MOVES
Motor Vehicle Emission Simulator

The webinar will begin shortly

MOVES5 Introduction & Overview

U.S. Environmental Protection Agency
Office of Transportation & Air Quality
Public Webinar, December 18, 2024

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Logistics

- Webinar is scheduled from 2-3:30pm EDT
- We will be using Teams Webinar for today's presentation
  - Everyone except the presenters will be on mute during the presentations
  - Please enter any questions in the chat
    - If your question refers to a particular slide, please note the slide number
    - If you get a message that chat is "only available during the meeting," try closing the chat & reopening
    - If you are not able to use the chat, you can also reach us at mobile@epa.gov
- All of the presentations will be posted online after the webinar is complete. We do not plan to post the recording

Turning on Captions

1. Click "***. . . More***" at the top
2. Click "**Record and Transcribe**"
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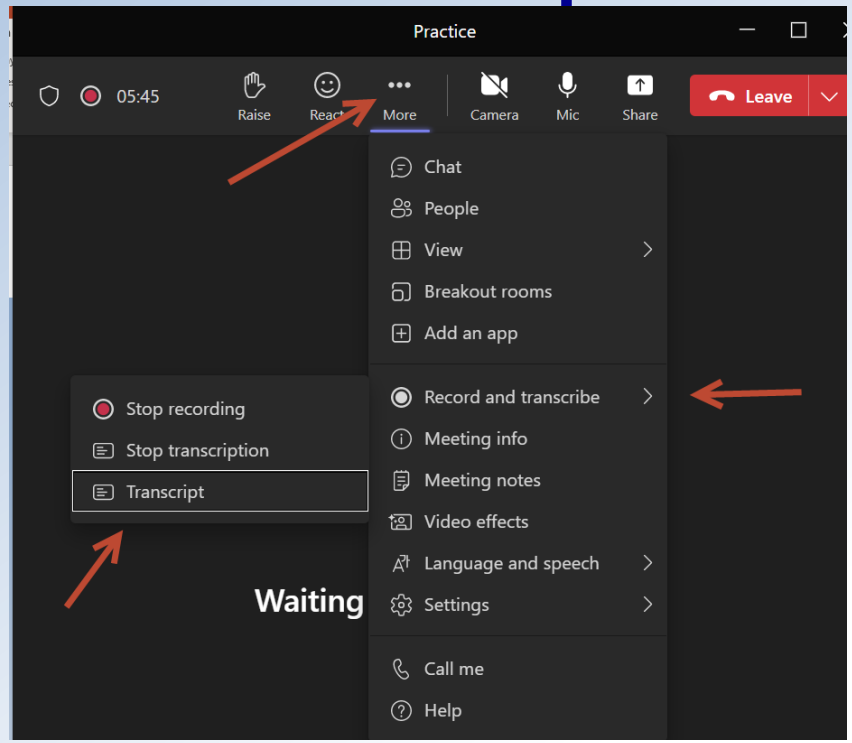
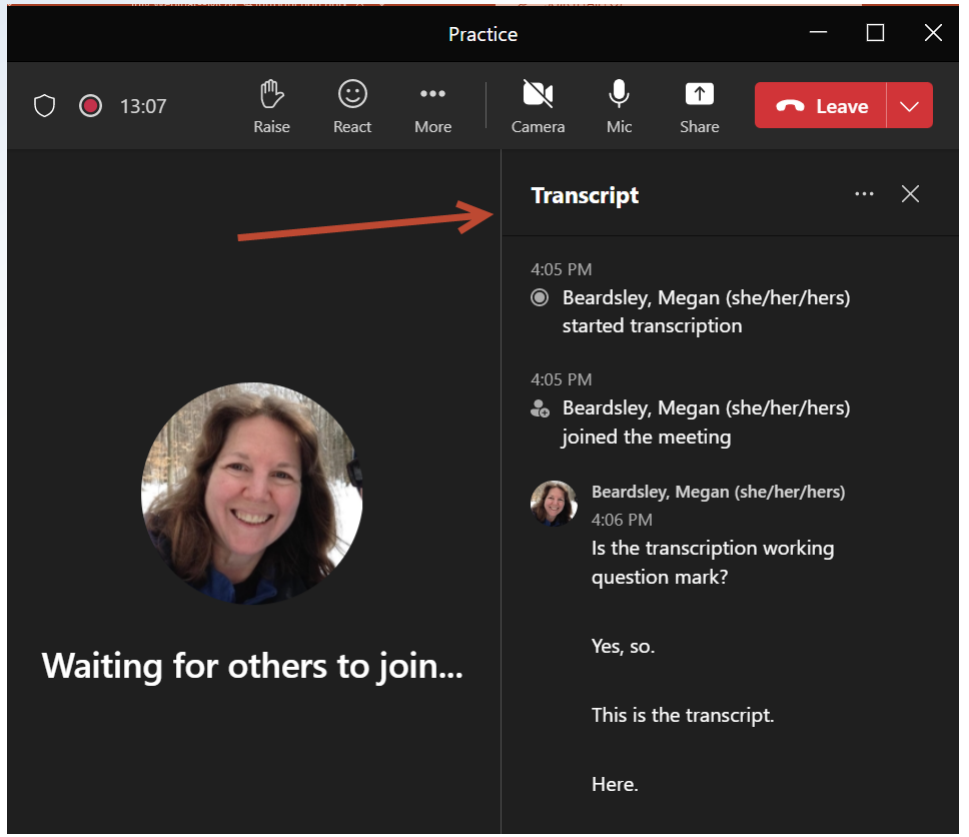


4. The transcript will appear at the far right of the screen



Welcome

- Welcome to EPA's webinar explaining how and when to use the EPA MOtor Vehicle Emission Simulator, MOVES5
- MOVES5 replaces the MOVES4 series of models as EPA's latest model for estimating air pollution emissions from cars, trucks, motorcycles, and buses, as well as many categories of nonroad equipment
- MOVES5
  - Allows users to model the benefits from new regulations promulgated since MOVES4 was released,
  - Incorporates the latest vehicle and emissions data, and
  - Expands model capabilities

Today's Agenda

1. What's changed in MOVES5?
2. How MOVES5 emission results compare to MOVES4
3. Guidance overview: when and how to use MOVES5 for SIP development, transportation conformity, and other purposes
4. Using MOVES4 and MOVES3 inputs with MOVES5
5. MOVES resources

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What's Changed in MOVES5?

MOVES5—New Rules

MOVES5 includes the emissions effects of new EPA final rules:

- Accounts for EPA's Light- and Medium-Duty Multi-Pollutant Rule with higher projected electric vehicle (EV) fractions and more stringent standards for carbon dioxide (CO_2), particulate matter (PM), non-methane organic gases (NMOG) and oxides of nitrogen (NO_X)
- Accounts for EPA's Heavy-Duty Greenhouse Gas Emissions-Phase 3 Rule with higher projected EV fractions and updated energy consumption estimates for heavy-duty EVs

Other Major Updates

- Incorporates new data on light-duty (LD) and heavy-duty (HD) brake wear emissions
  - Rates from LD brake dynamometer test campaign led by EPA and CARB, and a companion HD data set from a study led by Caltrans
- Expands detailed calculations to vehicles of the last 40 model years, instead of 30
- Updates onroad and nonroad fuel properties for calendar year 2021 and later
- Updates historical and forecast default vehicle miles travelled (VMT), vehicle populations, age distributions, and fuel distributions
- Many other minor changes

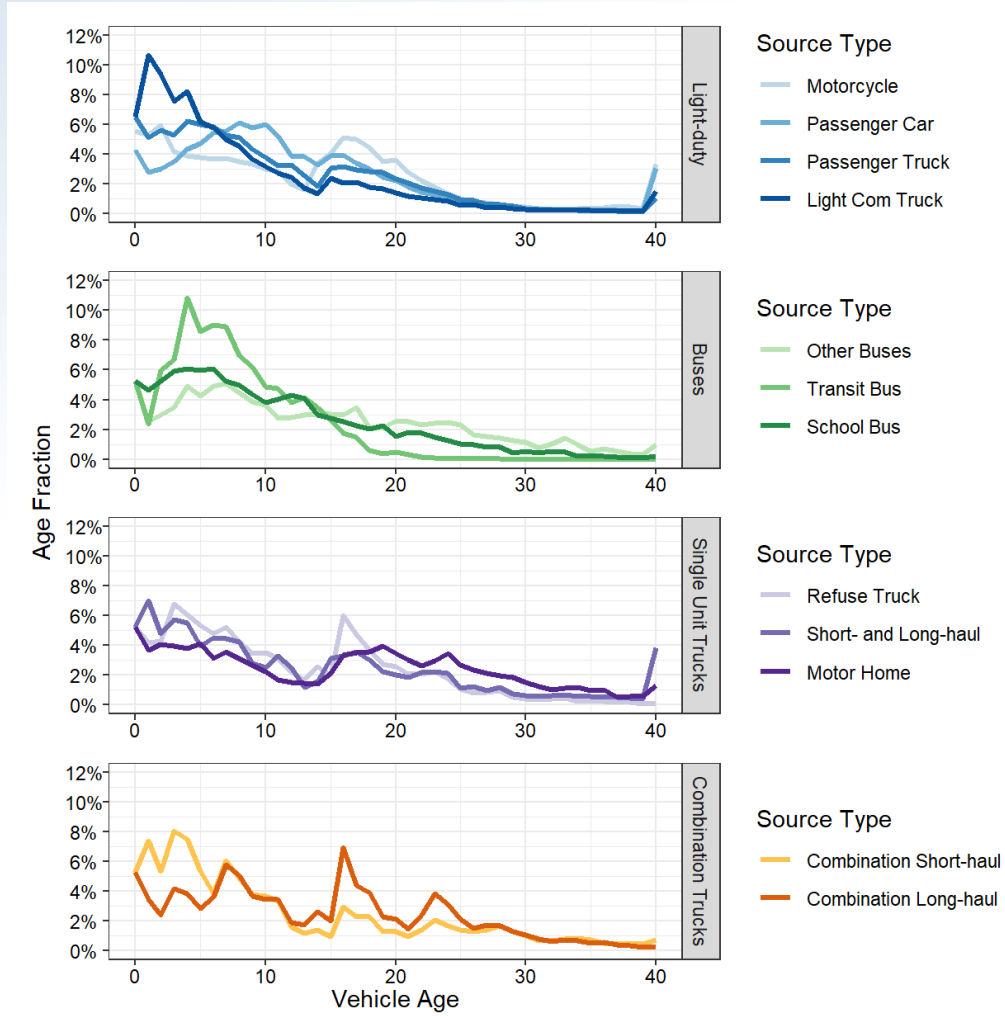
Brake Wear

- For model years 2011 and later, MOVES5 incorporates analysis of new data from a light-duty brake dynamometer test campaign jointly led by EPA and CARB, and a companion heavy-duty data set from Caltrans
  - The tests covered a range of common vehicle and brake configurations, including different brake pad materials, and measured particle mass, number, and size distribution
- In general, the new $PM_{2.5}$ brake wear rates are:
  - Lower for light- and medium-duty vehicles, light-heavy-duty vehicles and urban buses
  - Higher for other heavy-vehicle classes, most notably for heavy-heavy-duty vehicles
- This results in an overall increase in $PM_{2.5}$ emissions from brake wear, compared to MOVES4
- Particle size data from these studies also allowed us to update the $PM_{10}/PM_{2.5}$ ratios in MOVES
  - The new data imply lower PM_{10} emission rates for all vehicle classes
- For more information, see Brake and Tire Wear Emissions from Onroad Vehicles in MOVES5

Extended Age Distributions

- MOVES4 and earlier versions of the model reflect 31 model years in any individual calendar year analysis (vehicle ages 0 through 30+)
  - Vehicles older than 30 years are assigned characteristics of age 30 vehicles
- MOVES5 does calculations for 41 model years (vehicle ages 0 through 40+)
  - Better quantifies emissions from vehicles in the 31-40 age range
  - Allows pre-OBD vehicles and pre-OBD I/M tests to be modeled
  - Vehicles older than 40 years are assigned characteristics of age 40 vehicles (a much smaller number of vehicles and VMT)

Calendar year 2023 age distributions by source type



Fuel Properties

- In MOVES4 and previous versions of MOVES, gasoline fuel properties were primarily based on volume-weighted fuel production information
- In MOVES5, we updated the gasoline fuel supply using new retail survey data
  - The Fuels Regulatory Streamlining Rule, published in 2020, created a nationwide retail survey program for gasoline properties
    - Beginning in January 2021, gasoline samples have been collected from each state
    - Collection is proportional to the share of national gasoline sales, and within each state accounting for population density and transportation corridors
    - The resulting dataset includes all octane grades, sampled proportional to their sales share
    - While this program does not account for every batch of fuel, it is a large, statistically designed survey that has the advantage of capturing fuel properties at the point of use
  - These new data indicate that sulfur levels are generally higher than predicted in MOVES4, summer RVP values are generally lower, and winter RVP values are generally higher
- For more information, see Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5

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Result Comparisons

Emissions Change Overview

Results will vary depending on local inputs, but compared to MOVES4, MOVES5 national default onroad vehicle emission estimates:

In the 2020s and 2030s, tend to be higher:

- Detailed modeling of older vehicles (age 31-40) leads to higher onroad inventories for **NO_x, $PM_{2.5}$, VOC and CO** until about 2040
- Brake wear is higher after 2011 based on new data on brake wear from heavy-duty (HD) trucks

Exception: in these years, CO_2 emissions in MOVES5 are lower

In the longer term, are lower:

- **CO_2:** Almost 15 percent lower in 2035 and almost 35 percent lower in 2050 due to EPA's new emission standards
- **NO_x:** Slightly lower in 2040 and more than 20 percent lower in 2050 due to EPA's new emissions standards
- Future **CO** and **VOC** emissions are also lower in the new model
- **Exhaust $PM_{2.5}$**: About 10 percent lower in 2035 and almost 70% lower in 2050 due to EPA's new emission standards

Emission Graphs

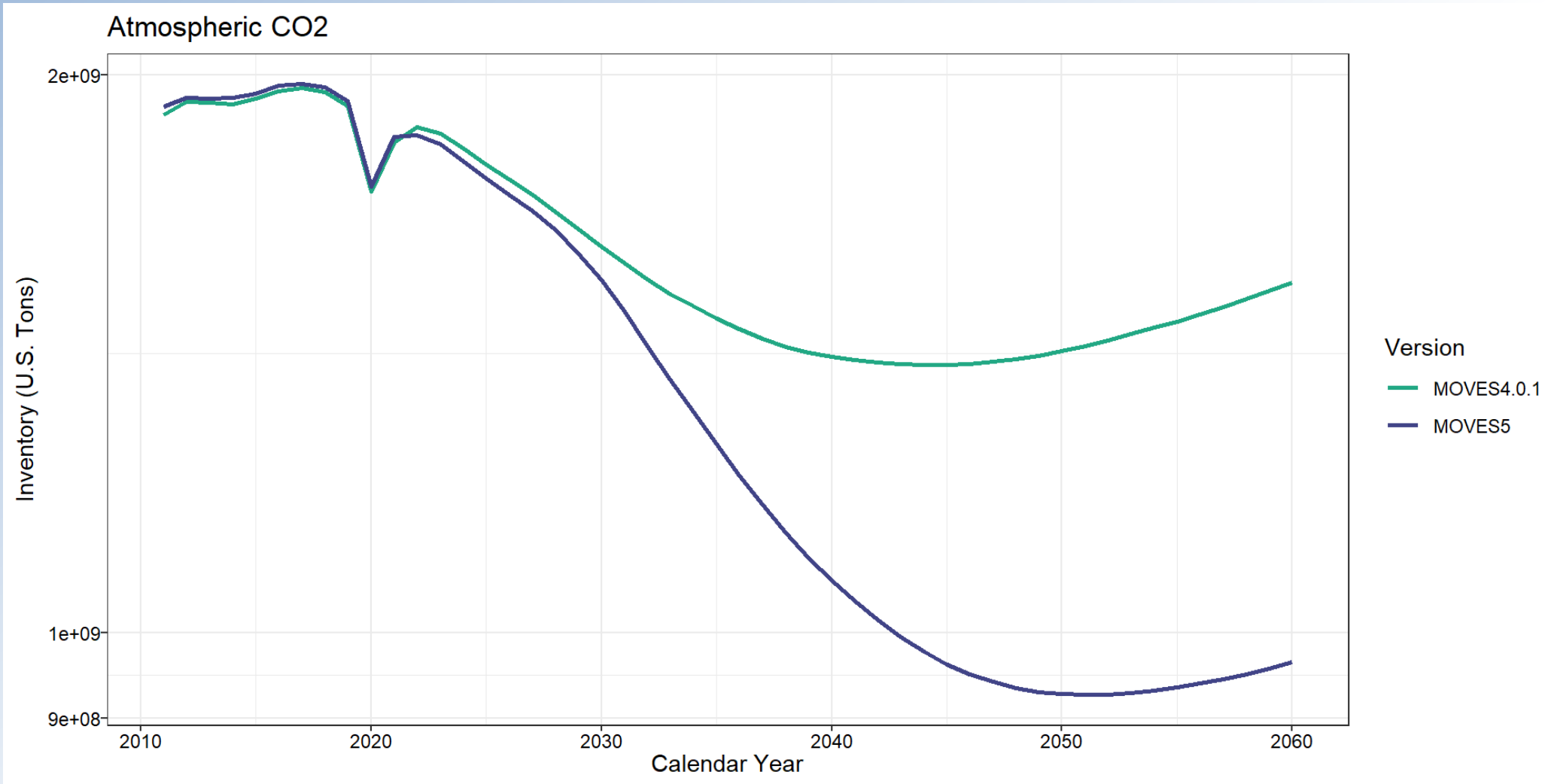
National Comparisons

- Reflect MOVES default inputs with MOVES4 and MOVES5
- Inputs are average values across the year and across the country
- The y-axis is in log space and changes from slide to slide

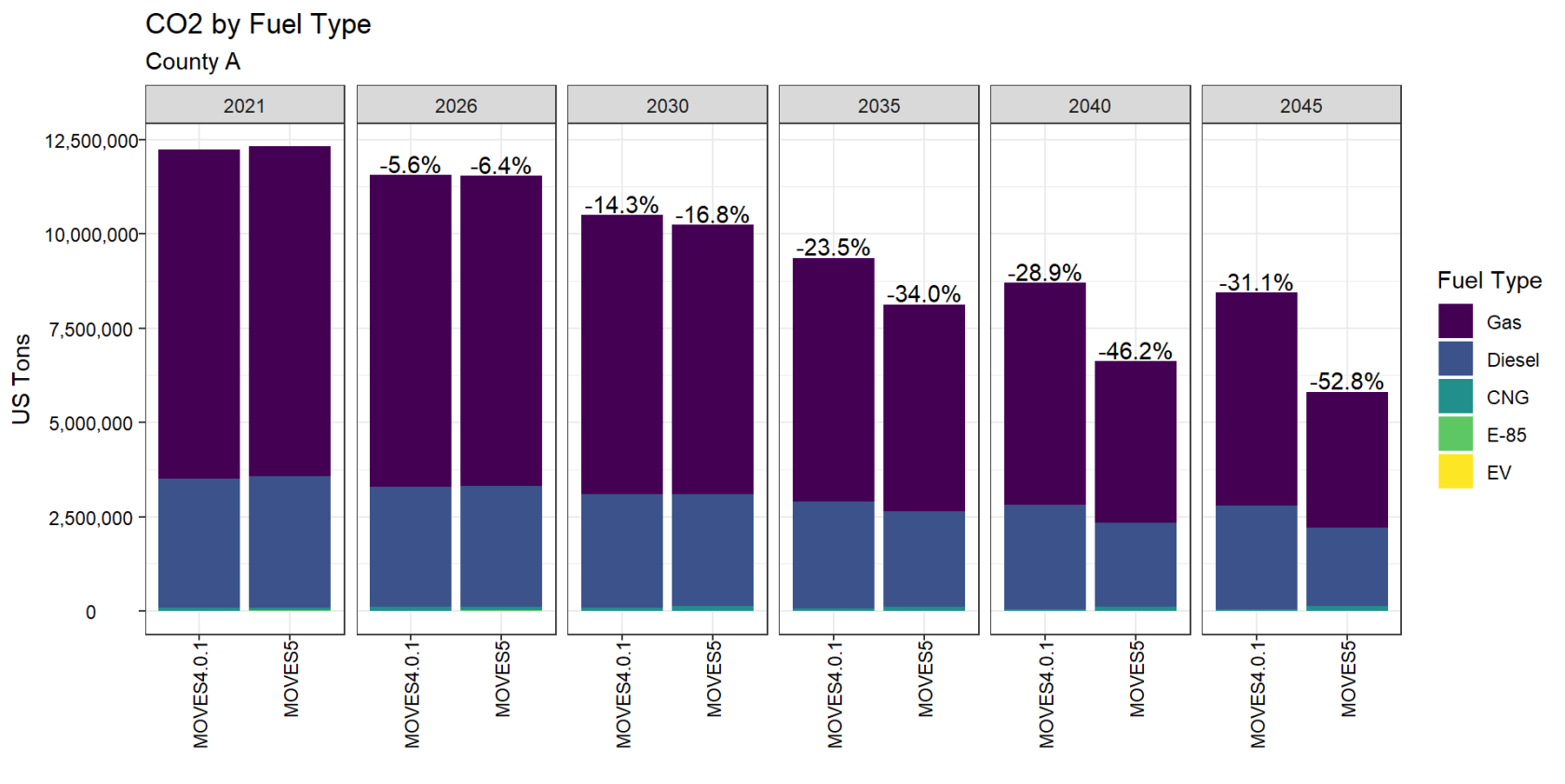
County Comparisons

- A specific urban county modeled with local inputs is presented
  - Results for other counties will differ
- The same local inputs were used for the MOVES4 and MOVES5 runs, except
  - Age distributions differ because MOVES5 includes 0-40+ years
  - The mix of gasoline, diesel, CNG, FFVs using E85 and EVs have changed mostly because the HDP3 and LMDV rules have changed our projection methodology
- Percents indicate change from the same version in CY 2021

National Onroad Exhaust CO_2

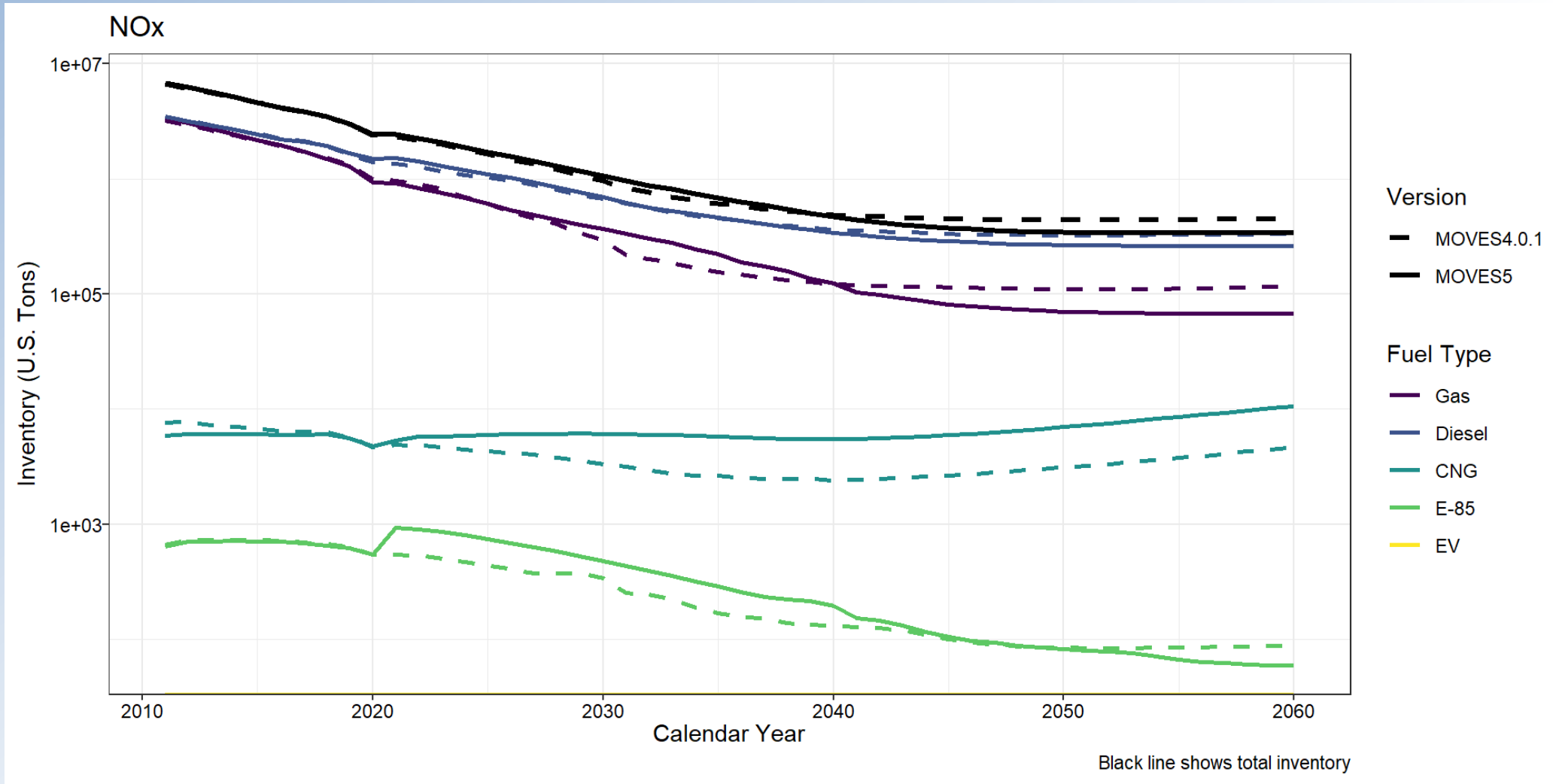


County Example: Onroad Exhaust CO2

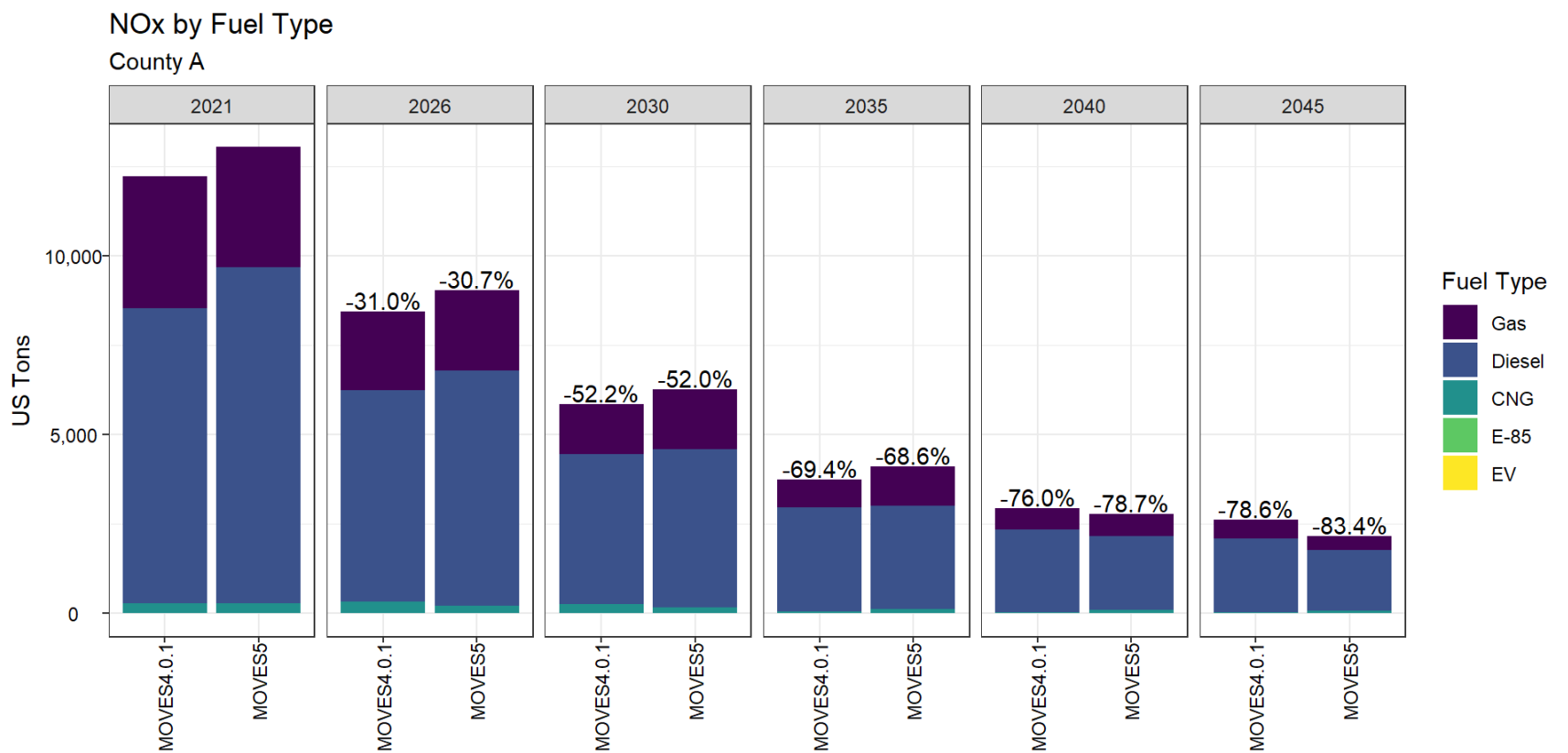


- Initially, MOVES5 modeling of older vehicles causes slight increase
- In later years, CO_2 is lower with MOVES5

National Onroad NO_x

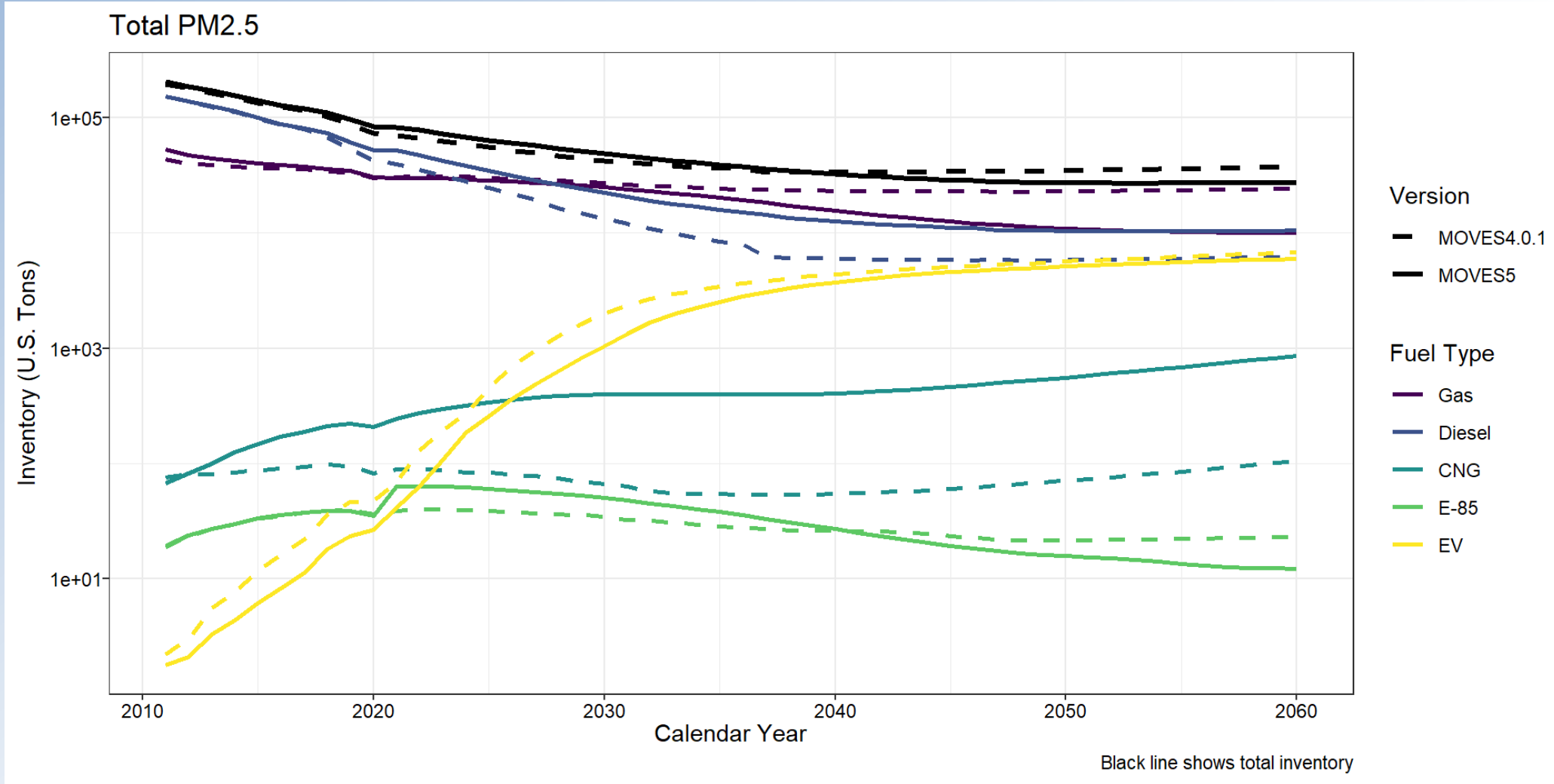


County Example: Onroad NO_x

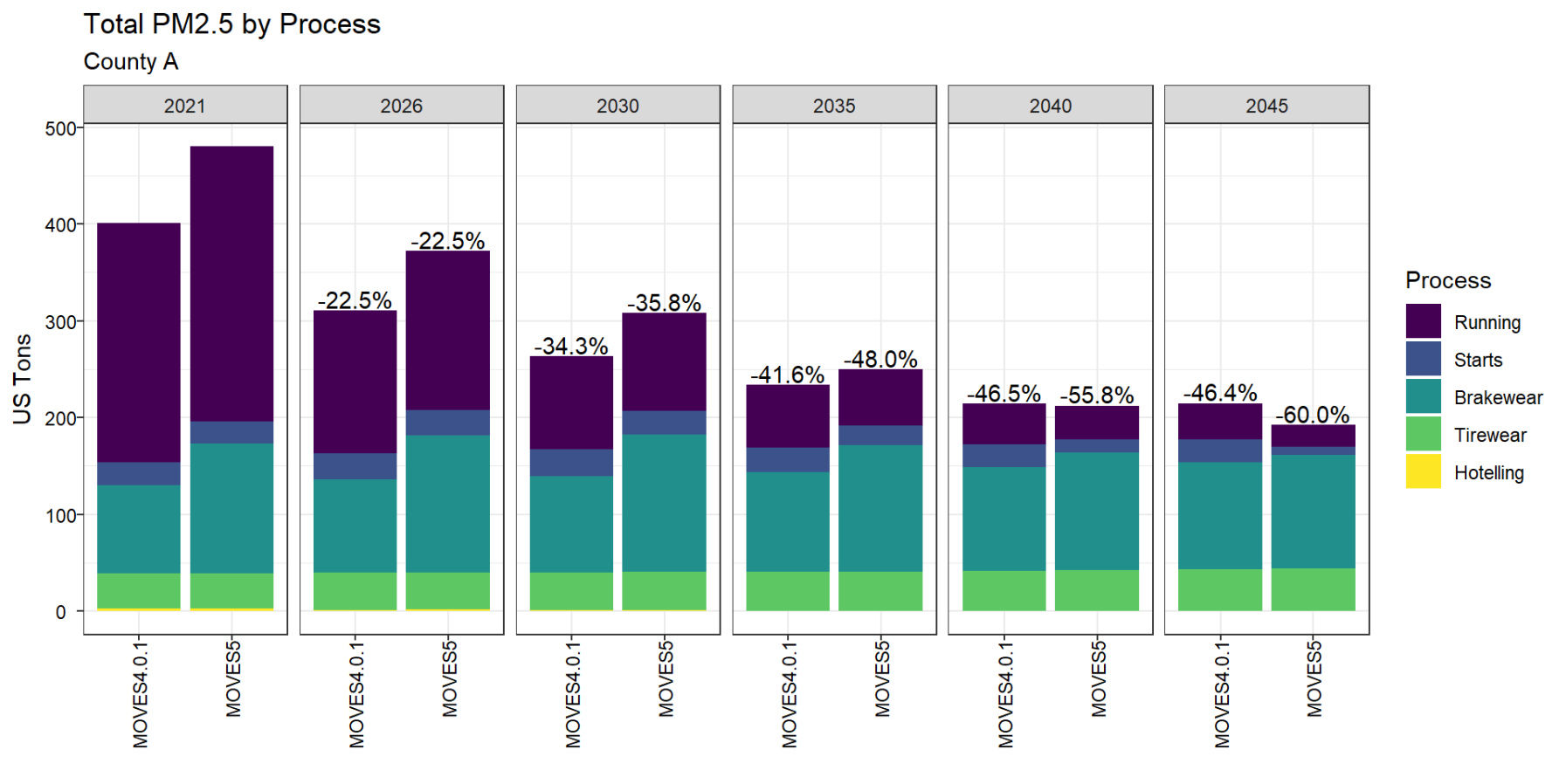


- Both MOVES4 and MOVES5 include effects of HD2027 rule
- Compared to a 2021 base year, percent reductions are similar in the two models

National Onroad $PM_{2.5}$



County Example: Onroad $PM_{2.5}$ by Process



- Brake wear continues to dominate future onroad $PM_{2.5}$ emissions– even more so with the new data in MOVES5
- Compared to a 2021 base year, percent reductions are often higher with MOVES5

More Graphs

MOVES5 Overview Report includes graphs for:

- Onroad comparisons:
  - National VMT, GHGs, NO_x, $PM_{2.5}$, VOC, CO, NH_3, SO_2
  - Sample county graphs for VMT, CO_2, NO_x, $PM_{2.5}$, PM_{10}, VOC, CO,
- Nonroad
  - National SO_2 comparisons
  - Summary graphs for CO_2, CH_4, NO_x, $PM_{2.5}$, VOC, CO

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MOVES5 Guidance

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MOVES5 Policy Guidance

When to use MOVES5

MOVES5 Policy Guidance: Use of MOVES for State Implementation Plan Development, Transportation Conformity, General Conformity, and Other Purposes (EPA-420-B-24-038)

State Implementation Plans

- MOVES5 must be used to develop new SIPs after its release – there is no grace period
- However, if a state has done significant work on a SIP using MOVES4 (or MOVES3), it may continue with that model
- In general, incorporating MOVES5 into the SIP now could be useful in some areas; MOVES5 will have to be used for transportation conformity at the end of the grace period

Transportation Conformity

- EPA's December 11, 2024 *Federal Register* notice announced the availability of MOVES5 and establishes a two-year grace period for using MOVES5 for both:
  - regional emissions analyses (unless MOVES5-based SIP budgets become applicable sooner) and
  - project-level conformity $PM_{2.5}$, PM_{10}, and CO hot-spot analyses

- Grace period will end two years from FR publication date: *December 11, 2026*
  - Analyses that are started during the grace period may use either MOVES5 or MOVES4
  - Analyses started after the grace period must use MOVES5

- Note: the *MOVES4* grace period is unchanged; ends September 12, 2025
  - See the MOVES5 Policy Guidance and the MOVES4 FR Notice for details

Using MOVES5 for Other Purposes

- General conformity
- Greenhouse gas analyses
- Mobile source air toxics analyses
- EPA's National Emissions Inventory (NEI)

- See the MOVES5 Policy Guidance for more information

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MOVES5 Technical Guidance

How to use MOVES5 for SIP and transportation conformity analyses

MOVES5 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA-420-B-24-043)

MOVES5 Technical Guidance

- Similar to the MOVES4 version of this guidance with updates throughout
- Some updates to highlight:
  - When using input databases created with earlier versions of MOVES, any default data should be updated with new MOVES5 default data (Section 1.5)
  - New: options for minimizing run time (Section 2.5)
  - Pollutants and Processes Panel now appears before Road Type Panel (Sections 3.6 and 3.7)
    - Choices made on Pollutants and Processes Panel result in automatic selections on the Road Type Panel

MOVES5 Technical Guidance, continued

- MOVES5 covers a 41-year range of vehicles; guidance has options for modelers with recent registration data that was used with MOVES4 or 3 (Section 4.4):
  - Reanalyze registration data using 41 ages instead of 31, or
  - Convert existing 31-year age distributions to 41-year distribution using converter tools
- Fuels: AVFT Tool (for entering fuel type fractions) was updated
  - One AVFT Table can be created that can be used for all analysis years
  - MOVES5 AVFT Tool has 3 gap-filling methods for years in the past, and 4 projection methods for years in the future

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MOVES Tools and Converters

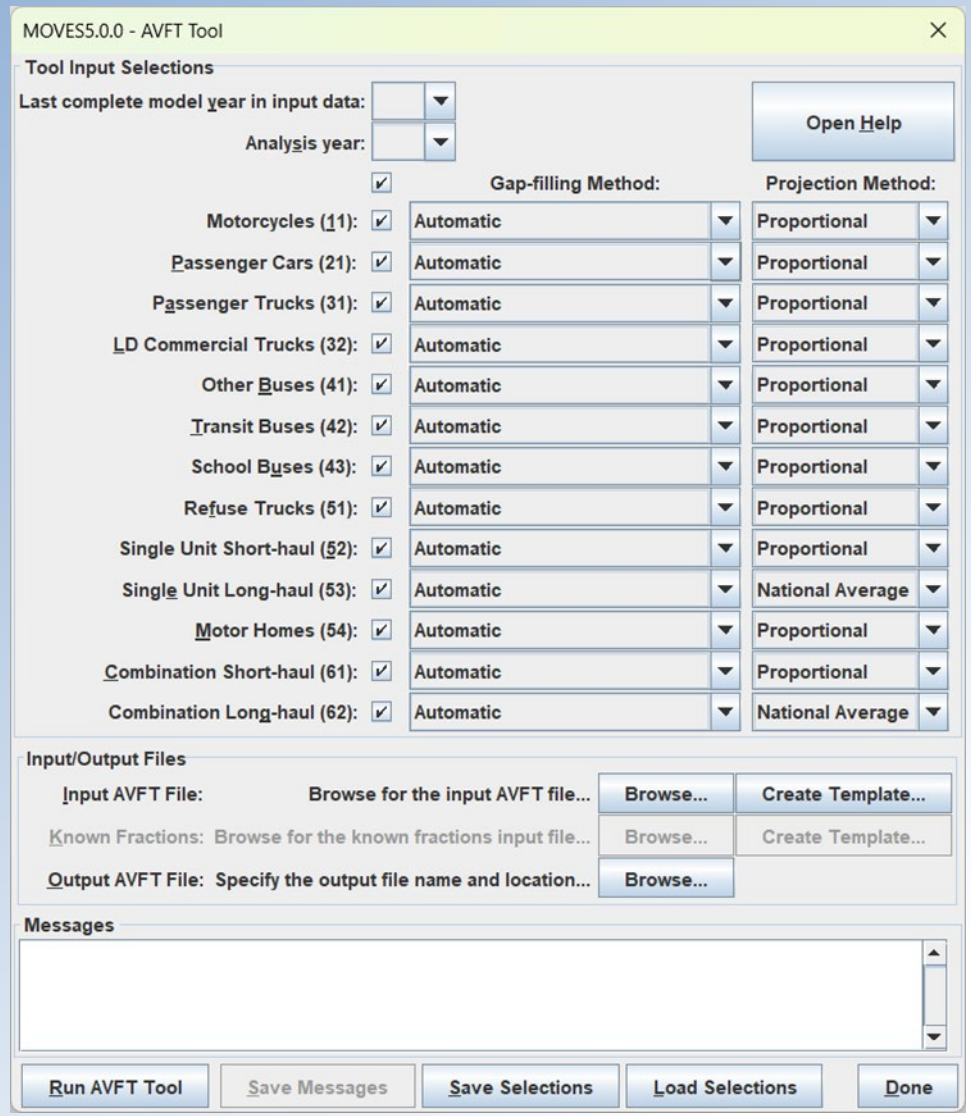
Switching from MOVES4 to MOVES5

- The MOVES5 installer will automatically install all the prerequisite software, including Java and MariaDB, along with the MOVES code and database
  - The installer is available on the MOVES website
  - The installer includes a troubleshooting guide
  - MOVES4 can remain installed
- RunSpecs created with MOVES4 should work with MOVES5
  - The only exception to this is if a MOVES4 RunSpec includes CO_2 equivalent and one or two (but not all) of CO_2, CH_4, or N_2O
  - Since MOVES5 requires all three to be selected to run CO_2 equivalent, opening such a RunSpec in the MOVES GUI will show a red X on the Pollutants and Processes panel
  - This issue can be resolved by clicking the "Select Prerequisites" button and saving the RunSpec
- **If you are switching to MOVES5 from MOVES3, also review the MOVES4 release materials**

Database Conversion Tools

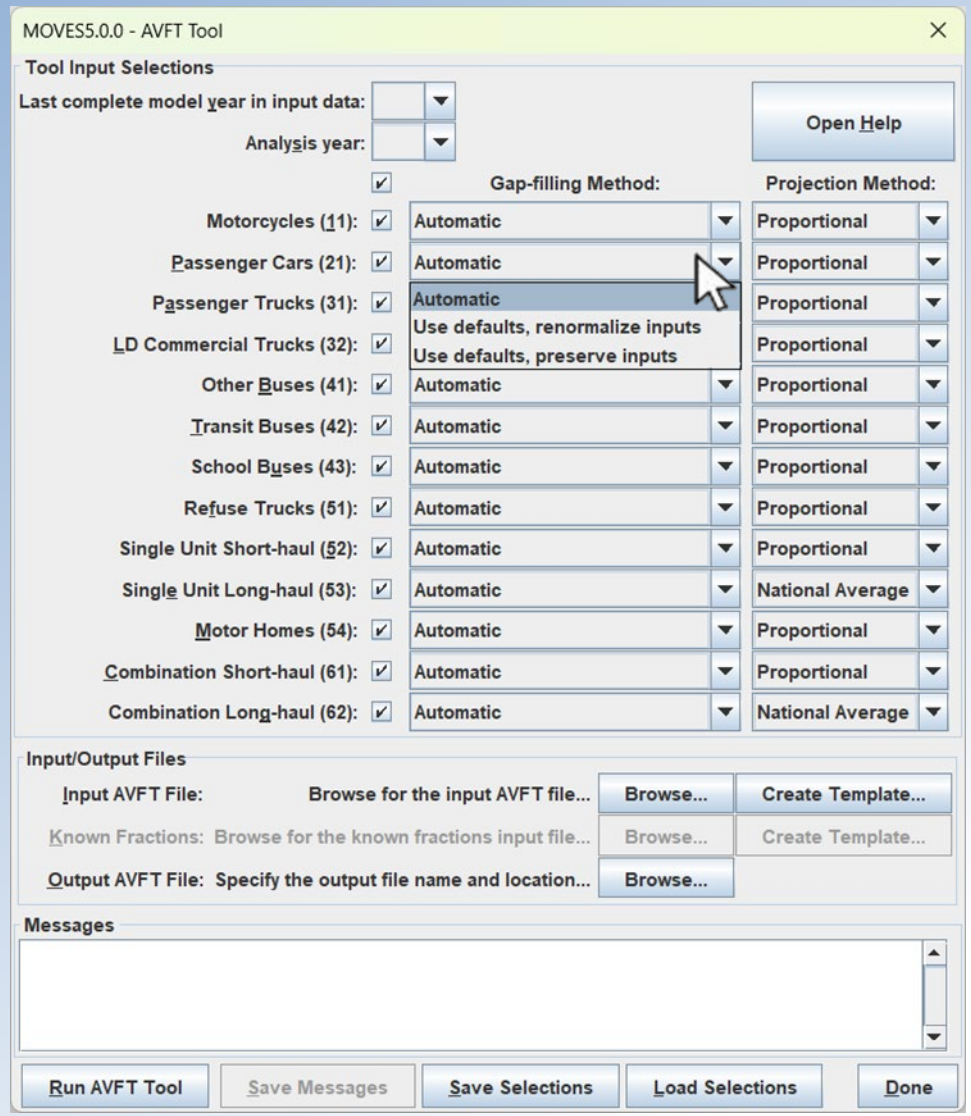
- MOVES5 contains database conversion tools that may be used to help convert a MOVES4 or MOVES3 database to the MOVES5 format
  - First, confirm that the user input databases still contain the latest data
  - The tools contain detailed instructions on performing this task
  - Notes:
    - When converting an input database that contains default data, use default data from MOVES5 instead of default data from earlier versions of MOVES (see the MOVES5 Technical Guidance, Section 1.5)
    - The converter tools can approximate 41-year age distributions from your input 31-year age distributions
    - They will also handle the optional startsopmodedistribution input (which also requires data for 41 ages), if provided
    - However, they cannot handle other optional input tables that require data for 41 ages. If provided, these tables will need to be reanalyzed to account for 41 ages before using with MOVES5: hotellingagefraction, startsageadjustment, and starts

AVFT Tool Updates



- Better error handling
- A single run of the tool can be used for multiple MOVES runs:
  - Gap-filling algorithm is run back to MY1950 (previously only gap-filled 30 model years prior to the analysis year)
  - The analysis year can be any year (previously had to have been after the last complete model year)
- Improved the Known Fractions template
  - Tool will ask you what fuel types are known, and the template will only include relevant source type / fuel type / model year combinations
- Added a control to turn on/off source types for runs that only include specific source types
- Added buttons to save/load selections
- Added a command line option to run the AVFT Tool in batch mode

AVFT Tool Updates (cont.)



- Changes in gap-filling methods:
  - Added "Automatic" method, which fills any missing values with 0s. Where this would result in all 0s for a particular model year, it fills with defaults instead
  - Renamed "Use defaults and renormalize" to "Use defaults, renormalize inputs". This option fills gaps with default values as-is, then scales the user-input values so that the distribution sums to 1
  - Added "Use defaults, preserve inputs". This option fills gaps with default values, but scales them so that the distribution sums to 1

Additional Tips

- MOVES5 Technical Guidance has detailed information on creating a RunSpec and input database
  - MOVES Hands-On Training is based on guidance and includes screenshots and examples, also especially helpful for how to review/process output
- MOVES5 Overview Report includes a detailed list of changes to the MOVES interface
- If MOVES run time is an issue,
  - We recommend breaking up large runs into smaller runs and configuring MOVES to improve run time
  - See Section 2.5 of the "MOVES5 Technical Guidance: Using MOVES to Prepare Emission Inventories in State Implementation Plans and Transportation Conformity," found at EPA's State and Local Transportation Resources website
  - Also see the updated Tips for Faster MOVES Runs at the MOVES GitHub site

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Resources

MOVES Website

MOVES website is the starting point for all MOVES information, with links to:

- Latest model (MOVES5)
- Limited use models (MOVES4 & MOVES3)
- Tools
- Training
- Background Information
  - Technical Reports
  - Software Information

MOVES5 Web Page

Latest MOVES model page has links and documents for MOVES5, including:

- EPA Releases MOVES5 Mobile Source Emissions Model: Questions and Answers
- MOVES Overview Report
- Policy and Technical Guidance
- MOVES5 Installation File
  - Instructions and trouble shooting guide are included

MOVES GitHub Site

- MOVES GitHub site has links to the MOVES source code
- MOVES GitHub/docs has links to additional user support documents, including:

- *Command Line MOVES*
- *Input DB changes in MOVES5*
- *Tips for faster MOVES runs*
- *Onroad Cheat Sheet*
- *Nonroad Cheat Sheet*

Additional Resources

- MOVES5 Policy Guidance and MOVES5 Technical Guidance are also available at the Policy and Technical Guidance for State and Local Transportation website
- Join EPA's MOVES listserv to receive MOVES announcements, including training:

Coming Soon

- “Under the hood” webinars on the data & analysis that went into MOVES5
- Updated MOVES Hands-on Training slides
- Research-grade tampering tool
  - We are drafting a “research-grade” tool that would allow modelers to do "what if" analyses on various tampering frequency scenarios
    - The tool would allow modelers to define tampering scenarios with tampering frequencies by regulatory class and model year
    - The tool would be for research purposes only and not an official part of MOVES or approved for use for any official purposes
  - Plan to make a draft version available next year.

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Thank you!