Questions and Answers

EPA Releases MOVES5 Mobile Source Emissions Model

1. What is MOVES, and why is the EPA releasing MOVES5?

EPA's MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics. MOVES5 allows users to model the benefits from new regulations promulgated since MOVES4 was released, incorporates the latest emissions data, and has improved functionality.

2. What has changed from MOVES4 to MOVES5?

MOVES5 incorporates several important updates, including:

- Accounting for EPA's Light- and Medium-Duty Multi-Pollutant Rule with higher projected electric vehicle (EV) fractions and more stringent standards for CO2, particulate matter (PM), non-methane organic gases (NMOG), and NOX.
- Accounting for EPA's Heavy-Duty Greenhouse Gas Emissions-Phase 3 Rule with higher projected EV fractions and updated energy consumption for heavy-duty EVs.
- Incorporating new data on light-duty and heavy-duty brake wear emissions.
- Expanding detailed calculations for a given analysis year to vehicles up to 40 years old, instead of 30.
- Updating fuel properties for calendar year 2021 and later.
- Updating historical and forecast default travel activity, vehicle population, age distributions, and fuel distributions.

The structure of MOVES5 is fundamentally the same as MOVES4, but to take advantage of new capabilities, modelers will need to modify their inputs.

As for emissions, EPA performed a comparison of MOVES4 to MOVES5 using default information in MOVES at the national level, and for sample urban counties with different local travel patterns and ambient conditions. Results will vary depending on local inputs but, in general, compared to MOVES4, MOVES5 emissions:

EPA United States Environmental Protection Agency

Office of Transportation and Air Quality
EPA-420-F-24-031
November 2024

- Tend to be higher in 2020s and 2030s:
  - Better modeling of older vehicles (age 31-40) leads to higher onroad inventories for **NOx, $PM_{2.5}$,**[1] **Volatile Organic Compounds (VOC) and CO** until about 2040.
  - $PM_{2.5}$ from brake wear is higher after 2011 based on new data on brake wear from heavy-duty (HD) trucks.
  - Methane (**CH_4**) is higher in all years, mostly due to compressed natural gas (CNG) vehicles. But total greenhouse gas emissions are still dominated by CO_2, which declines.
- Are lower in the long term:
  - **CO_2**: Almost 15 percent lower in 2035 and almost 35 percent lower in 2050 due to EPA's new GHG emission standards.
  - **NOx**: Slightly lower in 2040 and more than 20 percent lower in 2050.
  - 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 new EPA standards.

In practice, the results from using MOVES5 will depend upon the unique circumstances and local information that is used for a given area. For more information, including a detailed list of changes to the MOVES interface, see "Overview of EPA's MOtor Vehicle Emission Simulator (MOVES5)," available on the MOVES latest version web page.

3. What needs to be done to switch 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 includes a troubleshooting guide. MOVES4 can remain installed.

RunSpecs created with MOVES4 should work with MOVES5.[2] For user input databases that still contain the latest data, MOVES5 contains database conversion tools that may be used to help convert a MOVES4 or MOVES3 database to the MOVES5 format. The tools contain detailed instructions on performing this task.

4. How has EPA reviewed the new model?

Technical reports that describe the new MOVES5 inputs and algorithms have been reviewed by independent experts under EPA's peer review policies and procedures. The MOVES development team performs rigorous testing throughout the model development life cycle. This includes unit testing to ensure that every change to MOVES affects emissions and activity as expected, and systematic integrated testing to ensure changes do not have unintended side effects. A draft version of MOVES5 was tested by a small group of experienced MOVES users who alerted EPA to

[1] $PM_{2.5}$ refers to fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.

[2] 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.

potential errors and provided comments on the MOVES5 documentation. We also publicly shared the MOVES5-RC2 "release candidate" version of MOVES5 for modelers who wanted to become familiar with MOVES5 prior to the official release.

5. When should MOVES4 be used for state implementation plans (SIPs) and transportation conformity?

Details on when and how MOVES5 should be used for regulatory purposes are provided in EPA's "MOVES5 Policy Guidance: Use of MOVES for State Implementation Plan Development, Transportation Conformity, General Conformity, and other Purposes," which EPA is releasing with MOVES5. This guidance is available at EPA's Policy and Technical Guidance for State and Local Transportation website. MOVES5 will be required for new SIPs that are developed after its release. However, state and local agencies that have already completed significant work with an earlier version of MOVES can continue to use it in order to allow for timely submission of the SIP. MOVES5 will be required for transportation conformity determinations at the end of a two-year grace period, for both regional emissions analyses and hot-spot analyses. The transportation conformity grace period will begin with the publication of a Federal Register notice of availability for MOVES5, soon after the release of the model.

During the two-year grace period, agencies making transportation conformity determinations can use either MOVES4 or MOVES5. Note that the grace period established with the release of MOVES4 allows MOVES3 to be used for transportation conformity purposes until September 12, 2025. Consult the guidance for more information.

6. Does the release of MOVES5 affect the transportation conformity grace period EPA established with the release of MOVES4?

No, the grace period established by EPA's MOVES4 Notice of Availability in the Federal Register (88 FR 62567) continues to be in effect until September 12, 2025. For more information, please see EPA's MOVES5 Policy Guidance, available at EPA's Policy and Technical Guidance for State and Local Transportation website.

Modelers switching directly from MOVES3 to MOVES5 can also review the MOVES4 release documentation available on the MOVES website to understand the cumulative changes between the models.

7. Is additional training required to use MOVES5?

Users who are familiar with MOVES4 will find MOVES5 easy to use. We plan to offer a webinar in late 2024 to talk about changes to the model and answer questions about changing from MOVES4 to MOVES5. Slides from this webinar will be posted on the MOVES training page.

Modelers new to MOVES should review the MOVES training materials available on the web since most of this information is still relevant. We will be updating these materials to reflect MOVES5 soon.

When EPA schedules training, we update the MOVES training website with the information about how to register, and we publicize this information via the MOVES listserv. Instructions on signing up for the listserv are available at EPA's MOVES Listserv website.

8. What other resources are available for MOVES5?

The "Overview of EPA's MOtor Vehicle Emission Simulator (MOVES5)," available on the MOVES latest version website provides information about MOVES updates, model scope, appropriate use, structure, and algorithms. It also provides more information on MOVES testing and evaluation, and a comprehensive guide to MOVES documentation and guidance.

EPA's MOVES website is the source for MOVES software as well as technical reports that document the data and algorithms used in MOVES, tools for use with MOVES, frequently asked questions, and information on MOVES training. EPA MOVES staff may be contacted at mobile@epa.gov.

In addition, EPA developed "MOVES5 Technical Guidance: Using MOVES to Prepare Emission Inventories in State Implementation Plans and Transportation Conformity" to describe how to use MOVES for SIP development and regional transportation conformity analyses. This and other guidance documents can be found at EPA's State and Local Transportation Resources website. See MOVES guidance documents for additional EPA contact information.

9. What changed between the MOVES5-RC2 "release candidate" posted in October 2024 and the current model?

In October, EPA posted a MOVES5 release candidate for testing purposes and for modelers to become familiar with functional changes between MOVES4 and MOVES5 before MOVES5.0.0 was released. While results generated with MOVES5-RC2 are similar to official MOVES5 results, they will not be identical. MOVES5-RC2 cannot be used for regulatory purposes.

Changes since MOVES-RC2 include:

- Updated rates for CNG vehicle extended idle ammonia emissions.
- Updated information on Delaware's vehicle emissions Inspection and Maintenance program
- MOVES now requires CO_2, CH_4, and N_2O to be included in a run when CO_2 equivalent is requested.
- Minor performance improvements
- Updates to light duty diesel emission rates
- Updates to LEV III criteria pollutant emission rates to account for changes to California vehicle emission regulations.

10. Why does MOVES5 expand detailed calculations to vehicles up to 40 years old, instead of 30?

MOVES4 and earlier MOVES versions account for only 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 in these models.

MOVES5 has been updated to account for 41 model years (vehicle ages 0 through 40+). Adding model years better quantifies emissions from vehicles in the 31-40 age range and allows better modeling of vehicles without onboard diagnostic systems (OBD) and pre-OBD inspection and maintenance programs. Vehicles older than 40 years are modelled as 40-year-old vehicles, but the number of vehicles in this group, and their VMT, is much smaller.

11. Why have fuel properties for gasoline changed from those in MOVES4?

In MOVES4 and previous versions of MOVES, gasoline fuel properties were primarily based on volume-weighted fuel production information. However, 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 proportional to its 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. Thus, starting with CY 2021, the gasoline fuel supply has been redeveloped in MOVES5 based on this more appropriate retail survey data. 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.

12. Why have brake wear estimates changed from MOVES4?

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 a study led by 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 PM2.5 brake wear rates are lower for light and medium-duty vehicles, light-heavy-duty vehicles and urban buses, but they are higher for other heavy-vehicle classes, most notably for heavy-heavy-duty vehicles. This results in overall increase in PM2.5 emissions from brake wear, compared to MOVES4. Particle size data from these studies also allowed us to update the PM10/PM2.5 ratios in MOVES. The new data imply lower PM10 emission rates for all vehicle classes. For more information, see Brake and Tire Wear Emissions from Onroad Vehicles in MOVES5.

13. How does MOVES model brake and tire wear from electric vehicles?

In MOVES, tire wear from electric vehicles is modelled as the same as for conventional vehicles. Brake wear emission rates for electric vehicles are lower than for internal combustion engine vehicles after accounting for both increased vehicle mass and regenerative braking. For more information, see Brake and Tire Wear Emissions from Onroad Vehicles in MOVES5.

14. Does MOVES5 take longer to run than MOVES4?

In part because MOVES5 expands the calculations to 40 model years instead of only 30, modelers may see longer run times with MOVES5 compared to earlier versions of MOVES4. Where MOVES run time is an issue, we recommend breaking up large runs into smaller runs, and otherwise 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, and our updated Tips for Faster MOVES Runs at the MOVES GitHub site.