A summary of the key capabilities of the MOVES2014a model, EPA’s current tool for estimating emissions from onroad and nonroad mobile sources.
The U.S. Environmental Protection Agency (EPA) has a 40-year history of developing mobile source inventory modeling software. The first model, MOBILE1, was released in 1978 and replaced lookup tables formerly used for estimating vehicle emission factors. Since then, there have been five major revisions to the MOBILE series, ending with MOBILE6.2 released in 2004. Concurrently, the agency developed the NONROAD series of models for estimating emissions of nonroad mobile sources, which began with NONROAD1998 and concluded with NONROAD2008a released in 2009. Each successive release of both models built upon their predecessors and reflected substantive updates in terms of data, methods, and algorithms accounting for impacts of operational characteristics, ambient conditions, fleet characteristics, emission control devices, and fuel quality.

EPA fundamentally overhauled its approach to mobile source emissions estimation with release of the MOtor Vehicle Emission Simulator (MOVES) in 2009. The MOVES modeling suite—developed as a wholly revised platform, using new methods and data—replaced both the MOBILE and NONROAD models. MOVES2010, the first official version, covered onroad motor vehicles, and the first major revision, MOVES2014, added the nonroad sector.

MOVES Overview

Platform

MOVES is written in Java and the MySQL relational database management system, with some elements written in FORTRAN and the Go programming languages. The model is typically operated on a Windows operating system through the graphical user interface overlay, which contains several features for input development and conversion to MySQL, as well as post-processing routines.

Features

Key features of the model are outlined below.

- **Pollutants**: MOVES can address 156 distinct species, including criteria pollutants, toxic compounds, speciated hydrocarbons, speciated particulate matter (PM), energy consumption, and carbon-bond speciation used in certain photochemical models.

- **Emissions Processes**: MOVES accounts for emissions that occur both when vehicles are in operation and when they are at rest. Modeled emission processes include startup, running exhaust, crankcase, hoteling, permeation, fuel vapor venting, liquid fuel leaks, refueling, tire wear, and brake wear.

- **Modal Emission Rates**: For onroad vehicles, operational emissions (i.e., running exhaust) are defined at the 1 hertz resolution to support macro-scale and micro-scale modeling.

Domain/Scale: Macro-scale onroad and nonroad emissions can be estimated at the sub-county, county, state, or national level. Micro-scale modeling, referred to as “project level” modeling in MOVES, is available for onroad motor vehicles.

Vehicles/Equipment: There are 12 types of onroad vehicles supported, including motorcycles, passenger vehicles, and commercial trucks and buses, and 88 types of nonroad equipment.

Fuels: Fuel types supported include gasoline, E85, diesel, electricity, compressed natural gas (CNG), and liquefied petroleum gas (LPG).

Data

MOVES input data are contained in 222 MySQL data tables representing the default modeling database. There are multiple mechanisms for users to substitute for any number of data tables. Default tables generally fall into the fleet, activity, or emission rates categories.

Notably, the model contains default data for the entire United States; therefore, the model can be operated to represent any county in the United States without additional inputs. However, use of MOVES for purposes such as State Implementation Plan (SIP) development does require the collection of local input data.

MOVES Uses

County and State Analyses

One common use of the MOVES model is to estimate mobile source emissions inventories for counties and states, which are often developed as part of SIPs focused on bringing areas into compliance with National Ambient Air Quality Standards (NAAQS).

While MOVES contains default data for all counties and states, EPA recommends use of local data for vehicle activity, population, and fuels to more accurately represent actual emissions. Sources of local data include Department of Motor Vehicles registrations, traffic analyses, travel demand modeling, and vehicle surveys. SIP inventories serve two main purposes: planning and modeling. The planning inventory establishes future-year emissions and emissions budgets used for transportation conformity. Modeling inventories are inputs developed for ambient air quality models when used to determine compliance with a given NAAQS.

National-Level Analyses

MOVES is used to estimate emissions at the national level to support federal rulemakings and recurring planning inventories. Rulemaking analyses include revisions to the NAAQS, onroad motor vehicle standards, fuel regulations, and interstate pollutant transport.
The national domain in MOVES covers 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands, encompassing 3,228 counties or county-level equivalents. Although EPA maintains county databases of onroad and nonroad inputs supplied by local and state agencies for each county, completing national inventories using these data would be time prohibitive. Instead, the agency has developed an inventory process that relies on estimating emission factors from “representative counties” over a range of conditions and then post-processing the national inventory externally to MOVES. That process is the subject of the below case study.

**Case Study: The NEI**

The National Emissions Inventory (NEI) is a comprehensive compilation of criteria and toxic air pollutants in the United
States emitted from essentially all anthropogenic and biogenic sources. The NEI is a triennial effort using data provided by state, local, and tribal air agencies for sources in their jurisdictions and supplemented by data developed by EPA. Version 2 of the 2014 NEI is the current, complete version; the 2017 NEI is under development.

The onroad emissions inventory development process for the NEI is shown in Figure 1. The process begins by updating the national county databases, followed by an assessment of representative counties applied to the contiguous 48 states. The 2014 NEI updated onroad data inputs for more than 1,800 counties; 297 representative counties were identified for inventory processing.

Following identification of the representative counties, emissions inventory processing begins. For onroad motor vehicles, MOVES can be operated in either “inventory” or “emission rate” mode. To support the development of the NEI, MOVES is operated in emission rate mode for the representative counties over a range of vehicle speeds and ambient conditions. As shown in Figure 1, these data are combined with county-level meteorology data and activity data using the SMOKE program to produce the final on-road emissions inventory. SMOKE is an EPA emissions processing software used to develop inventories for photochemical modeling; a distinct SMOKE–MOVES model was created to estimate on-road inventories using the representative counties procedure.

The county-level on-road inventory of the 2014 NEI is presented in Figures 2 and 3 for volatile organic compounds (VOC) and oxides of nitrogen (NOx), respectively. The national total onroad inventory in 2014 equals 2.3 and 4.8 million tons per year of VOC and NOx, respectively.

**Project-Level Analyses**

Project level is the MOVES equivalent of micro-scale. The model estimates running exhaust emissions for roadway segments (links) while assigning other emissions (e.g., startup exhaust) to locations off of the roadway (off-network). In this manner, the model can evaluate individual intersections and facilities that include both roadway and parking locations. These features give MOVES the ability to support a wide range of project-level analyses.

**GHG Inventories**

With respect to greenhouse gas (GHG) emissions, MOVES generates estimates of carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4). EPA has issued guidance on the use of MOVES for GHG inventory development for state and local agencies. EPA’s official national GHG inventory is prepared following Intergovernmental Panel on Climate Change (IPCC) guidelines in which the MOVES model is used to provide N2O and CH4 emission rates, with CO2 emissions being derived from fuel consumption estimates.

MOVES2014a reflects all current light-duty GHG regulations and the Phase 1 heavy-duty onroad fuel efficiency
regulations; the Phase 2 regulations will be included in a subsequent MOVES update. Notably, EPA has used various versions of MOVES to analyze the impact of national GHG and fuel efficiency regulations on GHG emission inventories.\(^7\)

**MOVES Going Forward**

EPA is tentatively planning to release a minor update, MOVES2014b, in summer 2018. EPA is referring to the next major model revision as MOVES201X, with a release in early 2019 at the soonest. \(^\text{em}\)

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