# MOVES5 Technical Guidance:

## Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity

United States Environmental Protection Agency

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Office of Transportation and Air Quality
U.S. Environmental Protection Agency

United States Environmental Protection Agency

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# Section 1. Introduction

## *1.1 Purpose of this Guidance*

MOVES (the MOtor Vehicle Emissions Simulator) is a state-of-the-science model designed by the U.S. Environmental Protection Agency (EPA) to estimate air pollution emissions from mobile sources in the United States. MOVES can be used to estimate exhaust and evaporative emissions as well as brake and tire wear emissions from all types of onroad vehicles. MOVES can also be used to estimate emissions from many kinds of nonroad equipment.[1] The onroad and nonroad modeling capabilities exist as separate modules in MOVES.

This guidance is intended to apply to all versions of MOVES5. In this guidance, the term "MOVES" generally means MOVES5 and applies to all versions of MOVES5. To distinguish between the onroad and nonroad components in MOVES, this guidance refers to them as "MOVES-Onroad" and "MOVES-Nonroad," respectively.

This document provides guidance on the use of MOVES for inventory development in state implementation plans (SIPs) and for regional emissions analysis for transportation conformity determinations in states other than California.[2,3] This document includes guidance on developing onroad and nonroad inventories using MOVES. While MOVES can also produce estimates of greenhouse gases, air toxics, and total energy consumption, the focus of this guidance is the use of MOVES for estimating emissions of criteria pollutants and their precursors for SIP and transportation conformity purposes:

- The Clean Air Act (CAA) and implementation rules for the NAAQS require that SIP inventories and control measures be based on the most current information and applicable models that are available when a SIP is developed.[4]
- Similarly, section 176(c)(1) of the CAA requires transportation conformity determinations to be based on "the most recent estimates of emissions." Additionally, the transportation conformity rule (40 CFR 93.111) requires conformity analyses to be based on "the latest emissions estimation model available," and further states that this requirement is satisfied if the most current version of EPA's motor vehicle emissions model is used. In addition, the transportation conformity rule (40 CFR 93.110) requires conformity determination to be based on the "latest planning assumptions," meaning "the most recent planning assumptions in force at the time the conformity analysis begins."

This document provides guidance for meeting these requirements.

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[1] See Appendix B for the list of nonroad equipment that can be modeled with MOVES. Note that MOVES cannot be used to model emissions from locomotive, commercial marine, or aviation engines.

[2] In California, a different onroad emissions model, EMFAC, is used for regulatory purposes instead of MOVES. MOVES can also model emissions in the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.

[3] Project-level analyses for transportation conformity are covered in other guidance documents; see Section 1.6 for more information.

[4] See Clean Air Act section 172(c)(3). Also see the discussion of emissions inventory requirements in the "Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements" rule (81 FR 58029, August 24, 2016) and in the "Implementation of the 2015 National Ambient Air Quality Standards for Ozone: Nonattainment Area State Implementation Plan Requirements" rule (83 FR 63022, December 6, 2018).

A "regional emissions analysis" for transportation conformity purposes involves estimating onroad motor vehicle emissions at the regional level. However, this term could be confused with the process of creating an inventory for a SIP. To avoid that confusion, an analysis done for transportation conformity is referred to as a "regional conformity analysis" in this document.

This document presumes that users already have a basic understanding of how to run MOVES.[5] It also presumes a basic understanding of SIP and conformity regulatory requirements and policy.[6]

MOVES can estimate onroad motor vehicle emissions through various domain/scale options: Default Scale, County Scale, and Project Scale.[7] The County Scale is necessary for estimating onroad emissions for SIPs and regional conformity analyses. The onroad portion of this guidance covers the use of the County Scale only.[8] Sections 2, 3, and 4 of this guidance focus on determining what the appropriate inputs are and how MOVES should be run to develop emission estimates for onroad vehicles for SIPs and regional conformity analyses. MOVES-Nonroad only operates at the Default Scale. Section 5 includes discussion of how to develop county-level nonroad emissions estimates using MOVES-Nonroad at Default Scale.

MOVES-Onroad includes a default database of meteorology, vehicle fleet, vehicle activity, fuel, and emission control program data for the entire United States. The data included in this database come from a variety of sources and may not be the most current or best available information for any specific county. This guidance describes when the use of that default database is appropriate for SIPs and regional conformity analyses.

This document covers the input options in MOVES that are most relevant for SIPs and regional conformity analyses. Use of MOVES to analyze certain specific control programs, such as a program to replace diesel vehicles or equipment with electric ones, are addressed separately in updates to guidance documents for those programs.[9] MOVES users should always check with their EPA Regional Office if there is any question about the applicability of guidance to any specific situation. Refer to Section 1.8 for information about EPA Regional contacts.

## *1.2 How does EPA distinguish model versions?*

MOVES5 is a major revision to the previous versions of MOVES4. As shown in Table 1-1, under EPA's MOVES naming convention, future minor revisions would be designated by increments of the number after a decimal point (e.g., MOVES5.1).[10] EPA may also use an additional decimal point to designate minor patches (e.g., MOVES5.0.1).

[5] For information about how to run MOVES, please see the resources available on EPA's MOVES Training website.
[6] For more information, see EPA's State and Local Transportation Resources website.
[7] The Default Scale can be used to model the Nation, states, or counties by using built-in default data.
[8] See Section 1.6 for a list of guidance documents that address use of MOVES at the Project Scale.
[9] MOVES users should check EPA's Guidance on Control Strategies for State and Local Agencies website for updates to EPA guidance documents for estimating reductions from various control programs.
[10] Prior to MOVES3, minor revisions were denoted by letters (e.g., MOVES2014a).

**Table 1-1. MOVES Naming Convention**

| Type of Release | Naming Convention | Examples |
|---|---|---|
| Major release | "MOVES" followed by a new number in sequence | MOVES5 |
| Minor revision | Addition of a decimal followed by a new number in sequence | MOVES5.1, MOVES5.2 |
| Minor patch, e.g., new user features | Addition of a second decimal followed by a new number in sequence | MOVES5.0.1, MOVES5.0.2 |

## *1.3 How is this guidance organized?*

This document has five sections, and updates for MOVES5 have been included in each of these sections:

- Section 1 is a general introduction to this guidance. This section includes how MOVES5 is different from the preceding model, MOVES4 (see Section 1.4).
- Section 2 helps with planning an onroad emissions analysis with MOVES.
- Section 3 focuses on the individual parameters used to create a MOVES Run Specification (RunSpec) file for an onroad emissions analysis. In general, these parameters define the type of MOVES run, the time period, location, vehicle types, pollutants, road types, and how detailed MOVES output will be.
- Section 4 describes the input options in the County Data Manager (CDM) used for onroad emissions analyses. The CDM is where users enter locally specific data such as meteorology, fleet and activity data, fuel specifications, and inspection and maintenance (I/M) program information if applicable. Section 4 includes guidance for estimating percentages of electric vehicles (EVs) in the fleet and information about the tool that helps modelers do so (see Section 4.8.3).
- Section 5 focuses on using MOVES for nonroad emissions analysis, including the parameters to create a nonroad RunSpec in MOVES, use of the Nonroad Data Importer to incorporate local meteorological and fuel data, and use of emission factor post-processing scripts to apply local nonroad equipment population and activity information to MOVES nonroad output.

MOVES users are urged to check the MOVES website regularly and subscribe to EPA's mobile source emissions model Listserv to receive announcements related to MOVES and MOVES guidance.

## *1.4 How does MOVES5 compare with MOVES4?*

MOVES5 is a major revision to the MOVES series of models and is the latest emissions model for SIP and conformity purposes. MOVES5 includes many changes, including new vehicle

standards, new emissions and activity data, and new features. As a result of these changes, estimates of emissions from MOVES5 may be different from versions of MOVES4.

The structure of MOVES5 is fundamentally the same as MOVES4, but the emission rates and activity included in MOVES5 differ from MOVES4. The net impact of these changes on calculated emissions will depend on many factors, including the specific area being modeled and the inputs used.

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 carbon dioxide ($CO_2$), particulate matter (PM), non-methane organic gases (NMOG) and oxides of nitrogen (NOx).[11]
- Accounting 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.[12]
- Incorporating new data on light-duty (LD) and heavy-duty (HD) brake wear emissions.
- Expanding detailed calculations to vehicles up to 40 years old, instead of 30.
- Updating onroad and nonroad fuel properties for calendar year 2021 and later.
- Updating historical and forecast default vehicle miles travelled (VMT), vehicle populations, age distributions, and fuel distributions.

For additional information on the updates included in MOVES5, please refer to the *Overview of EPA's MOtor Vehicle Emissions Simulator (MOVES5)*, found at EPA's MOVES Latest Version website. Specific information about MOVES5 inputs and algorithms can be found in EPA's MOVES onroad and nonroad technical reports, found at EPA's MOVES websites for Onroad Technical Reports and Nonroad Technical Reports, respectively.

MOVES is a flexible model using an array of input and output options, allowing more than one way to use MOVES to develop emissions estimates. Like its predecessors, MOVES5 includes the capability to estimate vehicle exhaust and evaporative emissions as well as brake wear and tire wear emissions for criteria pollutants and precursors. However, like previous versions, MOVES5 does not include the capability to estimate emissions of re-entrained road dust. To estimate emissions from re-entrained road dust, practitioners should continue to use the latest approved methodologies.[13]

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[11] See EPA's final rule, "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles," published in the *Federal Register* on April 18, 2024 (89 FR 27842).
[12] See EPA's final rule, "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles—Phase 3," published in the *Federal Register* on April 22, 2024 (89 FR 29440).
[13] See EPA's Notice of Availability, "Official Release of the January 2011 AP-42 Method for Estimating Re-Entrained Road Dust from Paved Roads," published in the *Federal Register* on February 4, 2011 (76 FR 6328).

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 major versions MOVES4 or MOVES3; we recommend breaking up large runs into smaller runs, and otherwise configuring MOVES to improve run time. See Section 2.5 for additional discussion.

## *1.5 Can I use input databases created with earlier MOVES versions in MOVES5?*

When running the model for regulatory purposes, MOVES inputs should be based on the latest available data. Generally, this means that modelers should create new input databases based on the latest available data including, at minimum, the latest information on vehicle miles travelled (VMT), speeds, fleet mix, and any SIP control measures.

However, EPA has developed tools to convert existing input databases that were created for use with MOVES3 or MOVES4 into input databases that can be used with MOVES5.[14] These tools may be used if the MOVES3 or MOVES4 input databases still contain the latest available information.[15] They are available in the "Tools" dropdown menu in the MOVES graphical user interface (GUI). These conversion tools have instructions and a help file available in the GUI.

MOVES5 includes significant updates to default fleet, activity, fuels, and I/M program data. Where user input databases contain default information, the default data from MOVES5 should be used instead of default data from earlier versions of MOVES. This includes any defaults which are used directly (e.g., long-haul truck age distributions, see Section 4.4), data derived from MOVES tools (e.g., the Age Distribution Projection Tool or the Alternate Vehicle Fuel and Technology (AVFT) Tool, covered in Sections 4.4 and 4.8.3, respectively), and defaults used to adjust local data (e.g., using model defaults to estimate relative population splits between source types within an HPMS vehicle class, as described in Section 4.3). Note that these are examples rather than an exhaustive list. Therefore, after using a converter tool, additional steps are necessary before using the converted databases with MOVES5, as detailed in the converter tools' help files.

## *1.6 What other MOVES guidance and documentation are available?*

In addition to this guidance document, EPA has developed policy guidance to assist in implementing MOVES:

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

[14] Modelers should be able to load RunSpecs created with MOVES4 in MOVES5. The one exception is if a MOVES4 RunSpec includes "$CO_2$ equivalent" and does not include all three greenhouse gas pollutants. 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.

[15] For more information, see the EPA and DOT's joint *Guidance for the Use of Latest Planning Assumptions in Transportation Conformity Determinations*, EPA420-B-08-901, December 2008.

038, November 2024, addresses general policy issues for MOVES such as timing of the use of MOVES in SIPs and regional conformity analyses. This guidance is available at EPA's Policy and Technical Guidance for State and Local Transportation website.

Other resources for using MOVES that generally apply to MOVES5 include:

- *PM Hot-Spot Guidance: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and $PM_{10}$ Nonattainment and Maintenance Areas*, provides guidance on using MOVES at the Project Scale for quantitative $PM_{10}$ and $PM_{2.5}$ hot-spot analysis for transportation projects. The latest version of this guidance is available on EPA's Project-Level Conformity and Hot-Spot Analyses website.

- *Using MOVES3 in Project-Level Carbon Monoxide Analyses,* provides guidance on using MOVES at the Project Scale for CO emissions from transportation projects. The latest version of this guidance is available on EPA's Project-Level Conformity and Hot-Spot Analyses website.

- *Performance Standard Modeling for New and Existing Vehicle Inspection and Maintenance (I/M) Programs Using MOVES Mobile Source Emissions Model* describes when and how to conduct performance standard modeling to demonstrate in an I/M SIP that a vehicle emission I/M program meets the applicable performance standard as defined within the I/M regulations. The latest version is available on EPA's Vehicle Emissions Inspection and Maintenance website.

- *Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions,* describes state-of-the-science methodologies for preparing an emissions inventory for the mobile source sectors found at ports and freight terminals, including ocean-going vessels, harbor craft, recreational marine, cargo handling equipment, onroad vehicles, and rail. The latest version of this guidance is available on EPA's Port Emissions Inventory Guidance website].

- *MOVES GHG Guidance: Using MOVES for Estimating State and Local Inventories of Onroad and Nonroad Greenhouse Gas Emissions and Energy Consumption*, describes how to use MOVES to estimate greenhouse gas (GHG) emissions and/or energy consumption from onroad vehicles in a state or metropolitan area. This GHG guidance provides additional options for estimating GHG emissions with MOVES that are not acceptable for SIP and conformity purposes. The latest version of this guidance document is available on EPA's Estimating Greenhouse Gas Emissions website.

- EPA's MOVES Hands-on Training Course, which provides detailed information on how to use MOVES consistent with this guidance. The course covers MOVES at all three scales, with an emphasis on using the County Scale for SIP and regional conformity analyses based on this guidance. The Hands-on Training Course includes a presentation file of all modules as well as example files so that the training can be self-guided.

- In addition to the Hands-on Training Course, other MOVES training materials can be found on MOVES Training.

EPA's MOVES website includes guidance and documentation about the MOVES model, including information about the latest version, instructions for downloading MOVES, training materials and notices of upcoming MOVES training, and instructions for subscribing to EPA's MOVES email announcements.

Information on the use of MOVES in SIPs and regional conformity analyses (including this guidance as well as the Policy Guidance mentioned above) may also be found on EPA's Policy and Technical Guidance for State and Local Transportation website.

## *1.7 Does this guidance create new requirements?*

No. The discussion in this document is intended solely as guidance. The statutory provisions and EPA regulations described in this document contain legally binding requirements. This document is not a regulation itself, nor does it change or substitute for statutory provisions and regulations. Thus, it does not impose legally binding requirements on EPA, the DOT, states, or the regulated community. EPA retains the discretion to consider and adopt approaches on a case-by-case basis that may differ from this guidance, but still comply with the statute and regulations. Any decisions regarding a particular SIP or conformity determination will be made based on the statute and regulations. This guidance may be revised periodically without an opportunity for public comment.

## *1.8 Who do I contact for additional information?*

General questions about MOVES or this guidance should be sent to EPA's "MOVES Inbox," mobile@EPA.gov. Questions about the application of this guidance to specific SIPs or regional conformity analyses should be addressed to the EPA Regional Office SIP or transportation conformity contact. A list of the EPA Regional mobile source contacts can be found in Section 16.2 on EPA's Office of Transportation and Air Quality Contact by Topic website. Regional contacts for transportation conformity can be found on EPA's Regional Contacts regarding State and Local Transportation website.

# Section 2. Planning an Emissions Analysis for Onroad Vehicles

MOVES is a flexible model using an array of input and output options, allowing more than one way to use MOVES to develop emissions estimates. This section covers approaches to developing onroad inventories for SIP and regional conformity analysis purposes using MOVES. These approaches affect the number of runs that will be needed and the degree to which additional data calculations or post-processing of the MOVES output will be necessary after the runs. The interagency consultation process should be used to determine which options will best meet the needs of the area or region. This section addresses how to make that determination when planning MOVES runs. This section covers the following topics:

- The types of inventories that users may need to create;
- The types of data that will be needed to run MOVES;
- Options for calculating an inventory within or outside of MOVES;
- Options for modeling a county, a partial county, and more than one county; and
- A summary of planning approaches for a SIP inventory or regional conformity analysis.

## *2.1 For what purposes are onroad emission inventories created?*

State and local air quality and transportation agencies estimate onroad vehicle emissions for a variety of different regulatory purposes. As described in more detail in the *Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter NAAQS and Regional Haze Regulations* (EPA-454-B-17-002),[16] planning inventories for nonattainment areas are required for reasonable further progress, attainment, and maintenance SIPs. The attainment projected inventory for the nonattainment area may serve as the basis for the SIP motor vehicle emissions budgets, which are used in regional conformity analyses. Emission estimates are also created specifically for air quality modeling for attainment demonstrations, as described in the *Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5 and Regional Haze* (EPA 454-R-18-009).[17] Onroad emissions are calculated as part of the regional conformity analysis for metropolitan transportation plan and transportation improvement program (TIP) conformity determinations as well as the regional conformity analysis associated with projects in isolated rural nonattainment and maintenance areas. Users may create emission inventories for more general planning purposes, such as comparison of different emission scenarios prior to development of a SIP. EPA recommends using as much local information as possible when preparing inventories for SIPs and regional conformity analyses. However, EPA recognizes that state and local agencies sometimes use different methods and different levels of detail in creating inventories depending on the intended purpose.

To provide the necessary inputs for air quality modeling, emission inventories created for attainment demonstrations may need to be based on meteorology and activity for a specific nonattainment episode or for a large number of specific days covering all or part of a season or

[16] Available at EPA's Air Emission Inventory Guidance for Implementation of Ozone and Particulate Matter NAAQS and Regional Haze Regulations website.
[17] Available at EPA's Support Center for Regulatory Atmospheric Modeling SIP Attainment Demonstration Guidance website.

year to be modeled in the attainment demonstration. For the development of the SIP's motor vehicle emissions budgets and regional conformity analyses, an emission inventory based on typical seasonal day (e.g., ozone season day for ozone precursors or average-season-day for the 24-hour $PM_{2.5}$ standard) or annual inventory (e.g., annual or 24-hour $PM_{2.5}$ standard) would typically be sufficient. Users should consult with their EPA Regional Office if questions arise.

## *2.2 What data are required to run MOVES?*

MOVES needs certain information regarding the time and place being modeled to calculate emissions, including information about vehicle miles traveled (VMT) by vehicle type, the number of each type of vehicle in the fleet (that is, the population of vehicles), vehicle age distributions, fuel information, meteorological data, etc. Section 4 of this guidance describes the information that is needed to run MOVES and how users can enter it.

When running the model for regulatory purposes, MOVES inputs should be based on the latest data available (see Section 1.1 for the discussion of statutory and regulatory requirements). This means that users should provide up-to-date local data for most inputs but note that there are some inputs where relying on MOVES defaults is acceptable or recommended. As with any model, the quality of the inputs affects the quality of the model's results. Including specific information about a particular county or set of counties helps to ensure that the emissions estimates from MOVES will be as accurate as possible. For some of the inputs, the data in the default MOVES database will not be the most current or best available for a specific county. However, there are some instances where the use of default data is recommended, and some instances where default information can be used without affecting the quality of the results. Section 4 discusses the data fields for which it would be acceptable or recommended to use default data.

## *2.3 What options do users have for calculating an inventory within or outside of MOVES?*

For a County Scale analysis, MOVES offers two options for calculation type:

- In Inventory mode, users input local activity data (e.g., VMT and vehicle population) into MOVES and the model calculates the inventory. Output is total emissions in units of mass.

- In Emission Rates mode, MOVES produces emission rates and users calculate the inventory by multiplying these rates by the appropriate local activity data (e.g., VMT and vehicle population). Note that VMT and vehicle population data are still needed as inputs for an Emission Rates MOVES run. The Emission Rates mode produces look-up tables of emission rates. Output examples include emissions per unit of distance for running emissions, per profile for evaporative processes, or per vehicle for starts and hotelling emissions. Users should take care to ensure that the proper measure of activity is used for each emission process.

Users may select either the Inventory or Emission Rates mode to develop emissions estimates for SIPs and regional conformity analyses.[18] Differences in inputs for Inventory versus Emission Rate calculations are noted in Section 4. Using the Inventory mode may be preferable when the user wants to minimize post-processing steps, thus avoiding inadvertent errors during post-processing. The Emission Rates mode may be preferable when the user wants to apply emission rates to multiple geographic locations. If the Emission Rates mode is selected, users will need to calculate emissions inventories outside of the MOVES model.

In general, EPA recommends that the same mode be used in any analysis that compares two or more cases (e.g., the base year and attainment year in a SIP analysis or the SIP motor vehicle emissions budget and the regional conformity analysis). The interagency consultation process should be used to agree upon a common approach for emission estimates that are made for SIP or conformity purposes. If different modes are used for the SIP budget and the regional conformity analysis for practical reasons, the interagency consultation process should be used to determine how to address (and minimize) any differences in results and the documentation of the regional conformity analyses should include the reason(s) for this choice. The methods used to develop inventories should be fully documented in the SIP submission and conformity determination documentation; for more information about documenting MOVES runs, see Section 2.6.

## *2.4 What are the options for creating inventories for areas made up of multiple counties?*

There is more than one approach for creating an onroad emission inventory for an area made up of more than one county, such as a metropolitan area. For example:

- Each county could be modeled individually, using either the Inventory or Emission Rates mode, depending on the user's preference. A partial county can also be modeled with MOVES at the County Scale, using either Inventory or Emission Rates. In this case, the inputs would reflect the partial county rather than the entire county.

- A second option would be to model one county as a representative county with the Emission Rates mode to generate emission rates at various temperatures and speeds. These emission rates could then be applied to a larger area, if the age distribution, fuel used, and the I/M program in the larger area is the same as that modeled for the representative county. More detail about this approach is found in Sections 3.3.5 and 4.2.2.

Table 2-1 summarizes the combinations of calculation type and geographic area definition that users can employ for creating emissions inventories using the County Scale. Any of the combinations will produce accurate results when executed correctly. The number of counties included in the area to be modeled and whether results for each individual county are needed are key considerations in choosing an approach.

[18] Section 3.2.3 includes a discussion of the equivalency of the Inventory and Emission Rates modes in calculating emissions.

**Table 2-1. Summary of Modeling Approaches Using the County Scale**

| Geographic Area | Approach | Advantages | Considerations |
|---|---|---|---|
| One county (or partial county) | Use Inventory | • Shorter run time and smaller output files | |
| | Use Emission Rates | • Rates can be applied to detailed activity data from travel demand models if desired<br>• Can be used as inputs for emissions processing for air quality modeling | • Longer run time, larger output files<br>• Post-processing of running, start, evaporative, and hotelling rates is necessary to create an inventory |
| Multi-county area | Use Inventory to model each county separately | • Produces results for each county without needing to post-process<br>• Able to model counties with different vehicle characterization (age distribution, fuels data, I/M) and/or different temperatures | • An individual run is needed for each county, so this strategy is more feasible if the number of counties is small<br>• Post-processing may still be needed to adjust results if the boundaries of the analysis (e.g., a nonattainment or maintenance area) contain partial counties |
| | Use Emission Rates to model a representative county (or counties), and create inventories from rates with activity data for each county | • Only one run per representative county is necessary<br>• Rates can be applied on a link basis if desired<br>• Able to model an area when vehicle characterization (age distribution, fuels data, I/M) are uniform in the area, but temperatures vary widely | • Emission rates from the representative county can be used for other counties only if they have the same age distribution, fuels and I/M program as the representative county (i.e., a separate run is needed for each combination of age distribution, fuel type and I/M program present in the area). See Section 4 for more information about these inputs.<br>• Post-processing of running, start, evaporative, hotelling, and off-network idle rates is necessary to create an inventory. |

## *2.5 What options are available for minimizing MOVES run time?*

MOVES run time depends on many factors, such as run parameters and system hardware. In instances where MOVES run time is an issue, modelers may be interested in exploring options available for minimizing MOVES run time.

A general suggestion for minimizing run time is to select only the pollutants necessary for your purposes. Including unnecessary pollutants in a run will cause MOVES to do more work and increases run time. See Section 3.6 for more information regarding selecting which pollutants to include.

A similar suggestion is select only the needed output detail. The more output detail that can be aggregated together, the faster MOVES will run. See Section 3.9 for more information regarding output emission detail.

Another technique for minimizing MOVES run time is to split up a large MOVES run into several smaller runs. In some cases, several smaller runs performed sequentially may finish 5-25% faster than one large run while still producing the same results. In EPA's testing, it is most effective to split up a MOVES run either by source type or by month and day.

A MOVES run is split up by creating multiple RunSpecs. All split RunSpecs should be identical except for the parameter that you are splitting the run by; that parameter should be unique in each RunSpec. In general, the best practice is to create a complete (that is, unsplit) RunSpec and develop its corresponding input database following the guidance in this document. Then, use the GUI to create copies of the complete RunSpec that vary the parameter that you are splitting the run by. Specifically:

- If you are splitting by source type, you would first create a complete RunSpec and input database. Then you would create a copy of that RunSpec, and in that first copy remove all source types except for motorcycles. In the second copy, you would remove all source types except for passenger cars, and so on. After repeating this process for all 13 source types, you would have 13 distinct RunSpecs.
- If you are splitting by month and day, you would first create a complete RunSpec and input database. Then you would create RunSpec copies and include only a single month and day combination in each RunSpec. For example, if you need to model all months, the first RunSpec would be for January weekends, the second for January weekdays, the third for February weekends, etc. In this example, you would end up with 24 distinct RunSpecs.

It is important to note that the same input database can be used with all split RunSpecs because MOVES allows input databases to contain more information (i.e., more source types, months, and days) than is used for an individual run. The same output database can be used as well, allowing similar post-processing steps as if the analysis was performed as part of a single run.

Once a MOVES run is split up, another option for reducing run time is to perform the split runs in parallel. This is an advanced technique, but if you have access to multiple computers, virtual machines, or cloud instances, you can perform the split up runs at the same time (instead of sequentially) to significantly reduce overall run time. In this case, modelers may wish to

combine the results from each MOVES run associated with the analysis into a single database to simplify post-processing.

Additional details regarding RunSpec considerations, splitting up MOVES runs, running MOVES in parallel, and system configuration optimizations can be found in Tips for Faster MOVES Runs on GitHub.

## *2.6 How do states that have adopted California's new motor vehicle emission standards, consistent with CAA section 177, use MOVES5 to model them?*

Where EPA has granted a waiver, under section 209(b) of the CAA, for a California new motor vehicle emission regulation, other states can adopt the California regulation if such states meet the criteria in CAA section 177. In these states, MOVES can be used to estimate emission reductions from an adopted California regulation, including:

- California's Light-Duty Vehicle (LDV) Low Emission Vehicle (LEV) Program: In states that have adopted any of California's LEV regulations, modelers would create an input database that has start and running emission rates that reflect their adoption of the applicable California LEV regulation(s) (e.g., LEV II, LEV III).[19] Modelers can find the "Build LEV Database" tool under the "Tools" menu within MOVES, which includes detailed instructions for use. After creating the input database(s) with this tool, modelers can include these database(s) in the RunSpec through the "Input Data Sets" section of the Advanced Features Panel, which is covered in Section 3.11 of this guidance. The tool reflects the California LEV standards that have been issued a waiver under section 209 of the CAA; California's ACC I regulation includes LEV III through but not beyond the 2025 model year.

- California's LDV Zero Emission Vehicle (ZEV) Sales Program, including those in California's initial Advanced Clean Car program (ACC I): In states that have adopted a California ZEV sales regulation within the ACC I program (that has received an EPA waiver), modelers would change the fraction of vehicles that are meeting the zero emissions requirements (e.g., battery electric vehicles – BEVs) for the relevant model years within the AVFT Table. The AVFT Table is one of the four tables in the Fuels input within the County Data Manager. See Section 4.8.3 for additional details about the AVFT Table. California's ACC I standards include a ZEV sales regulation that requires increasing ZEV sales percentages through but not beyond the 2025 model year.[20]

- California's Heavy-Duty (HD) Advanced Clean Truck (ACT) Regulation: This regulation requires that a certain percentage of heavy-duty vehicles meet zero-emission

[19] A description of California's LEV program as well as the CAA Section 209 waiver for the LEV III regulation is at 78 FR 2211 (January 9, 2013).

[20] A description of California's ZEV sales regulations, including those contained in the ACC I regulation, is at the CAA Section 209 waiver at 78 FR 2211 (January 9, 2013). EPA reinstated the ZEV sales regulation waiver (as part of the initial ACC I waiver) by action taken on March 14, 2022 (see 87 FR 14332).

standards.[21] In states that have adopted this California regulation, modelers would change the fraction of trucks that are zero emission (e.g., electric or fuel cell, etc.) vehicles within the AVFT Table, one of the four tables in the Fuels input within the County Data Manager. See Section 4.8.3 for additional details about the AVFT Table.

The most current information on the implementation of regulations should be used in SIP inventory and regional conformity analyses.

## *2.7 What aspects of a MOVES analysis should be documented?*

When MOVES is used for SIP or transportation conformity purposes, documentation is important to facilitate review by interagency consultation parties as well as members of the public. As indicated below, there are legal requirements related to interagency consultation and public review on SIPs and transportation conformity determinations:

**Interagency consultation.** The transportation conformity regulation requires interagency consultation procedures to be established whereby representatives of entities including the MPOs, State and local air quality planning agencies, and State and local transportation agencies must consult with each other and with local or regional offices of EPA, FHWA, and FTA on the development of certain SIPs, transportation plans, transportation improvement programs, and associated conformity determinations (40 CFR 93.105(b)(1)). The regulation also requires consultation procedures to include a process for circulating or providing access to draft documents and a process for responding to significant comments from involved agencies (40 CFR 93.105(b)(2)(iii) and (v)). In addition, interagency consultation procedures must also include processes for evaluating and choosing a model (or models) and associated methods and assumptions to be used in hot-spot analyses and regional emissions analyses (40 CFR 93.105(c)(1)(i)).

**Public review**. The CAA and EPA's implementing regulations require opportunities for public comment during the review and approval process for each SIP. Specifically, CAA section 110(l) requires that SIPs submitted to EPA be adopted by states after reasonable notice and public hearing. EPA regulations require that states provide notice, provide the opportunity to submit written comments and allow the public the opportunity to request a public hearing (40 CFR 51.102). The transportation conformity regulation also requires that "[a]ffected agencies making conformity determinations on transportation plans, programs, and projects shall establish a proactive public involvement process which provides opportunity for public review and comment by, at a minimum, providing reasonable public access to technical and policy information considered by the agency at the beginning of the public comment period…" (40 CFR 93.105(e)).

To meet these statutory and regulatory requirements for interagency and public review, MOVES runs should be fully documented. Complete documentation of a MOVES run not only provides transparency to the other agencies reviewing the analysis as well as the public, but it also serves as a reference for future MOVES runs.

[21] A description of California's HD ACT regulation is at the CAA Section 209 waiver at 88 FR 2088 (April 6, 2023).

Therefore, documentation in general should be detailed sufficiently to allow a full discussion and review of modeling, associated methods, and assumptions within interagency consultation, to meet the requirements in the transportation conformity regulation noted above. When draft SIPs and conformity determinations that include MOVES results are circulated either for interagency consultation or made available for public review, agencies should include the following items in their documentation:

- The MOVES version used,
- Descriptions of the data and analysis used to populate input databases (including, e.g., data sources, dates the data were obtained, and how processed),
- Other methods and assumptions, including methods and files used to post-process output,
- RunSpec files (covered in Sections 3 and 5.1),
- Input databases (described in Sections 4 and 5.2),
- Output databases (see Sections 3.8 and 3.9 for additional discussion), and
- AVFT Tool inputs and results (see Section 4.8.3).

Describing data and analyses used to populate the input database in a narrative is good practice that supports the requirements noted at the beginning of this section, including ensuring that interagency consultation processes can evaluate and choose models, associated methods, and assumptions, and that the public has access to technical and policy information considered. In addition to noting the MOVES version used, documentation should include a narrative description of the sources of data used in developing the input database; references and initial data used can also be included if it makes sense to do so. The narrative should also include a description of how source data were processed into MOVES input data. For example, if data were mapped, averaged, or otherwise processed, the narrative should explain what steps were taken and documentation should include any scripts, spreadsheets, or other analysis tools used. One approach that could be used is to include a table summarizing for each input, the data source, date that data were obtained, and any data processing using EPA tools or other approaches.

Sources of vehicle fleet and activity data are important to include. For meteorological inputs, documentation should include the meteorological data station that is used as the source of temperature and humidity inputs, as well as the time period of those data. For MOVES runs that include I/M programs, Section 2.7 of EPA's *Performance Standard Modeling for New and Existing Vehicle Inspection and Maintenance (I/M) Programs Using MOVES Mobile Source Emissions Model* also provides recommendations for appropriate documentation.[22]

[22] *Performance Standard Modeling for New and Existing Vehicle Inspection and Maintenance (I/M) Programs Using the MOVES Mobile Source Emissions Model,* EPA-420-B-22-034, October 2022. This guidance can be found on EPA's Vehicle Emissions Inspection and Maintenance Policy and Technical Guidance website.

# Section 3. Developing Onroad Inventories in MOVES: Creating an Onroad Run Specification File

## *3.1 How is a Run Specification (RunSpec) created?*

Users establish a RunSpec file to define the place and time period of the analysis as well as the vehicle types, road types, fuel types, and the emission-producing processes and pollutants that will be included in the analysis. The RunSpec is a computer file in XML format that can be edited and executed directly, or that can be accessed, changed, and run through the MOVES GUI.

The Navigation Panel in the MOVES GUI is used to access a series of other panels and tabs that specify the RunSpec file. The following subsections describe each set of input options needed to create the RunSpec, as defined in the Navigation Panel. When estimating emissions for a SIP or regional conformity analysis, the user would progress through the Navigation Panel and make the appropriate selections or include data on each of the following panels:

- Description
- Scale and Calculation Type (Inventory or Emission Rates)
- Time Spans
- Geographic Bounds
- Onroad Vehicles
- Pollutants and Processes
- Road Type
- General Output
- Output Emissions Detail
- Create Input Database
- Advanced Features

Each panel is described below.

Selections made in some panels affect available options in other panels, so panels should be filled out in the order they appear in the Navigation Panel.[23] Panels marked with a double yellow tilde ("~") can be viewed and assessed for completeness; panels marked with a red "x" are required and not yet complete. When a modeler completes a panel, the GUI will display a green check mark. MOVES can be run when all items on the Navigation Panel show either a green check or a double yellow tilde.

[23] In MOVES5, the Pollutants and Processes Panel has been reordered to come before the Road Type Panel because choices on the Pollutants and Processes Panel affect selections on the Road Type Panel. See Sections 3.6 and 3.7 for more information.

***Tip: Complete the RunSpec in the order the panels appear so that all RunSpec selections are made before creating the input database.***

### 3.1.1 Description

The Description Panel allows the user to enter a description of the RunSpec with no restrictions on length or character type. Entering a complete description of the RunSpec will help users keep track of their MOVES runs. The description may also be helpful in documenting the run for external reviewers of a SIP or conformity analysis.

## *3.2 Scale and Calculation Type*

Selecting Scale on the Navigation Panel in MOVES brings up the Model, Domain/Scale, and Calculation Type Panel. MOVES allows users to choose either onroad or nonroad emissions. MOVES provides users with the ability to conduct onroad analyses at three scales: Default, County, and Project. MOVES also provides two options for onroad calculation type: Inventory or Emission Rates. Users are free to use either the Inventory or Emission Rates mode depending on their preference. This guidance provides additional detail where necessary to emphasize differences between these two options.

### 3.2.1 Model

MOVES includes the capability of estimating emissions of nonroad equipment and engines. Within MOVES, the onroad and nonroad capabilities exist as separate modules, and users can select one or the other. Use of MOVES for nonroad emission inventories is covered in Section 5 of this document. The remainder of Section 3 and all of Section 4 applies to onroad emissions.

### 3.2.2 Domain/Scale

Each option in MOVES has its own intended purpose and the amount of data that the user must supply varies depending on the selection:

- Default Scale can be used to estimate emissions for the entire country, a group of states, an individual state, a group of counties, or an individual county. With this option, MOVES uses a default national database of inputs, based on a mix of national data, allocation factors, and some pre-loaded local data, to estimate emissions at the state and county level. EPA cannot certify that the default data in the national database is the most current or best available information for any specific county. Because of this, **users should not use the Default Scale option when developing emission estimates for SIPs or regional conformity analyses.**

- County Scale requires the user to enter data to characterize local meteorology, fleet, and activity information through the County Data Manager (CDM). The CDM facilitates the input of local data and allows the user to review county data included in the MOVES default database. **The County Scale is the only scale appropriate for developing emission estimates for SIPs or regional conformity analyses.** Detailed guidance on

specific inputs for the CDM, including the use of default inputs, is given in Section 4 of this guidance.

- Project Scale allows the user to perform micro-scale analyses of emissions on individual roadway links or locations where emissions from vehicle starts or extended idling activity occur. The Project Scale is not intended for use in SIPs or regional conformity analyses. Guidance on the use of the Project Scale in MOVES for quantitative hot-spot analysis in CO, $PM_{2.5}$ and $PM_{10}$ nonattainment and maintenance areas is described in separate guidance documents (see Section 1.6 for references).

### 3.2.3 Calculation Type

The Scale Panel also requires that the user select a calculation type of either Inventory or Emission Rates. If Inventory is selected, MOVES provides emission estimates as mass, using VMT and vehicle population entered by the user. If Emission Rates is selected, MOVES provides emission rates as mass per unit of activity. The Emission Rates mode produces tables of emission rates that must be post-processed to produce an inventory. The selection of calculation type is required early in the RunSpec construction process because this choice affects the available options in later panels. When Emission Rates is selected, users must also include a "MOVES Scenario ID" of 40 characters or less, which will appear in the output database. If multiple runs are needed to produce all the emission rates needed for a particular scenario, the same scenario ID can be used for each run.

Users may choose either the Inventory or Emission Rates mode depending on their preference. As discussed in Section 2 of this document, each mode has advantages and considerations, and users will need to decide which approach is more appropriate for the type of analysis they are conducting. Both modes use the same underlying emission data and will produce the same results if the user calculates an inventory using Emission Rates in the same way that MOVES does this internally with Inventory mode. Table 2-1 provides a summary of modeling approaches.

As noted in Section 2.3, the Emission Rates mode is more complex than the Inventory mode. Successful application of this mode requires careful planning and a clear understanding of the rates calculations in MOVES. Large differences in results between the Inventory and Emission Rates modes usually indicate a mistake in post-processing of the emission rates generated using the Emission Rates mode. The most common mistakes when using the Emission Rates mode are:

- not including all pollutant processes, and
- multiplying emission rates by the wrong activity.

To correctly compile an emission inventory using rates, running rates must be multiplied by VMT, while per-vehicle emission rates from processes that occur when the vehicle is parked (such as start, evaporative, and extended idling emission rates) must be multiplied by the total population of vehicles in the area. Off-network idling rates must be multiplied by the number of hours of off-network idling activity. Note that there are alternative rates for some of the

processes that occur when the vehicle is parked, and these can be used with alternative measures of activity:

- Start emission inventories can be calculated either by multiplying the rate per vehicle by the total population of vehicles in the area, or by multiplying the rate per start by the total number of starts;
- Hotelling emissions can be calculated by multiplying the rate per vehicle by the total population of long-haul combination trucks in the area or by multiplying the rate per hour by the hours of hotelling activity.[24]

Even when done correctly, minor differences in post-processing methods can create small differences in results. EPA recommends that the same mode be used in any analysis that compares two or more cases (e.g., the base year and attainment year in a SIP analysis or the SIP motor vehicle emissions budget and the regional conformity analysis). The interagency consultation process should be used to agree upon a common approach. If different modes are used for the SIP budget and the regional conformity analysis for practical reasons, the interagency consultation process should be used to determine how to address (and minimize) any differences in results. The methods used to develop inventories should be fully documented in the SIP submission and conformity determinations.

EPA has developed tools to automate the use of the Emission Rates mode to create inputs for EPA's Sparse Matrix Operator Kernel Emissions (SMOKE) model for SIP development purposes. These tools simplify the process of post-processing MOVES output for air quality modeling in SIPs and are described on the Community Modeling and Analysis System website.

## *3.3 Time Spans*

The Time Spans Panel includes four sections—one each to select specific Years, Months, Days, and Hours. Guidance for each of these inputs is described separately in this section.

To get a green check for this panel, modelers must make selections on all four sections of this panel. For example:

- When modeling an entire year, modelers need to select the appropriate year and include all shorter units of time to ensure the estimate is complete: the year to be modeled, all 12 months, both day-types, and all 24 hours.
- When modeling a shorter period of time such as a typical day, modelers still need to make selections on all four sections of the panel: the appropriate year, month(s), day-type, and all 24 hours.

Sections 3.3.1 through 3.3.4 provide more details.

### 3.3.1 Calendar Year of Evaluation

MOVES can model calendar years 1990 and 1999 through 2060. The County Scale in MOVES allows only a single calendar year in a RunSpec. Users who want to model multiple analysis

[24] More information about creating complete inventories using the Emission Rates calculation type can be found in the presentations used in EPA's MOVES Hands-On Training Course.

years will need to create multiple RunSpecs, with local data specific to each analysis year, and run MOVES multiple times.

### 3.3.2 Month of Evaluation

MOVES allows users to calculate emissions for any month of the year. A single RunSpec may produce emissions for multiple months. Users should choose the appropriate months for the pollutant being analyzed, e.g., months representing the ozone season for NOx and HC, the $PM_{2.5}$ season or episode for the 24-hour $PM_{2.5}$ standard, or the winter CO season. To develop an annual inventory, all months should be selected.

In cases where the user intends to model multiple months within a single year, the user should be aware of how MOVES treats the input data. Fuel Supply, Hotelling, Off-Network Idle, Meteorology, Starts, and VMT inputs can vary by month in a single RunSpec, because month is identified in the data tables used for these inputs. However, other inputs in the CDM (described in Section 4 of this document) cannot be varied by month. Therefore, if the user has, for example, Average Speed Distribution data that vary by month, the user would have to execute multiple RunSpecs to use each data set with the corresponding month.

### 3.3.3 Type of Day of Evaluation

Weekdays and weekend days can be modeled separately in MOVES. MOVES provides the option of supplying different speed and VMT information for weekdays and weekend days to allow the calculation of separate emissions estimates by type of day. The inputs in the CDM where MOVES can differentiate between weekdays and weekend days are:

- Average Speed Distribution,
- Day VMT Fraction,
- Hour VMT Fraction,
- Hotelling,
- Off-Network Idle, and
- Starts.

Section 4 covers each input in detail. When modeling emissions for a single day (e.g., an ozone season day for an ozone SIP or average-season-day for a 24-hour $PM_{2.5}$ SIP), the user should select Weekday in the Time Span Panel and use weekday data. Additionally, weekday data should be used for any inventory that represents an ozone season day, whether in summer or winter.

When modeling emissions for a longer time period, e.g., for a multi-day period or an annual inventory, both weekday and weekend day should be checked in the Time Span Panel, and both weekday and weekend day data should be included for the CDM inputs where they can differ (listed above). However, if these inputs are available for only one type of day, users should use the same information for both day-types. Doing so will make using MOVES' built-in post aggregation tools easier. These tools are covered in Section 3.9 of this document, which covers the Output Emission Detail Panel. If only one day-type is selected and Month or Year is selected in this panel, MOVES will provide an incomplete result. The emissions for the month or year will be the total emissions from only one day-type (e.g., weekdays) in that month or year and emissions from the other day-type (e.g., weekend-days) will be missing.

***Tip: Unless emissions are needed for only one day, select both day types.***

For the Day VMT Fraction, users can generate the appropriate mix of VMT on each type of day with the EPA-provided AADVMT Converter for MOVES5 (described in Section 4.5 of this document). If only one type of day is selected, the calculator will appropriately adjust the day fraction to account for VMT for a single weekday or weekend day.

The Hour VMT Fraction can also differ by type of day and users can supply this information if available; however, if information is only available for a single type of day, either the default value or the user-supplied value for the single day can be used for the other type of day.

### 3.3.4 Hour of Evaluation

To estimate emissions for a day, month, or year properly, the user must select all 24 hours. Also, selection of all 24 hours is required by MOVES to evaluate non-running evaporative hydrocarbon emissions because they depend on the daily temperature variance.

### 3.3.5 Time Span Panel Selections: Emission Rates Mode

When the Emission Rates mode is selected, users may choose to approach the selection of options in the Time Spans Panel differently than when running MOVES in Inventory mode. This works because the variation in activity over time is handled during post-processing. For example, when modeling running emission rates, instead of entering a diurnal temperature profile for 24 hours, users can enter a range of 24 temperatures in increments that represent the temperatures over a period of time. By selecting more than one month and using a different set of incremental temperatures for each month, users could create a table of running emission rates by all the possible temperatures over an entire season or year.

Additionally, users can create tables for start, hotelling, and evaporative emissions that could be used for an entire season or year by selecting more than one month and entering a different diurnal temperature range or profile for each month.

Users should consult Section 4.2.2 for additional guidance on developing rate lookup tables.[25]

## *3.4 Geographic Bounds*

In County scale, the Geographic Bounds Panel is used to specify the county to be modeled. Selecting a county determines what default MOVES database inputs are available for the run. Section 4 describes the use of default information vs. local information for SIP and regional conformity analyses.

Only one county can be modeled per run in County Scale. See Table 2-1 for a summary of modeling approaches for modeling multiple counties.

[25] See EPA's MOVES Hands-On Training Course (specifically, the modules about Emission Rates and Special Topics) for additional information.

## *3.5 Onroad Vehicles*

The Onroad Vehicles Panel is used to specify the vehicle types that are included in the MOVES run. MOVES describes vehicles by a combination of vehicle type, known as source use type in the model, and the fuel that the vehicle can use.

MOVES allows the user to select from among 13 source use types (e.g., passenger car, passenger truck, light commercial truck, etc.). For more information about source types, see Sections 4.3 and 4.5 of this document.

For each source type selected, MOVES automatically selects all the appropriate fuel types for that source type: gasoline, diesel, compressed natural gas (CNG), ethanol (E-85), and electricity. All valid combinations of source type and fuel type are then listed in the panel and those listed will be included in the run. Some combinations of source type and fuel type are not included in the MOVES database, such as diesel motorcycles.

> ***Tip: Include all vehicle types for a complete onroad emissions inventory.***

For SIP and regional conformity analyses, users should include all vehicle types present in the area of analysis to properly estimate an emissions inventory. Deleting any source type/fuel type combination from the list will remove all entries for that source type. Changes in source types and fuel type combinations to reflect local conditions, e.g., a fuel type that is not used in the modeled area, cannot be addressed on this panel, but instead would be handled in the Fuel Tab in the CDM as described in Section 4.8 of this document. For example:

- If there is no E-85 sold locally, users would address this in the Fuel Tab using the Fuel Usage Fraction input.
- If the local transit bus or refuse truck fleet uses just one type of fuel instead of a combination of electricity, CNG, diesel, and gasoline, users would address this in the Fuel Tab using the AVFT input.

See Section 4.8 for more information about the Fuel Tab and its inputs.

Detailed information describing the local vehicle fleet and its activity can be entered in the CDM. See Section 4 of this document for more information.

## *3.6 Pollutants and Processes*

In MOVES, "pollutant" refers to pollutants or pollutant precursors, such as CO or NOx, while "process" refers to the mechanism by which emissions are created, such as running exhaust or start exhaust. Processes in MOVES are mutually exclusive types of emissions and users must select all processes associated with a particular pollutant to account for all emissions of that pollutant. For example, there are 12 separate pollutant processes in MOVES for hydrocarbon

emissions. In most cases, all 12 of these processes must be selected to properly account for all hydrocarbon emissions from motor vehicles.[26]

In the MOVES5 GUI, the Pollutants and Process Panel comes before the Road Type Panel. Each type of emissions process occurs on one or more specific road types, so the choices made on the Pollutants and Processes Panel result in automatic selections on the Road Type Panel:

- Running processes emissions occur when the vehicle is operating on the four "network" road types, so when a running process is selected, the rural and urban restricted and unrestricted access road types are automatically chosen on the Road Type Panel.
- Start and evaporative emissions occur when the vehicle is parked, so when one of these processes is selected, the off-network road type is automatically chosen on the Road Type Panel.

Having the Pollutants and Processes Panel come before the Road Type Panel in the GUI should help modelers see why a road type is selected and cannot be unselected.

In Inventory mode, the total emissions for a particular pollutant are the sum of the emissions for all pollutant processes that apply to the pollutant. In Emission Rates mode, the total emissions for a particular pollutant are the sum of the product of emission rates and the appropriate activity measure (e.g., VMT or vehicle population) for each vehicle type for all pollutant processes that apply to that pollutant and vehicle type.

For many pollutants, the emissions calculation in MOVES is based on prior calculation of another pollutant. In such cases, users must select all of the base pollutants that determine a particular dependent pollutant. For example, when selecting Primary Exhaust $PM_{2.5}$, the prerequisites Elemental Carbon and Composite Non-ECPM (non-elemental carbon particulate matter) must also be selected. MOVES will display error messages in the box on the Pollutants and Processes Panel until all necessary base pollutants are selected. Clicking the button "Select Prerequisites" automatically selects all necessary pollutants and will clear the error messages.

When modeling particulate matter ($PM_{2.5}$ or $PM_{10}$), to include all particulate emissions from onroad vehicles, users should select:

- Primary Exhaust PM – Total,
- Primary PM – Brakewear Particulate, and
- Primary PM – Tirewear Particulate.[27]

***Tip: It may be necessary to use the bottom scroll bar to view all the process choices.***

[26] Two of the 12 hydrocarbon emission categories, refueling displacement vapor loss and refueling spillage loss, are sometimes included in the SIP as an area source and left out of the onroad mobile source inventory and motor vehicle emissions budget. In that case, the two refueling emission processes which are not included in the motor vehicle emission budget would not be included in a regional conformity analysis. The interagency consultation process should be used to confirm that there is consistency in the approach used to account for refueling emissions in the SIP and regional conformity analysis.

[27] Vehicles of all fuel types, including electricity, emit PM from brake and tire wear.

Note that in addition to pollutants, MOVES can also estimate total energy consumption. If that is of interest, modelers can select it on this panel.

### 3.6.1 Pollutants and Processes in Emission Rates Mode

For Emission Rates runs, MOVES produces separate output tables with rates that the user multiplies by different activity types for different emission processes. To calculate a total emissions inventory using the Emission Rates mode properly, users need to sum the products of emission rates and activity for each vehicle type and applicable pollutant process, using the applicable rate tables in the output database.

Following are the tables produced by an Emission Rates run and the processes included in each table. The rates labeled "alternative" below represent alternative forms (units) of some of the emissions reported in the Rate per Vehicle table, not additional emissions. Modelers should not apply both the Rate per Vehicle and the alternative rates for an emissions process in the same onroad inventory, to avoid double-counting.

- Rate per Distance Table – provides emission rates in terms of mass per distance (e.g., grams/mile); user multiplies these rates by total VMT by vehicle type:
  - Running exhaust
  - Crankcase running exhaust
  - Brake wear (PM only)
  - Tire wear (PM only)
  - Evaporative permeation (HC only)
  - Evaporative fuel vapor venting (HC only)
  - Refueling displacement vapor loss (HC only)
  - Refueling spillage loss (HC only)

- Rate per Vehicle Table – provides emission rates in terms of mass per vehicle (e.g., grams/vehicle); user multiplies these rates by total vehicle population by vehicle type:
  - Start exhaust
  - Crankcase start exhaust
  - Evaporative permeation (HC only)
  - Evaporative fuel leaks (HC only)
  - Refueling displacement vapor loss (HC only)[28]
  - Refueling spillage loss (HC only)
  - Exhaust extended idle emissions (long-haul combination trucks only)
  - Crankcase exhaust extended idle emissions (long-haul combination trucks only)
  - Auxiliary power exhaust (long-haul combination trucks only)

[28] Refueling displacement vapor loss and refueling spillage loss in MOVES are calculated based on fuel consumption associated with both running and start activity. As a result, these emissions appear in both the Rate per Distance table and the Rate per Vehicle table. Total refueling emissions are the sum of emissions calculated from both tables.

- Rate per Profile Table (HC only) – provides emission rates in terms of mass per vehicle (e.g., grams/vehicle); user multiplies this rate by total vehicle population by vehicle type:
    - Evaporative fuel vapor venting (HC only)

- Rate per Start (alternative to using Rate per Vehicle Table for start emissions) – provides emission rates in terms of mass per start (e.g., grams/vehicle-start); user multiplies these rates by the number of individual vehicle starts:
    - Start exhaust
    - Crankcase start exhaust

- Rate per Hour (alternative to using Rate per Vehicle table for extended idle and auxiliary power emissions) – provides emissions from hotelling activity in terms of mass per hour (e.g., grams/hour); user multiplies these rates by the number of hours of hotelling activity:
    - Extended idle exhaust (long-haul combination trucks only)
    - Extended idle crankcase exhaust (long-haul combination trucks only)
    - Auxiliary Power Exhaust (long-haul combination trucks only)

In addition to the information here, modelers may want to review EPA's MOVES Hands-on Training Course, available on EPA's MOVES Training website. The training course includes information specifically about using MOVES in Emissions Rates mode, including an exercise to illustrate the concept of using MOVES emission rates to create an inventory.

## *3.7 Road Type*

The Road Type Panel is used to select the types of roads that are included in the run. MOVES defines five different Road Types:

- Off-Network (road type 1) – all locations where the predominant activity is vehicle starts, parking and idling (parking lots, truck stops, rest areas, freight or bus terminals)
- Rural Restricted Access (2) – rural highways that can only be accessed by an on-ramp
- Rural Unrestricted Access (3) – all other rural roads (arterials, connectors, and local streets)
- Urban Restricted Access (4) – urban highways that can only be accessed by an on-ramp
- Urban Unrestricted Access (5) – all other urban roads (arterials, connectors, and local streets)

All SIP and regional conformity analyses must include all road types; omitting one or more road types will lead to an incomplete emissions estimate. In the case where a county has no roads of a particular road type, all road types should still be selected in this panel; in the County Data Manager in the Road Type Distribution input, the modeler should provide a value of zero VMT for the road type(s) that is not present. (This input is covered in further detail in Section 4.7.) As described in Section 3.6, choices made on the Pollutants and Processes Panel result in automatic selections on the Road Type Panel, so in MOVES5, the Road Type Panel comes after the Pollutants and Processes Panel:

- When a running process is selected, road types 2, 3, 4, and 5 are automatically chosen on the Road Type Panel.
- When a start or evaporative emissions process is selected, road type 1 is automatically chosen on the Road Type Panel.

MOVES uses Road Type to assign default drive cycles to activity on road types 2, 3, 4, and 5. For example, for unrestricted access road types, MOVES uses drive cycles that assume stop and go driving, including multiple accelerations, decelerations, and short periods of idling. For restricted access road types, MOVES uses drive cycles that include a higher fraction of cruise activity with less time spent accelerating or idling, although ramp activity is also included.[29]

Different characteristics of local activity by road type are entered in the CDM using the Average Speed Distribution and Road Type Distribution Importers as described in Sections 4.6 and 4.7 below.

## *3.8 General Output*

The General Output Panel includes three sections: Output Database, Units, and Activity.

### 3.8.1 Output Database

Users can create databases and name them according to personal naming conventions, but EPA recommends that users indicate that a database is an output database (such as using "_out" at the end of the output database name).[30] Results from multiple RunSpecs can be stored in a single output database, but generally there should be a reason to do so. For example, the same output database could be used for RunSpecs where the user intends to compare results (e.g., RunSpecs that are identical except that a different fuel formulation was used) or sum them (e.g., RunSpecs for multiple counties that are part of the same nonattainment area). EPA recommends that users create a new output database for new or unrelated analyses. Users will also want to consider total database size when deciding which RunSpecs should use the same output database.

### 3.8.2 Units

Users are free to choose any of the mass unit selection options, but should choose a unit whose magnitude is appropriate for the parameters of the RunSpec so that interpretation and processing of the output is easier. For example, selecting tons in the output for a run aggregated hourly may produce emissions of zero if emissions are considerably less than one ton. When modeling criteria pollutants and their precursors or mobile source air toxics, grams should be selected to avoid these rounding losses.

### 3.8.3 Activity

MOVES allows the user to select multiple activity output options. These options are:

- Distance Traveled,

[29] For a discussion on the drive cycles in MOVES, as well as information on how MOVES models ramp activity at County Scale, see Section 9 of the technical report, *Population and Activity of Onroad Vehicles in MOVES5* (EPA-420-R-24-019), available at MOVES Onroad Technical Reports.

[30] Database names can include only letters, numbers, and underscores. No spaces or other characters are allowed.

- Source Hours,
- Hotelling Hours,
- Source Hours Operating,
- Source Hours Parked,
- Population, and
- Starts.

For Inventory calculations, activity output is not required, but can be useful to verify whether activity was properly entered in MOVES. Therefore, it is good practice to select "Distance Traveled" and "Population," so that the user can compare these outputs with the VMT and population that the user included in the input database. Users providing vehicle start information through the Starts Tab of the CDM should also select the Starts option. Likewise, users providing hotelling information using the Hotelling Importer of the CDM should also select the Hotelling Hours option. For Emission Rates runs, hotelling hours, population, and starts are reported automatically.

## *3.9 Output Emission Detail*

This panel allows the user to select the amount of detail that will be provided in the output, i.e., the level of disaggregation of the output. Modelers should consider what output detail is needed and how the results will be post-processed. In general:

- Selecting *more detail* can be useful as the user can later aggregate these results so that the output can be analyzed in a variety of ways. However, too much detail can lead to very large output tables and longer database query execution times and lead to increased possibility of user errors when results need to be aggregated.
- Selecting *less detail* may save the modeler work in post-processing results. However, once MOVES aggregates output, it is not possible to disaggregate it, so if those details are needed later, the modeler will need to re-run MOVES with those details selected.

Output Aggregation:

- Time: Output at the Hour level is recommended for the time aggregation selection unless the user is certain that emission results are not needed by hour or time of day. Longer periods of aggregation could be chosen where the modeler is certain that output by a shorter time period is not needed. For example, if the modeler chooses Year here, it would not be possible to see emissions differentiated by month, type of day, or hour without rerunning the model.

  Note: As described in Section 3.3, if the user selected only a single type of day in the Time Spans Panel, then selecting any time period longer than the Portion of the Week would not be appropriate, and MOVES will display a warning message.

- Geographic: The County Scale only allows one county to be modeled at a time, so County should be selected.

For All/Vehicle Equipment Categories:

- Model Year: In most cases, the user should not select Model Year, unless the user has activity information by model year or has another specific reason to obtain emissions by model year. EPA recommends not selecting Model Year because doing so will increase the number of rows of output by a factor of 41.

- Fuel Type: Detailing output by Fuel Type (gasoline, diesel, electricity, CNG, E-85) may be helpful if the AVFT will be used to input activity by alternate fuel vehicles or if emissions by fuel type are needed.

- Emission Process: Users can select Emission Process to obtain output for each emissions process selected on the Pollutants and Processes Panel; otherwise MOVES will aggregate the results.

- SCC: SCC is an abbreviation for Source Classification Code, a system that EPA uses to classify different types of anthropogenic emission activities. The existing SCCs for onroad vehicles are combinations of vehicle type and road type based on MOVES source type and road type IDs. For most uses, EPA recommends selecting Source Use Type and/or Road Type in the Onroad box rather than using the SCC output option.

Onroad:

- Road Type: Users can select Road Type to differentiate emissions by restricted and unrestricted roadways.

- Source Use Type: Users can select Source Use Type to differentiate emissions by vehicle type, e.g., to determine emissions from light- and heavy-duty vehicles.

- Regulatory Class is a system EPA uses to classify vehicles for emission standards purposes and is therefore not needed for SIP or regional conformity analyses.

### 3.9.1 Output Emission Detail When Using Emission Rates Mode

With Emission Rates mode, Emission Process and Road Type are automatically selected in the Output Emission Detail Panel, meaning that emission rates will be produced for each emissions process and road type.

Users should also select Source Use Type when using the Emission Rates mode so that emission rates for each type of vehicle can be multiplied by the appropriate amount of activity for that type of vehicle. If Source Use Type is not selected, MOVES will calculate aggregate emission rates for all source types based on the VMT and population by source type used as an input in the RunSpec (i.e., values entered using the CDM). Thus, the output emission rates would only be valid for the specific mix of VMT and population by source type input.

Post-processing can be more refined when Source Use Type is selected in this panel along with the automatically selected Road Type, because MOVES will produce lookup tables of emission rates by source type and road type. For running emissions, users then post-process these lookup tables outside of MOVES to apply local VMT by source type, road type and speed bin to the gram per mile emission rates for each speed bin (based on local distributions of speed). For start,

hotelling, and evaporative emissions, users would post-process the corresponding lookup tables outside of MOVES to apply local source type population information to the gram per vehicle emission rates (or alternative gram per start table for starts or gram per hour table for hotelling, as described in Section 3.7.1).

EPA recommends leaving model year and fuel type unchecked, unless the user has VMT and population by model year or fuel type that could be applied to these more specific rates. Producing these more detailed rates tables can provide flexibility, by allowing these rates to be applied across large geographic areas that have different age, fuel type or VMT distributions, but in general, most modelers would not need to create rates by model year or fuel type.

Additional detail on the applicability of data entered in the CDM when using the Emission Rates mode is provided in the individual parts of Section 4 of this document.

## *3.10 Create Input Database*

This option becomes available after all the other Navigation Panel items have been completed and have green checks. The user can open the CDM by clicking on the "Enter/Edit Data" button. It is not necessary to create the database before opening the CDM.

***Tip: Complete the RunSpec before creating an input database.***

Once a database has been completely populated (see Section 4) and the CDM has been closed, users should ensure that the correct database is selected on the Create Input Database Panel. If it is not auto-populated, users may have to hit the Refresh button to make sure the database they created appears in the drop-down list.

## *3.11 Advanced Features*

The Advanced Features Panel is used to invoke features that are used for model diagnostics and other special purposes. In general, the features on this panel are not appropriate for SIP and transportation conformity use, except for states that have adopted California Low Emission Vehicle (LEV) criteria pollutant standards and states in the Ozone Transport Commission (OTC) that received early implementation of National Low Emitting Vehicle (NLEV) standards. In these cases, the "Input Data Sets" feature on this panel should be used in conjunction with the LEV/NLEV tools accessed through the Tools drop-down menu in the MOVES GUI.

Specifically:

- OTC states that did not adopt California LEV standards but were subject to the early implementation of NLEV should use the "Build NLEV Input Database" tool.
- OTC states that adopted California LEV standards prior to the 2001 model year should use the "Build LEV Input Database" tool.
- OTC states that were subject to the early implementation of NLEV and adopted California LEV standards beginning with model year 2001-or-later should use both the use the "Build NLEV Input Database" and the "Build LEV Input Database" tools.

- All other states that adopted California LEV standards in any year should use the "Build LEV Input Database" tool.

Detailed instructions on how to use both tools are available in the MOVES GUI: after opening the tool via the Tools drop-down menu, click the "Open Instructions" button.

After creating the input database(s) with the appropriate tool, users should include these databases in the RunSpec through the "Input Data Sets" section of the Advanced Features Panel. Select the appropriate input database in the database drop-down menu (users may need to click the Refresh button if the database does not appear in the list), and then click the Add button.

Refer to Section 2.5 for information about using MOVES to estimate California's vehicle regulations.

# Section 4. Developing Onroad Inventories in MOVES: Adding Local Onroad Data via the County Data Manager

## *4.1 How do users enter information with the County Data Manager?*

When running at County Scale, MOVES uses local information contained in a user-created input database to supplement or override the data in the MOVES default database. The County Data Manager (CDM) is a user interface developed to simplify importing specific local data for a single county into an input database without requiring direct interaction with the underlying database. This section guides users on each element of the CDM, noting differences between Inventory and Emission Rates modes where applicable.

Before a user can input any locality specific data, a database must be created on the Database Tab. EPA recommends that this database name end with "_in" to indicate it is a user input database.[31] When the database is created, MOVES records the selections in the RunSpec at that moment and uses this information to determine which database entries will be necessary to create fully populated tables. Users should avoid making changes to the RunSpec after the input database has been created, because this can create inconsistencies between the input database and the rest of the RunSpec. Users can review the appropriate sections of the MOVES training for more information on creating a RunSpec and an input database (see Section 1.6).

The CDM includes multiple tabs, each of which opens importers that are used to enter specific local data into the user's input database:

- Meteorology Data
- Source Type Population
- Age Distribution
- Vehicle Type VMT
- Average Speed Distribution
- Road Type Distribution
- Fuel
- I/M Programs
- Starts
- Idle
- Retrofit Data
- Hotelling
- Generic

Each of the importers allows the user to create an import template file with required data field names and with some key fields populated. The user then edits this template to add specific local data with a spreadsheet application or other tool and imports the data files into the user-created input database. In some importers, there is also the option to export default data from the MOVES database to review it. Once the user determines that the default data are accurate and applicable to the analysis or determines that the default data need to be changed and makes those

[31] Note that only letters, numbers, and underscores can be used for database names.

changes, the user then imports that data into the user-created input database. Details of the mechanics of using the data importers are provided in the MOVES training. Guidance for the use of these importers for SIPs and regional conformity analyses is given below.

In Emission Rates runs, vehicle activity inputs affect the calculated emission rates, and reasonable activity inputs are important even though activity data will be applied outside of MOVES to calculate an inventory. Vehicle activity inputs are important because they are used by MOVES to calculate the relative amounts of running activity and resting activity, which in turn affect the rates for start, evaporative, and extended idle emissions processes. As a general rule, users should input accurate activity estimates for the scenario being modeled regardless of whether MOVES is being used in Inventory or Emission Rates mode.

Although there is currently no importer in the CDM to enter local specifications for a Stage II program, this section of the document also includes guidance in Section 4.14 on entering local information of Stage II refueling programs in MOVES.

The following table provides a summary of the SIP and conformity guidance in Section 4 for each of the tabs in an input database. The summary is meant to provide an at-a-glance reminder of whether local information is necessary for an input and is not a substitute for the detailed information found subsequently in this section.

**Table 4-1: Summary of MOVES Inputs**

| Input | Guidance: | Notes |
|---|---|---|
| **Meteorology** | Use local data | Default data is included for each county but current local data should be used. Temperatures used for regional conformity analyses must be consistent with those used to establish the motor vehicle emissions budgets in the SIP (40 CFR 93.122(a)(5) |
| **Source Type Population** | Use local data | Guidance includes options for when population is not available |
| **Age Distribution** | Use local data for most source types;<br>Use MOVES national defaults for long-haul trucks | Guidance includes options when local data is not available for a source type. Default data represents the age distribution for the nation as a whole |
| **Vehicle Type VMT** | Use local data | Default data is national and apportioned to each county; not appropriate to use |
| **Average Speed Distribution** | Use local data | Guidance includes options when local data is not available for a source type |
| **Road Type Distribution** | Use local data | Guidance includes options when local data is not available for a source type |

| Input | Guidance: | Notes |
|---|---|---|
| **Fuels** | | Default data is included as explained in the fuel supply technical report[32] |
| • Fuel Supply<br>• Fuel Formulation | Use default data and if necessary, Fuel Wizard to reflect RVP requirements | Local data should be used only if local fuel property study available |
| • Fuel Usage Fraction | Use local data if available | |
| • AVFT | Use local data if available | Vehicle registration data would be a source of local data. See guidance in Section 4.8.3 |
| **Inspection and Maintenance Programs** | Start with default data and make changes as appropriate<br>(if no I/M program, check radio button) | Default data is included as explained in the "adjustments" technical report.[33] In addition to the guidance in Section 4.9, see also EPA's Performance Standard Modeling Guidance[34] |
| **Starts** | Optional; only use if local data are available | |
| **Hotelling** | Optional; only use if local data are available | |
| **Idle Data** | Optional; only use if local data are available and better than the MOVES defaults | |
| **Stage II Refueling Programs** | Start with default data and make changes as appropriate | Use the Generic Importer. See Section 4.14 |

## *4.2 Meteorology*

Local temperature and humidity data are required inputs for SIP and regional conformity analyses with MOVES. Ambient air temperature is a key factor in estimating emission rates for onroad vehicles due to its substantial effects on many pollutant processes. For example, with MOVES5, temperature affects NOx running exhaust.[35] Relative humidity is also important for estimating NOx emissions from motor vehicles. MOVES requires a temperature (in degrees Fahrenheit) and relative humidity (0 to 100 percent) input for each hour selected in the RunSpec. Therefore, MOVES requires a 24-hour temperature and humidity profile to model a full day of emissions on an hourly basis.

[32] See *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5*, available at MOVES Onroad Technical Reports.
[33] See *Emission Adjustments for Onroad Vehicles in MOVES5*, available at MOVES Onroad Technical Reports.
[34] *Performance Standard Modeling for New and Existing Vehicle Inspection and Maintenance (I/M) Programs Using MOVES Mobile Source Emissions Model,* available at EPA's Vehicle Emissions Inspection and Maintenance Policy and Technical Guidance website.
[35] Ibid.

The MOVES database includes default average monthly temperature and humidity data for every county in the country, but EPA does not recommend these default data for SIPs or regional conformity analyses. These default temperature and humidity data are based on average temperatures for each county from the National Climatic Data Center for the period from 2001 to 2011. Instead, MOVES users should include local information. For example, detailed local meteorological data are available from the National Centers for Environmental Information.

Sources of temperature data and any methods used to adjust them to fit the requirements of MOVES should be documented in any official SIP submission or conformity determination documentation. Temperature assumptions used for regional conformity analyses must be consistent with those used to establish the motor vehicle emissions budget in the applicable SIP as required in the transportation conformity rule at 40 CFR 93.122(a)(6).

### 4.2.1 Meteorology: Guidance for Inventory Mode

When modeling a county using the Inventory mode, a 24-hour temperature and humidity profile should be defined for each month selected in the RunSpec. The choice of specific temperature and humidity data will depend on the type of analysis being performed:

- For air quality modeling of a specific exceedance episode (e.g., for SIP attainment modeling), hourly meteorological data for the episode or for a longer period would be necessary.

- For more generic modeling of average summer or winter day ozone, $PM_{2.5}$, or CO conditions for SIP or regional conformity purposes, users should input average daily temperature profiles during the months when exceedances typically occur (in coordination with the EPA Regional Office):
    - For ozone season analysis, users need to enter the local average temperature profile for the period chosen to represent the area's ozone season (typically June, July and August; or July, August, and September).
    - For $PM_{2.5}$ season or episodic analysis, users need to enter the local average temperature profile for the chosen months.
    - For CO season analysis, users need to enter the local average temperature profile for January, or for the three-month period that best represents the CO season (typically December, January, and February).

- For an annual analysis, users need to enter the local average temperature profile for all months.

In the situation where a diurnal temperature profile is not available, or where an average temperature profile is needed for month, local average temperature profiles can be based on average minimum and maximum temperatures.

### 4.2.2 Meteorology: Guidance for Emission Rates Mode

If the Emission Rates calculation type is chosen, emission rates for all running processes that vary by temperatures and humidities can be post-processed outside of MOVES to calculate emissions for any mix of temperatures and humidities that can occur during a day. Users can

enter a range of 24 different temperatures and humidities for each hour of the day, to create an emission rate table that varies by temperature/humidity combination for running emission processes. This creates the potential to create a lookup table of emission rates by temperature/humidity for the range that can occur over a longer period of time such as a month or year from a single MOVES run. In one run, users may specify as many as 288 temperatures, i.e., 24 temperatures for 12 months. When using this approach for running emissions (RatePerDistance), the hour and month being modeled are merely placeholders for particular temperatures. In other words, a temperature of 40 degrees for Hour 18 in January, for example, will result in the same emission rate as a temperature of 40 degrees for Hour 6 in July (assuming the model is run with identical fuels in both months).

Emission Rates mode may be used for certain SIP purposes in conjunction with modeled meteorology data, for example from the Weather Research and Forecasting (WRF) model.[36] More information on using such an approach for modeling for attainment demonstrations is available in the SIP Air Quality Modeling Guidance referenced in Section 2.1. In addition, users may post-process WRF data for use in calculating emission rates and then apply those emission rates to calculate modeling inputs using the Sparse Matrix Operator Kernel Emissions (SMOKE)-MOVES system. This tool is not required to be used. More information on SMOKE-MOVES can be found in the latest SMOKE documentation, available on the SMOKE website.[37]

However, for emissions from any non-running processes that occur on the "off-network" road type, including evaporative, start, and hotelling emissions, it is still necessary to define a temperature profile for each hour of the day. Non-running off-network emissions depend on both temperature and hour of day, and for evaporative vapor venting emissions, the temperature in the previous hour.

It is possible to model both running emissions and non-running off-network emissions in one run by defining temperature intervals for several months and defining diurnal temperature profiles with the remaining months. For example, four months could be used to define temperature from 1 degree through 96 degrees in one-degree intervals to get running emission rates at each of those temperatures, and the remaining eight months could be used to define diurnal temperature profiles for eight representative days to get non-running emission rates. The resulting lookup table can be post-processed into an inventory for both running emissions and non-running off-network emissions. Note that "off-network idle" is considered a running process and is therefore included in the running emission rates.

In addition to the information here, modelers may want to review EPA's MOVES Hands-on Training Course, available on EPA's MOVES Training website. The training course includes a section about building an emission rates lookup tables.

[36] Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. Duda, X.-Y. Huang, W. Wang, and J.G. Powers, (2008), A Description of the Advanced Research WRF Version 3, (No. NCAR/TN-475+STR). University Corporation for Atmospheric Research. doi:10.5065/D68S4MVH. Available at: https://dx.doi.org/10.5065/D68S4MVH.

[37] Available at: https://www.cmascenter.org/smoke.

## *4.3 Source Type Population*

Source type (vehicle type) population is used by MOVES to calculate start and evaporative emissions.[38] Start and evaporative emissions depend on both vehicle population and VMT, but population is the more important contributor. Because vehicle population directly determines start and evaporative emissions in MOVES, users must develop local data for this input – there is no default information that users can export at the County Scale.

MOVES categorizes vehicles into 13 source types, which are subsets of five Highway Performance Monitoring System (HPMS)[39] vehicle types, as shown in Table 4-2.

**Table 4-2. MOVES Source Types and HPMS Vehicle Types[40]**

| Source Type ID | Source Types | HPMS Vehicle Type ID | HPMS Vehicle Type |
|---|---|---|---|
| 11 | Motorcycle | 10 | Motorcycles |
| 21 | Passenger Car | 25 | Light Duty Vehicles – Short and Long Wheelbase |
| 31 | Passenger Truck | | |
| 32 | Light Commercial Truck | | |
| 41 | Other Buses[41] | 40 | Buses |
| 42 | Transit Bus | | |
| 43 | School Bus | | |
| 51 | Refuse Truck | 50 | Single Unit Trucks |
| 52 | Single Unit Short-haul Truck | | |
| 53 | Single Unit Long-haul Truck | | |
| 54 | Motor Home | | |
| 61 | Combination Short-haul Truck | 60 | Combination Trucks |
| 62 | Combination Long-haul Truck | | |

### 4.3.1 Source Type Population: Guidance for Inventory Mode

Modelers should be able to develop population data for many of these source type categories from state motor vehicle registration data (e.g., for motorcycles, passenger cars, passenger trucks, light commercial trucks) and from local transit agencies, school districts, bus companies, and refuse haulers (for transit buses, school buses, other buses, and refuse trucks, respectively).

[38] Alternatively, MOVES can calculate start emissions based on user-supplied start activity information (see Section 4.10)

[39] There are actually six HPMS vehicle classes but MOVES uses five. MOVES uses HPMSVTypeID 25 to represent short wheelbase light-duty and long wheelbase light-duty vehicle classes for VMT input.

[40] HPMS Vehicle Type IDs are only used in MOVES for VMT input. All other applicable inputs, including vehicle population, are by MOVES Source Type and MOVES continues to calculate emissions separately for all Source Types. See Section 4.5 for addition details. This table is only presented here to show the mapping of Source Types to HPMS Vehicle Type IDs.

[41] "Other buses" include all buses that are not in the transit or school bus categories. Transit buses are buses owned by a public transit organization for the primary purpose of transporting passengers on fixed routes and schedules. School buses are buses designed to carry more than 10 passengers and used to transport K-12 students between their home and school.

Estimating population for the remaining source types may be done with other techniques:

- If population is not available for a particular source type, users could estimate it based on the MOVES default split of that source type within the HPMS vehicle class.
- In the absence of any other source of population data, users could estimate population of a source type using the VMT estimates for a particular source type and the ratio of MOVES default population to VMT by source type. That ratio can be calculated by doing a simple MOVES run at the Default Scale for the county in question and including VMT and population in the output (a running emissions process must be selected to generate VMT). Local VMT multiplied by the ratio of default population to default VMT will give an estimate of local population based on local VMT.

***Tip: A useful quality check on population and VMT inputs is to divide VMT for each source type by that source type population to estimate VMT per vehicle, and then determine whether these estimates are reasonable.***

### 4.3.2 Source Type Population: Guidance for Emission Rates Mode

If the Emission Rates mode is used, and Source Type is selected in the Output Emission Detail Panel, MOVES will produce emission rates for start, hotelling and non-running evaporative emissions by source type in terms of grams per vehicle. Total start, hotelling and non-running evaporative emissions would then be calculated outside of MOVES by multiplying the emission rates by the vehicle populations for each source type. However, users will still need to enter reasonable data using the Source Type Population Importer that represent the population of vehicles in the total area where the look-up table results will be applied. This is necessary because MOVES uses the relationship between source type population and VMT to determine the relative amount of time vehicles spend parked vs. running. If the look-up table results will be applied to a large number of counties, use the total source type population for all the counties covered. The guidance in this section concerning the use of local vehicle population data applies both for generating the total population as an input to the model and for generating more geographically detailed population values to use in applying the emission rate results.

To generate the non-running portion of the inventory from rates, multiply the rates from the RatePerVehicle and RatePerProfile tables by vehicle population. Alternatively, for start emission processes, use the RatePerStart output, which requires multiplying by the number of vehicle starts and/or for hotelling processes, use the RatePerHour output, which requires multiplying by the number of hotelling hours).

## *4.4 Age Distribution*

The age distribution of vehicle fleets can vary significantly from area to area. Per mile, older vehicles generally have higher emissions than comparable newer vehicles for two reasons:

1. Older vehicles typically have experienced more deterioration in emission control systems.

2. Vehicle emission standards have become tighter over time. Older vehicles were certified to meet standards in place when they were manufactured, rather than the current emissions standards.

Surveys of registration data indicate considerable local variability in vehicle age distributions, which is not reflected in the default age distributions in MOVES. When relying on the defaults, MOVES uses the same national average age distribution for each vehicle type in each year for every county.

For SIP and conformity purposes, EPA recommends and encourages states to develop local age distributions for all source types other than single unit long-haul trucks (sourceTypeID 53) and combination long-haul trucks (sourceTypeID 62). This guidance applies whether using the Inventory or Emission Rates mode.
Local age distributions can be estimated from local vehicle registration data. EPA recommends compiling data according to MOVES vehicle classifications and model year. Note that vehicle registration data are typically pulled mid-year (July 1) or year-end (December 31). Either can be used with MOVES, but the pull date should be noted in the documentation if known.

A typical vehicle fleet includes a mix of vehicles of different ages. At the County Scale, MOVES allows the modeler to specify the fraction of vehicles in each age, from zero (a new vehicle) to 40 years old, for each of the 13 source types in the model.[42] Age is calculated by subtracting the model year from the calendar year, with the following exceptions:

- Future model years (i.e., vehicles that would have a negative age by subtracting the model year from the calendar year) should be assigned ageID 0.
- Vehicles 40 years and older should be grouped together and assigned ageID 40.

While MOVES5 covers a 41-year range of vehicle ages, from 0 to 40+, earlier versions of MOVES cover a 31-year range, from 0 to 30+. If modelers have recently pulled vehicle registration data for use with MOVES3 or MOVES4, those data could still be used with MOVES5.[43] In this case, modelers can either:

- Reanalyze their local registration data using 41 ages instead of 31, or
- Convert their existing 31-year age distributions to 41-year age distributions using the converter tools provided in the MOVES graphical user interface (see Question 1.5 for more information on these converter tools). For example, modelers could use converted age distributions until they are able to reanalyze their local registration data using 41 ages instead of 31.

Detailed local age distribution data may not be readily available for all 13 of these source types. If local age distribution information is available for only one source type within an HPMS vehicle class, states can use the same age distribution for the other source types within that class (see Table 4-1 above). For example, states could use the same age distribution for Source Types

[42] For more information, see the *Overview of EPA's MOtor Vehicle Emission Simulator (MOVES5) Report*, available on the Latest Version MOVES website.
[43] For more information, see the EPA and DOT's joint *Guidance for the Use of Latest Planning Assumptions in Transportation Conformity Determinations*, EPA420-B-08-901, December 2008.

31 and 32 if separate age distributions for passenger trucks and light commercial trucks are not available.

For single unit long-haul and combination long-haul trucks, it is generally more appropriate to use MOVES national default age distributions because long-haul trucks often drive in areas other than where they are registered. National default age distributions for all source types are available for export from the Age Distribution tab in the CDM. The default age distributions in MOVES are specific for each calendar year and, in future years, include projections of changes in age distributions over time.

If local registration age distributions are used and the analysis year is in the future, users have two choices:

1. Apply the current age distribution to all future calendar years, i.e., assume that in the future, the age distribution is the same as the latest registration age distribution information currently available; or
2. Use the Age Distribution Projection Tool to account for the effects of historic national economic impacts on the fleet.

EPA has created the *Age Distribution Projection Tool for MOVES5* (available on EPA's Tools to Develop or Convert MOVES Inputs website) that can be used to update a local age distribution for a future year using the same methods that EPA uses for projecting default national age distributions. For example, during an economic recession, people are more likely to defer replacing older vehicles, thus the fleet becomes older. The tool helps users estimate age distributions in years after a recession, since the effect of a recession persists in the affected model years but diminishes in amplitude over time. Note that the MOVES5 version of this tool covers 41 ages and includes a new question, asking if the default age distributions should be used for the long-haul source types. In general, modelers should select "yes" so that the tool will insert the national average age distributions for these source types.

Regardless of approach, states should fully document the sources of data and methods used to develop local age distributions used in modeling for SIP and regional conformity purposes (see Section 2.7, which discusses documenting MOVES analyses). States that want to use a method other than the EPA tool described here to project future age distributions should consult with EPA early in inventory development.

## *4.5 Vehicle Type Vehicle Miles Traveled (VMT)*

EPA expects users to develop local VMT estimates for SIPs and regional conformity analyses, regardless of whether using the Inventory or Emission Rates mode. Travel demand models are often the source of information used by metropolitan planning organizations (MPOs) and state departments of transportation (DOTs) to estimate VMT, though reasonable professional practice may also be used in many areas. Transportation modelers for MPOs and state DOTs traditionally adjust estimates of VMT generated through the travel demand modeling process to the HPMS estimates of VMT and/or other locally developed actual vehicle counts. These procedures generate consistent VMT estimates from travel demand models for roadway functional classes within HPMS for use in SIP analysis. Section 3, Developing Locality-Specific

Inputs from Travel Demand Models, of the EPA document *Volume IV: Chapter 2, Use of Locality-Specific Transportation Data for the Development of Mobile Source Emission Inventories*, discusses how to reconcile traffic demand model results with HPMS VMT estimates. For regional conformity analysis, the transportation conformity regulations allow the interagency consultation process to determine if other information or procedures, such as locally developed count-based programs, may be acceptable (40 CFR 93.122(b)(3)).

MOVES allows the option of entering either annual VMT or daily VMT. EPA recommends that users with average annual daily VMT take advantage of the daily VMT input option. As another option, EPA has created a spreadsheet-based tool, the *AADVMT Converter for MOVES5*, that allows users to input average annual daily VMT as well as monthly and weekend day adjustment factors. This tool then uses this information to create the annual VMT by HPMS class and appropriate monthly and daily adjustments needed when selecting the annual VMT option in MOVES5.[44] This tool may be useful for those who want to take advantage of capabilities in MOVES to allocate annual VMT across different time periods.

MOVES includes the option to enter VMT by either HPMS vehicle classes or by the MOVES source types shown in Table 4-1 above. If VMT is input by HPMS class, MOVES will allocate VMT to source type using default assumptions. For users who can develop VMT data by the MOVES source types, entering VMT by source type will bypass the default allocation of VMT from HPMS class to source type that MOVES does internally. Either option is acceptable for SIP and conformity purposes, but differences between the default allocation of VMT from HPMS classes to source types in MOVES and the user supplied source type VMT could result in differences in results between the two options.

When inputing VMT by HPMS class, note that MOVES uses modified HPMS vehicle classes. In the HPMS methodology used by the Federal Highway Administration to estimate VMT, there are two categories of light-duty vehicles: short wheelbase and long wheelbase.[45] Because the short wheelbase/long wheelbase distinction does not correspond well to MOVES source types, MOVES uses a single class to include all VMT for light-duty cars and trucks, HPMS Vehicle Type 25. Therefore, VMT for the short and long wheelbase categories should be summed and entered as class 25. Note that although these HPMS categories are combined for VMT entry purposes in MOVES, all other fleet and activity inputs (e.g., vehicle population, age distribution, and average speed distribution) are by source type in MOVES, so all emission calculations and results are based on the emission and activity characteristics of each source type.

EPA recommends that the same VMT input approach be used in any analysis that compares two or more cases (e.g., the base year and attainment year in a SIP analysis or the SIP motor vehicle emissions budget and the regional conformity analysis). For example, if annual VMT is entered for the first case, use annual VMT (rather than daily) for the comparison case. Likewise, if VMT is entered by MOVES source type in one case, then VMT should be entered by MOVES source type (rather than HPMS class) in the comparison case. The interagency consultation process should be used to agree upon a common approach. If different approaches are used for the SIP

[44] The AADVMT Converter can be found at EPA's Tools to Develop or Convert MOVES Inputs website. Instructions for use of the converter can be found within the spreadsheet.
[45] For more information, see https://www.fhwa.dot.gov/policyinformation/statistics.cfm.

budget and the regional conformity analysis for practical reasons, the interagency consultation process should be used to determine how to address (and minimize) any differences in results. The methods used to develop inventories should be fully documented in the SIP submission and conformity determinations.

### 4.5.1 Vehicle Type VMT: Guidance for Emission Rates Mode

If the Emission Rates mode is used, and Source Use Type is selected in the Output Emission Detail Panel, MOVES will produce emission rates for running emissions by source type and road type in terms of grams per mile. Total running emissions would then be calculated outside of MOVES by multiplying the emission rates by the VMT for each source type and road type. However, users will still need to enter data using the Vehicle Type VMT Importer that reflects the VMT in the total area where the look-up table results will be applied. This is necessary because MOVES uses the relationship between source type population and VMT to determine the relative amount of time vehicles spend parked vs. running. If the look-up table results will be applied to a large number of counties, use the total VMT for all the counties covered. The guidance in this section concerning the use of local VMT data applies both for developing the total VMT to input and for developing the geographically detailed VMT to use when applying the emission rates.

## *4.6 Average Speed Distribution*

Vehicle power, speed, and acceleration have a significant effect on vehicle emissions. At the County Scale, MOVES models these emission effects by using distribution of vehicles hour traveled (VHT) by average speed. MOVES uses the speed distribution to select specific drive cycles, and then uses these drive cycles to calculate operating mode distributions. The operating mode distributions in turn determine the calculated emission rates. The use of local speed distribution data is important whether the modeler uses Inventory mode or Emission Rates mode.

### 4.6.1 Average Speed Distribution: Guidance for Inventory Mode

For SIP development and regional conformity analyses, where activity is averaged over a wide variety of driving patterns, a local speed distribution by road type and source type is necessary. The Average Speed Distribution Importer in MOVES calls for a speed distribution in VHT in 16 speed bins, by each road type, source type, and hour of the day included in the analysis. EPA urges users to develop the most detailed local speed information that is reasonable to obtain. However, EPA acknowledges that average speed distribution may not be available at the level of detail that MOVES allows. The following paragraphs provide additional guidance regarding the development of average speed distribution inputs.

Average speed, as defined for use in MOVES, is the distance traveled (in miles) divided by the time (in hours). This is not the same as the instantaneous velocity of vehicles or the nominal speed limit on the roadway link. The MOVES definition of speed includes all operation of vehicles including intersections and other obstacles to travel which may result in stopping and idling. As a result, average speeds, as used in MOVES, will tend to be less than nominal speed limits for individual roadway links.

Estimating vehicle speeds is a complex process. One recommended approach for estimating average speeds is to post-process the output from a travel demand model. In most transportation

models, speed is estimated primarily to allocate travel across the roadway network. Speed is used as a measure of impedance to travel rather than as a prediction of accurate travel times. For this reason, speed results from most travel demand models should be adjusted to properly estimate actual average speeds.

An alternative approach to develop a local average speed distribution is to process on-vehicle Global Positioning System (GPS) data. There are several commercial vendors that can provide raw or processed vehicle speed data from cell phone and other on-vehicle GPS collection devices. This information can be used to calculate a MOVES average speed distribution, and EPA used this as the main approach in developing MOVES default average speed distributions. Users who want to process their own GPS data into an average speed distribution should ensure that the data are representative of the modeling domain, and accurately capture variation in vehicle average speeds across the day, and year, and that the methodology is fully documented. The Federal Highway Administration (FHWA) also has resources that may be useful for developing a speed distribution for MOVES that are available free of charge.[46]

Speed is entered in MOVES as a distribution rather than a single value. Table 4-3 shows the speed bin structure that MOVES uses for speed distribution input. EPA encourages users to use underlying speed distribution data to represent vehicle speed as an input to MOVES, rather than one average value. Use of a distribution will give a more accurate estimate of emissions than use of a single average speed.

**Table 4-3. MOVES Speed Bins**

| Speed Bin ID | Average Bin Speed | Speed Bin Range |
|---|---|---|
| 1 | 2.5 | speed < 2.5mph |
| 2 | 5 | 2.5mph <= speed < 7.5mph |
| 3 | 10 | 7.5mph <= speed < 12.5mph |
| 4 | 15 | 12.5mph <= speed < 17.5mph |
| 5 | 20 | 17.5mph <= speed <22.5mph |
| 6 | 25 | 22.5mph <= speed < 27.5mph |
| 7 | 30 | 27.5mph <= speed < 32.5mph |
| 8 | 35 | 32.5mph <= speed < 37.5mph |
| 9 | 40 | 37.5mph <= speed < 42.5mph |
| 10 | 45 | 42.5mph <= speed < 47.5mph |
| 11 | 50 | 47.5mph <= speed < 52.5mph |
| 12 | 55 | 52.5mph <= speed < 57.5mph |
| 13 | 60 | 57.5mph <= speed < 62.5mph |
| 14 | 65 | 62.5mph <= speed < 67.5mph |
| 15 | 70 | 67.5mph <= speed < 72.5mph |
| 16 | 75 | 72.5mph <= speed |

[46] See FHWA's National Performance Management Research Data Set (NPMRDS): https://ops.fhwa.dot.gov/perf_measurement/, and FHWA's Database for Air Quality and Noise Analysis (DANA): https://www.fhwa.dot.gov/environment/air_quality/methodologies/dana/. Users of these tools should ensure their use for SIP or transportation conformity purposes is consistent with this guidance.

As is the case for other MOVES inputs, EPA does not expect that users will be able to develop distinct local speed distributions for all 13 source types. If a local average speed distribution is available for only one source type within an HPMS vehicle class, states can use the same average speed distribution for the other source types within that class (see Table 4-2). For example, states could use the same average speed distribution for Source Types 31 and 32 if separate average speed distributions for passenger trucks and light commercial trucks are not available. States could also use the same speed distributions across multiple HPMS vehicle classes if such speed distributions are considered to be more representative of vehicle activity in the area than the MOVES default speed distributions.[47]

Average speed estimates for calendar years other than the calendar year on which the average speed estimates are based should be logically related to the current year methodology and estimates, with no arbitrary or unsupported assumptions of changes in average speeds. Future average speed estimates should account for the effect of growth in overall fleet VMT on roadway congestion and average speeds.

#### 4.6.1.1 Additional Guidance for Inventories Used in Attainment Modeling

Results from photochemical models are sensitive to differences in the estimated inventory by time of day. For SIP-related onroad vehicle emission inventories for photochemical models, EPA encourages states to develop and use their own specific estimates of VHT by average speed by hour of the day. However, hourly estimates are not required. In the absence of local hourly speed data, users could develop peak and off-peak speed distributions, if available, or develop a daily average speed distribution. However, generating a daily average speed distribution for a highway network with a considerable number of highly congested links at certain times of day is not recommended. Because the relationship between speed and emissions is not linear, and emissions tend to be highest in congested conditions, using a daily average speed distribution in an area with significant congestion at certain times of day can result in significant underestimation of emissions. In this case, using peak and off-peak speed distributions is recommended at a minimum. The VHT fractions by average speed used in inventory modeling for SIPs and regional conformity analyses should be consistent with the most recent information used for transportation planning.

#### 4.6.1.2 Additional Guidance for Speeds on Local Roadways

MOVES uses four different roadway types that are affected by the average speed distribution input:

- Rural restricted access,
- Rural unrestricted access,
- Urban restricted access, and
- Urban unrestricted access.

In MOVES, local roadways are included with arterials and collectors in the urban and rural unrestricted access roads category. Therefore, EPA recommends that the average speed distribution for local roadway activity be included as part of a volume-weighted distribution of average speed across all unrestricted roads, local roadways, arterials, and connectors. Users who

[47] MOVES default speed distributions can be found in *Population and Activity of Onroad Vehicles in MOVES5* (EPA-420-R-24-019), available at MOVES Onroad Technical Reports.

want to treat local roadways and arterials separately can develop separate average speed distributions and estimate results using two separate MOVES runs, each with appropriate VMT, one using the local roadway average speed distribution for unrestricted access roads and one using the arterial average speed distribution for unrestricted access roads. However, using properly weighted average speed distributions for the combination of all unrestricted access roads should give the same result as using separate average speed distributions for arterials and local roadways.

#### 4.6.1.3 Average Speed Distributions for Highways and Ramps

For rural and urban restricted access highways, users should enter the speed distribution of vehicles traveling on the highway, including any activity that occurs on entrance and exit ramps.

### 4.6.2 Average Speed Distribution: Guidance for Emission Rates Mode

If the Emission Rates mode is used, and Source Type is selected in the Output Emission Detail Panel, MOVES will produce a table of emission rates by source type and road type for each speed bin. Total running emissions would then be calculated outside of MOVES by multiplying the emission rates by the VMT on each road type for each source type in each speed bin. However, vehicle speed inputs are still important because they are used by MOVES to calculate the relative amounts of running and non-running activity, which in turn affects the rates for the non-running processes and off-network idling. Therefore, speed inputs for Emission Rates runs should reflect realistic activity for the area.

## *4.7 Road Type Distribution*

The fraction of VMT by road type varies from area to area and can have a significant effect on overall emissions from onroad mobile sources. EPA expects states to develop and use their own specific estimates of VMT by road type. For each source type, the Road Type Distribution table of the input database stores the distribution of VMT by road type (e.g., the fraction of passenger car VMT on each of the road types). These fractions will sum to 1 for each source type. Note that there are five road types but Road Type ID 1 is Off-Network, which is used for estimating non-running emissions such as those from vehicle starts, evaporation, and hotelling. No VMT occurs on the off-network road type. Thus VMT for each source type will be apportioned across the other four road types: rural restricted, rural unrestricted, urban restricted, and urban unrestricted.

### 4.7.1 Road Type Distribution: Guidance for Inventory Mode

The VMT fractions by road type used in inventory modeling for SIPs and regional conformity analyses should be consistent with the most recent information used for transportation planning.

As is the case for other MOVES inputs, EPA does not expect that users will be able to develop local road type distributions for all 13 vehicle source types. If local road type distribution information is available for only one source type within an HPMS vehicle class, states can use the same road type distribution for the other source types within that class. For example, states could use the same road type distribution for Source Types 31 and 32 if separate average speed distributions for passenger trucks and light commercial trucks are not available. States could

also use the same road type distribution across multiple HPMS vehicle classes if appropriate when more detailed information is not available.

### 4.7.2 Road Type Distribution: Guidance for Emission Rates Mode

If the Emission Rates mode is used, MOVES will automatically produce a table of running emission rates by road type. Total on-network running emissions would then be calculated outside of MOVES by multiplying the emission rates by the VMT on road types 2-5 for each source type in each speed bin (see Section 4.12.2 for calculating off-network running emissions in Emission Rates mode). In this case, it is still necessary to enter data in the Road Type Distribution Importer. While these distributions do not directly affect the calculated on-network emission rates, the road type distribution inputs are important for Emission Rates runs involving non-running processes, because they are used by MOVES to calculate the relative amounts of running and non-running activity, which in turn affects the rates for the non-running processes. Road type distribution inputs for Rates runs that include any non-running processes should reflect realistic activity for the area. The guidance in this section concerning the use of local road type data applies whether local road type distributions are applied within MOVES using the Inventory mode or outside of MOVES using the Emission Rates mode.

## *4.8 Fuels (Fuel Supply, Fuel Formulation, Fuel Usage Fraction, and AVFT)*

MOVES has four tables – FuelSupply, FuelFormulation, FuelUsageFraction, and AVFT (Alternate Vehicle Fuel and Technologies) – that interact to define the fuels used in the area being modeled.

- The FuelSupply Table identifies the fuels used in a region by fuel formulation ID, (the RegionCounty table defines which specific counties are included in these regions) and each formulation's respective market share;
- The FuelFormulation Table defines the properties, such as RVP, sulfur level, ethanol volume, etc. of each fuel;
- The FuelUsageFraction Table defines the frequency at which E-85 capable (flex fuel) vehicles use E-85 vs. gasoline; and
- The AVFT Table is used to specify the fraction of fuel types capable of being used (such as gasoline only, electric, and flex fuel vehicles) by model year and source type.

The MOVES defaults for all four tables are accessible using the Export Default Data button in the Fuel Tab of the CDM.

The MOVES default database includes base emission rates for each fuel type. MOVES calculates additional fuel adjustments based on the attributes defined in the FuelFormulation table. MOVES then uses the marketShare field from the FuelSupply table to appropriately weight and apply the fuel adjustment factors. Finally, the adjusted emission rates are applied to the appropriate activity defined through the FuelUsageFraction and AVFT tables.

For all fuel tables but AVFT, users should begin by exporting and reviewing the MOVES default fuel tables for the county being analyzed.

- For the first two tables, Fuel Supply and Fuel Formulation, the MOVES default data is appropriate with the exception for RVP noted in Section 4.8.1.

- For the Fuel Usage Fraction table, local data should be used if available; see Section 4.8.2 for more information.
- For AVFT, local data should also be used if available and additional guidance is found in Section 4.8.3.

The default fuel properties in MOVES5 are described in *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5,* available on EPA's MOVES Onroad Technical Reports website.

For new major MOVES versions such as MOVES5, EPA develops updated fuel properties by region. In previous versions of MOVES, gasoline fuel properties were primarily based on volume-weighted fuel production information. In MOVES5 starting with calendar year 2021, the gasoline fuel supply has been redeveloped in MOVES5 based on nationwide retail survey data. For more information, see the MOVES5 Fuel Supply Defaults report. [48]

As a result, converted default fuel tables from any previous version of MOVES should not be used in MOVES5 for SIPs or conformity analyses, even if they have been modified to reflect differences in local fuels. Instead, users should export the default MOVES5 fuel tables for the county being analyzed, make any changes needed to reflect local fuel differences consistent with the guidance in this document, and then re-import those modified MOVES5 fuel tables back into their input database.

The following subsections specify situations where changes to the MOVES default fuel data are appropriate. This guidance applies for Emission Rates and Inventory runs.

### 4.8.1 Fuel Formulation and Fuel Supply Guidance

MOVES has default gasoline and diesel fuel formulation and supply information for every county-year-month combination that can be selected. In MOVES5, the default values in the FuelFormulation and FuelSupply tables were developed as described in the fuel supply report for MOVES5,[49] and do not necessarily reflect later changes made to local fuel requirements (e.g., an area becomes subject to Federal reformulated gasoline (RFG) requirements).[50]

In general, users should rely on the default county-level information in MOVES for Fuel Supply and Fuel Formulation inputs.[51] Users should first review the default fuel formulations and fuel supply, and make changes only where precise local volumetric fuel property information is available or where local fuel requirements have changed. Where local requirements have not changed, EPA strongly recommends using the default fuel properties for a region unless a full

[48] *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5,* available at MOVES Onroad Technical Reports.
[49] See *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5,* available at MOVES Onroad Technical Reports.
[50] For more information, refer to EPA's Reformulated Gasoline website.
[51] With the exception of Denver: EPA will update the fuel properties associated with the implementation of Federal reformulated gasoline (RFG) in the area when we have sufficient data to do so. In the meantime, when modeling Denver area counties, modelers should work with EPA to develop Denver area fuel inputs for regulatory modeling. Counties in the Denver RFG implementation area include Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer (part), and Weld (part).

local fuel property study exists. Because fuel properties can be quite variable, EPA does not consider single or yearly station samples adequate for substitution.

One exception to this guidance is in the case of Reid Vapor Pressure (RVP). A modeler should change the value to reflect any specific local regulatory requirements and differences between ethanol- and non-ethanol blended gasoline not reflected in the default database. Any changes to RVP (or to any other gasoline formulation parameter) should be made using the "Fuels Wizard" tool in the Fuel Tab of the CDM. For example, modelers in the states where the 1.0 psi ethanol waiver for E10 has been removed, effective April 2025, will need to use the Fuel Wizard to reflect this change.[52]

The Fuels Wizard can be used to adjust a gasoline formulation based on a change in a specific property. For instance, changing a fuel's RVP will affect other volatility parameters due to changes in refinery configuration required to create the new fuel. The Fuels Wizard calculates the appropriate values consistent with EPA's refinery modeling and should be used whenever changing any default fuel property for gasoline and gasoline-ethanol blends in the FuelFormulation table.[53] This approach could also be used for determining the impacts of relaxing low RVP requirements: two runs could be done and they would be the same except for the change to RVP through the Fuels Wizard, then the emissions compared. If fuel supply or fuel formulation are changed, modelers can expect both onroad and nonroad emissions to change, since the same fuel properties are used for both the onroad and nonroad modules of MOVES.

Users who want to determine the benefits of a current Federal RFG requirement can do so by comparing the emissions inventory with Federal RFG to the emissions inventory for their county calculated using the fuel supply and fuel formulations from an adjacent non-Federal RFG county in the same state. EPA encourages modelers to contact EPA (see Section 1.8) to confer on the appropriate properties of a new Federal RFG fuel. This comparison should be done for both onroad and nonroad inventories.

#### 4.8.1.1 Fuel Formulation Data Fields

The key fields in the fuel formulation that a user might modify based on the guidance above are described below. Modelers may modify these fields for gasoline or diesel if appropriate but should not make any changes for compressed natural gas (CNG) or electricity, as there is only one form of these fuels. Therefore, no parameters for CNG or electricity should be adjusted.

Fuel Formulation ID identifies the fuel and is entered in the FuelSupply table to define the fuel(s) used in the fuel region being modeled. Users can either modify characteristics for an existing fuelFormulationID or create a new fuelFormulationID. It is recommended that if a new fuelFormulationID is created, it be an unused number within the range for each fuel type:

- for gasoline and ethanol-gasoline blends, 1000–20000;
- for onroad diesel, 25000-26000;
- for E-85, 27000-28000.

[52] The states affected are Illinois, Iowa, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin. Refer to 89 FR 14760, February 29, 2024, for more information.
[53] The Fuels Wizard is not used for E-85, Diesel, or CNG fuels.

New fuel formulations should not be created for CNG or electricity as there is only one form of these fuels.

Fuel Subtype ID provides an additional level of detail about the type of fuel the formulation is describing. The FuelSubType table in the default database contains the list of values for fuel subtypes that can be entered for this field. It is important that the fuel subtype represent the fuel formulation being described, but in some cases, there may be more than one fuel subtype that describes the fuel formulation. Almost all reformulated gasoline is blended with 10% ethanol and therefore has a fuelSubTypeID of 12 for Gasohol (E10) (generally speaking, any gasoline blended with ethanol should have one of the gasohol or ethanol fuel subtypes).[54]

RVP stands for Reid Vapor Pressure and is measured in pounds per square inch (psi). This is a commonly used property to define the volatility of gasoline and users may be able to provide local information for this field where data has been collected; however, regulatory RVP levels should be used for future years as over-compliance on the part of fuel suppliers is not an enforceable measure.

- Areas covered by the federal volatility control program should see 40 CFR 1090.215(a) for applicable RVP values and areas with SIP fuel programs should rely on the state regulations describing the fuel program when modeling future years.[55]
- Prior to 2021, there was no specific RVP requirement in RFG areas. Historically, this resulted in summertime RVP levels between 7.0 and 7.4 psi, depending on other properties of the particular gasoline batch. Starting in 2021, RFG has a summertime RVP cap of 7.4 psi. For more information, see 40 CFR 1090.215(a)(3).
- When regulatory RVP values are used in future years, users should be sure to properly account for the 1 psi ethanol blend waiver allowed under 40 CFR 1090.215(b). In areas where this waiver applies, gasoline blended with 10% ethanol typically has RVP set 1 psi above the applicable standard, while all other blend levels (including non-ethanol fuel) have RVP set at the applicable standard. See 40 CFR 1090.215(a) for the applicable standards.
- For diesel fuel, a value of zero should be entered for RVP.

***Tip: Ethanol blends other than E10 do not receive the 1 psi ethanol waiver and should not be adjusted.***

Sulfur level is measured in parts per million (ppm) in terms of weight. EPA rulemakings have resulted in changes in sulfur levels in both gasoline and diesel fuels over the period of years that MOVES can model (see Tier 2 and Tier 3 gasoline sulfur and Ultra-Low Sulfur Diesel (ULSD) rules, 65 FR 6698, 79 FR 23414, and 66 FR 5002, respectively). At this point, these fuel regulations have been completely phased in. When modeling a year in the past, the use of MOVES defaults will appropriately account for the regulation phase-in. Therefore, users can rely on default information if local data are not available, but additional detail is given below.

[54] FuelSubTypeID=11 is no longer used in MOVES because RFG is no longer blended with an oxygenate other than ethanol, such as MTBE, ETBE, or TAME. For more information about fuel subtypes, see EPA's report, *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5*, found at MOVES Onroad Technical Reports.
[55] For more information, see EPA's Final Rulemaking: Streamlining and Consolidating of Existing Gasoline and Diesel Fuel Programs website.

- Gasoline: The Tier 2 gasoline sulfur rule established a national average of 30 ppm sulfur (S) with a per-gallon cap of 80 ppm, which was implemented in 2006 (except for the Geographic Phase-In Area, see 65 FR 6755, February 10, 2000). The Tier 3 rule further reduced the national average standard to 10 ppm with a phase-in from 2017 to 2020 (the per-gallon cap was left at 80 ppm). Users should not adjust the sulfur value unless local sulfur data are available. MOVES can calculate benefits of gasoline sulfur reduction down to 5 ppm, so values below 5 ppm should not be used.

- Diesel: Between 2006 and 2010, the Ultra-Low Sulfur rule required at least 80% of the highway diesel fuel sold meet the 15 ppm sulfur standard; the remaining 20% had to meet the Low Sulfur Diesel standard of 500 ppm sulfur. The MOVES default diesel fuel for onroad vehicles has a sulfur level of 15 ppm for 2006 and later. If users have volumetric data for diesel fuel sulfur levels in the area being modeled, this information can be entered in the sulfurLevel and marketShare fields of the FuelFormulation and FuelSupply tables, respectively.

ETOH Volume is the percent by volume of ethanol the gasoline/ethanol mixture. The second Renewable Fuel Standard rule (RFS2, 75 FR 14670, March 26, 2010) greatly increased the amount of ethanol blended into gasoline. For years 2014 and later, only two ethanol blend levels, E-10 and E-85, are included in the MOVES default fuel supply with nonzero market shares. Formulations for two additional levels, E-0 and E-15, are present for each fuel region but with market share set to zero. These blend levels are sold throughout the country in small volumes, but there is insufficient data to designate market shares for these blend levels. Since E-0 and E-15 are included in the default fuel supply with zero market share, users should apportion market share to these fuels via the Fuel Supply table (and not via the Fuels Wizard or other means) if local data indicate that they are sold in the area. Gasoline with other ethanol volumes below E-15 can be modeled by selecting an existing fuel with the nearest ethanol volume and using the Fuels Wizard to set the ethanol volume to the desired level and adjust other properties. MOVES should not be used to model gasoline fuels with ethanol concentrations above 15%, other than E85.

For a diesel fuel, a value of zero should be entered for ETOH Volume.

#### 4.8.1.2 Fuel Supply Data Fields

After the fuel formulations have been reviewed and/or modified, the FuelSupply table can be populated. There are six fields in this table. The regionID field identifies the area being modeled.[56] The monthGroupID is the same as the monthID; monthGroupID was built in to allow for the possibility of seasonal fuels, but that option is not currently functional. The fuelFormulationID is explained above.

The marketShare is each fuel formulation's fraction of the volume consumed in the area. Within each fuel type, multiple fuel formulations can be listed as long as the market share sums to one for each month within each fuel type listed in Table 4-4.

[56] For more information on fuel regions in MOVES, see the *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5* at MOVES Onroad Technical Reports.

**Table 4-4. Onroad Fuel Types in MOVES**

| fuelTypeID | Description |
|---|---|
| 1 | Gasoline |
| 2 | Diesel Fuel |
| 3 | Compressed Natural Gas (CNG) |
| 5 | E-85 |
| 9 | Electricity |

For example, a county being modeled could have three January gasoline fuel formulations with market shares of 0.5, 0.4, and 0.1 and two diesel fuel formulations with market shares of 0.6 and 0.4.

### 4.8.2 Fuel Usage Fraction Guidance

E-85 capable vehicles, also known as flex-fuel vehicles (FFVs) exist throughout the country and are capable of using either gasoline or E-85 fuel, which is a blend of 85% ethanol and 15% gasoline. The FuelUsageFraction table allows the user to change the frequency at which E-85 capable vehicles use E-85 fuel vs. conventional fuel, when appropriate. In this table, the column sourceBinFuelTypeID refers to the engine capability:

- sourceBinFuelTypeID 1 = gasoline only
- sourceBinFuelTypeID 2 = diesel
- sourceBinFuelTypeID 3 = CNG
- sourceBinFuelTypeID 5 = FFV
- sourceBinFuelTypeID 9 = electricity

The column fuelSupplyFuelTypeID in the FuelUsageFraction table refers to the fuel being burned by the engine. For vehicles with gasoline, diesel, CNG, or electric engines (i.e., sourceBinFuelTypeIDs 1, 2, 3, or 9), the fuelSupplyFuelTypeID is the same as the sourceBinFuelTypeID. However, FFV vehicles can be assigned a fuelSupplyFuelTypeID of either 1 (gasoline) or 5 (E-85). The usageFraction column of this table defines how much E-85 compared to gasoline is being burned by FFVs.

MOVES contains the same default estimate of E-85 fuel usage for each county in the U.S., which represents the national average.[57] In most cases, users should rely on the default information. If local data are available that indicate different E-85 usage, the fraction of gasoline (fuelSupplyFuelTypeID 1) and E-85 (fuelSupplyFuelTypeID 5) can be specified for sourceBinFuelTypeID 5. Usage fractions for sourceBinFuelTypeIDs 1, 2, 3, and 9 (gasoline, diesel, CNG, and electricity) should not be changed.

[57] For more information on default E-85 usage fractions in MOVES, see *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5* at MOVES Onroad Technical Reports.

Please note that this table defines the fraction of E-85 use among E-85 capable vehicles, not the fraction of E-85 use among *all* vehicles, or the fraction of E-85 capable vehicles in the fleet.

The following table provides examples for what entries to make in the FuelUsageFraction table:

**Table 4-5: Examples for Fuel Usage for Flex-Fuel Vehicles**

| If the flex fuel vehicles in the area being modeled use: | Then change the usage fractions in the FuelUsageFraction table for sourceBinFuelTypeID 5 as follows: |
|---|---|
| **Exclusively gasoline** | 1.0 for fuelSupplyFuelType ID 1<br>0.0 for fuelSupplyFuelType ID 5 |
| **Exclusively E-85** | 0.0 for fuelSupplyFuelType ID 1<br>1.0 for fuelSupplyFuelType ID 5 |
| **On average,<br>75% gasoline and<br>25% E-85** | 0.75 for fuelSupplyFuelType ID 1<br>0.25 for fuelSupplyFuelType ID 5 |

These are just examples; use the correct fractions for the area being modeled.

### 4.8.3 AVFT Guidance

The AVFT (Alternate Vehicle Fuel and Technology) table allows users to modify the fraction of vehicles capable of using different fuels and technologies. Specifically, for each source type and model year, the AVFT Table allows users to define the fraction of vehicles that are designed to run on:

- gasoline,
- diesel,
- E-85,[58]
- CNG,
- battery electric (BEV), and
- fuel cell electric (FCEV). [59]

The decimal values between 0 and 1 in the AVFT Table represent the fraction of each model year and source type designed to run on each of the above fuels and technologies; they sum to 1 for each model year of each source type. Hybrid gasoline/electric and plug-in hybrid electric vehicles (HEVs and PHEVs, respectively) are not listed separately here. In MOVES, modelers should include these vehicles in the gasoline vehicle category, consistent with EPA's regulations for these vehicles as they are subject to the gasoline vehicle standards. MOVES does not include propane as a fuel type, so modelers should include propane-powered vehicles in the CNG

[58] The E-85 fraction represents the fraction of flexible fuel vehicles (FFVs), that is, vehicles designed to run on gasoline or gasoline-ethanol blends up to E-85. The fraction of these vehicles that are actually fueled with E-85 is input with the fuel usage fraction, described in Section 4.8.2.

[59] Not all source type/fuel type combinations are available in MOVES. Users should check the list of available combinations in the Onroad Vehicles Panel before editing the AVFT Table.

category. Note that MOVES will assume the same driving behavior for a source type, regardless of fuel or technology (e.g., the same average speed and road type distributions).[60]

Fractions of fully electric vehicles in the fleet are highly variable by county. The default AVFT information represents the nation as a whole and therefore will not reflect the fleet in any particular county. The use of local information would improve the characterization of vehicle fuels/technologies for most source types because national defaults are likely not representative of the local fleet. For example:

- The national average fractions likely underestimate electric vehicle prevalence rates in states with Zero-Emission Vehicle (ZEV) programs and overestimate rates in other areas.
- The national default AVFT Table in MOVES assumes that most heavy-duty truck fleets include a mix of gasoline, diesel, and CNG vehicles. However, some fleets of buses or refuse trucks in a county may consist of only a single fuel type or may have a distribution of fuel types much different from the national average.

The AVFT Table is used to adjust fuel type distributions to reflect local information, such as vehicle registration data. For example, if in a certain county, registration data show that fewer electric vehicles are in operation than indicated by the default AVFT Table for a particular source type, this table should be modified to reflect the actual fuel type distributions, as calculated from the registration data.

The interagency consultation process should be used to determine what information is appropriate to use for the AVFT input. There are two options that could be used, depending on data availability:

1. Where available, agencies should use their own data, for example, based on vehicle registration records for light-duty vehicles, or based on information from large fleet owners, and include this local information about fuel type distribution in the AVFT Table.

2. If such data are not available, modelers can use the most recent AVFT information that EPA has compiled as inputs for the National Emissions Inventory (NEI).[61] This information is a combination of state submitted data and EPA information. The 2020 NEI data are available from EPA's 2020 NEI data website. Modelers would need to

[60] If the user has information detailing distinct driving behavior for the different vehicle-fuel combinations, then individual RunSpecs would have to be used for each combination to capture how this will impact emissions. For example, if diesel buses have a different activity from CNG buses, those emissions cannot be estimated in the same run.

[61] At the time of this writing, the most recent version is the 2020 NEI. However, information compiled for the 2023 NEI is expected to be published in March 2026 and will be available from EPA's National Emissions Inventory website.

download and "unzip" their state's file, locate the county of interest, and save the AVFT input file.[62] This would then be the starting point for the AVFT Tool described below.[63]

The one situation where it may make sense to MOVES default AVFT information instead of one of these two options is when modeling a year in the past, when EVs were not prevalent within the fleet.

Vehicle registration data provides information about the vehicle fleet for a snapshot in time: the date when that registration data is pulled. However, when using MOVES to model a future year, that information will need to be adapted for the future year. To project fuel type distributions for future years, modelers should consider current distributions, national projections, and relevant state and local regulations. The AVFT Tool, described below, facilitates input of historical and future distributions that are consistent with the available data and EPA guidance.

**Last Complete Model Year.** When developing AVFT inputs for MOVES, EPA recommends using registration data only for model years with complete data ("complete model years"). For example, registration data pulled on July 1, 2024 would include some model year 2024 vehicles and may even include some model year 2025 vehicles. However, since both model year 2024 and 2025 vehicles would continue to be sold after this date, these registration data would provide only a partial view of these model year vehicles, and therefore these data may not be representative for model years 2024 and 2025. In this example, sales of model year 2023 vehicles can be assumed to be finished, and therefore data for that model year would be considered "complete." In general, the fuel type distribution for the last (i.e., most recent) complete model year should be used as the baseline for future year projections. However, another recent year could be used instead, if, for example, it is believed to be more representative. When using AVFT data from the 2020 NEI, the last complete model year would be 2019. In the AVFT Tool, described below, the modeler needs to identify the last complete model year; as noted, there is flexibility in this choice.

#### 4.8.3.1 AVFT Tool

The AVFT Tool is found in the Tools drop-down menu in the MOVES GUI. It can be used to create a complete AVFT Table based on the modeler's current fuel type distribution for the last complete model year (described above), and that complete AVFT Table can then be imported into MOVES using the County Database Manager.

[62] Please see the 2020 NEI supporting data directory for county scale input databases by state. The data file will be in the format of a MariaDB database. Modelers would need to export the AVFT table to a spreadsheet format (.xlsx or .csv). This process is covered in EPA's MOVES Hands-on Training Course, and in the "Quick Start Guide to Accessing MariaDB Data," which is available in the \docs folder of a computer where MOVES has been installed.

[63] For additional information about the NEI, please refer to EPA's *2020 National Emissions Inventory Technical Support Document: Onroad Mobile Sources*, EPA-454/R-23-001e, January 2023.

This tool has two functions:

- It can project future fuel type distributions based on the combination of local historic data and projected national trends.
- It can gap-fill local historic fuel type distribution data, as necessary, which is needed because MOVES models vehicles with an age distribution from 0 (brand new) to 40+ years old.

To use the tool, modelers must provide known local fuel type distributions in the format of the AVFT Table for all available source types and model years as an input to the tool and select the gap-filling and projection methods for each source type. The tool also requires the modeler to identify the last complete model year (see description in Section 4.8.3, above) and the analysis year to be specified in the tool's GUI. The tool will gap-fill data beginning with 1950 up to the user-specified last complete model year and truncate any input data beyond that model year. The projections are then calculated for model years beyond the last complete model year in the input data to the user-specified analysis year. If multiple calendar years are to be modeled, you can select the latest analysis year and use the tool output for all MOVES runs. Detailed instructions can be found within the tool itself ("AVFT Tool Help").

This tool presents three gap-filling methods and four projection methods. The methodology and the circumstances under which each method is recommended for use is described below.

**Gap Filling Methods.** Typical registration data would include vehicles of various source types, fuel types, and ages. However, there may be combinations of source type, fuel type, and age that are not present in registration data. The selection of which gap-filling method may vary by source type and depends on the types of gaps present in the source data for local fuel type distributions.

The AVFT Tool's gap-filling methods are *Automatic; Use defaults, renormalize inputs;* and *Use defaults, preserve inputs*. If the input data do not contain gaps, none of these methods will affect the input data. If there are model years of a source type with no input data at all, all three methods will include the MOVES national default fuel distributions as-is for those model years. The difference in the three methods is in how gaps are filled for model years of a source type that are only partially complete:

- Automatic:
    - For model years and source types where some fuel types are present in the input data, but not all, this method identifies the source type and fuel type combinations that MOVES is capable of modelling that are missing and fills them with 0s.
    - EPA recommends using this method when the input data contain all model year and fuel type combinations that exist locally. In this case, combinations that do not exist locally simply do not have rows in the data. Since the MOVES AVFT importer will produce error messages for missing values, selecting this method will ensure that all missing combinations are filled with a 0 value where possible, and default values if filling with 0s would result in 0s for all fuel types. It will not change the local data values.

    - EPA also recommends this method for source types where local data are not available and/or not applicable, such as for long-haul trucks. To ensure the national default data are used for long-haul trucks, do not include these source types (sourceTypeIDs 53 and 62) in the input file used with the AVFT Tool. With "automatic" selected for these source types, the output of the tool will include the national default fuel type distributions for these vehicles.
    - This is the default method for all source types.
- Use defaults, renormalize inputs:
    - For model years and source types where some fuel types are present in the input data, but not all, this method sets the fractions for the missing fuel types to the national default values, and the input data are renormalized so that the fuel type distributions sum to 1.
    - EPA recommends this method when the local data are known to be incomplete (e.g., if the local data are known to be missing a specific fuel type, such as CNG).
    - Before using this method, ensure that all known 0s are present in your input data (e.g., if it is known that no CNG is used locally, ensure that the input data contain CNG rows for all model years, and that those rows contain a value of 0).
- Use defaults, preserve inputs:
    - For model years and source types where some fuel types are present in the input data, but not all, this method keeps the user inputs as-is and renormalizes the national default values to fill in the missing fuel types so that the fuel type distributions sum to 1.
    - This method is only useful when the modeler has information about a limited number of fuel types (for example, if you know the local sales fractions for EVs and want to use the default distributions for internal combustion vehicles).
    - This method would not be appropriate for a source type where vehicle registration data are available, as those registration data would include all fuel types, not just one. Therefore, EPA anticipates that this method would generally not be used in MOVES runs for SIP or transportation conformity purposes.

In summary, when data are missing altogether for a source type/model year, all three methods will fill the table in with default fuel type distributions, as is. The methods differ when data are incomplete for a source type/model year, as shown in Table 4-6:

**Table 4-6: AVFT Gap-Filling Methods Summary**

| Gap Filling Method | When data are incomplete for a source type / model year, this method: | This method is appropriate when: |
|---|---|---|
| **Automatic** | Fills missing fuel types with 0s | • The input data contain all model year and fuel type combinations in the local fleet<br>• Local data are not available or not applicable, e.g., for long-haul trucks |
| **Use defaults, renormalize inputs** | Fills missing fuel types with default data, and then renormalizes the input values so that the distributions sum to 1.0 | • Local data are incomplete, e.g., known to be missing a specific fuel type that is present in the local area |
| **Use defaults, preserve inputs** | Fills missing fuel types with default data, and then renormalizes only the default values so that the distributions sum to 1.0 | • Input data are only available for a single fuel type (e.g., the percentage of EVs is known)<br>• This method is generally not recommended for SIP or transportation conformity purposes |

**Projection Methods.** The AVFT Tool can be used to project fuel type distributions into the future, which is helpful when modeling a future year for which vehicle registration data do not yet exist. The AVFT Tool includes four projection methods: *Proportional, National Average, Known Fractions,* and *Constant.* The appropriate method to use varies by source type and depends on anticipated changes in future fuel type distributions.

In general:

- If the anticipated changes in future fuel type distributions are unknown for source types where local registration data are representative of the activity in the local area (e.g., light-duty vehicles, buses, and local heavy-duty trucks), the *Proportional* method should be selected. This method applies national trends in fuel type distributions to the local data.
- However, if anticipated changes in future fuel type distributions are known for certain source types (e.g., due to an enforceable ZEV program), the *Known Fractions* method should be selected.
- For source types where the local registration data are not representative of activity in the local area (e.g., long-haul vehicles), the *National Average* method should be selected.

The AVFT Tool's projection methods and when to select them are further described as follows:

- Proportional:
    - This method projects future fuel type distributions based on proportional differences between the local and the national distributions in the last complete model year in the input data. This preserves differences between local conditions and the national average, while still accounting for expected changes in national fuel type distribution trends. Note that this method includes boundary limits so that extreme differences between the national averages and local conditions will not be fully reflected in the projected data.

    - This method is recommended for source types that are expected to have a larger proportion of electric vehicles in the future, where their exact fractions are not known and using the national averages would not be appropriate.
    - This is the default method for all source types other than long-haul vehicles.
- National Average:
    - This method applies the national default fuel type distributions for all model years beyond the last complete model year in the input data.
    - This method is recommended for source types where local data are not available and/or not applicable, such as for long-haul source types.
    - This is the default method for Single Unit Long-haul and Combination Long-haul trucks.
- Known Fractions:
    - This method allows the user to provide known fuel fractions for specific source types and fuel types. Model year and fuel type combinations that are not provided by the modeler will be projected with the proportional method.
    - Known fractions can be provided for one or more fuel types and should be provided for all projected model years (that is, all model years between the last complete model year and the analysis calendar year).
    - This method is recommended for source types that have known future fractions. For example, this may be the case if the local area is subject to a ZEV program. In this case, the modeler would provide the projected ZEV rates as the known future EV fractions and not supply any of the other fuel types for future model years. The AVFT Tool would then use the proportional method to project the other fuel types.
- Constant:
    - This method applies the last complete model year in the input data distributions as-is to all projected model years.
    - This method is recommended for source types that are not expected to have significant changes in local fuel type distributions. For example, if the newest vehicles in the local fleet of refuse trucks were all CNG-fueled, and it is expected that all future additions to the fleet will also be CNG-fueled, this would be the appropriate method to choose.

These methods are summarized in Table 4-7 below.

**Table 4-7: AVFT Projection Methods Summary Table**

| AVFT Projection Method | Default Recommended Use | Considerations |
|---|---|---|
| **Proportional** | All source types except long-haul source types | |
| **National Average** | Single-unit long haul trucks<br>Combination long-haul trucks | Use for additional source types when local registration fractions are not available or not applicable |
| **Known Fraction** | -- | When future year fractions for any fuel type and source type are mandated by state or local law, or known for other reasons |
| **Constant** | -- | When current fractions are expected to remain constant in future years |

For detailed help on how to use the AVFT Tool, users should refer to the AVFT Tool help document, available by clicking the Open Help button from within the AVFT Tool GUI. This help document also includes an example on how to create an AVFT Table from registration data. After running the AVFT Tool, users should review the tool's output to ensure that the results appear reasonable based on local conditions.

If there is uncertainty as to what local data should be used, which projection methods should be chosen, or if the results appear reasonable, the interagency consultation process should be used to resolve those issues.

Documentation of a MOVES run for SIP or transportation conformity purposes should include the AVFT input file, rationale for the choice of last complete model year, and the AVFT Tool output file. See Section 2.6 of this guidance for additional discussion of documenting a MOVES analysis.

## *4.9 Inspection and Maintenance Programs*

Inspection and maintenance (I/M) programs continue to be important local control programs in many nonattainment and maintenance areas. MOVES includes the capability of modeling the essential design elements of an I/M program.

EPA recommends that users attempting to characterize the emissions impact of an I/M program use the same approach, as described below, for Inventory and Emission Rates runs. The emission rates calculated in MOVES will be based on the I/M program specified by the user.

EPA recommends that users modeling an existing I/M program in MOVES begin by examining the default I/M program description included in MOVES for the particular county in question. The default I/M data can be reviewed by selecting the Export Default Data button in the I/M Tab of the CDM. Users should review the details of the default I/M program and make any necessary changes to match the actual local program. In particular, users should note that grace period for

new vehicles or an exemption period for older vehicles in an I/M program need to be reflected in the beginning and ending model years based on the calendar year of evaluation as discussed in Section 4.9.5 of this document. Section 2.7 of this document references other guidance for documenting I/M programs.

The default I/M data (e.g., the geographic coverage of a current program and the model years addressed) have been updated in MOVES5. As a result, a converted I/M data table based on defaults in any previous version of MOVES should not be used with MOVES5. See Section 1.5 for general information about converting databases.

I/M programs are characterized in MOVES through an input called the IMCoverage Table. The IMCoverage Table consists of 13 columns:

- polProcessID
- stateID
- countyID
- yearID
- sourceTypeID
- fuelTypeID
- IMProgramID
- inspectFreq
- testStandardsID
- begModelYearID
- endModelYearID
- useIMyn
- complianceFactor

### 4.9.1 Pollutant Process ID

MOVES estimates emission reductions from I/M programs for hydrocarbons, NOx, and CO. For exhaust emissions, I/M programs can affect both running and start emissions. For evaporative emissions, I/M programs affect hydrocarbon emissions from fuel vapor venting and fuel leaks. Each combination of pollutant and process has a unique ID in MOVES, which is a concatenation of the pollutant ID and the process ID. Table 4-8 below shows the association between pollutants and processes for modeling an I/M program.

**Table 4-8: Pollutant Process Identifier Decoder**

| polProcessID* | pollutantID | pollutantName | processID | processName |
|---|---|---|---|---|
| 101 | 1 | Total Gaseous Hydrocarbons | 1 | Running Exhaust |
| 102 | 1 | Total Gaseous Hydrocarbons | 2 | Start Exhaust |
| 112 | 1 | Total Gaseous Hydrocarbons | 12 | Evap Fuel Vapor Venting |
| 113 | 1 | Total Gaseous Hydrocarbons | 13 | Evap Fuel Leaks |
| **201** | 2 | Carbon Monoxide (CO) | 1 | Running Exhaust |
| **202** | 2 | Carbon Monoxide (CO) | 2 | Start Exhaust |
| 301 | 3 | Oxides of Nitrogen (NOx) | 1 | Running Exhaust |
| 302 | 3 | Oxides of Nitrogen (NOx) | 2 | Start Exhaust |

*polProcessID is a concatenation of pollutantID and processID.

### 4.9.2 State ID

The stateID value defines the state in which the analysis is being conducted. This is the 2-digit, state-level Federal Information Processing Standard (FIPS) code for the state. If exporting a blank I/M Program template using the CDM, this value will be populated based on information selected in the MOVES RunSpec.

### 4.9.3 County ID

The countyID value defines the county for which the analysis is being conducted. This is the 5-digit FIPS code for the county. If exporting a blank I/M Program template using the CDM, this value will be populated based on information selected in the MOVES RunSpec.

### 4.9.4 Source Type ID and Fuel Type ID

These entries are used to describe the source (vehicle) types and fuel types included in the I/M program. Users should check to make sure that the vehicle and fuel types match the I/M program parameters for the vehicles included in the local program. MOVES currently calculates I/M program benefits only for gasoline vehicles.

I/M programs have historically applied to vehicles by regulatory weight class; however, MOVES applies I/M benefits by source type. This can lead to discrepancies between the number of vehicles covered in the actual I/M program and the number of vehicles that MOVES assumes is covered. For example, an I/M program that targets trucks with a Gross Vehicle Weight Rating (GVWR) less than 8501 lbs (i.e., EPA weight classes LDT1, LDT2, LDT3, and LDT4) would include parts of two MOVES source types: passenger trucks (sourceTypeID 31) and light commercial trucks (sourceTypeID 32). However, these source types also include vehicles with GVWR greater than 8501 lbs. When an I/M program is applied to source types 31 and 32 in MOVES, the benefits of the I/M program are applied to all the vehicles in these source types. Users need to adjust the compliance factor to account for the fraction of vehicles within a source type that are actually covered by the I/M program. This process is described in Section 4.9.6.

### 4.9.5 I/M Program ID

In MOVES, the IMProgramID is a numeric identifier used to differentiate between different parts of an I/M program such as different combinations of emission tests and vehicle coverage.

The IMProgramID is unique number for each combination of model year range, inspection frequency, and test standard. For example:

- OBD I/M programs for gasoline passenger cars that have both exhaust and evaporative inspection components should be modeled as two separate, simultaneous programs identified using different I/M program ID numbers in the I/M program ID column, as the two components are different test standards. If these tests also apply to gasoline light-duty trucks, the IMCoverage Table would include additional rows for passenger trucks (source type 31) and light commercial trucks (source type 32) that refer to the same two IMProgramIDs as used in the passenger car rows.
- An I/M program that applies different tests to different model years of the same vehicle type (e.g., an IM240 program that applies to gasoline passenger cars of older model years and an OBD program that applies to gasoline passenger cars of newer model years) would also be modeled as two separate, simultaneous programs identified using different I/M program ID numbers in the I/M program ID column, and using the beginning and ending model year columns to differentiate the model years covered by each program.

For a user defined I/M program, the IMProgramID column within the IMCoverage Table is assigned by the user.

### 4.9.6 Inspection Frequency

MOVES allows users to enter either annual or biennial test frequency. MOVES also allows an entry for continuous I/M, however, there are currently no emission benefits assigned to this option in MOVES, and it should not be selected. MOVES assigns slightly lower emissions benefit for biennial inspections than it does for annual inspections.

### 4.9.7 Test Standards ID

MOVES allows users to choose between 12 exhaust emissions tests and 7 evaporative emissions tests, as listed in Table 4-9.

**Table 4-9. MOVES I/M Emission Test Types**

| Test Standards ID | Test Standards Description | Description |
|---|---|---|
| 11 | Unloaded Idle Test | Test performed while vehicle idles in Park or Neutral |
| 12 | Two-mode, 2500 RPM/Idle Test | Test performed while vehicle idles and at 2500 rpm |
| 13 | Loaded / Idle Test | Test performed while vehicle operates on a chassis dynamometer at constant load |
| 21 | ASM 2525 Phase-in Cutpoints | Test performed on a dynamometer, under load, through a defined steady state driving cycle at 25 mph and 25% load, at phase-in cutpoints. |
| 22 | ASM 5015 Phase-in Cutpoints | Test performed on a dynamometer, under load, through two defined steady state driving cycles at 25 mph and 25% load, and 15 mph and 50% load, at phase-in cutpoints. |

| Test Standards ID | Test Standards Description | Description |
|---|---|---|
| 23 | ASM 2525/5015 Phase-in Cutpoints | Test performed on a dynamometer, under load, through two defined steady state driving cycles at 25 mph and 25% load, and 15 mph and 50% load, at phase-in cutpoints. |
| 24 | ASM 2525 Final Cutpoints | Test performed on a dynamometer, under load, through a defined steady state driving cycle at 25 mph and 25% load, at final cutpoints. |
| 25 | ASM 5015 Final Cutpoints | Test performed on a dynamometer, under load, through a defined steady state driving cycle at 15 mph and 50% load, at final cutpoints. |
| 26 | ASM 2525/5015 Final Cutpoints | Test performed on an inertia-weighted dynamometer through two defined steady state driving cycles at 25 mph and 25% load, and 15 mph and 50% load, at final cutpoints. |
| 31 | IM240 Phase-in Cutpoints | Test performed on a dynamometer, under load, through a pre-defined transient driving cycle of up to 240 seconds at phase-in cutpoints. |
| 33 | IM240 Final Cutpoints | Test performed on a dynamometer, under load, through a pre-defined transient driving cycle of up to 240 seconds. |
| 41 | Evaporative Gas Cap Check | A test conducted by pressurizing the gas cap for the purpose of identifying leaks in the gas cap. |
| 42 | Evaporative System Pressure Check | A test conducted by pressuring the evaporative system by way of the fuel tank's fillneck and sometimes referred to as the fillneck pressure (FP) test. |
| 43 | Evaporative System OBD Check | Test of the evaporative emission related systems and components performed by visual check of the MIL and scan of the OBD computer system for readiness, MIL status, and stored trouble codes, on 1996 and newer, OBD-equipped vehicles. |
| 44 | Evaporative Gas Cap and Pressure Check | A pair of tests to identify leaks in the gas cap (GC) and the rest of the vehicle's evaporative system. The latter test is conducted by pressuring the evaporative system by way of the fuel tank's fillneck and is referred to as the fillneck pressure (FP) test. |
| 45 | Evaporative Gas Cap and OBD Check | The evaporative OBD test performed in conjunction with a separate check of the gas cap (GC) for the purpose of identifying leaks in the gas cap not otherwise identified by the evaporative OBD check. This combination of tests can only be conducted on 1996 and newer, OBD-equipped vehicles. |
| 46 | Evaporative Pressure and OBD Check | The evaporative OBD test performed in conjunction with a separate fillneck pressure test. |

| Test Standards ID | Test Standards Description | Description |
|---|---|---|
| 47 | Evaporative Gas Cap, Pressure and OBD Check | The evaporative OBD test performed in conjunction with a separate fillneck pressure test and gas cap test. |
| 51 | Exhaust OBD Check | Test of exhaust-related systems and components performed by visual check of Malfunction Indicator Light (MIL) and scan of on-board (OBD) computer for system readiness, MIL status and stored trouble codes, on 1996 and newer OBD-equipped vehicles only |

### 4.9.8 Beginning and Ending Model Years

MOVES uses these two columns to specify the beginning and ending model years affected by a particular part of the I/M program. For I/M programs without a grace period for new vehicles or an exemption period for older vehicles, this is simply the first and last model year affected by the program.

For I/M programs with a grace period for new vehicles or an exemption period for older vehicles, this entry should reflect the actual model years covered by the program in the calendar year of evaluation. As a result, the beginning and ending model years for an I/M program may vary depending on the calendar year of analysis. For example, a typical OBD I/M program might apply to all model years beginning with 1996, and thus would list begModelYearID as 1996 for all relevant calendar years. However, if that program also includes a grace period during which newer vehicles are exempt from the program, the ending model year of the program should reflect the most recent model year included in the program based on the calendar year of analysis. For a program with a three-year grace period, a MOVES run for calendar year 2025 would list 2022 as the ending model year; similarly, a MOVES run for the same program in calendar year 2030 would list an ending year of 2027, and so on.

Similar adjustments to the beginning model year should be made to account for exemptions of older model years as well. In that case, the beginning model year of the program should reflect the earliest model year still being tested. For example, some programs include a 20-year rolling exemption, meaning that only the newest 20 model years are tested. Therefore, if the analysis year is 2025, the oldest model year still being tested in a program with this type of exemptions would be the 2005 model year, so the IMCoverage Table for analysis year 2025 would have a beginning model year of 2005 and ending model year of 2025. An analysis of the same program for calendar year 2030 would have a beginning model year of 2010.

***Tip: For I/M programs with grace periods or exemption periods, a unique set of I/M inputs will be needed for each calendar year modeled, because I/M beginning and end years will differ.***

Another type of I/M vehicle exemption is mileage-based vehicle exemption. There are two types of mileage-based exemptions that a few states have chosen to grant to motorists. The first type is similar to the grace period for newer vehicles mentioned above. For this type of mileage-exemption, a vehicle gets an "initial grace distance": a vehicle is exempted from its regular inspection until it has clocked a set number of miles on its odometer, for example, 40,000 miles. The second type of mileage exemption is based on the quantity of miles traveled since the vehicle's last required inspection cycle (annual or biennial period). For example, some I/M programs may allow vehicles to be exempt from I/M testing if they traveled less than 5,000 miles since their last annual registration renewal cycle.

Any area considering mileage-based exemptions should also consider how the odometer readings are to be tracked and verified for quality assurance purposes, especially if these exempt vehicles might not need to visit an emission inspection station. I/M programs with this type of exemption often also have a vehicle safety inspection program so that the odometer reading can be coordinated with the safety-portion of the vehicle's inspection and registration process.

Neither of these types of mileage-based exemptions can be directly input in the MOVES model since the model does not account for an individual vehicle's annual or accumulated VMT. As a result of this and since these vehicles receive no I/M benefit, both types of mileage-based exemptions should be treated like waived vehicles and as such should be included in the estimation of waiver rate (described below in Section 4.9.10).

For areas considering the first type of mileage-based exemption (an initial grace distance), it may be prudent and advantageous to consider a model year exemption (a grace period) instead, since, as discussed above, this can be directly input into MOVES.

### 4.9.9 UseIMyn

The MOVES I/M input parameters include a column labeled useIMyn, which allows the user to turn off ("N") or on ("Y") the portion of the I/M program described in that row of the table.

### 4.9.10 Compliance Factor

MOVES uses the compliance factor input to account for I/M program compliance rates, waiver rates, failure rates, and adjustments needed to account for the fraction of vehicles within a source type that are covered by the I/M program (these last adjustments will be referred to here as the "regulatory class coverage adjustment"). The compliance factor is entered as a decimal number from 0 to 100 and represents the percentage of vehicles within a source type that actually receive the benefits of the program. The compliance factor entered in MOVES is calculated as:

$$CF = CR \times (1 - WR \times FR) \times RCCA$$

Where
$CF$ = Compliance factor
$CR$ = Compliance rate
$WR$ = Waiver rate
$FR$ = Failure rate
$RCCA$ = Regulatory class coverage adjustment

The following subsections describe each component used to calculate the compliance factor.

#### 4.9.10.1 Compliance Rate

The compliance rate is the percentage of vehicles in the fleet covered by the I/M program that completes the I/M program and receives either a certificate of compliance (i.e., vehicles that pass inspection) or a waiver (i.e., vehicles that do not pass a retest but still receive a certificate). This is calculated by adding the number of vehicles that receive a certificate of compliance with the number of vehicles that receive a waiver, and dividing the sum by the number of total vehicles that are subject to I/M testing:

$$Compliance\ Rate = \frac{Compliant\ Vehicles + Waived\ Vehicles}{Subject\ Vehicles} \times 100$$

Historical compliance should be determined by sticker surveys, license plate surveys, or a comparison of the number of final tests to the number of vehicles subject to the I/M requirement.

Note, "Subject Vehicles" includes all vehicles registered in the county that meet the I/M program's model year and weight class requirements. Additionally, note that the compliance rate is a percentage between 0 and 100.

#### 4.9.10.2 Waiver Rate

For each IMProgramID, the waiver rate is the fraction of vehicles that fail an initial I/M test and do not pass a retest, but still receive a certificate. This is calculated as the number of vehicles that do not pass a retest but receive a certificate divided by the number of vehicles that fail an initial I/M test:

$$Waiver\ Rate = \frac{Waived\ Vehicles}{Initially\ Failing\ Vehicles}$$

Actual historical waiver rates should be used as the basis for estimating future waiver rates.

Note that the waiver rate is a fraction between 0 and 1.

#### 4.9.10.3 Failure Rate

For each IMProgramID, the failure rate is the fraction of all tested vehicles that fail an initial I/M test (regardless of the vehicle's final outcome). This is calculated as the number of vehicles that fail an initial I/M test divided by the number of unique vehicles that were tested:

$$Failure\ Rate = \frac{Initially\ Failing\ Vehicles}{Unique\ Vehicles\ Tested}$$

Actual historical failure rates should be used as the basis for estimating future failure rates.

Note that "Unique vehicles tested" is not the same as the total number of I/M tests because it does not include vehicle retests. Additionally, note that the failure rate is a fraction between 0 and 1.

#### 4.9.10.4 Regulatory Class Coverage Adjustment

I/M programs entered in MOVES are applied to source types. However, as discussed in Section 4.9.2, this association of I/M programs and source type may be inconsistent with state I/M program regulations that define I/M programs by the vehicle weight classes. MOVES source types are composed of several vehicle weight classes and, therefore, applying I/M benefits to the entire MOVES source type may be inappropriate. Table A-1 in Appendix A can be used to develop adjustments to the compliance factor to account for this discrepancy. The adjustments are population fractions of vehicles by the various regulatory weight classes within a source type. After reviewing the table, users should sum the adjustments for weight classes within a source type that are covered by an I/M program. This sum provides users with a multiplicative factor that can be applied when calculating the compliance factor, as described above. An example of this process is provided in the next section. Note that the adjustment factor is a fraction between 0 and 1.[64]

Users who believe a local set of regulatory class coverage adjustments are more appropriate than the Table A-1 defaults should provide documentation in the SIP or regional conformity analysis of the local data and methods used to derive those adjustments.

#### 4.9.10.5 Example Compliance Factor Calculation

Using the example from Section 4.9.2, an I/M program that targets trucks less than 8501 lbs GVWR (i.e., EPA weight classes LDT1, LDT2, LDT3, and LDT4) would include some vehicles from two MOVES source types: passenger trucks (sourceTypeID 31) and light commercial trucks (32). Users should first determine the compliance rate, waiver rate and failure rate for the trucks covered by that program. For this example, we will assume that the compliance rate is 95%, the waiver rate is 0.25, and the failure rate is 0.20.

The user would then determine the regulatory class coverage adjustment by summing the percentages of those regulatory classes less than 8501 lbs GVRW separately for source types 31 and 32 using the information in Table A-1 in Appendix A. For source type 31, the regulatory class coverage adjustment is 0.9727. For source type 32, the regulatory class coverage adjustment is 0.7630.

Using these results, the compliance factor for source type 31 is:

$$CF = CR \times (1 - WR \times FR) \times RCCA$$
$$87.7862\% = 95\% \times (1 - 0.25 \times 0.20) \times 0.9727$$

The compliance factor for source type 32 is:

$$CF = CR \times (1 - WR \times FR) \times RCCA$$
$$68.8608\% = 95\% \times (1 - 0.25 \times 0.20) \times 0.7630$$

These values would be entered as compliance factors of 87.7862 for source type 31 and 68.8608 for source type 32.

[64] As of MOVES3.1, Class 2b and 3 gasoline trucks with a gross vehicle weight rating of between 8,500 and 14,000 pounds (Regulatory Class 41) receive the same proportional I/M benefit for exhaust emissions as lower classification gasoline trucks.

## *4.10 Starts*

The Starts Tab is used to import local information on vehicle start activity. This input is optional and should only be used if local data are available. There are several sources for vehicle start information. In the past, this has typically been derived from origin/destination surveys used for travel demand modeling but could also be derived using telematics data.[65] If no starts information is available, this importer should not be used and MOVES will calculate start activity based on user-supplied vehicle populations (via the SourceTypeYear input) and default assumptions of vehicle activity.

The following information about starts applies primarily to MOVES running in Inventory mode. However, the StartsOpModeDistribution input table discussed below can be used in either Inventory mode or Emission Rates mode.

The Starts Tab contains importers for multiple tables, which interact to calculate vehicle start activity in MOVES. Users have the option of directly importing detailed data into the Starts table, which contains start information by source type, hour, day, month, and vehicle age. However, local data may not be available to populate every dimension of the Starts table. Therefore, users also have the option to provide some local information via shaping tables and to rely on default assumptions for dimensions not covered by the local data.

The importers available under the Starts Tab include:

- StartsPerDayPerVehicle,
- StartsPerDay,
- StartsHourFraction,
- StartsMonthAdjust,
- StartsAgeAdjustment,
- StartsOpModeDistribution, and
- Starts.

Table 4-10 below summarizes the tables available in the Starts tab.

[65] For an example of how telematics data were used to derive MOVES starts inputs, see Evaluating the Sensitivity of MOVES2014a to Local Start Activity Data, Coordinating Research Council Report No. A-106, December 2017.

**Table 4-10: Summary of Options under the Starts Input**

| Type of Table | Table Name | Usage |
|---|---|---|
| **Entire Starts table:** If Starts table used, do not use other tables to enter number of starts or shaping tables | Starts | Use when you have all information: starts by sourceTypeID, hourDayID, modelYearID, monthID |
| **Tables to enter number of starts:** Use only one of these two tables, in combination with any shaping tables | StartsPerDayPerVehicle | Use when you know the starts per vehicle |
| | StartsPerDay | Use when you have the total number of starts per day |
| **Shaping Tables:** Use any of these tables in combination with StartsPerDayPerVehicle or StartsPerDay | StartsHourFraction | Use when you know the distribution of starts throughout the day |
| | StartsMonthAdjust | Use to adjust start activity by month |
| | StartsAgeAdjust | Use to adjust start activity by vehicle age |
| **Other** | StartsOpModeDistribution | Adjusts vehicles soak times |

The Starts, StartsPerDayPerVehicle, and StartsPerDay tables can be used to provide the number of vehicle starts, depending on data availability and format.

StartsHourFraction, StartsMonthAdjust, and StartsAgeAdjustment are shaping tables that can be used individually or with any of the other tables (except for the Starts table, as explained below) to adjust or allocate the number of vehicle starts.

StartsOpModeDistribution is a separate input, which is described below.

In the case where a modeler supplies one or more of StartsPerDayPerVehicle, StartsPerDay, or any of the shaping tables, MOVES will use that information to calculate the Starts table and will rely on default information for the inputs not provided. For instance, if the user provides only total starts per day through the StartsPerDay table, those values will be allocated to hour and adjusted by month and vehicle age based on MOVES default allocations and adjustments.

Users should confirm in the output that MOVES used the correct number of starts. By selecting "Starts" Activity in the General Output Panel of the RunSpec, the number of starts used in the MOVES run will be reported in the MOVESactivityoutput table of the output database. This table can be used to confirm that the correct number of starts and/or correct allocations were used in MOVES.

**Starts**

The Starts table, which appears last in the list of start importers, can be used to completely replace the MOVES-calculated Starts table. To use this input, vehicle starts information must be

available for all fields and information on starts must be provided by monthID, hourDayID, sourceTypeID, and vehicle ageID. This importer should not be used in conjunction with StartsPerDayPerVehicle, StartsPerDay, StartsHourFraction, StartsMonthAdjust, or StartsAgeAdjustment. Note that a complete table must be provided, including all combinations of monthID, hourDayID, and sourceTypeID selected in the RunSpec. If the user has some but not all of the information required for this table, use one or more of the tables described below instead of the Starts table, as appropriate.

**StartsPerDayPerVehicle**
The StartsPerDayPerVehicle table can be used when the average number of starts per vehicle by source type is known for a typical weekday and weekend day (dayIDs 5 and 2, respectively). When using this table, MOVES will calculate total starts by combining this information with the user-supplied source type population data (this input is described in Section 4.3). StartsPerDayPerVehicle can be used independently or in combination with other start tables (except "Starts" or StartsPerDay).

**StartsPerDay**
The StartsPerDay table can be used when the total number of vehicle starts by source type is known for a typical weekday or weekend day (dayIDs 5 and 2, respectively). When using this table, MOVES will use the total vehicle starts provided and will not use source type population information to calculate number of starts. This input can be used independently or in combination with other start tables (except "Starts" or StartsPerDayPerVehicle).

**StartsHourFraction**
The StartsHourFraction table can be used when local start information is available by hour of day. Fractions can be provided by the user to allocate starts to the appropriate hour. Fractions should be provided for both day types, weekday and weekend day, and they should sum to one for each day type. This input can be used independently or in combination with other start tables (except "Starts").

**StartsMonthAdjust**
The StartsMonthAdjust table can be used to vary the vehicle starts between different months. An adjustment factor of 1.0 for each month will model the unlikely situation where annual starts are evenly divided between months. Usually, start activity increases in the summer and decreases in the winter. Local starts information can be used to adjust starts up or down depending on the month (or season) by changing the adjustment factors for each month. These adjustment factors are applied directly to the calculated starts per day. For example, a value of 1.12 for sourceTypeID 21 and monthID 8 will increase the calculated passenger car starts in August by 12%. This input can be used independently or in combination with other start tables (except "Starts").

**StartsAgeAdjustment**
The StartsAgeAdjustment table can be used when local start information is available by vehicle age. This table makes relative adjustments to starts per vehicle by age. It is important to note that the absolute values in this table are not used; only the relative differences between ages affect the distribution of calculated vehicle starts.

To illustrate this input with an overly simplified example using passenger cars: if in the StartsAgeAdjustment table, ageIDs 0-9 are assigned a value of 1, ageIDs 10-19 are assigned a value of 0.8, and ageIDs 20-40 are assigned a value of 0.5, then a new car will be modeled with 1.25 times the starts per vehicle as a 10-year-old car and twice the starts per vehicle as a 20-year-old car (as 1.25 is the ratio between 1 and 0.8, and 2 is the ratio between 1 and 0.5, respectively). A 10-year-old car will be modeled with 1.6 times the starts per vehicle of a 20-year-old car (as 1.6 is the ratio between 0.8 and 0.5). Furthermore, because the absolute values in this table are not used, the same results would be obtained if adjustment values of 10, 8, and 5 were used instead, as they have the same proportional differences.

The StartsAgeAdjustment input conserves the total number of starts. That is, providing this input will not change the number of vehicle starts (either provided directly in StartsPerDay, calculated from StartsPerDayPerVehicle, or when relying on MOVES defaults). Instead, it only affects the allocation of starts per vehicle by vehicle age. The StartsAgeAdjustment table is used by MOVES in conjunction with the SourceTypeAgeDistribution table (this input is described in Section 4.4) to determine total vehicle starts by age.

The StartsAgeAdjustment input can be used independently or in combination with other start tables (except "Starts").

**StartsOpModeDistribution**

The StartOpModeDistribution table can be used to provide local soak-time distributions by source type, day type, hour, and vehicle age. A soak-time is the period between "key-off" and "key-on." If local data are available, the MOVES default soak-time assumptions can be overwritten by changing the opmodedistribution fractions in this table. This input can be used independently or in combination with any of the other start tables (including "Starts"). Note that this table only affects start emissions; evaporative emissions will not be affected by changing this table.

## *4.11 Hotelling*

The Hotelling Tab is used to import information on long-haul combination truck hotelling activity. This input is optional and should only be used if local data are available. If no hotelling information is available, this importer should not be used, and MOVES will calculate hotelling activity based on long-haul combination truck VMT on restricted access roads.

> ***Tip: All hotelling processes apply only to long-haul combination trucks, sourceTypeID 62.***

The following information about hotelling applies primarily to MOVES running in Inventory mode. However, the HotellingActivityDistribution input table discussed below can be used in either Inventory mode or Emission Rates mode.

Hotelling is defined in MOVES as any period of time one hour or longer that drivers of long-haul combination trucks spend resting in their vehicles during mandated down times while

making long distance deliveries. During the mandatory down time, drivers can stay in motels or other accommodations, but most of these trucks have sleeping spaces built into the cab of the truck and drivers stay with their vehicles. Hotelling activity is included in MOVES in order to account for use of the truck engine (referred to as "extended idling") to power air conditioning, heat, and other accessories and account for the use of auxiliary power units (APU), which are small onboard power generators. Extended idling while hotelling results in emissions that are different from incidental idling while operating on roads (which is included in the underlying drive cycles used to calculate running emissions in MOVES) and from off-network idling addressed in Section 4.12. Emissions from hotelling are reported as four processes:

- Extended Idle Exhaust, for truck engine emissions,
- Crankcase Idle Exhaust, also for truck engine emissions,
- Auxiliary Power Exhaust, for APU emissions, and
- Hotelling Shore Power, for energy consumption used when plugged in.

The Hotelling Tab contains five importers. Depending on the information available, one or more of these importers can be used to supply local hotelling information. These importers are:

- HotellingHoursPerDay,
- HotellingHourFraction,
- HotellingAgeFraction,
- HotellingMonthAdjust, and
- HotellingActivityDistribution.

Typically, local data will not be available to populate all of these tables. In a case where a user supplies information for only some of these importers, MOVES will use that information and will rely on default information for the inputs not provided. For instance, if the only local information available is the number of hotelling hours per day, this information can be provided through the HotellingHoursPerDay table. MOVES will distribute the total hotelling hours per day by hour of the day, month, vehicle age, and type of hotelling activity based on default allocations and adjustments. If local data are used to populate any of these tables, users should fully document how those data were collected.

**HotellingHoursPerDay**

The HotellingHoursPerDay table can be used when the total hours of hotelling per day are known. Total hotelling hours should be provided for a typical weekday and weekend day (dayIDs 5 and 2, respectively). Total hotelling hours should include total time spent in all of the four operating modes defined in the HotellingActivityDistribution table. This input can be used independently, or in combination with other hotelling input tables. Users can confirm the number of hotelling hours used by MOVES by selecting "Hotelling Hours" Activity in the General Output Panel of the RunSpec. The hotelling hours used in the MOVES run will be reported in the MOVESactivityoutput table of the output database.

**HotellingHourFraction**

The HotellingHourFraction table can be used when local hotelling information is available by hour of the day. Fractions can be provided by the user to allocate hotelling activity to the appropriate hour. Fractions should be provided for both day types, weekday and weekend day,

and they should sum to one for each day type. This input can be used independently or in combination with other hotelling input options.

**HotellingAgeFraction**
The HotellingAgeFraction table can be used when local hotelling information is available by age, e.g., to account for newer trucks having more hotelling activity. The fractions in the table allocate hotelling activity by vehicle age, and therefore they should sum to 1.0. This input can be used independently or in combination with other hotelling input options.

**HotellingMonthAdjust**
The HotellingMonthAdjust table can be used to vary hotelling activity between different months. An adjustment factor of 1.0 for each month will model a situation where annual hotelling hours are evenly divided between months. Local hotelling information can be used to adjust hotelling hours up or down depending on the month (or season) by changing the adjustment factors for each month. These adjustment factors are applied directly to the hotelling hours per day. For example, a value of 1.1 for monthID 1 will increase the hotelling hours per day in January by 10%. This input can be used independently or in combination with other hotelling input options.

**HotellingActivityDistribution**
The HotellingActivityDistribution table can be used to change the default operating mode distribution of hotelling activity by model year. MOVES divides hotelling activity into four operating modes:

1. Extended Idle: long-duration idling with more load than standard idle and a different idle speed. It is used to account for emissions during hotelling operation when a truck's engine is used to support loads such as heaters, air conditioners, microwave ovens, etc.
2. Diesel Auxiliary Power (APU): the use of diesel-fueled auxiliary power units that allow for heating/cooling/power for the cab without running the truck's engine.
3. Shore Power (plug-in): the use of electric infrastructure to provide power for heating/cooling/power for the cab without running the truck's engine.
4. Battery or All Engines/Accessories Off: hotelling when the truck's engine is off, an APU and truck-stop electrification are not being used.

In most cases, users should rely on the national default hotelling operating mode fractions. However, if local data are supplied, this input can be used independently or in combination with other hotelling input options.

## *4.12 Idle Data*

There are three types of idling activity that MOVES accounts for:

- *Extending idling* can occur when long-haul combination trucks are resting. This type of idling is represented by hotelling information, which is discussed above in Section 4.11 and not in this section.

- *Idling associated with driving* occurs with all vehicle types. The drive cycles in MOVES account for idling at traffic signals, stop signs, and in traffic as part of the running exhaust and crankcase running exhaust processes on the urban and rural restricted and unrestricted

road types. MOVES determines the amount of this type of idling based on average speed distribution and road type distribution inputs, which are covered in Sections 4.6. and 4.7, respectively.

- MOVES also accounts for *off-network idling*. Off-network idle (ONI) is defined in MOVES as time (other than hotelling) during which a vehicle engine is running idle not as part of a drive cycle. ONI could occur, for example, in a parking lot, in a driveway, or on the shoulder of a road. This engine activity contributes to total mobile source emissions and in MOVES it is accounted for on the off-network road type.

  Some examples of ONI activity include:
  - Light-duty passenger vehicles idling while waiting to pick up children at school or to pick up passengers at the airport or train station,
  - Single unit and combination trucks idling while loading or unloading cargo or making deliveries, and
  - Vehicles idling at drive-through restaurants.

  Emissions during these types of events are included in MOVES output as running exhaust and crankcase running exhaust on the off-network road type.

The user input on the Idle Tab is the *total idle fraction*, which is the total time spent idling divided by the source operating time (see below for more details). MOVES calculates off-network idling activity as the difference between total idle activity and idling associated with driving. Therefore, if this optional information is provided, it will only affect the calculation of off-network idling activity; it will not change how MOVES estimates idling associated with driving, which is determined based on average speed distributions and road type distributions as described above.

This user input is optional and should only be used if better local idling data are available. The default data included in MOVES for light-duty vehicles were derived from telematics data that included about 40 million trips. The default data used for heavy duty vehicles were derived from a study of 415 vehicles during over 120,000 hours of operation.[66] Survey data, limited observations, or assumptions about efficacy of idle restrictions should not be used to replace the default data in MOVES.

Section 4.12.1 provides guidance on how to import local idling data when running MOVES in Inventory mode. Local idling data do not need to be imported when running MOVES in Emission Rates mode. However, guidance on how to calculate an off-network idle emission inventory when using Emission Rates mode, with or without local idling data, is provided in Section 4.12.2. Including the ONI emissions is a necessary step in calculating a complete emissions inventory when using the Emission Rates mode.

[66] For more information on the default idle activity data in MOVES and how off-network idling is calculated, see Section 10 of the technical report *Population and Activity of Onroad Vehicles in MOVES5* (EPA-420-R-24-019), available at MOVES Onroad Technical Reports.

### 4.12.1 Off-network Idle: Guidance for Inventory Mode

The Idle Tab contains four importers. This tab is optional and should only be used if better local data for vehicle idling are available. Depending on the information available, one of two primary input tables can be used: TotalIdleFraction or IdleModelYearGrouping. Additionally, if the IdleModelYearGrouping table is supplied, IdleMonthAdjust and IdleDayAdust should also be supplied; default MOVES assumptions will not be used to supplement any user-supplied data for these inputs. Note, if local data are used to populate any of these tables, users should fully document how those data were collected.

**TotalIdleFraction**

The TotalIdleFraction table can be used if local data are available on the total time spent idling as a fraction of source hours operating by source type, model year range, month, and day type. The fractions here are total idle times, which include off-network idle as well as idling occuring on roadways (such as incidental idle at signals, stop signs, and in traffic). For example, a total idle fraction of 0.22 represents 22% of time between a vehicle's "key-on" and "key-off" is spent idling. However, note that for long-haul combination trucks, this fraction should not include idle time while hotelling, as that is a separate process (see Section 4.11 for more information). If this table is used, IdleModelYearGrouping, IdleMonthAdjust, and IdleDayAdjust should not be used.

**IdleModelYearGrouping**

The IdleModelYearGrouping table is an alternate input for providing the total time spent idling (including off-network idle as well as idling occuring on roadways) as a fraction of source hours operating. The units are the same as for the TotalIdleFraction table, but this table may be preferable, depending on the format of the local data, as it allows the user to provide total idle fraction data by source type and model year range. However, note that if this table is used, IdleMonthAdjust and IdleDayAdjust should also be supplied.

**IdleMonthAdjust**

The IdleMonthAdjust table is used to vary idle activity provided in the IdleModelYearGrouping table between different months. An adjustment factor of 1.0 for each month will model a situation where the total idle fraction does not change between months. Local idling information can be used to adjust the idle fraction up or down depending on the month (or season) by changing the adjustment factors for each month.

**IdleDayAdjust**

The IdleDayAdjust table is used to vary idle activity provided in the IdleModelYearGrouping table by day type (weekday or weekend day). An adjustment factor of 1.0 for each day will model a situation where the total idle fraction does not change by day type. Local idling information can be used to adjust the idle fraction up or down for weekdays separately from weekend days.

### 4.12.2 Off-network Idle: Guidance for Emission Rates Mode

When using the Emission Rates mode, the user calculates off-network idle emissions by multiplying the roadTypeID 1 emission rates in the RatePerDistance table with the corresponding hours of off-network idling activity. The hours of activity should be provided at the same level of detail as the emission rates. For example, if source type is selected in the

output emission detail, then the hours of off-network idling activity should include detail at the source type level. Note that all other emission rates in the RatePerDistance table are in units of mass per distance; only the roadTypeID 1 emission rates in this table are in units of mass per hour.

Also note that the relevant idle activity data are different between Inventory mode and Emission Rates mode: in Inventory mode, the user input is TotalIdleFraction, whereas in Emission Rates mode, the idle activity data are hours of off-network idle.

If local data on the number of hours of off-network idling are unavailable, default MOVES data for this activity may be used instead, which can be obtained using the ONI Tool. This feature is available by opening the Tools drop-down menu in the MOVES GUI and selecting ONI Tool. The ONI Tool combines data in the user input database with MOVES default data to provide the same hours of off-network idling that MOVES would internally calculate when running in Inventory mode. Therefore, users need to complete their RunSpec and finish populating their input database before running this tool. The ONI tool can be run before or after MOVES is run, as long as the input database is the same. The ONI Tool outputs hours of idling activity that the user can then multiply by the corresponding roadTypeID 1 emission rates in the RatePerDistance table. Detailed instructions on how to use the ONI Tool are available in the MOVES GUI: after opening the tool via the Tools drop-down menu, click the "Open Instructions" button.

## *4.13 Retrofit Data*

The Retrofit Data Tab in MOVES allows users to enter heavy-duty diesel retrofit and/or replacement program data that apply adjustments to vehicle emission rates. For example, a replacement program may fund the purchase of electric or CNG heavy-duty vehicles to replace diesel ones. Users are not required to input such data into MOVES; they would only do so if they have a retrofit or replacement program that they want to model. There are no default retrofit or replacement data in MOVES. Users should consult the latest version of EPA's guidance for estimating the emission reductions from these programs for SIP and conformity purposes available on EPA's Guidance on Control Strategies for State and Local Agencies website.

## *4.14 Stage II Refueling Programs*

MOVES can model the effects of Stage II vehicle refueling controls. The two types of refueling emissions included in MOVES are vapor displacement and spills. Stage II control programs can affect both types of losses and therefore emissions, and MOVES allows the user to specify the impact of controls on each type separately. The impact of controls for refueling losses are affected by a combination of the efficiency of the control technology, the coverage of the program (including the impact of exemptions) and the state of repair of the equipment, which is affected by the frequency of formal inspections.[67]

[67] Two of the 12 hydrocarbon emission categories, refueling displacement vapor loss and refueling spillage loss, are sometimes included in the SIP as an area source and left out of the onroad mobile source inventory and motor vehicle emissions budget. In that case, the two refueling emission processes which are not included in the motor vehicle emission budget would not be included in a regional conformity analysis. The interagency consultation process should be used to confirm that there is consistency in the approach used to account for refueling emissions in the SIP and regional conformity analysis.

There is currently no dedicated importer for this in the CDM. Stage II information is included in the CountyYear table. An alternative CountyYear table can be imported using the Generic Tab (described below). Using this tab, users can export the default CountyYear table for the county being modeled, modify the values as necessary, and import a revised table.

MOVES includes default county-level Stage II control efficiencies, with a value of zero for counties and years that do not have an active program. These values were updated for MOVES5, but users should check that the default data are accurate for the local area. MOVES separates the Stage II control efficiency into two factors, a refueling vapor adjustment factor, and a spillage adjustment factor, which are measures of the efficiency of the Stage II program at reducing vapor displacement and spillage. Calculation of Stage II efficiency is addressed in Section 4 of the EPA document *Volume IV: Chapter 1, Preferred and Alternative Methods for Gathering and Locating Specific Emission Inventory Data*. In the absence of any local information that differentiates the efficiency of the Stage II program for controlling vapor displacement and spillage, a value of 0 should be used for the spillage adjustment factor.

## *4.15 Generic*

The Generic Tab can be used to export, modify, and re-import any of the default MOVES tables not covered by specific tabs in the CDM. Users should note that there are complex interactions between tables in MOVES, and there may be unintended consequences from changing any table. Other than the Stage II inputs mentioned above, most tables should never be changed, and results will not be acceptable if such tables are modified. EPA recommends that users consult with their EPA Regional Office before modifying any of the default MOVES tables accessible through the Generic Tab.

# Section 5. Developing Nonroad Inventories with MOVES

The onroad and nonroad modeling capabilities exist as separate modules in MOVES, and users must select one or the other in each run of the model.

The basic nonroad emission rates and population and activity estimates in MOVES5, including estimates of population growth, have not changed from MOVES4. However, MOVES5 should be used when modeling nonroad emissions because it includes updated fuel information, which does affect estimates of nonroad emissions.

MOVES-Nonroad can be used to estimate emissions from 12 different sectors of nonroad equipment containing 88 equipment types at the county level based on default assumptions of county-level nonroad equipment populations and activity. Nonroad equipment population growth rates in MOVES are based on state and regional growth estimates.[68] Equipment populations and activity are then allocated to the state and county level based on surrogates such as construction spending for construction equipment, harvested cropland for agricultural equipment, number of manufacturing employees for industrial equipment, etc.[69] While this approach has limitations, EPA recognizes that estimating local data on nonroad equipment populations and activity can be challenging, so relying on MOVES default nonroad population and activity data is acceptable for SIPs and other regulatory purposes.

The rest of this section addresses the development of nonroad RunSpec files, importing local meteorological and fuel data, and alternatives to using default nonroad population and activity data for developing local nonroad emissions inventories.

In addition to the information here, modelers may want to review EPA's MOVES Hands-on Training Course, available on EPA's MOVES Training website. The training course includes information specifically about using the MOVES-Nonroad, including an exercise to illustrate how to create an emissions inventory for nonroad sources.

## *5.1 Developing a Nonroad RunSpec*

This section focuses on the navigation panels that differ from the equivalent onroad panels.

### 5.1.1 Scale

When Nonroad is selected as the model type, Default Scale is the only option for domain/scale. Default Scale uses the national and county-level default information in MOVES to calculate inventories at the national or county level. Users can create an input database with the Nonroad Data Importer to enter local meteorology, fuels, and retrofit data.

"Inventory" is the only option offered for Calculation Type. Users who want to work with nonroad emission rates or want to apply local nonroad equipment population and activity data

[68] For more information, see *Nonroad Engine Population Growth Estimates in MOVES2014b*, July 20218, EPA-420-R-18-010.
[69] For additional details, see *Geographic Allocation of Nonroad Engine Population Data to the State and County Level*, December 2005, NR-014d.

can use post-processing scripts in MOVES to convert inventory output to emission rates. These scripts are available in the Post Processing Menu. See Section 5.3 for more information.

### 5.1.2 Time Spans

MOVES-Nonroad does all calculations at the day level with no hourly detail. Multiple years, months, and day types can be specified in a single RunSpec, but not individual hours. Users creating a nonroad input database for a nonroad run in MOVES should limit the RunSpec to a single year. Users should choose the appropriate months for the pollutant being analyzed, e.g., months representing the ozone season for NOx and HC, the months of the $PM_{2.5}$ season or episode for the 24-hour $PM_{2.5}$ standard, or the winter CO season. To develop an annual inventory, all months should be selected. Choice of day type should be consistent with choices made for the onroad portion of the inventory.

### 5.1.3 Geographic Bounds

MOVES-Nonroad allows for the selection of multiple counties in a single RunSpec. However, users creating a nonroad input database through the Nonroad Data Importer should limit the RunSpec to a single county.

Note that the output from MOVES-Nonroad is for individual counties. Post-processing may be needed to adjust results to the boundaries of the analysis (e.g., a nonattainment or maintenance area).

### 5.1.4 Vehicles/Equipment: Nonroad Vehicle Equipment

MOVES-Nonroad divides nonroad equipment into 12 economic sectors containing 88 equipment types. These sectors are:

- Agriculture
- Airport Support
- Commercial
- Construction
- Industrial
- Lawn/Garden
- Logging
- Oil Field
- Pleasure Craft
- Railroad
- Recreational
- Underground Mining

The Nonroad Equipment Panel lets users select nonroad equipment by a combination of sectors containing specific equipment types and the fuel that those equipment types can use. For a list of equipment included in each sector, see Appendix B. The fuel types available include compressed natural gas, gasoline, liquified petroleum gas, marine diesel fuel, and nonroad diesel

fuel. Note that since MOVES-Nonroad does not model emissions from electric equipment, users may assume these equipment have zero emissions.[70]

For SIP analyses, users should select all valid sector and fuel combinations that occur within the modeled geographic domain. Note that MOVES-Nonroad does not model emissions from locomotives, commercial marine vessels, or aircraft.[71]

### 5.1.5 Road Type

There is only one Nonroad road type ("Nonroad"), and it will automatically be selected in the Road Type Panel.

### 5.1.6 Pollutants and Processes

The pollutant processes in MOVES-Nonroad are mutually exclusive types of emissions; therefore, users must select all processes associated with a modeled pollutant to account for all emissions of that pollutant.

### 5.1.7 Output

The Output Panel provides access to two additional panels, General Output and Output Emissions Detail, which operate in a similar manner to the corresponding panels in MOVES-Onroad (see Sections 3.8 and 3.9). In general, users can generate output in whatever form works best for their specific needs. The following subsections provide guidelines to consider when specifying output details and format.

#### 5.1.7.1 General Output

The General Output Panel in MOVES-Nonroad does not include an option to select specific activity output options. By default, MOVES-Nonroad includes all applicable activity types in the MOVESActivityOutput table populated during the run.

#### 5.1.7.2 Output Emissions Detail

This panel allows the user to select the level of detail reported in the output database. As noted in Section 5.1.2, MOVES-Nonroad does all calculations at the day level. County is the recommended selection for Location. If MOVES-Nonroad results will be post-processed using a script provided with MOVES (e.g., an emission factor script), choices in this panel must be compatible with the script. The use of emission factors scripts is described in detail in Section 5.3 below.

## *5.2 Use of the Nonroad Data Importer*

The Nonroad Data Importer is accessed from the Create Input Databases Panel by selecting "Enter/Edit Data." Once a database is selected or created, the importer provides three tabs, each of which opens importers that are used to enter specific local data:

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[70] See also the nonroad equipment portion of EPA's FAQ about modeling electric vehicles and equipment.

[71] The "Railroad" sector in MOVES-Nonroad includes only railway maintenance equipment; "Pleasure Craft" includes only personal watercraft and recreational boats with outboard or inboard/sterndrive motors; and "Airport Support" includes only ground support equipment used at airports. For information about modeling emissions from locomotives, commercial marine vessels, and aircraft, see EPA's Emissions Models and Other Methods to Product Emission Inventories website.

- Meteorology
- Fuel
- Generic (used for importing user data to the nonroad retrofit table (nrRetrofitFactors) as well as equipment population and activity tables)

Each tab allows the user to create and save a template file with column headings and other key fields populated. The modeler then enters local data into the created template using a spreadsheet application (e.g., Microsoft Excel) and imports the edited spreadsheet into MOVES. In some cases, there is also the option to export default data from the MOVES database, which can be reviewed and/or edited. Once the modeler determines that the default data are accurate and applicable to the analysis or determines that the default data need to be changed and makes those changes, they would then import that data into MOVES. Details of the mechanics of using the data importers are provided in the MOVES training materials (see Section 1.6). Guidance for the use of the data importers for SIPs is given below.

### 5.2.1 Meteorology

MOVES-Nonroad uses the same default meteorology data as MOVES-Onroad. For SIPs, EPA recommends using local meteorology data for each month that is specified in the RunSpec. The choice of specific temperature and humidity data may depend on the type of analysis being performed:

- For air quality modeling of a specific exceedance episode (e.g., for SIP attainment modeling), hourly meteorological data for the episode or for a longer period may be necessary.
- For more generic modeling of average summer or winter day ozone, $PM_{2.5}$, or CO conditions, users should input average daily temperature profiles for the months when exceedances typically occur (in coordination with the EPA Regional Office):
    - For ozone season analysis, users should enter either the local average temperature profile for the period chosen to represent the area's ozone season (typically June, July and August; or July, August, and September).
    - For $PM_{2.5}$ season or episodic analysis, users should enter the local average temperature profile for the chosen months.
    - For CO season analysis, users should enter the either local average temperature profile for January, or the local average temperature profile for the three-month period that best represents the CO season (typically December, January, and February).
- For an annual analysis, users need to enter the local average temperature profile for all months.

For a given analysis, the nonroad inventory should be based on the same meteorology data used for the onroad inventory – see Section 4.2 for guidance about meteorology data for onroad MOVES runs. Local average temperature profiles can be based on the average minimum and maximum temperatures.

### 5.2.2 Fuels (Fuel Supply and Fuel Formulation)

MOVES-Nonroad uses two tables, the NRFuelSupply and FuelFormulation tables, that interact to define the fuels used in the modeling domain.

- The NRFuelSupply table identifies the fuel formulations used in a region and each formulation's respective market share. This is a separate table from the onroad fuel supply, which is simply called the FuelSupply table.
- The FuelFormulation table defines the properties (such as RVP, sulfur level, ethanol volume, etc.) of each fuel. This is the same table as used in the onroad portion of MOVES.

The MOVES defaults for both tables are accessible using the Export Default Data button in the Fuel Tab of the Nonroad Data Importer. The NRFuelSupply table serves the same function as the FuelSupply table in MOVES-Onroad. For a full description of the FuelSupply and FuelFormulation tables and data fields, see Section 4.8.1 of this document.

In MOVES5, the default values in the FuelFormulation and NRFuelsupply tables are based on the information in the fuel supply report for MOVES5,[72] and do not necessarily reflect later changes made to local fuel requirements (e.g., an area becomes subject to the Federal reformulated gasoline requirement). Users should first review the default fuel formulation and fuel supply, and then make changes only where precise local volumetric fuel property information is available or where local fuel requirements have changed.[73] Where local requirements have not changed, EPA strongly recommends using the default fuel properties for a region unless a full local fuel property study exists. Because fuel properties can be quite variable, EPA does not consider single or yearly station samples adequate for substitution.

One exception to this guidance is in the case of Reid Vapor Pressure (RVP) where a user should change the value to reflect any specific local regulatory requirements and differences between ethanol- and non-ethanol blended gasoline not reflected in the default database. Any changes to RVP (or to any other gasoline formulation parameters) should be made using the "Fuels Wizard" tool in the Fuel Tab of the Nonroad Data Importer. This tool can be used to adjust unknown gasoline properties based on known properties. For instance, changing a fuel's RVP will affect other fuel properties due to changes in refinery configuration in order to create that new fuel. The Fuels Wizard calculates the appropriate values consistent with EPA's refinery modeling. The Fuels Wizard should be used whenever changing any default fuel property for gasoline and gasoline-ethanol blends in the Fuel Formulation table.[74] This approach could also be used for determining the impacts of relaxing low RVP requirements. Comparisons of emissions should be done for both onroad and nonroad inventories.

Users who want to determine the benefits of a current reformulated gasoline (RFG) requirement can do so by comparing the emissions inventory with RFG to the emissions inventory for their county calculated using the fuel supply and fuel formulations from an adjacent non-RFG county in the same state. EPA encourages modelers to contact EPA through the MOVES Inbox (see

[72] See *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES5,* available at MOVES Nonroad Technical Reports. (The same report is available at MOVES Onroad Technical Reports.)
[73] With the exception of Denver: EPA will update the fuel properties associated with the implementation of Federal reformulated gasoline (RFG) in the area when we have sufficient data to do so. In the meantime, when modeling Denver area counties for regulatory purposes, modelers should work with EPA to develop fuel inputs. Counties in the Denver RFG implementation area include Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer (part), and Weld (part).
[74] The Fuels Wizard is not used for E-85, Diesel, CNG, or LPG fuels.

Section 1.8) to confer on the appropriate properties of a new Federal RFG fuel. This comparison should be done for both onroad and nonroad inventories.

Unlike the algorithm for onroad fuel supplies, any user-supplied nonroad fuel supply will fully replace the MOVES default. This means that any user-supplied NRFuelSupply table must include all the required fuel information, including gasoline, CNG, LPG, nonroad diesel, and marine diesel fuels for all relevant years.

> ***Tip: Ensure that any user-supplied NRFuelSupply table includes all the required fuel information, including gasoline, CNG, LPG, nonroad diesel, and marine diesel fuels for all relevant years.***

For more information about fuel formulations, see Section 4.8.1. Note that Nonroad cannot model fuels with ethanol volumes greater than 12.5%.

### 5.2.3 Generic Tab

The Generic Tab can be used to import a nonroad retrofit table that describes a local nonroad retrofit program. Instructions and guidance on the use of this table, as well as additional information on modeling nonroad equipment replacement programs, are provided in the latest version of EPA's guidance for estimating the emission reductions from these programs for SIP and conformity purposes available on EPA's Guidance on Control Strategies for State and Local Agencies website.

The Generic Tab can be also used to export, modify, and re-import any other default MOVES tables not covered by a specific tab in the Nonroad Data Importer, including tables that affect local equipment population and activity. However, these tables in MOVES-Nonroad interact in complex ways and changing one table may have unintended consequences for other tables and on emission estimates. In general, EPA discourages the use of these tables to apply locally-derived equipment populations and activity. For modelers who do have locally-derived population and activity data, EPA recommends incorporating these data using the method described in Section 5.3.

## *5.3 Using Emission Factor Scripts to Apply Local Population and Activity Data*

As noted in the introduction to Section 5, use of default equipment population and activity data in MOVES-Nonroad is acceptable for SIP inventories. However, some users may prefer to use locally-derived population and activity data when developing nonroad inventories. When this is the case, EPA recommends the following approach for developing nonroad inventories using local data:

1. Run MOVES using default population and activity data.
2. Convert inventory results into emission rates by using emission factor scripts provided in the MOVES Post Processing Menu.
3. Multiply the resulting emission rates by the appropriate local population or activity measure to calculate a new emissions inventory.

EPA has provided 10 emission factor scripts, available in the MOVES Post Processing menu, that can be used in step 2 above, depending on the type of local data available. Table 5-1 below summarizes what each of the scripts does and what kind of local activity data is needed to obtain an inventory using the results of the script. Note that each script has different requirements for level of output detail selected in the Output Emissions Detail Panel prior to running MOVES.

To calculate activity in hp-hours, the following equation can be used:

$$\begin{aligned} hp\text{-}hours = {} & rated\ horsepower \times load\ factor \\ & \times\ total\ hours\ of\ operation\ per\ equipment \\ & \times\ number\ of\ equipment\ operating \end{aligned}$$

To calculate activity in operating hours, the following equation can be used:

$$hours\ = total\ hours\ of\ operation\ per\ equipment\ \times number\ of\ equipment\ operating$$

To calculate activity in vehicle-days, the following equation can be used:

$$vehicle\text{-}days = number\ of\ equipment\ operating\ \times number\ of\ days\ of\ operation$$

When calculating the total hours operation or the number of days of operation, the timespan of the inventory should be considered. For example, if the inventory is for one day, the total hours should account for all hours of operation throughout the day. If the inventory is for a year, the total hours should account for all hours of operation throughout the year. However, multiple runs may be required to account for seasonal variations in emission factors.

EPA strongly recommends taking the following steps to reduce the size of the MOVES output database before using one of these scripts in Table 5-1 to reduce the possibility of excessive post-processing script run times:

- In the RunSpec, select only those sectors in the Nonroad Equipment Panel for which there are appropriate activity data.
- In the RunSpec, choose only the detail needed, based on Table 5-1, in the Output Emissions Detail Panel.
- After the run completes, delete equipment types from the output file for which activity information are not available. An example script that could be used to delete equipment types is included in Appendix C.

Taking these steps before running an emission factor script will reduce the run time of the script.

**Table 5-1. Nonroad Emission Factor Scripts in MOVES**

| Script Title | Description of script output | Select in Output Emissions Detail Panel | To Calculate an Inventory, Multiply Resulting Emission Factors By: |
|---|---|---|---|
| EmissionFactors_per_hphr_by_Equipment.sql | Emission factors in g/hp-hr for each *equipment type* | SCC | Total number of hp-hours for appropriate equipment type |
| EmissionFactors_per_hphr_by_Equipment_and_Horsepower.sql | Emission factors in g/hp-hr for each *equipment type and horsepower class* | SCC, HP Class | Total number of hp-hours for appropriate equipment type and horsepower class |
| EmissionFactors_per_hphr_by_SCC.sql | Emission factors in g/hp-hr for each *SCC* | SCC | Total number hp-hours for appropriate SCC |
| EmissionFactors_per_hphr_by_SCC_and_ModelYear.sql | Emission factors in g/hp-hour for each *SCC, horsepower class, and model year* | SCC, HP Class, Model Year | Total number of hp-hours for appropriate SCC, horsepower class, and model year |
| EmissionFactors_per_OperatingHour_by_Equipment.sql | Emission factors in g/hour for each *equipment type* | SCC | Total hours of operation for appropriate equipment type |
| EmissionFactors_per_OperatingHour_by_Equipment_and_Horsepower.sql | Emission factors in g/hour for each *equipment type and horsepower class* | SCC, HP Class | Total hours of operation for appropriate equipment type and horsepower class |
| EmissionFactors_per_OperatingHour_by_SCC.sql | Emission factors in g/hour for each *SCC* | SCC | Total hours of operation for appropriate SCC |
| EmissionFactors_per_Vehicle_by_Equipment.sql | Emission factors in g/vehicle per day for each *equipment type* | SCC | Total number of vehicle-days for appropriate equipment type |
| EmissionFactors_per_Vehicle_by_Equipment_and_Horsepower.sql | Emission factors in g/vehicle per day for each *equipment type and horsepower class* | SCC, HP Class | Total number of vehicle-days for appropriate equipment type and horsepower class |
| EmissionFactors_per_Vehicle_by_SCC.sql | Emission factors in g/vehicle per day for each *SCC* | SCC | Total number of vehicle-days for appropriate SCC |

# Appendix A MOVES Source Types by Regulatory Class

I/M programs entered in MOVES are applied to source types. However, as discussed in Section 4.9.4, this association of I/M programs and source type may be inconsistent with state I/M program regulations that define I/M programs by the vehicle weight classes. Users can correct for this inconsistency by including gasoline regulatory class coverage adjustments in the calculation of the compliance factor as described in Section 4.9.10. Note that Class 2b trucks with two axles or more and at least six tires, colloquially known as "duallies," should be classified as single-unit trucks in regulatory class 41 regardless of GVWR.

**Table A-1. MOVES5 Gasoline Regulatory Class Distributions by Source Type**

| Source Type Description | Source Type ID | Regulatory Class Description | Corresponding MOVES Reg Class ID | Gasoline Vehicle Regulatory Class Coverage Adjustment |
|---|---|---|---|---|
| Motorcycle | 11 | Motorcycles | 10 | 1.0000 |
| Passenger Car | 21 | Light Duty Vehicles | 20 | 1.0000 |
| Passenger Truck | 31 | Light Duty Trucks | 30 | 0.9727 |
| Passenger Truck | 31 | Class 2b Trucks (8,500 lbs < GVWR <= 10,000 lbs)* | 41 | 0.0273 |
| Light Commercial Truck | 32 | Light Duty Trucks | 30 | 0.7630 |
| Light Commercial Truck | 32 | Class 2b Trucks (8,500 lbs < GVWR <= 10,000 lbs)* | 41 | 0.2370 |
| Other Buses | 41 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.8853 |
| Other Buses | 41 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.0929 |
| Other Buses | 41 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0217 |
| Transit Bus | 42 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.9934 |
| Transit Bus | 42 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.0027 |
| Transit Bus | 42 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0039 |

| Source Type Description | Source Type ID | Regulatory Class Description | Corresponding MOVES Reg Class ID | Gasoline Vehicle Regulatory Class Coverage Adjustment |
|---|---|---|---|---|
| School Bus | 43 | Class 3 Trucks (10,000 lbs < GVWR <= 14,000 lbs)** | 41 | 0.0014 |
| School Bus | 43 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.5733 |
| School Bus | 43 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.4192 |
| School Bus | 43 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0061 |
| Refuse Truck | 51 | Class 3 Trucks (10,000 lbs < GVWR <= 14,000 lbs)** | 41 | 0.0292 |
| Refuse Truck | 51 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.0633 |
| Refuse Truck | 51 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.8696 |
| Refuse Truck | 51 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0378 |
| Single Unit Short-haul Truck | 52 | Class 3 Trucks (10,000 lbs < GVWR <= 14,000 lbs)** | 41 | 0.5709 |
| Single Unit Short-haul Truck | 52 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.3130 |
| Single Unit Short-haul Truck | 52 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.1158 |
| Single Unit Short-haul Truck | 52 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0004 |
| Single Unit Long-haul Truck | 53 | Class 3 Trucks (10,000 lbs < GVWR <= 14,000 lbs)** | 41 | 0.5798 |
| Single Unit Long-haul Truck | 53 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.2948 |

| Source Type Description | Source Type ID | Regulatory Class Description | Corresponding MOVES Reg Class ID | Gasoline Vehicle Regulatory Class Coverage Adjustment |
|---|---|---|---|---|
| Single Unit Long-haul Truck | 53 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.1251 |
| Single Unit Long-haul Truck | 53 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0003 |
| Motor Home | 54 | Class 3 Trucks (10,000 lbs < GVWR <= 14,000 lbs)** | 41 | 0.2167 |
| Motor Home | 54 | Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs) | 42 | 0.5467 |
| Motor Home | 54 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.2355 |
| Motor Home | 54 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.0011 |
| Combination Short-haul Truck | 61 | Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs) | 46 | 0.1813 |
| Combination Short-haul Truck | 61 | Class 8a and 8b Trucks (GVWR > 33,000 lbs) | 47 | 0.8187 |

* Class 2b trucks with two axles or more and at least six tires, colloquially known as "duallies," are classified as single-unit trucks in regulatory class 41 regardless of GVWR.

** Class 3 trucks that are engine-certified are classified in regulatory class 42 regardless of GVWR.

# Appendix B Nonroad Equipment Types

The table below lists nonroad equipment types and the sectors they are assigned to in MOVES.

**Table B-1. Nonroad Equipment Types**

| NREquipTypeID | Description | SectorID | Sector |
|---|---|---|---|
| 1 | Snowmobiles | 1 | Recreational |
| 2 | Off-road Motorcycles | 1 | Recreational |
| 3 | All-Terrain Vehicles | 1 | Recreational |
| 4 | Golf Carts | 1 | Recreational |
| 5 | Specialty Vehicle Carts | 1 | Recreational |
| 6 | Pavers | 2 | Construction |
| 7 | Tampers/Rammers | 2 | Construction |
| 8 | Plate Compactors | 2 | Construction |
| 9 | Rollers | 2 | Construction |
| 10 | Paving Equipment | 2 | Construction |
| 11 | Surfacing Equipment | 2 | Construction |
| 12 | Signal Boards/Light Plants | 2 | Construction |
| 13 | Trenchers | 2 | Construction |
| 14 | Bore/Drill Rigs | 2 | Construction |
| 15 | Concrete/Industrial Saws | 2 | Construction |
| 16 | Cement & Mortar Mixers | 2 | Construction |
| 17 | Cranes | 2 | Construction |
| 18 | Crushing/Proc. Equipment | 2 | Construction |
| 19 | Rough Terrain Forklift | 2 | Construction |
| 20 | Rubber Tire Loaders | 2 | Construction |
| 21 | Tractors/Loaders/Backhoes | 2 | Construction |
| 22 | Skid Steer Loaders | 2 | Construction |
| 23 | Dumpers/Tenders | 2 | Construction |
| 24 | Other Construction Equipment | 2 | Construction |
| 25 | Aerial Lifts | 3 | Industrial |
| 26 | Forklifts | 3 | Industrial |
| 27 | Sweepers/Scrubbers | 3 | Industrial |
| 28 | Other General Industrial Eqp | 3 | Industrial |
| 29 | Other Material Handling Eqp | 3 | Industrial |
| 30 | AC Refrigeration | 3 | Industrial |
| 31 | Terminal Tractors | 3 | Industrial |
| 32 | Lawn mowers (residential) | 4 | Lawn/Garden |
| 33 | Lawn mowers (commercial) | 4 | Lawn/Garden |
| 34 | Rotary Tillers < 6 HP (residential) | 4 | Lawn/Garden |
| 35 | Rotary Tillers < 6 HP (commercial) | 4 | Lawn/Garden |
| 36 | Chain Saws < 6 HP (residential) | 4 | Lawn/Garden |

| NREquipTypeID | Description | SectorID | Sector |
|---|---|---|---|
| 37 | Chain Saws < 6 HP (commercial) | 4 | Lawn/Garden |
| 38 | Trimmers/Edgers/Brush Cutter (residential) | 4 | Lawn/Garden |
| 39 | Trimmers/Edgers/Brush Cutter (commercial) | 4 | Lawn/Garden |
| 40 | Leaf blowers/Vacuums (residential) | 4 | Lawn/Garden |
| 41 | Leaf blowers/Vacuums (commercial) | 4 | Lawn/Garden |
| 42 | Snow Blowers (residential) | 4 | Lawn/Garden |
| 43 | Snow Blowers (commercial) | 4 | Lawn/Garden |
| 44 | Rear Engine Riding Mowers (residential) | 4 | Lawn/Garden |
| 45 | Rear Engine Riding Mowers (commercial) | 4 | Lawn/Garden |
| 46 | Front Mowers (commercial) | 4 | Lawn/Garden |
| 47 | Shredders < 6 HP (commercial) | 4 | Lawn/Garden |
| 48 | Lawn & Garden Tractors (residential) | 4 | Lawn/Garden |
| 49 | Lawn & Garden Tractors (commercial) | 4 | Lawn/Garden |
| 50 | Chippers/Stump Grinders (commercial) | 4 | Lawn/Garden |
| 51 | Commercial Turf Equipment (commercial) | 4 | Lawn/Garden |
| 52 | Other Lawn & Garden Equipment (residential) | 4 | Lawn/Garden |
| 53 | Other Lawn & Garden Equipment (commercial) | 4 | Lawn/Garden |
| 54 | 2-Wheel Tractors | 5 | Agriculture |
| 55 | Agricultural Tractors | 5 | Agriculture |
| 56 | Combines | 5 | Agriculture |
| 57 | Balers | 5 | Agriculture |
| 58 | Agricultural Mowers | 5 | Agriculture |
| 59 | Sprayers | 5 | Agriculture |
| 60 | Tillers > 6 HP | 5 | Agriculture |
| 61 | Swathers | 5 | Agriculture |
| 62 | Other Agricultural Equipment | 5 | Agriculture |
| 63 | Irrigation Sets | 5 | Agriculture |
| 64 | Generator Sets | 6 | Commercial |
| 65 | Pumps | 6 | Commercial |
| 66 | Air Compressors | 6 | Commercial |

| NREquipTypeID | Description | SectorID | Sector |
|---|---|---|---|
| 67 | Gas Compressors | 6 | Commercial |
| 68 | Welders | 6 | Commercial |
| 69 | Pressure Washers | 6 | Commercial |
| 70 | Hydro Power Units | 6 | Commercial |
| 71 | Chain Saws > 6 HP | 7 | Logging |
| 72 | Shredders > 6 HP | 7 | Logging |
| 73 | Forest Equipment - Feller/Bunch/Skidder | 7 | Logging |
| 74 | Airport Support Equipment | 8 | Airport Support |
| 75 | Other Oil Field Equipment | 10 | Oil Field |
| 76 | Scrapers | 2 | Construction |
| 77 | Excavators | 2 | Construction |
| 78 | Graders | 2 | Construction |
| 79 | Off-highway Trucks | 2 | Construction |
| 80 | Rough Terrain Forklifts | 2 | Construction |
| 81 | Crawler Tractor/Dozers | 2 | Construction |
| 82 | Off-Highway Tractors | 2 | Construction |
| 83 | Commercial Mowers (commercial) | 4 | Lawn/Garden |
| 84 | Other Underground Mining Equipment | 9 | Underground Mining |
| 85 | Outboard | 11 | Pleasure Craft |
| 86 | Personal Water Craft | 11 | Pleasure Craft |
| 87 | Inboard/Sterndrive | 11 | Pleasure Craft |
| 88 | Railway Maintenance | 12 | Railroad |

# Appendix C Nonroad Post-Processing Scripts

The nonroad post-processing scripts in MOVES can take a long time to run depending on the size of the output database. Users can reduce the size of their output databases by choosing just the amount of detail needed in the Output Emissions Detail Panel of MOVES, only selecting the sectors for which there are available activity data, and deleting equipment types for which there is no activity information.

If planning to delete records from MOVES output tables, EPA recommends that users make a copy of the original MOVES output so that runs do not need to be repeated if the information is needed later. An example script that makes a copy of MOVES output is as follows:[75]

```
CREATE TABLE output_database.movesoutput_copy
SELECT * FROM output_database.movesoutput;

CREATE TABLE output_database.movesactivityoutput_copy
SELECT * FROM output_database.movesactivitysoutput;
```

When using this script, replace `output_database` with the actual name of the MOVES output database.

To reduce the size of the MOVES output database and to reduce post-processing script runtimes, SQL scripts may be used to manually delete equipment types. For example, if you only had activity data for pavers (NREquipTypeID 6) and rollers (NREquipTypeID 9), the following example SQL script could be run on your output database to reduce the output to only pavers and rollers:[76]

```
DELETE output_database.movesoutput
FROM output_database.movesoutput
INNER JOIN movesdb20241112.nrscc USING (SCC)
INNER JOIN movesdb20241112.nrequipmenttype USING (NREquipTypeID)
WHERE NREquipTypeID NOT IN (6, 9);

DELETE output_database.movesactivityoutput
FROM output_database.movesactivityoutput
INNER JOIN movesdb20241112.nrscc USING (SCC)
INNER JOIN movesdb20241112.nrequipmenttype USING (NREquipTypeID)
WHERE NREquipTypeID NOT IN (6, 9);
```

When using this script, `output_database` should be replaced with the actual name of the MOVES output database, and the equipment type IDs that there are data for should be specified in the NOT IN clause. See Appendix B for a list of nonroad equipment type IDs.

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[75] These SQL scripts can be run in an SQL editor, such as HeidiSQL (https://www.heidisql.com) or MySQL Workbench (https://www.mysql.com/products/workbench).

[76] When running `DELETE` commands in MySQL Workbench, the "Safe Updates" option may need to be unchecked in the Edit > Preferences… > SQL Editor panel.

Once this step is completed, users may execute the desired nonroad post-processing script in MOVES.