

A Roadmap to MOVES2004

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What is the purpose of this document?

This document provides a general overview of MOVES2004 and its documentation. It is meant to give users a first look at the model and to assist them in determining which documents they should consult to learn more about MOVES design, use and technical inputs.

What is MOVES2004?

MOVES2004 is EPA's initial release of the MOrtor Vehicle Emission Simulator. This version can be used to estimate inventories and projections through 2050 at the county level for energy consumption, nitrous oxide (N₂O), and methane (CH₄) from highway vehicles. It comes with a full suite of default data to estimate these results for the entire U.S. It also includes an interface with an updated version of Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy uses in Transportation (GREET) model to include "well-to-pump" estimates of energy consumption and emissions. Future versions of the model are planned to estimate non-highway mobile source emissions, estimate criteria pollutant emissions, and operate at smaller scales.

The first version of MOVES estimates energy consumption in order to validate model performance against top-down estimates of fuel consumption, compiled from fuel sales tax records. Validation of MOVES2004 results is important not only to gauge the accuracy of MOVES energy consumption estimates, but also because many aspects of energy and emission estimation methodology used in MOVES2004 will form the basis for criteria pollutant emission estimation in later versions. Positive validation results provide assurance that the underlying MOVES methodology and activity estimates are fundamentally sound. In addition to validation the release of MOVES2004 gives the broader user community an opportunity to work with MOVES while the advanced versions of the model (with regulated pollutants and multiple analysis scales) are developed.

How does MOVES differ from MOBILE?

MOVES2004 was developed from the ground-up, taking into account the needs of mobile source model users and recommendations on how to improve these models. As a result, MOVES2004 implements a number of "firsts" with regard to EPA's mobile source emission models, including: modeling energy consumption, N₂O and CH₄ explicitly; employing a "modal" emission rate approach as a prelude to finer-scale modeling; modeling a broad array of advanced technology vehicles; explicitly modeling periods of extended idling (e.g. heavy-duty "hoteling"); relying primarily on second-by-second data to develop emission rates; and including well-to-pump energy emission estimates to enable life-cycle analysis. Other significant changes from MOBILE are the use of a graphical user interface (GUI), using a relational database to store underlying data, and the calculation of total energy and emission inventories rather than simply calculating per-mile emission factors. These features will be carried over and expanded in the continued development of MOVES over the next few years.

What can MOVES2004 do?

The scope of MOVES2004 is as follows:

Output: MOVES2004 generates quantities of energy consumption (total, petroleum-based and fossil-based), emissions of nitrous oxide (N₂O) and methane (CH₄), and distance (e.g. vehicle miles traveled) for the geographic region and time period being modeled.

Sources: MOVES2004 models all on-road sources, including cars, light trucks, buses and heavy trucks and motorcycles, subdivided into 13 categories known as “source use types”.

Emission Processes: MOVES2004 estimates on-road “pump-to-wheel” energy consumption and emissions by the processes of running, start, and extended idle, and also includes fuel cycle “well-to-pump” energy and emissions via the GREET model.

Geography: Estimates can be generated for the entire U.S. (plus Puerto Rico and the U.S. Virgin Islands) at the county and roadway type level, with options to run at a more aggregate state or national level.

Time Spans: Estimates can be generated by hour of the day, day of the week, or month for calendar years 1999 through 2050, with options to run at a more aggregate day, month or year level.

Fuels: Gasoline (conventional, E10 and reformulated), diesel (conventional, biodiesel and Fischer-Tropsch), CNG, E85, M85, LPG, and electricity can be modeled for many source use types. Hydrogen (gaseous and liquid) will be added when well-to-pump pathway inputs become available.

Vehicle Technologies: Conventional internal combustion (all fuels), advanced internal combustion (gas and diesel), moderate hybrid-electric (gas and diesel), full hybrid-electric (gas and diesel) and dedicated electric can be modeled for most source use types. Fuel cell and hybrid fuel cell-electric will be added in conjunction with the addition of hydrogen to the model.

What is GREET?

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model was developed and is supported by Argonne National Laboratory’s Transportation Technology R&D Center, under the sponsorship of the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy. GREET is a tool for evaluating “well-to-wheel” energy and emission impacts of advanced vehicle and fuel technologies on an individual vehicle basis, accounting for energy consumed and emissions produced at every stage of fuel production and distribution (well-to-pump), and fuel use (pump-to-wheel). The first version of GREET was released in 1996, and Argonne has continued to update and expand the model since then. GREET is a stand-alone Microsoft Excel spreadsheet model, and more

recently has added a graphical user interface, GREET GUI, that eases execution. The model is available to the public free of charge.

The integration of GREET and MOVES results from a joint EPA/DOE commitment to advance the current state-of-practice for well-to-wheel analysis. The integration combines GREET well-to-pump estimates for numerous fuel production and distribution pathways, and MOVES' capability to estimate energy consumption and emission totals over multiple calendar years while assessing multiple advanced vehicle market penetration scenarios. Argonne developed a version of GREET specifically for MOVES2004 integration which is automatically installed as part of the MOVES installation package. The MOVES2004 interface can be used to change GREET fuel pathway parameters and update well-to-pump energy and emission effects used by MOVES.

Additional information on GREET is available at:
<http://www.transportation.anl.gov/software/GREET/index.html>.

What is PERE?

The Physical Emission Rate Estimator (PERE) is a stand-alone Microsoft Excel spreadsheet model developed to fill data gaps in MOVES2004 energy consumption rates, including rates for advanced technology vehicles such as hybrids. PERE uses vehicle parameters and second-by-second driving traces as input, and outputs second-by-second fuel consumption rates. PERE uses physical principles to model propulsion systems in the vehicle. The model is based on a simple model for the internal combustion engine. Simulation of hybridization is achieved by adding a secondary power source and energy storage device (usually a battery/motor combination). At this time, PERE is not integrated into MOVES2004; it is run independently with the results processed manually to generate the appropriate default inputs for MOVES. The PERE model and documentation are available for download on the MOVES web page.

What documentation is available for MOVES2004?

Several documents are available to provide information on model installation, use, design, technical inputs and results. Most are available either as part of the installation package, or posted as separate documents on the MOVES web page (<http://www.epa.gov/otaq/ngm.htm>). Any report can be requested via email to mobile@epa.gov.

Installation: An installation guide is included on the MOVES installation CD. It guides the user through the installation and initial execution of the MOVES program.

User Guide: "MOVES2004 User Guide" explains how to operate MOVES2004, including setting up input files ("run specs"), executing the model, and obtaining results. It is included on the installation CD, and is posted as a separate document on the MOVES web page. An "online" version of the User Guide is also available within the model via the "Help" menu option.

Software Design: “MOVES Software Design Reference Manual” covers the basic concepts and functional design of the software and the underlying MySQL database, including technical specifications for all calculations performed in the model. This report is on the MOVES web page.

Validation Results: “MOVES2004 Validation Results” presents a comparison of MOVES2004 to top-down fuel sales for the purpose of model validation, as well as comparisons of MOVES results to alternate estimates of CH₄ and N₂O inventories and fuel economy. This report is on the MOVES web page.

Technical Inputs: The documentation of technical inputs is categorized by those pertaining to 1) fleet and activity inputs and 2) energy and emission inputs. All reports are on the MOVES web page unless otherwise noted.

Fleet & Activity Inputs:

“MOVES2004 Highway Vehicle Population and Activity Data” explains the data sources and methods used to estimate default “fleet” (e.g. vehicle populations, age distribution) and “activity” (e.g. vehicle miles traveled, speed distribution, driving patterns) inputs used by MOVES2004.

“Roadway Specific Driving Schedules for Heavy-Duty Vehicles” explains the data sources and methodology used to generate heavy-duty driving schedules used in MOVES2004. This is available via request to mobile@epa.gov

Energy & Emission Inputs:

“MOVES2004 Energy and Emissions Inputs” explains the data sources and methods used to estimate default energy and emission rates and adjustments used by MOVES2004.

“Fuel Consumption Modeling of Diesel, Motorcycle and Advanced Technology Vehicles in the Physical Emission Rate Estimator (PERE)” documents the PERE model, used to fill energy rate “holes” and to develop advanced technology inputs in MOVES2004.

“Update of Methane and Nitrous Oxide Emission Factors for On-Highway Vehicles” documents the data and methodology behind the CH₄ and N₂O emission rates in MOVES2004.

GREET (Well-To-Pump Modeling): “User Manual and Technical Issues of GREET for MOVES Integration”, produced by Argonne National Laboratory, serves as a user guide for the version of GREET integrated with MOVES and documents a subset of default inputs used by the model. This report is on the MOVES web page. More comprehensive documentation on the GREET model is available at <http://www.transportation.anl.gov/software/GREET/index.html>

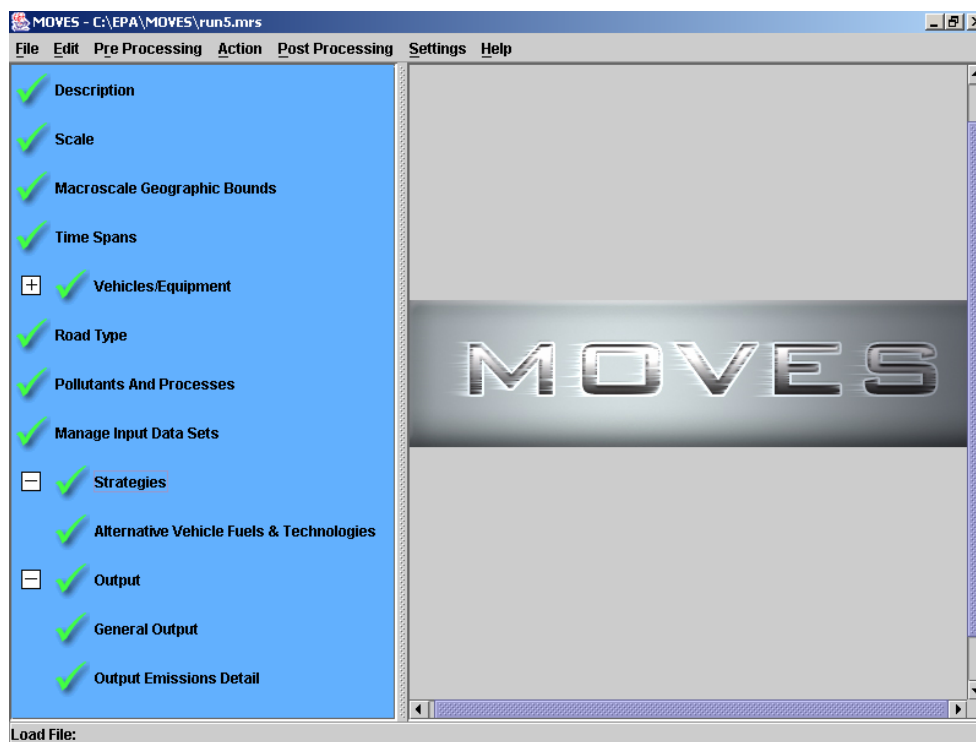
How do I get a copy of MOVES2004?

The MOVES2004 installation package is available for download from the MOVES web page (<http://www.epa.gov/otaq/ngm.htm>). An installation CD can also be requested via email to mobile@epa.gov. The installation package contains all of the software and underlying data necessary to install and run MOVES2004 (although Microsoft Excel is required to run GREET and PERE). Once the installation package has been downloaded and uncompressed according to instructions found on the MOVES web page, the installation guide (included in the package) should be consulted for step-by-step instructions on how to install MOVES2004.

How do I work with MOVES2004?

The MOVES2004 User Guide provides detailed information on running the model. MOVES2004 is an open-source program written in Java and the relational database program MySQL. In addition to the software code, an extensive MySQL database structure is used to store model input and output data. MOVES2004 uses a graphical user interface (GUI) to allow users to establish the specifications for a model run. The GUI is made up of several panes, which guide the user through selections of geography, time spans, vehicle classes, pollutants, emission processes, alternative input data, and output options (see figure below). Run specifications can be saved for later use and editing as well.

MOVES2004 GUI (Main Window)



MOVES is designed for transparency. Although populated with a full suite of default data, the relational database design provides maximum flexibility for providing alternate input data, working with different levels of output aggregation, or even changing fundamental elements of the design implementation such as vehicle classifications or operating mode definitions. Whereas MOBILE users wishing to alter underlying data commonly need to alter FORTRAN code, MOVES users wishing to alter underlying data will not need to alter the Java code at all; instead, changes the user might wish to make to subject matter content would be done in the MySQL database. MySQL can be worked with directly or can be set up to port to commonly available commercial database or analysis packages such as MS Excel, MS Access or FoxPro. It is important to note, however, that users are not required to manipulate every possible input; depending on the purpose of the modeling, default runs or runs with minor modifications to the default data may be suitable.

How do I customize MOVES2004?

MOVES2004 is populated with a full range of default data, to enable modeling of the entire U.S. plus territories at the county level through 2050. However, the model was designed for the ability for users to customize the model to meet their specific needs. In particular users may want to represent a local area better than the defaults, and/or alter inputs for “what-if” analysis, for example with regard to different advanced technology and fuel scenarios.

To customize MOVES2004 for a specific area, a user must first re-define the modeling domain, as well as the zones that make up the domain if sub-domain analysis was desired. The default modeling domain for MOVES2004 is the entire U.S., with counties defined as zones. At a minimum the user would need to enter local vehicle miles traveled (VMT) and geographic allocation factors, since the current defaults only apply to the entire nation. Beyond this basic requirement local customization could proceed on many levels. A simple example might involve using local vehicle age distributions or meteorology data, similar to what many users currently undertake with MOBILE. On the more complex end, local customization could involve replacing specific driving schedules culled from local in-use driving surveys.

Another aspect of customization is the ability to analyze “what-if” scenarios. MOVES2004, with integrated GREET, will provide a very broad range of “what-if” analysis capability across four areas: fuel and vehicle technology penetration, energy and emission performance of these technologies, upstream fuel pathway options and activity patterns.

Fuel and Vehicle Technology Penetration: Users can input alternate market penetration scenarios for advanced technology and alternative fuels through the MOVES GUI. This allows the user to address the question “what is the impact of having X percent of advanced technology Y in the fleet, in year Z?”

Energy and Emission Performance: Users can input alternative assumptions regarding the relative benefit of energy and emission performance of individual technologies via the Future Emission Rate Creator (FERC) pre-processing step. This allows the user to address the question “what is the impact of varying the energy consumption and emissions of advanced technology Y?”

Fuel Pathway Options: The integration with GREET will enable the user to select different fuel pathway options, or mixes of options, for specific fuel types in MOVES. It will also allow the user to alter inputs at each step of a given pathway. This allows the user to address the question “what is the impact of varying the source of fuel for advanced technology Y?”

Activity Patterns: MOVES2004 provides unprecedented flexibility in varying activity patterns of the fleet. This pertains to many parameters related to VMT growth and allocation, as well as driving patterns themselves. Specifically, MOVES2004 estimates energy and emissions using real-world driving patterns culled from in-use driving surveys. The user can investigate energy consumption and emissions differences between real-world urban vs. freeway driving or congested vs. uncongested conditions, across source use types.

What’s next for MOVES?

The release of MOVES2004 kicks off a stakeholder review period, with comments requested by July 15, 2005. Comments received at this point will be considered in the development of the next version of MOVES, planned for release in 2006. MOVES2006 will complete the on-road component of the model, adding HC (including non-exhaust emissions), CO, NO_x, PM, Toxics, CO₂, NH₃ and SO₂. MOVES2006 will be the draft replacement for MOBILE6, with an extensive review period planned before finalization with the release of MOVES2007. Off-road sources including commercial marine, aircraft and locomotive will be included in draft form in MOVES2007, with finalization in 2008.