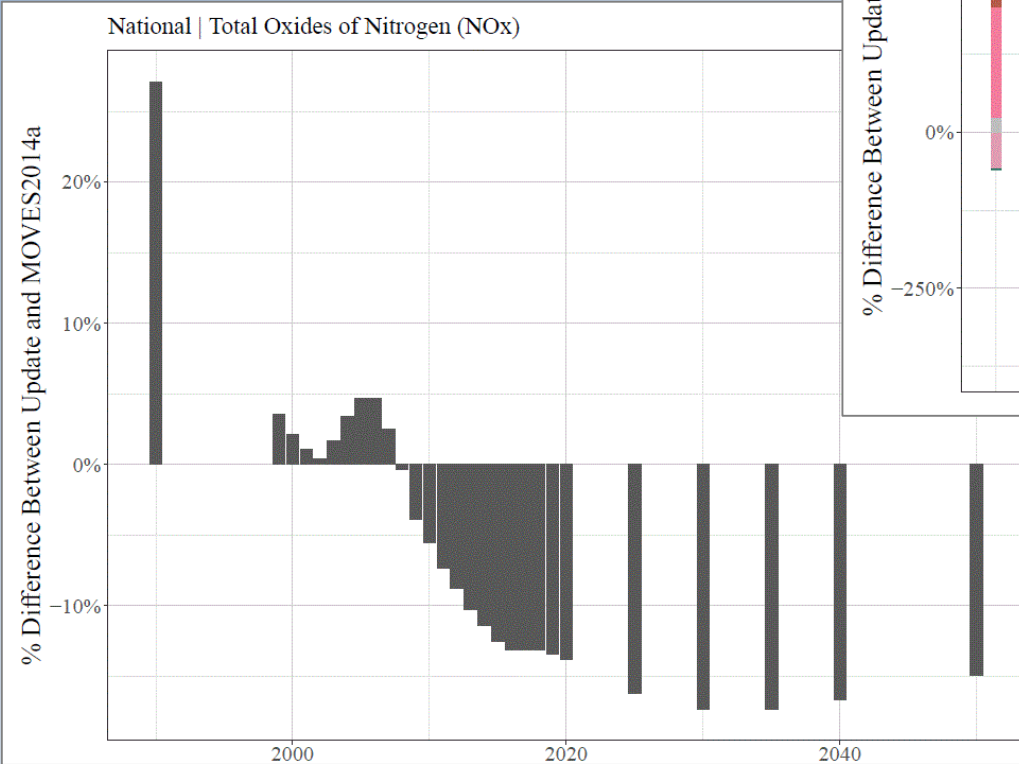
*State-level number of commercial operations (airport support) and state-level boat registrations and national-scale fuel consumption (recreational marine) used as surrogates for growth*

**MOVES2014a**  
**Update**



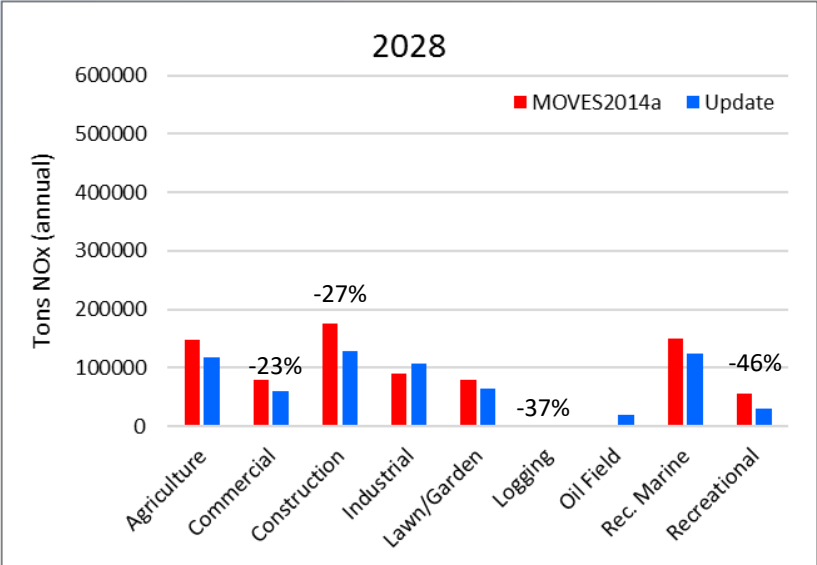
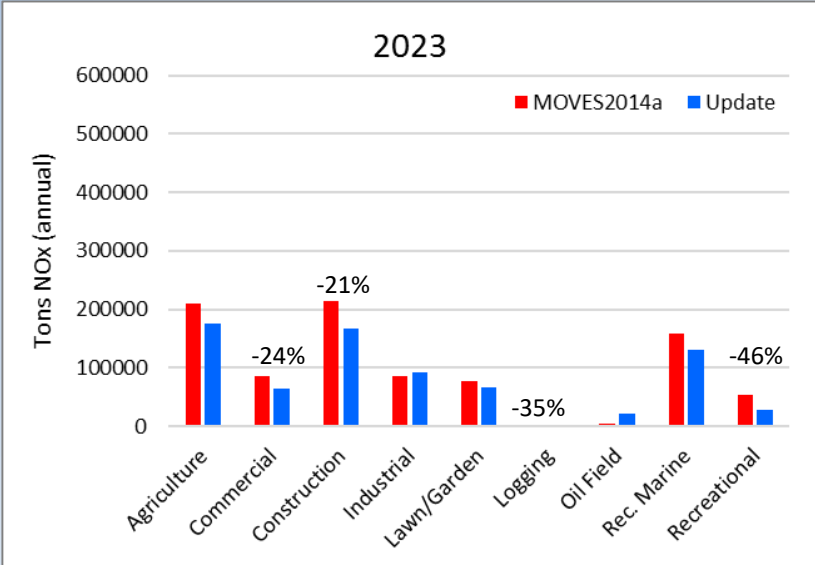
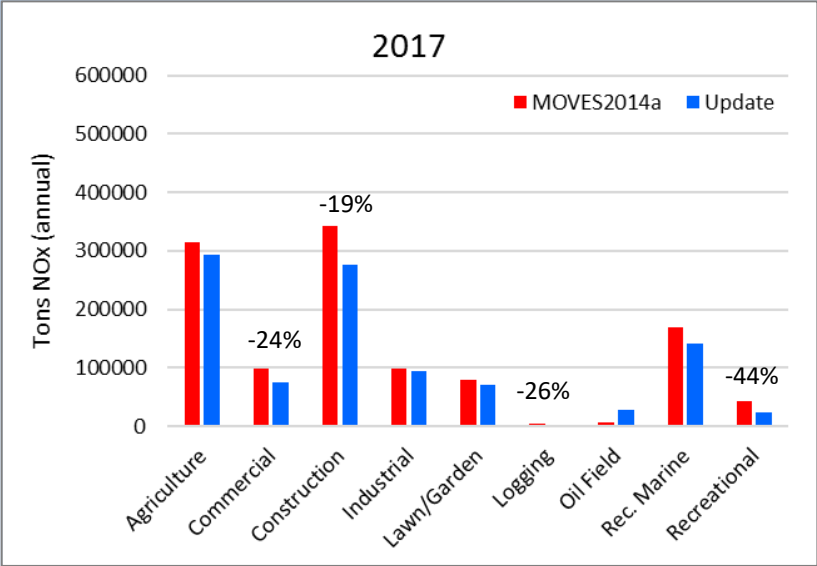
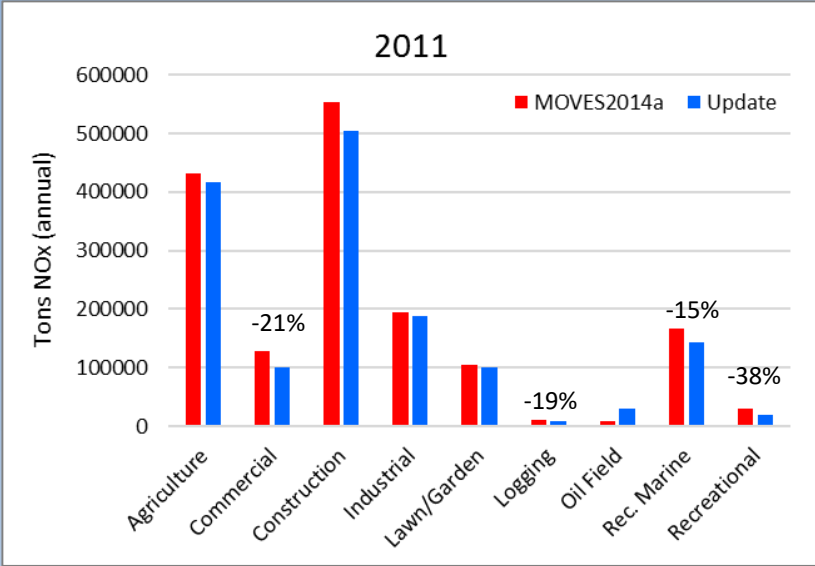
# Inventory Impacts – NOx

- Relative to MOVES2014, the growth update increases NOx emissions from the Oil Field and Industrial equipment categories
- Starting in 2008 aggregated nonroad NOx emissions *decrease* by up to 17% relative to MOVES2014



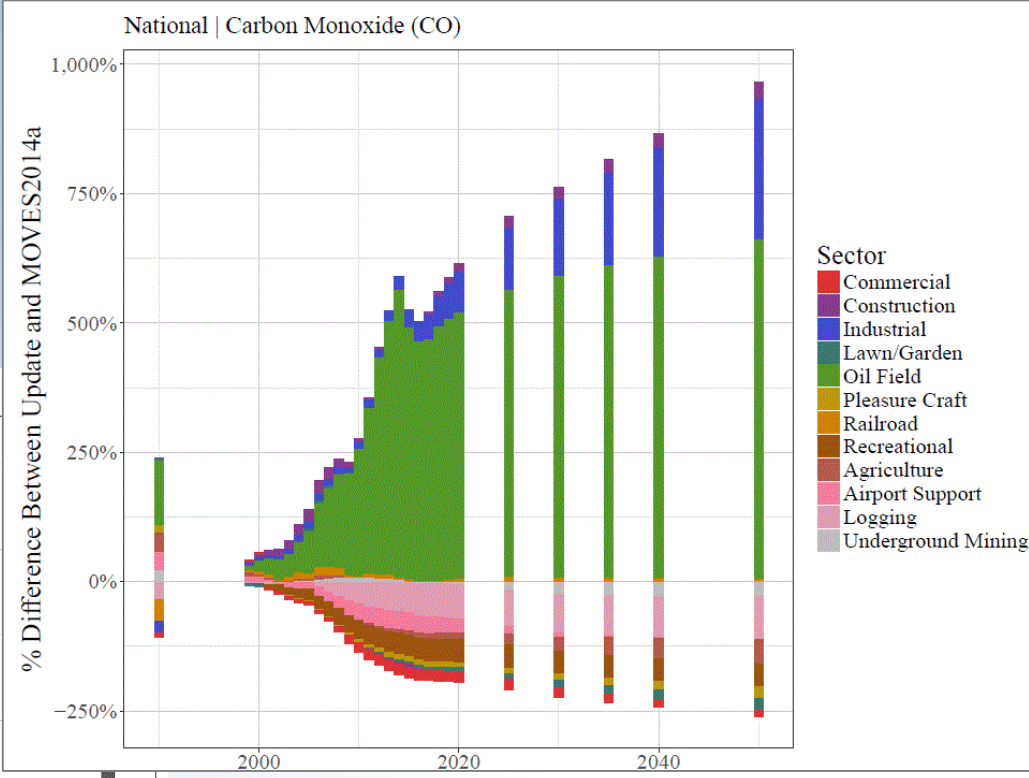
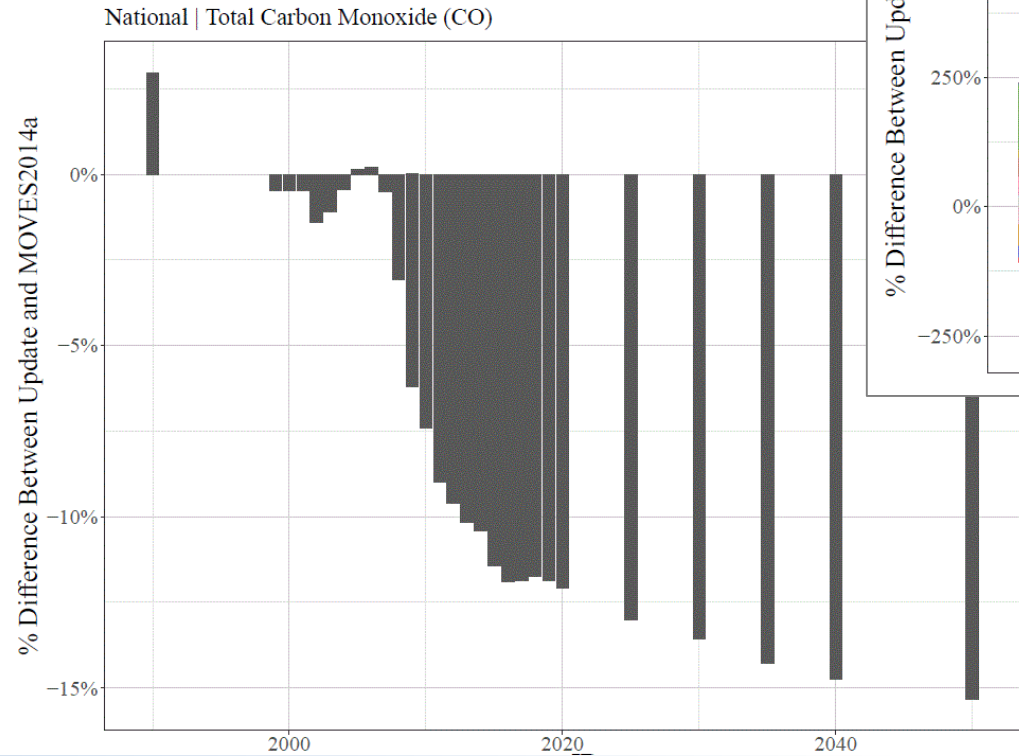


# Inventory Impacts – NOx (National)

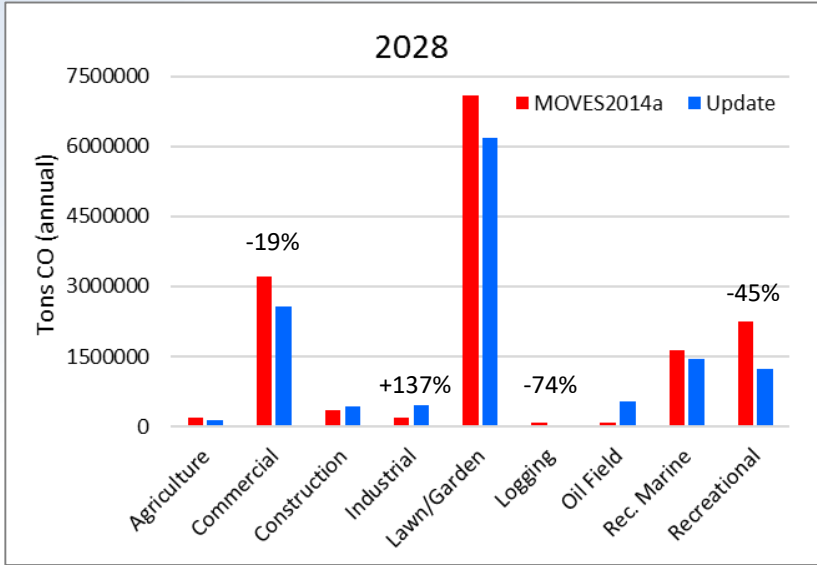
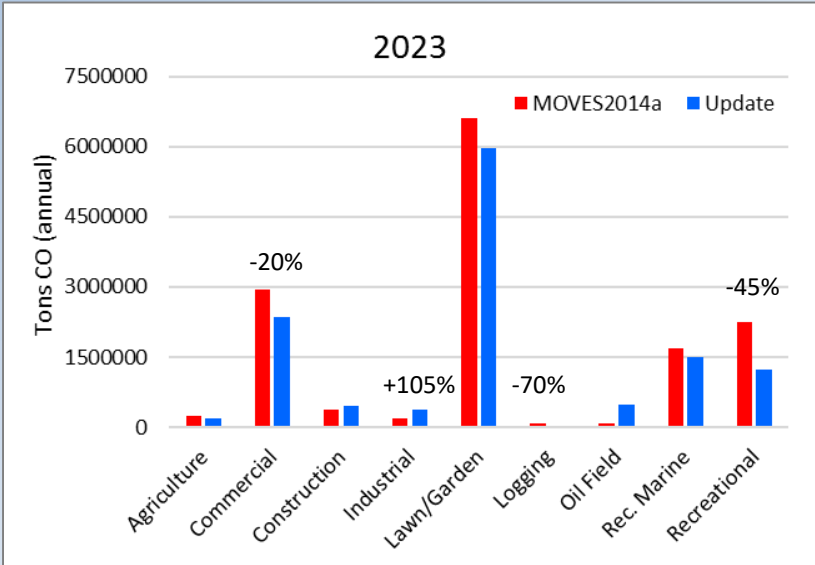
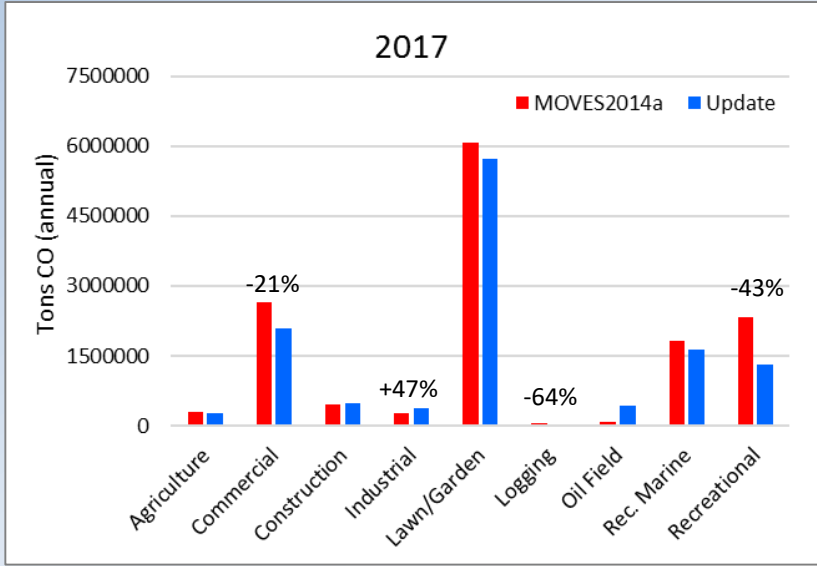
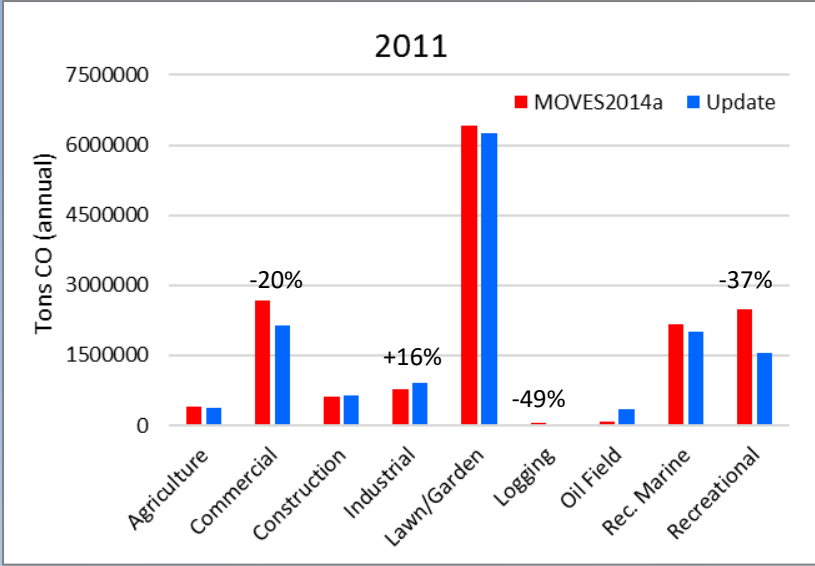


# Inventory Impacts – CO

- Growth update increases CO emissions from Railroad Support, Construction, Oil Field, and Industrial equipment
- Aggregated nonroad CO emissions *decrease* by up to 15% in future years, relative to MOVES2014



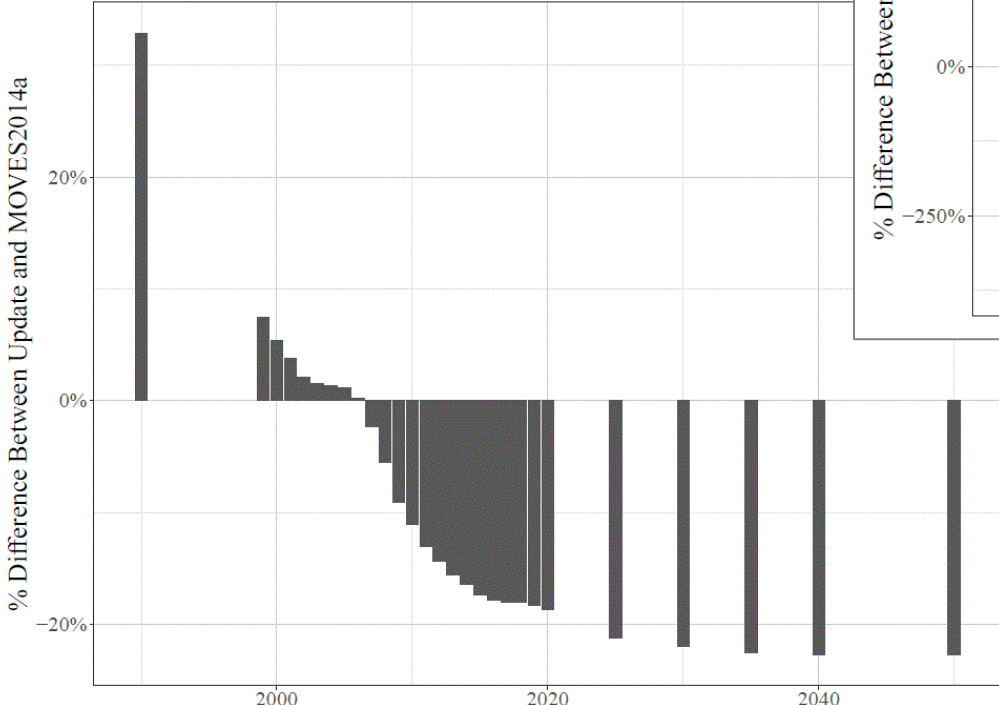
# Inventory Impacts – CO (National)



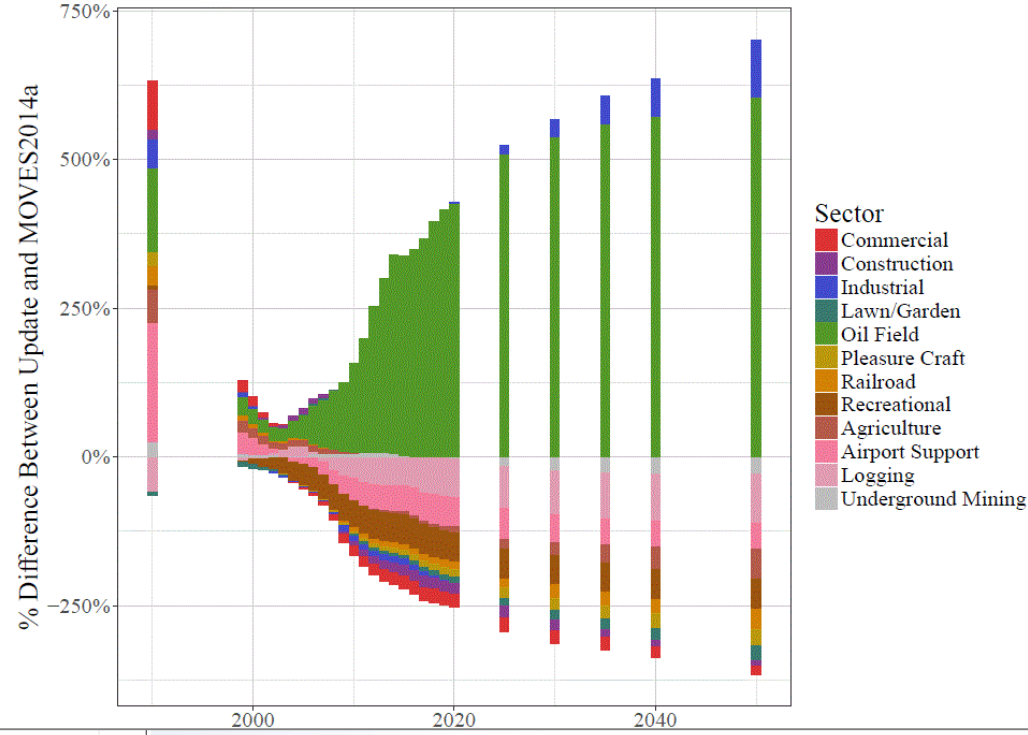
# Inventory Impacts – PM2.5

- Relative to MOVES2014, the growth update increases future-year PM2.5 emissions from Oil Field and Industrial equipment
- Starting in 2007, aggregated nonroad PM2.5 emissions *decrease* by up to 22% relative to MOVES2014

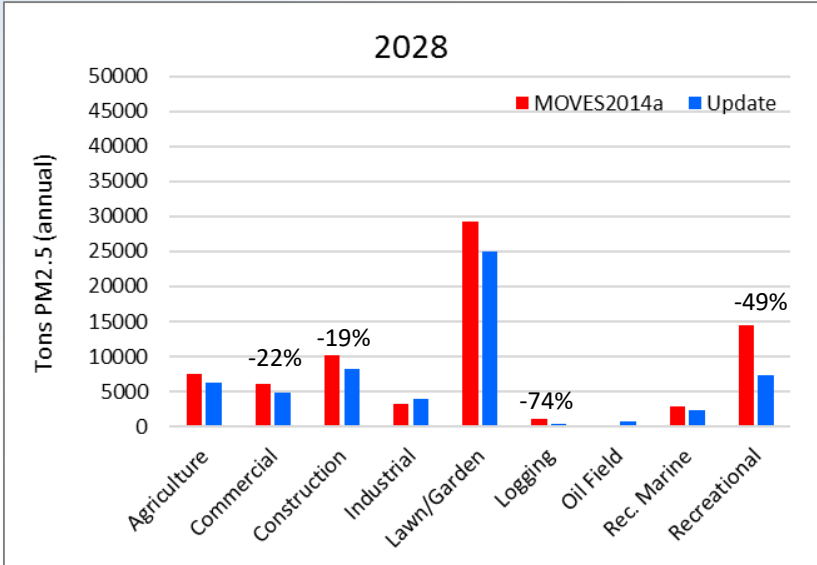
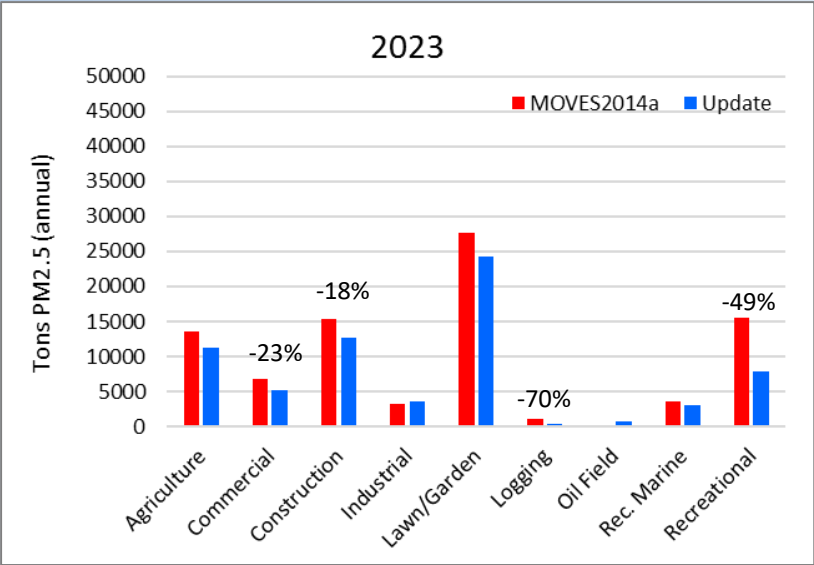
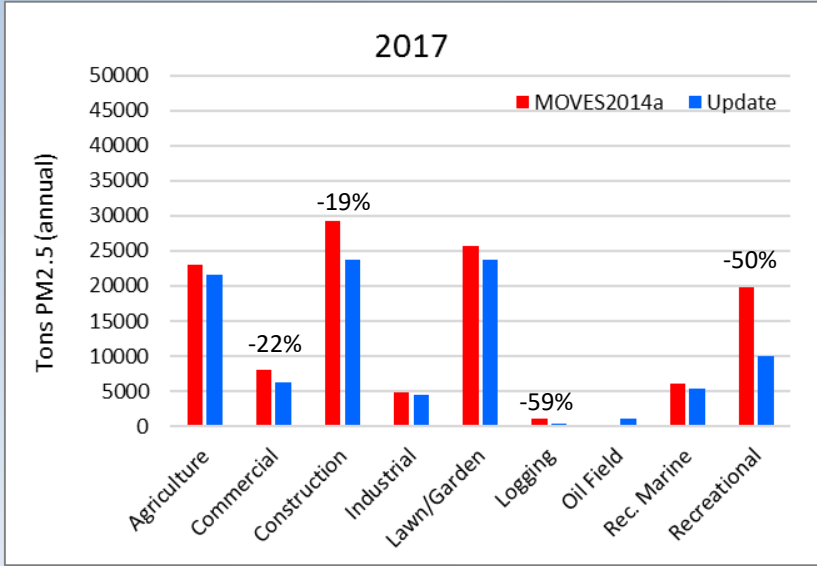
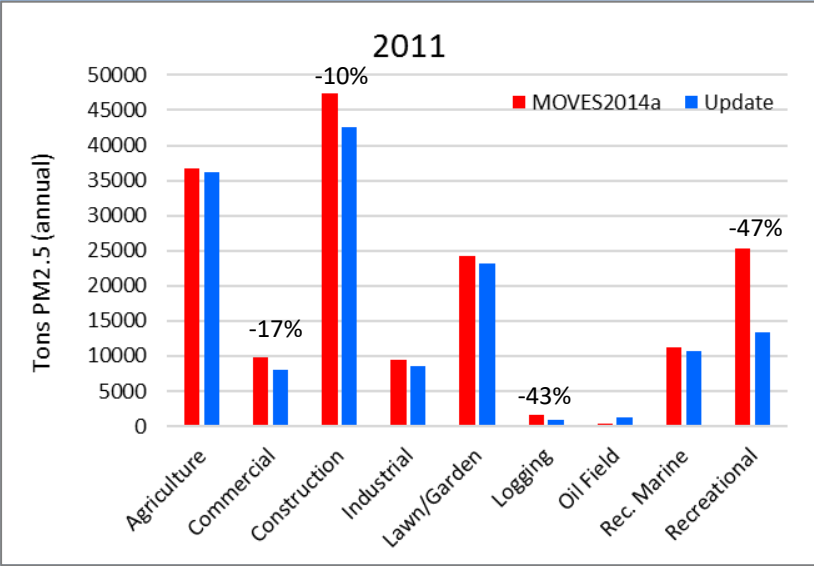
National | Total Primary Exhaust PM2.5 – Total



National | Primary Exhaust PM2.5 – Total



# Inventory Impacts – PM2.5 (National)



# Summary

- In lieu of updating MOVES-NONROAD equipment populations for the next MOVES release, EPA proposes refining the growth indices that are used to estimate equipment populations beyond the base year populations
- Projections of energy use, economic activity, human population, and equipment activity are matched with corresponding historical data to construct annual, state-level growth indices for each equipment category
  - Draft growth indices are independent of fuel type
  - Code change required to expand the nrgrowthindex input table from 564 to over 55,000 values
- Draft growth indices result in a decline in equipment populations in almost all equipment categories, particularly in future years
- Growth update results in lower emissions inventories (results vary by region and equipment type)

