MOVES Greenhouse Gas Guidance: Using MOVES for Estimating State and Local Inventories of Onroad Greenhouse Gas Emissions and Energy Consumption

United States Environmental Protection Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
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Section 1: Introduction

1.1 Purpose of this Guidance

The transportation sector, which includes onroad vehicles such as cars, trucks, buses, and nonroad sources like locomotives, aircraft, and construction equipment, is the largest source of U.S. greenhouse gas (GHG) emissions. In 2021, transportation represented approximately 29 percent of total U.S. GHG emissions. Between 1990 and 2021, GHG emissions in the transportation sector increased more in absolute terms than any other sector (i.e., electricity generation, industry, agriculture, residential, or commercial).[1] GHGs include carbon dioxide, methane, and nitrous oxide. In addition to GHGs, black carbon, a component of particulate matter also emitted by transportation sources, has been linked to a range of climate impacts, including increased temperatures and accelerated snow melt.[2]

The Environmental Protection Agency's (EPA) MOtor Vehicle Emissions Simulator (MOVES) model can be used to model these pollutants from the onroad transportation sector and the nonroad transportation sector other than locomotives, commercial marine vessels and engines, and aircraft.[3] MOVES is a state-of-the-science model for estimating air pollution emissions from mobile sources under a wide range of user-defined conditions. MOVES can estimate emissions from running and evaporative processes as well as brake and tire wear emissions for all types of onroad vehicles across multiple geographic scales. MOVES is EPA's best tool for estimating GHG emissions from U.S. mobile sources, except in California.[4] Section 1.2 describes recent updates in MOVES.

This document provides guidance on how to use MOVES to estimate GHG emissions to create state or local inventories for onroad or nonroad vehicles and equipment, and to estimate total energy consumption. The guidance can be used for state and local GHG planning, including EPA grant programs, such as the Climate Pollution Reduction Grants (CPRG) program. This guidance provides recommendations for using MOVES to develop county, regional, and state GHG baseline and future inventories for the transportation sector. This guidance could also be used to quantify the GHG reductions from emission reduction strategies and programs, including for meeting state or local GHG planning, tribal GHG planning, grant applications, and more. This guidance should help users develop an approach for using MOVES to estimate GHG emissions or energy consumption with the time and data resources available. This updated guidance replaces and supersedes the previous June 2016 guidance.[5] See Section 1.5 for how this updated guidance is related to EPA's Port Emissions Inventory Guidance.

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[1] EPA, "Fast Facts U.S. Transportation Sector Greenhouse Gas Emissions 1990-2021," EPA Office of Transportation and Air Quality, EPA-420-F-23-016, June 2023.
[2] More information can be found in the aerosol section of EPA's Basics of Climate Change website.
[3] Information about developing emissions inventories for locomotives, commercial marine vessels and engines, and aircraft, can be found on EPA's Emissions Models and Other Methods to Produce Emission Inventories website.
[4] In California, modelers can use the California Air Resources Board's EMission FACtor (EMFAC) model.
[5] EPA, "Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption," EPA-420-B-16-059, June 2016.

The guidance is organized into five sections:

- Section 1: provides introductory information about MOVES and GHG analyses.
- Section 2: describes approaches for developing an **onroad** GHG inventory in different geographic areas and the implications of each of these approaches.[6]
- Section 3: describes setting up a MOVES run for **onroad** emissions.
- Section 4: discusses the data input options that are most important for estimating **onroad** GHG emissions. It also discusses which local data are important to include versus when data from the MOVES default database can be used.
- Section 5: covers using MOVES for **nonroad** GHG emissions, and it covers how to set up a nonroad run, import data, and use post-processing scripts to manage output from the model.

This guidance covers the use of MOVES for estimating onroad and nonroad GHG emissions and energy consumption only; it should not be used for developing criteria pollutant inventories for state implementation plan (SIP) or conformity purposes. EPA has guidance for using MOVES for SIP and conformity purposes; see Section 1.4 for information about other MOVES guidance and information.

This guidance also does not cover the use of MOVES for Project Scale, which can be used to model an individual transportation project such as a highway, intersection, or transit project. While not covered in this document, MOVES is EPA's best tool for project-level mobile source GHG analyses.[7]

EPA coordinated with the Department of Transportation during the development of this guidance.

1.2 Latest Version of MOVES

Users should use the latest version of MOVES for conducting a new GHG or energy analysis. At the time of publication, MOVES4 is the latest major version of MOVES. While the model structure is the same as MOVES3, MOVES4 includes many changes, including new vehicle standards, new emissions and activity data, and new features, such as the Alternate Vehicle Fuel and Technology (AVFT) tool. As a result of these changes, estimates of emissions from MOVES4 will be different from emissions estimated with versions of MOVES3, including MOVES3.1.

Using the latest MOVES model to estimate GHG emissions or energy consumption allows users to take full advantage of recent improvements. MOVES4 includes the following updates, many of which specifically affect GHG emissions:

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[6] In GHG emissions literature, often a distinction is made between an "inventory," which is for a year in the past, and a "forecast," which is for a year in the future. The term "inventory" in this and other MOVES guidance refers to total emissions in a geographic area regardless of whether the year modeled is past, current, or future.

[7] Note: Project Scale can provide emissions for only one hour at a time, however, GHG inventories are typically for an entire year. For more information on using the Project Scale, see EPA's project-level MOVES CO guidance and PM hot-spot guidance could be helpful (see Section 1.4).

- The emission impacts of the EPA heavy-duty low NOx rule for model years 2027 and later[8] and the light-duty greenhouse gas rule for model years 2023 and later.[9]
- The ability to model heavy-duty battery-electric and fuel-cell vehicles, as well as compressed natural gas (CNG) long-haul combination trucks.
- Improved modeling of light-duty electric vehicles.
- The latest data and forecasts on vehicle populations (including electric vehicle fractions), travel activity, and emission rates, as well as updated fuel supply information at the county level. [10]

The net impact of these changes on calculated emissions will depend on many factors, including the years modeled, and which parts of an analysis rely on MOVES defaults, and which rely on local inputs.

This guidance specifically describes modeling with MOVES4.0.1, released in January 2024 to include another option for modelers with estimating GHG emissions, covered in Section 4.3 of this guidance.[11] In this guidance, "MOVES" refers to MOVES4.0.1 and later versions.

EPA will be updating the MOVES model over time to account for revisions to GHG emissions and fuel economy standards as well as other new information. The information in this guidance is applicable to future versions of the MOVES model unless EPA notes otherwise. EPA will revise this guidance as needed to reflect future versions of MOVES.

1.3 Types of GHG and Energy Analyses in MOVES

MOVES can produce onroad or nonroad inventories for the country, an individual county or state, and multi-state, multi-county, and metropolitan regions. MOVES can create an annual GHG emissions inventory for the year 1990 and any calendar year from 1999 through 2060.[12] MOVES can also calculate daily inventories, but this guidance does not specifically address daily inventories.[13] Specifically, MOVES can model any of the following:

- Carbon dioxide, CO_2
- Methane, CH_4
- Nitrous oxide, N_2O
- Elemental carbon (equivalent to black carbon)
- Total Energy Consumption (equivalent to the energy use of onroad processes per time for all fuel types)

[8] 88 FR 4296, January 24, 2023.

[9] 86 FR 74434, December 30, 2021.

[10] For additional information on the updates included in MOVES4, please refer to the document: "Overview of EPA's Motor Vehicle Emission Simulator (MOVES4)", EPA-420-R-23-019, August 2023.

[11] See EPA's MOVES4 Update Log website for information regarding how the latest version differs from the previous version.

[12] MOVES does not include life cycle GHG emissions, such as emissions from the production of fuel, generation of electricity, manufacture of vehicles, or the construction of roadways.

[13] See the MOVES Technical Guidance for an explanation on how to specify different time periods for analysis: "MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity," EPA-420-B-23-011, August 2023.

- CO_2 Equivalent

In MOVES, the CO_2 Equivalent pollutant is the sum product of all greenhouse gases multiplied by their associated global warming potential (GWP), expressed as a unit of CO_2. The calculation of CO_2 Equivalent is discussed further in Section 3.7.1.

MOVES captures the effects of fleet turnover and the change in vehicle emissions and fuels over time. MOVES includes vehicle and fuel technologies that are currently in widespread use or have historically been used. Since MOVES emissions estimates depend on vehicle types, vehicle ages, vehicle activity (including speeds and operating modes), road types, and fuel types, MOVES can answer the question of how emissions have changed from the past or would change in the future under various scenarios that affect any of these inputs. MOVES can estimate the effects of individual control measures and emission reduction strategies, or combinations of them, in any future year up to 2060.

MOVES can also be used for scenario planning and policy efficacy analysis for an area, be it a state, a region, a county, or a portion of a county. For example, with user-supplied information on VMT and travel speeds for two or more scenarios, MOVES can evaluate corresponding differences in GHG and energy use. This functionality can be useful for evaluating the impacts of various travel efficiency strategies, such as:

- Region-wide travel demand management, e.g., rideshare programs, employer-based programs;
- Land use and smart growth strategies, e.g., transit-oriented development policies, policies to increase diversity and density of land uses;
- Transit-promoting programs, such as increased transit frequency or lower fares; and
- Pricing strategies, such as parking pricing or mileage fees.[14]

In addition, MOVES can be used to evaluate GHG or energy impacts of other types of strategies, such as those that affect vehicle and fuel technologies or that are designed to change the composition of the vehicle fleet. For example, MOVES can model the emissions effects of strategies designed to increase the number of electric vehicles.

In some cases, metropolitan planning organizations (MPOs) and state DOTs are already using MOVES for analyzing criteria pollutants and precursors for state implementation plan (SIP) or transportation conformity purposes. In these areas, it may be possible for modelers to use MOVES inputs developed for these other purposes for their MOVES GHG runs.

1.4 What other MOVES guidance and documentation are available?

For the latest version of EPA's guidance related to MOVES, see our State and Local Transportation Resources web page. These guidance documents include:

[14] For more information about travel efficiency strategies and estimating emission reductions from them, please see the EPA's Estimating Emission Reductions from Travel Efficiency Strategies website, which includes links to the following documents: "Potential Changes in Emissions Due to Improvements in Travel Efficiency – Final Report," EPA-420-R-11-003, March 2011, and "Transportation Control Measures: An Information Document for Developing and Implementing Emission Reduction Programs," EPA-430-R-09-040, March 2011.

- MOVES Policy Guidance, addressing general policy issues for MOVES in SIPs and transportation conformity (on the Policy and Technical Guidance website)

- MOVES Technical Guidance, for SIP and transportation conformity analyses (on the Policy and Technical Guidance website)

- PM Hot-Spot Guidance, for transportation projects (on the Project-Level Conformity and Hot-Spot Analyses website)

- CO MOVES Hot-Spot Guidance, for transportation projects (on the Project-Level Conformity website)

- Port Emissions Inventory Guidance (on the Port Emissions Inventory Guidance website and discussed in more detail in Section 1.5)

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. The latest training materials are available on the MOVES training website. This page includes EPA's latest Hands-On Training Course, with presentations as well as example files so that the training can be self-guided.

EPA encourages MOVES users to check the MOVES website regularly and subscribe to EPA's mobile source emissions model listserv[15] to find information about updates to MOVES and guidance for its use.

1.5 How does this guidance relate to the Port Emissions Inventory Guidance?

This updated guidance is consistent with the methods for developing emissions inventories in the Port Emissions Inventory Guidance EPA issued in April 2022. The Port Emissions Inventory Guidance describes methodologies for preparing emissions inventories of any air pollutant, including GHGs, for the six mobile source sectors found at a port: ocean-going vessels, harbor craft, recreational marine, cargo handling equipment, onroad vehicles, and rail. Methods for three of six sectors are based on MOVES: onroad vehicles, recreational marine, and cargo handling equipment.

Onroad: The onroad vehicles section of the Port Emissions Inventory Guidance describes using the MOVES onroad model with either the County or Project Scale to create emissions inventories. In contrast, this GHG MOVES guidance focuses on using MOVES to model onroad GHG emissions at the County or Default Scale. The methods in these documents are generally consistent with each other. However, as noted elsewhere, MOVES at the Project Scale estimates

[15] To sign up for the listserv, follow the instructions on the EPA-MOBILENEWS Listserv website.

emissions for one hour at a time. Therefore, when an annual GHG inventory is needed, the County or Default Scales are more convenient to use.

Nonroad: The Port Emissions Inventory Guidance describes how to use the MOVES nonroad model for the two nonroad equipment sectors present at a port: recreational marine and cargo handling equipment. Section 5 of this GHG MOVES guidance covers using the MOVES nonroad model for all 12 nonroad sectors (see Section 5.1.4 for the list). As with onroad, the methods for using MOVES nonroad in these documents are consistent with each other, although users may find more specific information regarding these sectors, such as data inputs, in the Port Emissions Inventory Guidance.

1.6 Contact Information

General, technical, or policy questions related to this guidance or about using MOVES for estimating GHG emissions should be sent to mobile@epa.gov. For questions regarding the application of this guidance to specific locations, please contact the appropriate EPA Regional Office. A list of the EPA Regional mobile source contacts can be found in Section 16.2 of the OTAQ Contact by Topic list.

1.7 Does this document create any new requirements?

This document does not create any new requirements. The statutory provisions and EPA regulations referenced in this document contain legally binding requirements. It is not a regulation itself, nor does it change or substitute for statutory provisions and regulations. Thus, this document does not impose legally binding requirements on EPA, DOT, states, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA retains the discretion to consider and adopt approaches on a case-by-case basis that may differ from this document, but still comply with the statute and regulations. This document may be revised periodically without an opportunity for public comment.

Section 2: Planning an Emissions Analysis for Onroad Vehicles

2.1 Introduction

There are multiple ways to use MOVES to develop emissions and energy consumption estimates, and different approaches affect the precision of the analysis. Section 2 explores the approaches a modeler could choose to develop an annual onroad GHG inventory or estimate of onroad energy consumption using MOVES, including selections for:

- Calculation type: using an emissions inventory or emission rates;
- Domain/Scale: Using County or Default Scale; each of which provides options for modeling the particular geographic area of interest; and
- Time Span: Options for level of time aggregation and modeling the particular time period of interest.

When comparing GHG emissions between two cases, such as in two different years, or with and without a particular transportation strategy, EPA recommends using consistent selections across runs for calculation type, scale, geographic area, and time period.

2.2 Calculation Type Options

MOVES has two calculation types - Inventory and Emissions Rates. Either may be used to develop emissions estimates for GHGs or energy consumption.[16] However, each calculation type requires different inputs as noted later within the guidance text. For more information on the two calculation types, see the latest MOVES training materials, including the MOVES Hands-on Training Course.

- Inventory: MOVES calculates an output inventory of total emissions in units of mass. Using the Inventory approach is the simpler method to generate a GHG emissions inventory and may be preferable when the user wants to minimize post-processing MOVES outputs thus avoiding inadvertent errors during post-processing.

- Emissions Rates: MOVES generates a table of emission rates. The user must multiply each rate by the appropriate vehicle activity and sum the products to calculate an inventory. Output data include emissions per unit of distance for running emissions, emissions per vehicle or per start for start emissions, and emissions per vehicle or per idle hour for hotelling emissions.[17] (GHG emissions are not produced from evaporative processes; therefore, for a GHG inventory, users would not need to generate "emissions per profile" rates.) Users should take care to ensure that the proper measure of activity is used for each emission process. The Emission Rates method may be preferable when the

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

[17] MOVES defines "hotelling" as any long period of time (e.g., > 1 hour) that drivers spend in their long-haul combination truck vehicles (source type 62) during mandated rest times. Hotelling is differentiated from off-network idling because the engines are often idling under load while hotelling (e.g., to maintain cabin climate or run accessories).

user wants to apply emission rates to multiple geographic locations, or to use rates in conjunction with travel model post-processing software already developed to calculate total emissions of other pollutants.

2.3 Domain/Scale

MOVES allows users to analyze mobile emissions at various scales: Default, County, and Project.

- The Default Scale can be used to model the entire nation, one or more states, or one or more counties. The Default Scale largely relies on MOVES default data to perform inventory calculations.
- The County Scale can be used to model a single county, partial county, or multi-county area. Calculations at the County Scale rely heavily on user-supplied data.
- The Project Scale can be used to model an individual transportation project such as a highway, intersection, or transit project.

Either the County or Default Scale can be used for GHG inventories.[18] This guidance covers both of these scales. This document does not contain guidance for use of the Project Scale for estimating onroad GHG emissions or energy consumption.[19] However, MOVES is EPA's best tool for project-level GHG analyses, and EPA may offer such guidance in the future, particularly if there is interest from the user community.

Although both the Default and County Scales use the same underlying emission rates, the requirement to use local data differs. The Default Scale allows users to enter local information for inputs, but default data is also available for use for all inputs. The County Scale also allows users to enter local information for all inputs; however, users must enter local road type distributions, source type populations, and VMT, as there is no default data available for these inputs. In either case, EPA recommends that modelers always include local information for VMT and vehicle population in a GHG MOVES run, even when using the Default Scale. Table 2-1 compares the Default and County Scales for GHG analyses.

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[18] The County Scale is necessary to use for MOVES runs for SIP and transportation conformity purposes, to meet statutory and regulatory requirements. For more information, see the MOVES4 Technical Guidance (see Section 1.4).

[19] Note: Project Scale can provide emissions for only one hour at a time, however, GHG inventories are typically for an entire year. For more information on using the Project Scale, see EPA's project-level MOVES CO guidance and PM hot-spot guidance could be helpful (see Section 1.4).

Table 2-1: Comparison of Default and County Scales.

Feature	Default Scale	County Scale
Overall	• May be faster to set up • Less accurate emissions estimate than County Scale if using exclusively default data	• May take longer to set up because input data must be included • Accurate estimates
Data Needs	• Can rely on default information, some of which is national average • Local data can be included, but is optional	• Modeler needs to include local data for most inputs (some defaults available) • May already be available if area has SIP and conformity modeling
Geographic Area	• Can model one or more counties, one or more states, or the entire nation at once	• Models a single county, partial county, or multi-county area for each run (one county at a time)
VMT/Vehicle Population Data	• Use of local data recommended (default data is based on nationwide information and will not be accurate for the modeling area)[20]	• Must provide local data

2.3.1 County Scale

The County Scale can be used to create onroad GHG inventories for an individual, partial, or multi-county area, such as a metropolitan area, a region of a state, an entire state, or a multi-state area or region. EPA recommends using the County Scale for GHG or energy consumption analysis. The County Scale allows the user to enter county-specific data through the County Data Manager (covered in Section 4). As indicated earlier, providing local data significantly improves the precision of the modeling results. The County Scale is also appropriate when estimating differences that depend on detailed local data, such as comparing GHG emissions from various transportation planning alternatives in a metropolitan area.

Users only have one option for defining the Geographic Bounds when using the County Scale (described in Section 3.4 of this document). Users must first select a state and then choose one county. There are multiple approaches to create an onroad GHG inventory for an area made up of more than one county, such as a metropolitan area or an entire state. For example:

- Each county could be modeled individually, either with “Inventory” or with “Emission Rates,” depending on the user’s preference. This method allows users to easily access some of the MOVES default database inputs for individual counties, if appropriate, as described in Section 4 of this document. Each run where County is chosen will produce

[20] The ability to add local VMT and vehicle population data at the Default Scale is available starting with MOVES4.0.1.

output for the county selected. 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.

- Another option would be to model one county as a representative county with "Emission Rates" to generate emission rates at various temperatures. These emission rates could then be applied to a larger area, if the vehicle age distribution and fuel used in the larger area is the same as that modeled for the representative county. If methane emissions are modeled, the Inspection/Maintenance (I/M) program in the larger area also must be the same as that modeled for the representative county.

Table 2-2 summarizes the combinations of calculation type and geographic area definition that users can employ for creating GHG 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, whether results for each individual county are needed, and the ability to leverage existing work are key considerations in choosing an approach.

Table 2-2: Summary of Modeling Approaches Using the County Scale

Geographic Area to Be Modeled	Approach	Advantages	Considerations
One county (or partial county)	Use Inventory	• Shorter run time, smaller output files, and less post-processing.	
	Use Emission Rates	• Rates can be applied to detailed activity data from travel demand models if desired.	• Longer run time, larger output files. • Running, start, and hotelling rates must be post-processed to create GHG inventory.
Multi-county area	Use Inventory to model each county separately	• Produces results for each county without needing to post-process. • 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. • Post-processing may still be needed to adjust results if the boundaries of the analysis (e.g., a metropolitan statistical 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. • Rates can be applied on a link basis if desired. • 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 fuels, and if methane emissions are being modeled, the same I/M program as the representative county (i.e., a separate run is needed for each combination of fuel type and I/M program present in the area). See Section 4 for more information about these inputs. • Running, start, hotelling, and off-network idle rates must be post-processed to create the GHG inventory. Section 4 provides additional information.

2.3.2 Default Scale

The Default Scale is simple and convenient for GHG analyses. The Default Scale allows the user to model the entire nation or any smaller geographic region. Similarly, this scale allows the user to simultaneously model more than one geographic region (i.e., multiple counties or multiple states). The Default Scale also allows the user to model more than one year in one model run, but EPA recommends modeling one year at a time, as explained further below.

There may be cases where using the Default Scale is preferred to the County Scale. For example, because the user does not have to input local data, the Default Scale may help new users become familiar with the model. The Default Scale may be sufficient for users in areas that are not already using MOVES for other purposes. In addition, the Default Scale may be helpful for a screening analysis designed to inform more detailed subsequent analyses, or for some types of comparative GHG analyses, where the relative difference in emissions between different scenarios is more important than the precision of the absolute level of emissions. Examples of comparative analyses could include developing simple projections of GHG emissions trends over time or over different speeds, or comparing GHG emissions rates of different vehicle types (e.g., passenger cars versus passenger trucks) or different road types.

A Default Scale analysis can rely entirely on MOVES default data for data inputs. Default data are typically not the most current or best available information for any specific county, and therefore relying on default data exclusively will reduce the quality of the estimate. However, modelers may enter local data via the Data Importer, which is similar in structure to the County Data Manager and serves a comparable function at the Default Scale. Using locally-derived data is more important for some data fields, or inputs, than others. Section 4 discusses each input and provides guidance.

How default database information is applied to the area being modeled depends on the data field. For some data fields, such as vehicle age distributions and speed distributions, the national average data are used for the area as-is, meaning that MOVES will use the national average for any county or state selected. However, vehicle age distribution and speed distribution vary across the United States. For VMT and vehicle population ("source type population"), the national data are adjusted for the year modeled and then "scaled down" to the area using allocation factors within the model.[21] For fuel and I/M program inputs, the national default database includes survey data collected during model development that varies by county for fuel and I/M program type. The model will use the information it has for the specific county.

EPA recommends users always include local VMT and vehicle population data when using MOVES to develop more accurate onroad GHG inventories. EPA expects that users will always have more precise local information for these inputs than the Default Scale's information for the area. Starting with MOVES4.0.1, local VMT and vehicle population data can be imported via the Data Importer. More detail on using the Data Importer to include local information is described in Section 4.3.

[21] The most recent national default VMT data included in MOVES4 are for the year 2021. When a future year is modeled using the Default Scale, MOVES applies an annual growth rate to the 2021 national VMT for the appropriate number of years. A portion of this scaled-up VMT is then allocated to the geographic area of interest.

Although the Default Scale allows the user to model multiple years and multiple counties or states, the user can only enter a single set of data through the Data Importer. If the analysis is for more than one year and local data are entered, it will apply to all analysis years. If users have information that varies by analysis years, EPA recommends using a separate run to model each year, either at the Default or County Scale. Similarly, if the user is modeling two states and has information about each state's vehicle age distribution or speed distribution, both sets of information could not be entered at the Default Scale in one run. In this case, EPA recommends modeling them separately at the Default or County Scale and include the information unique to each state (see Section 2.3.1 for various County Scale approaches).

In summary, a Default Scale run that relies on MOVES default database information produces a less accurate estimate of onroad GHG emissions. Including local VMT and vehicle population information will improve the accuracy of this estimate. If in addition, the user has other local data, EPA recommends including those data as well. If the user has data that varies by analysis year, EPA recommends users include them in separate runs.

2.4 What if I don't have local data?

It is possible to perform a GHG emissions analysis in MOVES without local data. For example, a GHG emissions analysis done without local data may provide a helpful preliminary estimate. However, as mentioned in Section 2.3, including local data (especially VMT and vehicle population) will result in a more accurate emissions estimate. Although it is still possible to use MOVES to estimate GHG emissions by using the Default Scale and relying entirely on MOVES default information, EPA encourages modelers to incorporate local VMT and vehicle population data when available (see Section 4.5 and 4.7 for more information). The use of the Default Scale with default inputs is covered in Module 2 of the MOVES Hands-on Training slides.

2.5 Preaggregation Options

MOVES allows users to preaggregate location and time-specific input data when modeling emissions at the national and state level and over time periods longer than one hour. Preaggregating inputs to these larger scales is faster but reduces the model accuracy and precision compared to modeling at a more detailed level and aggregating the results at the end. These options could be useful for preliminary GHG analyses where a quicker result is required.

2.5.1 Time Preaggregation Options

MOVES can use a range of time periods to calculate an annual onroad GHG inventory. MOVES can generate an annual GHG inventory by estimating hourly emissions individually and summing them to produce the year's emissions. Or, a modeler can direct MOVES to use the average of each input over a period of time, such as a year, month, or day, and use those average inputs to calculate an annual emissions inventory. In MOVES, this second approach is referred to as "preaggregating" data over time to estimate emissions. The main reason for preaggregating hourly data over a longer time period such as "Year," "Month," or "Day," instead of "Hour" is to reduce model run time. For example, a modeler may want to preaggregate hourly data to the

"Year", if they are creating an annual inventory. Generally, preaggregation reduces model run time while also reducing precision.

When preaggregating over a specified time period, MOVES computes a weighted average of some data otherwise differentiated by a smaller unit of time, such as VMT and temperature, prior to the execution of the run. For example, if the user chooses Month, the model will average the temperature of all selected days and hours into an average Month set and perform the simulation with these average values for the selected month or months.

Preaggregation affects the various input data differently. Preaggregation accounts for hourly variations in travel activity data because the model weights each hour's activity when it averages over the time period. However, temperature effects are non-linear, therefore, preaggregation does not account as well for variations in temperatures, and some information about peak emissions at high and low temperatures will be lost. Runs using average temperatures typically produce lower emissions than runs that account for all the high and low temperatures.

EPA's general recommendation is for users to consider the purpose of the analysis and how the results will be used when deciding whether to preaggregate and over what time period. Users will want to consider how much variation exists in their input data, how sensitive MOVES is to those inputs, and whether any control strategies being considered will affect those inputs. For example, temperature and humidity vary over the course of a day and year, yet this variation may not be of concern for a particular run. At very low temperatures, elemental carbon emissions will be greater for light-duty gasoline vehicles, but this effect would be irrelevant if only CO_2 is being modeled. At high temperatures, air conditioner use, estimated by the model as a function of temperature and humidity, affects fuel economy and will increase CO_2 emissions, but this effect may be less of a concern in northern states. See Section 3.3 for more information on selecting Time Scale preaggregation options.

Users should consider whether preaggregating their runs will produce output that meets their needs for precision. There may be applications where precision is not as important as the general trends over time or differences between scenarios where preaggregation may make sense. There may also be some analyses, such as comparing an onroad GHG inventory to a GHG inventory for other source sectors, where precision is more important. Users may want to do a simple sensitivity analysis to determine whether the range of temperatures that occur in the area being modeled has a significant impact on their GHG emissions inventory.

Specific recommendations:

- If temperatures matter for a GHG inventory, EPA recommends using the default selection of Hour for the Time Aggregation choice on the Advanced Features Panel instead of preaggregating over a day, month, or year. EPA recommends that users model all 24 hours in a single run to reduce the post-processing steps needed. (There is no substantial advantage to running only some and not all hours. If users do not have unique data inputs for all 24 hours of the day, users should apply the data for the hours they do have to the 24 hours of the day as appropriate. Section 4 provides further information.) In addition to choosing all 24 hours, EPA recommends choosing all 12 months and both day-types (weekday and weekend day). Results will need to be aggregated appropriately (i.e., the

24-hour total emissions in each day-type, in each month need to be multiplied by the number of days of each type in that month, and these 12 monthly totals summed together) to represent emissions over the entire year.

- Where temperature variations are less important in the GHG analysis, users could save time when using Inventory mode by preaggregating by day, month, or year, depending on the level of detail desired in the output. Preaggregated MOVES runs may also be useful for purposes such as approximate comparisons of GHG emissions between two different years, even if they are not accurate enough for assessing the effects of various programs or emission reduction strategies. Before using preaggregated MOVES output for a GHG inventory, users may want to compare results with different levels of aggregation to determine how much these differences matter based on local inputs.

- When using Emission Rates instead of Inventory, the time aggregation level is automatically set to Hour and no other selections are available. Preaggregating time does not make sense when using Emission Rates and would produce emission rates that are not meaningful. Running and start emission rates can vary with temperature, and start emission rates also vary by time of day because vehicle activity differs throughout the day.[22] For example, the temperature may be the same at 8 am and 8 pm, but there are more starts at 8 am, and a higher fraction of those are cold starts. Thus, start emission rates at 8 am will be considerably higher than at 8 pm. This variation in emission rates in different hours would be lost if the Time Aggregation level was anything other than Hour.

2.5.2 Region Preaggregation Options

Preaggregation of the modeled geographic area can also be done in MOVES. When using the Default Scale, input data can be preaggregated to one or more states or the entire nation. For example, a modeler may want to preaggregate to the "State" level when creating a statewide GHG inventory. When using the County Scale, no regional preaggregation options exist because only one county may be run at a time.

When a Region Aggregation option is selected on the Advanced Features Panel when using the Default Scale, the Geographic Bounds Panel adjusts as follows:

- County: the modeler may choose one or more counties to model
- State: the modeler may choose one or more states to model
- Nation: the modeler does not need to make a selection in the Geographic Bounds Panel

As when preaggregating over a specific time period, when MOVES preaggregates (e.g., temperature and fuel properties) over a Region, the model runs faster, but the model accuracy and precision is reduced compared to modeling at a more detailed level and aggregating results at the end.

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[22] MOVES produces two different rates for starts, per vehicle and per start. The modeler would only use one of these, depending on what information (total number of vehicles or total number of starts) is known.

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

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. This section covers using MOVES for developing transportation sector onroad GHG inventories.

3.1 Creating a Run Specification (RunSpec) File

The MOVES Run Specification (RunSpec) defines the geography 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 accessed, changed, and run through the MOVES graphical user interface (GUI). It is needed for both the Default and County Scales, and this section of the guidance pertains to both of them.

Setting up a RunSpec involves accessing the Navigation Panel in the MOVES GUI. The Navigation Panel consists of a series of other panels and tabs that describe the input options to create the RunSpec. For a GHG inventory, the user would progress through the Navigation Panel and make the appropriate selections or enter the appropriate data in each one of the following panels:

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

Each panel is described below. Note that selections made in some panels affect available options in other panels. While MOVES allows the user to complete these panels in any order, we recommend completing them in the order they appear in the Navigation Panel. 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.

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

The information below applies for all GHG and energy consumption analyses unless otherwise indicated (e.g., there are some differences between the County and Default Scales).

3.1.1 Description

The Description Panel allows the user to enter a description of the RunSpec.[23] Entering a complete description of the RunSpec will help users keep track of their MOVES runs. Users may want to identify key aspects to help identify the run later, such as the pollutants, geographic area, and time period modeled.

3.2 Selecting Scale and Calculation Type

Selecting Scale on the Navigation Panel accesses the Model, Domain/Scale, and Calculation Type Panel. MOVES allows users to choose either onroad or nonroad emissions. Either the Default or County Scale can be used for estimating onroad GHG emissions for a county, a metropolitan area, a region of a state, or an entire state; Section 2 contains a discussion of the two scales. In addition, MOVES provides two options for calculation type: Inventory or Emission Rates. Either option can be used, depending on the user's preference and purpose, as described in Section 2.

This guidance provides additional detail where necessary to indicate the differences that result from selecting the Inventory versus the Emission Rates option.

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 must select one or the other. Use of MOVES for nonroad emission inventories is covered in Section 5 of this document.

3.2.2 Domain/Scale

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

- Default Scale[24] can be used to estimate emissions for the entire country, for a state, for a group of counties, or for individual counties. At the Default Scale, MOVES uses information in its default database to calculate emissions for the geographic area chosen. The default data used for a county or state is based on a mix of national data, allocation factors, and pre-loaded local data (see Section 2.3.2). EPA expects that users will always have more precise local information for these inputs than the Default Scale's information for the area, thus users can input local data using the Data Importer, if desired; see Section 4.3 for more information about the Data Importer.

[23] Restrictions on number and type of characters allowed in previous versions of MOVES were removed as of MOVES3.

[24] Prior to MOVES3, the Default Scale was known as "National Scale."

- County Scale requires the user to enter data to characterize local meteorology, fleet, and activity information through the County Data Manager. The County Data Manager facilitates the input of local data and also allows the user to review county data included in the MOVES default database. Because local data are necessary to include, the County Scale will generally give more precise GHG estimates compared to the Default Scale. See Section 2 for more information about choosing between the Default and County Scale. Section 2.3.1 describes possible approaches for creating inventories for geographic areas comprised of multiple counties. Detailed guidance on specific inputs in the County Data Manager, including the use of default inputs, is given in Section 4 of this guidance.

- Project Scale allows analysis of emissions on individual roadway links or locations where emissions from vehicle starts or hotelling activity occur. The Project Scale could be used to examine GHG emissions from a specific travel facility, or to examine GHG impacts of changes that affect travel (number of trips or driving behavior) on a specific facility. This document does not cover the use of the Project Scale for estimating onroad GHG emissions. EPA has provided guidance on the use of the Project Scale in MOVES for quantitative hot-spot analysis for transportation conformity.[25] Users can refer to that guidance for information about setting up run specifications and using the Project Data Manager for Project Scale MOVES runs.

For a GHG inventory of an area, choose either Default or County Scale. See Section 2.3 for more detail that can help you decide.

3.2.3 Calculation Type

Under the Scale Panel, MOVES gives users the option to calculate emissions either as:

- Inventory (total emissions in units of mass) or,

- Emission Rates (emissions per unit of distance for running emissions or per vehicle for starts and hotelling emissions) in a look-up table format.[26]

The selection of calculation type is required early in the RunSpec construction process because this choice affects the available options in later panels.[27]

- If Inventory is selected, MOVES provides emissions estimates as mass, using VMT and vehicle population entered by the user.

[25] The latest versions of EPA's hot-spot guidance are available on EPA's Project-Level Conformity and Hot-Spot Analyses website.

[26] Evaporative emission rates would not need to be generated when using MOVES to estimate onroad GHG emissions.

[27] If you select Emission Rates, you must include a MOVESScenarioID of 40 characters or less, which will appear in the rates tables of the output database. The MOVESScenarioID should be a unique identifier for the scenario for which the rates apply. 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.

- If Emission Rates is selected, MOVES provides emission rates as mass per unit of activity. The Emission Rates option produces a look-up table of emission rates that must be post-processed to produce an inventory. Even though vehicle activity is applied outside of MOVES in post-processing when developing an onroad GHG inventory using Emission Rates, vehicle activity 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 these processes.

As discussed in Section 2 of this document, each calculation approach has advantages and considerations and users will need to decide which approach is more appropriate for their type of analysis. Both approaches use the same underlying emission data and will produce essentially the same results if the user calculates an inventory from rates in the same way that MOVES does this internally. Table 2-2 in Section 2 provides a summary of modeling approaches for the County Scale.

As noted in Section 2, the Emission Rates approach is more complex than the Inventory approach. Successful application of this approach requires careful planning and a clear understanding of the rates calculations in MOVES. Large differences in results between the Inventory and Emission Rates approaches are usually an indication of a mistake in post-processing of the emission rates. The most common mistakes when using the Emission Rates approach are:

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

To correctly compile an onroad emissions 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 and hotelling emission rates must be multiplied by the total population of vehicles in the area. 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; and
- 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.[28]

There are no GHG emissions associated with refueling or evaporative processes in MOVES.

Even when done correctly, minor differences in post-processing methods can create small differences in results. EPA recommends that the same approach be used in any analysis that compares two or more cases (e.g., a comparison of emissions with and without a control strategy).

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[28] More information about creating complete inventories using the Emission Rates calculation type can be found in the presentations used in EPA's 2-day training course.

Unless there's a specific reason to choose Emission Rates, modelers may want to choose Inventory to simplify the analysis and avoid introducing user error.

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.

When modeling a specific period of time, modelers must select all shorter units of time to ensure the estimate is complete. Table 3-1, summarizes the selections necessary on the Time Spans Panel when modeling a time period longer than hour:

Table 3-1: Time Spans Panel Summary

If modeling GHG emissions for one:	Then on the Time Spans Panel, select:
Day	All 24 hours and the weekday day type. The modeler will also need to choose the relevant month and year
Month	All 24 hours and both day types, the relevant month, and year
Year	All 24 hours, both day types, all 12 months, and the relevant year

This general guidance about selecting all shorter units of time also applies when preaggregating time, discussed in Section 2.5. For example, when preaggregating information over a year, the modeler would need to choose all 24 hours, both day types, all 12 months, and the relevant year on this panel.

3.3.1 Calendar Year of Evaluation

MOVES can model calendar years 1990 and the years 1999 through 2060. The County Scale in MOVES allows only a single calendar year in a RunSpec. Users who want to model multiple analysis years using the County Scale will need to create multiple RunSpecs, with local data specific to each analysis year, and run MOVES multiple times. MOVES can be run in batch mode operation to automate the process of doing multiple MOVES runs.[29]

While modelers can include more than one year in a Default Scale run, EPA recommends each year be run separately when using the Default Scale as well. If a modeler is prioritizing model performance, running each year independently in batch mode will lead to quicker results. In addition, if the modeler has input data that varies by year, running each year independently is recommended.

[29] For information on batch runs, contact EPA's MOVES in-box at mobile@epa.gov.

3.3.2 Month of Evaluation

MOVES allows users to calculate emissions for any month of the year. Modelers can select one or more months in a single RunSpec to produce emissions for those months. To develop an annual inventory of onroad GHG emissions, select all months. Since MOVES can model all 12 months in one run, there is no advantage to running only some months and not all of them; doing so would give an incomplete result for an annual inventory.

When modeling multiple months (e.g., all 12), 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 County Data Manager (or CDM, described in Section 4 of this document) cannot be varied by month. Therefore, if the user had, 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.

If the user has selected the Emission Rates option, the Month can be used to input groups of temperatures as a shortcut for generating rate tables for use in creating inventories for large geographic areas. However, this is useful only for estimating running exhaust emissions, and not start or hotelling emissions. The MOVES training materials provide more details. [30]

3.3.3 Type of Day of Evaluation

Weekdays and weekend days are modeled separately in MOVES. If modeling one day, select weekdays. Otherwise, if modeling a month or a year, select both day types.[31]

Note that different speed and VMT information for weekdays and weekend days can be provided to MOVES 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. In general, if data for these inputs are available to differentiate between the day types, they should be used, but if certain data are available for only one type of day, use the same information for both types of days.

[30] The latest MOVES training materials can be downloaded from EPA's MOVES training website.

[31] If only one day type is selected, but Month or Year output aggregation is selected on the Output Emission Detail Panel (see Section 3.9), MOVES will provide an incorrect result. This is because the month or year emissions will be the total emissions from only the day type selected (e.g., weekdays), and the emissions from the other day type (e.g., weekend days) will be missing.

Tip: Unless emissions are needed for only one day type, 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 average annual daily VMT (AADVMT) Converter for MOVES (described in Section 4.7 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 available only 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

This option allows users to select single or multiple hours. However, to properly estimate emissions for a day, month or year, you must select all 24 hours.

3.3.5 Time Span Panel Sections: Emission Rates Mode

When Emission Rates is chosen, 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. The selected month will have no impact on the emissions results (assuming identical fuel and temperature inputs). For instance, a temperature of 40 degrees for a particular hour will result in the same emission rate regardless of what month is chosen.

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.

For start emissions, users can create a start emissions table 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.

This is an advanced approach and recommended only where lookup tables of emission rates are necessary. Users should consult Section 4.4.1 for additional guidance on developing rate lookup tables or refer to the MOVES training materials online.[32]

[32] The latest MOVES training materials can be downloaded from EPA's MOVES training website. Refer to the Emission Rates module.

3.4 Geographic Bounds

In Default and County Scales, the Geographic Bounds Panel is used to specify the county to be modeled. Only one county and year can be modeled per run in County Scale. See Table 2-2 for a summary of modeling approaches for modeling multiple counties.

The Default Scale can model one or more counties in a state or in multiple states at a time. The Default Scale can also model one or more entire states at a time.

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 4.5 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. 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. Selecting a vehicle type will select all fuel types for that vehicle.

For a GHG inventory, select all vehicle types present in the area of analysis: in the majority of cases, that will be all vehicle types. Deleting any source type/fuel type combination from the list will remove all entries for that source type, which will lead to erroneous calculation of the total emissions inventory for a county.

Selection of 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 4.10 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 CNG, diesel, and gasoline, users would address this in the Fuel Tab using the AVFT input.

See Section 4.10 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 (Data Importer at the Default Scale) using the Source Type Population, Age Distribution, Vehicle Type VMT, Average Speed Distribution, and Road Type Distribution Tabs. The CDM simplifies importing specific local data without requiring direct interaction with the underlying database. See Section 4 of this document for more information on these input options and the use of default vs. local information.

3.6 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)

Generally, all road types should be selected. Limiting 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. The determination of rural or urban road types should be based on the Highway Performance Monitoring System (HPMS) classification of the roads in the county being analyzed.[33]

Onroad GHG emissions estimates should include the Off-Network road type in order to account for GHG emissions from vehicle starts and hotelling activity. The Off-Network road type is automatically selected when start or hotelling pollutant processes are chosen. Off-Network activity in MOVES is primarily determined by the Source Type Population input, which is described in Section 4.5 of this document. County specific hotelling activity can be added in the County Data Manager when available.

MOVES uses Road Type to assign default drive cycles to activity on roadtypes 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 some ramp activity is also included.[34]

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[33] See the Federal Highway Administration's website at Highway Performance Monitoring System (HPMS).
[34] 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 MOVES4* (EPA-420-R-23-005).

Selection of road types in the Road Type Panel also determines the road types that will be included in the MOVES run results. Different characteristics of local activity by road type are entered in the CDM using the Average Speed Distribution and Road Type Distribution Importers, described in Section 4.

3.7 Pollutants and Processes

The Pollutants and Processes Panel allows users to select from various pollutants, types of energy consumption, and associated processes of interest. In MOVES, a pollutant refers to particular types of pollutants or precursors of a pollutant but also includes energy consumption choices. Processes refer to the mechanism by which emissions are created, such as running exhaust or start exhaust. Users should select all processes associated with a particular pollutant in order to account for all emissions of that pollutant. This can be done by checking the box to the left of the pollutant, which selects all of the relevant processes for that pollutant. Note that checking the box next to any of the GHG pollutants selects only running, start, and hotelling processes. Evaporative processes do not produce GHG emissions.

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

For many pollutants, the emissions calculation in MOVES is based on prior calculation of another pollutant. In such cases, users must select all the base pollutants that determine a particular dependent pollutant. 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 using the Inventory calculation type, the total emissions for a particular pollutant are the sum of the emissions for all pollutant processes that apply to the pollutant. When using the Emission Rates calculation type, 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.

Note that this is also the panel to select the Total Energy Consumption.

3.7.1 Pollutants

Users may want to select any of the following pollutants, depending on the purpose of their analysis:

- Atmospheric CO_2;
- Methane (CH_4);
- Nitrous Oxide (N_2O); and
- Elemental Carbon (equivalent to black carbon; available under Primary Exhaust PM2.5 - Species).

Atmospheric CO_2 is the sum of tailpipe CO_2, and CO and unburned fuel that is assumed to convert to CO_2 in the atmosphere. The difference between atmospheric CO_2 and tailpipe CO_2 is negligible—when tailpipe CO_2 is desired from MOVES, atmospheric CO_2 is the appropriate pollutant to use.

If "Atmospheric CO2" is chosen, then "Total Energy Consumption" must also be chosen. The "Select Prerequisites" button can be used in this case.

If methane is chosen, the user will be prompted to select "Total Gaseous Hydrocarbons." Using the "Select Prerequisites" button will select only the necessary processes, whereas checking the button to the left of Total Gaseous Hydrocarbons would select all processes for hydrocarbons, including evaporative processes. Evaporative processes for hydrocarbons need not be selected when modeling methane, because methane is a result of combustion.

"Elemental Carbon" can be found under "Primary Exhaust PM2.5 – Species" on the Pollutants and Processes Panel. When the user clicks "[+]," Elemental Carbon is in the list of $PM_{2.5}$ species displayed.

Additionally, users may select "CO_2 Equivalent" or CO_2e in the Pollutants and Processes Panel. The CO_2 Equivalent pollutant is the sum product of all greenhouse gases multiplied by their associated global warming potential (GWP), expressed as a unit of CO_2. The CO_2 equivalents that MOVES uses are as shown in Table 3-3:

Table 3-3: CO_2 Equivalence Factors in MOVES

Pollutant	CO_2 Equivalent[35]
CO_2	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298

If CO_2 equivalent is checked, MOVES will report the CO_2 equivalent of the pollutants that the user has selected. For example, if you want MOVES to calculate the CO_2 equivalent of methane only, select CO_2 equivalent from the list as well as methane. If you want the total CO_2 equivalent of all three GHGs, select CO_2 equivalent as well as CO_2, methane, and nitrous oxide. CO_2 equivalent will include CO_2 if CO_2 has been selected in this panel. MOVES provides reminders of which pollutants will not be included in the CO_2 equivalent calculation if all three have not been selected. Elemental carbon is not included in the CO_2 equivalent calculation even if elemental carbon is selected on the panel.

3.7.2 Pollutants and Processes in Emission Rates Mode

Users should be aware that MOVES produces separate output tables with different activity measures for different emission processes:

[35] Greenhouse gas equivalencies are quantified as CO_2-equivalent (CO_2e) emissions using weightings based on the 100-year Global Warming Potentials, using IPCC Fourth Assessment Report values unless otherwise stated.

- Rate per Distance Table - emissions in mass per distance (e.g., grams/mile); user multiplies these rates by total VMT by vehicle type:
    - Running exhaust
    - Crankcase running exhaust
    - Brake wear (select this process only if elemental carbon is being analyzed)
    - Tire wear (select this process only if elemental carbon PM is being analyzed)

  Note: The processes – Evaporative permeation, Evaporative fuel vapor venting, Refueling displacement vapor loss, and Refueling spillage loss – are not necessary to select as they produce no GHG emissions.[36]

- Rate per Vehicle Table – emissions in mass per vehicle (e.g., grams/vehicle); user multiplies their rates by total vehicle population by vehicle type:
    - Start exhaust
    - Crankcase start exhaust
    - Exhaust extended idle emissions (long-haul combination trucks only)
    - Crankcase exhaust extended idle emissions (long-haul combination trucks only)

  Note: Rates for evaporative and refueling processes are not necessary to use for a GHG inventory as they produce no GHG emissions.[37]

MOVES includes alternative rates for some of the emissions reported in the Rate per Vehicle Table. These rates represent alternative forms (units) of some of the emissions reported in the Rate per Vehicle Table, not additional emissions. Users should not apply both sets of rates to the same emissions processes, in order to avoid double-counting.

- Rate per Start Table (alternative to using Rate per Vehicle Table for start emissions) – emissions in 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) – emissions from hotelling activity in 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 order to calculate a total emissions inventory using the Emissions Rate mode, users need to properly sum the products of emission rates and activity for each vehicle type, for each applicable pollutant process in each of the applicable tables.

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[36] If a co-pollutant analysis is being completed, these processes may be necessary.
[37] If a co-pollutant analysis is being completed, these processes may be necessary.

3.8 General Output

In general, users can generate output in whatever form works best for their specific needs. The following subsections provide some considerations when specifying output details and format. 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 by including "_out" at the end of the output database name.[38] 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., runs that are identical except for the percentage of electric vehicles) or sum them (e.g., runs for multiple counties that are part of the same metropolitan area). EPA recommends that users create a new output database for new or unrelated analyses.[39] Users will also want to consider total database size when deciding which RunSpecs should use the same output database. For more recommendations, see the MOVES training materials.

3.8.2 Units

Users are free to choose any of the mass unit selection options, but should generally choose a unit whose magnitude is appropriate for the parameters of the run so that interpretation and processing of the output is easier. The unit chosen applies to all pollutants being modeled.

- If the run is for CO_2 emissions at the county level only, selecting tons may be appropriate.
- If the run includes other GHG emissions such as elemental carbon or methane, or other non-GHG pollutants such as criteria pollutants or mobile source air toxics, modelers should select a smaller unit such as grams. For these other pollutants, selecting tons for a run where emissions are reported for each hour may produce emissions of "zero" if emissions are significantly less than one ton.

3.8.3 Activity

MOVES allows the user to select multiple activity output options, i.e., for MOVES to report in the output. These options are:

- Distance Traveled,
- 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 and whether the monthly and daily VMT fractions are

[38] Database names can include only letters, numbers, and underscores. No spaces or other characters are allowed.
[39] Output databases created with MOVES4 are not compatible with output databases created with earlier versions of MOVES.

correctly allocating the annual VMT inputs. Therefore, EPA recommends selecting “Distance Traveled,” and “Population” so that you can compare these outputs with the VMT and population that you 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.

For Emission Rates calculations, distance and population are reported automatically, corresponding to the values used in MOVES intermediate calculations.

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. 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, additional detail results in larger output tables and longer database query times and can increase the likelihood of user errors when results need to be aggregated. Thus, users should consider the level of detail needed and consider how the results will be post-processed. Once the run is executed, detail that was not selected cannot be obtained without re-running MOVES. In the event that another run is needed for more output detail, MOVES run execution times for CO_2 and/or energy consumption are relatively short.

Output Aggregation:

- Time: Selecting the time aggregation level (i.e., Hour, Day, Portion of Week, Month, or Year) most appropriate for the modeler’s analysis time scale is recommend (e.g., for an annual emission inventory, select Year). If the model results may be used for a future analysis with a shorter time scale, output data cannot be disaggregated, so output at the Hour level would be best. 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 the Default Scale where more than one county is selected, the user can have the output reported by “Nation,” “State,” or “County.” If state is selected, MOVES will show the output by state but only for the counties selected. For example, if four counties in one state and five counties in another state were selected in the Geographic Bounds Panel and “State” is selected in the Output Emission Detail Panel, the output for these counties will be grouped by state.

For All/Vehicle Equipment Categories:

- Model Year: In most cases, you should not select Model Year, unless you have activity information by model year or have 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 31.

- Fuel Type: Detailing output by Fuel Type may be helpful if the AVFT will be used to input activity by alternate fuel vehicles or if emissions by fuel type - e.g., gasoline, diesel, electricity - 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 the 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 not critical for GHG modeling.

3.9.1 Output Emission Detail When Using Emission Rates Mode

With Emission Rates mode selected, Emission Process and Road Type are automatically selected in the Output Emission Detail Panel. Users with VMT by source use type should also always select Source Use Type when using the Emission Rates mode. 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 Road Type and Source Use Type are selected in this panel 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 mass 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 mass per vehicle emission rates (or alternative mass per start table for starts or mass per hour table for hotelling, as described in Section 3.7.2).

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 (and much larger) 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. However, smaller geographic areas may not have activity data in this level of detail, and users may find that more aggregated rates are easier to use in producing an inventory.

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 graphical user interface (GUI) for importing data (the Data Importer at the Default Scale, or the County Data Manager, CDM, at the County Scale) by clicking on the "Enter/Edit Data" button. It is not necessary to create the database before opening the Data Importer or 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 applicable for creating GHG inventories, 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. Modeling LEV will matter only if you are looking to estimate methane and/or elemental carbon emissions.

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 of the MOVES Technical Guidance for information about using MOVES to estimate California’s vehicle regulations.[40]

[40] MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, August 2023, EPA-420-B-23-011.

Section 4: Developing Onroad Inventories in MOVES: Creating the Input Database

After completing the RunSpec, the next step for developing onroad GHG inventories is to supply MOVES with data to create an input database. If using the Default Scale, the Data Importer can be used to incorporate local data, but it is optional, and a Default Scale run can operate with national default data instead. If using the County Scale, the County Data Manager (CDM) is used to create an input database and populate it with local data. Users can review the appropriate sections of the MOVES training for more information on creating a RunSpec and an input database. Refer to Section 2 for more information about the difference between the scales and when each would be appropriate for a GHG analysis.

As with any model, the quality of the data inputs greatly affects the accuracy of the outputs. MOVES requires input data to describe the location, time, and characteristics of the vehicle fleet being modeled to calculate emissions. Modelers can either rely on MOVES default information or local data that the user inputs. The data contained in the MOVES default database are typically not the most current or best available for any specific county. Therefore, with the exception of fuels, EPA recommends using local data for MOVES for GHG analyses when available to improve the accuracy of GHG emissions estimates. At a minimum, EPA strongly encourages the use of local VMT and vehicle population data.[41] EPA believes these inputs have the greatest impact on the quality of results. However, if local data are not available, MOVES default data may be useful for some inputs without substantially affecting the quality of the results. This section explores the process of entering data inputs and discusses the various data input tabs.

4.1 Data Importer and County Data Manager Tabs

The Data Importer, which is available when using the Default Scale, and the CDM available with the County Scale, serve the same function: they simplify importing specific local data without requiring direct interaction with the underlying input database. The Data Importer and CDM include multiple tabs, each one of which opens importers that are used to enter specific local data. These tabs and importers include the following:

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

[41] The default VMT data included in MOVES4 are for the year 2021. When a future year is modeled using the Default Scale (see Section 2.3.2), MOVES applies an annual growth rate to the 2021 national VMT for the appropriate number of years. A portion of this projected national VMT is then allocated to the geographic area of interest using factors derived from the 2020 NEI. Thus, EPA expects that users will always be able to find more recent and accurate VMT information than what is available within the MOVES model.

- Idle
- Retrofit Data
- Hotelling
- Generic
- Zone – only in the Data Importer

Each of the importers allows the user to create an import template file with required data field names and some key fields populated. The user will then edit these templates to add specific local data with a spreadsheet application, and import each data file into an input database for the run. In some importers, there is the option to export default data from the MOVES default database to review it. Once the user determines that the default data are applicable to the particular analysis or determines that the default data need to be changed and makes those changes, the user then imports that data into the input database. Details of the mechanics of using the data importers are provided in the MOVES training.[42] Guidance for the use of these importers for estimating onroad GHG emissions is given below.

4.2 Importing Local Data When Using the County Scale

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 CDM is a user interface developed to simplify importing specific local data for a single county into an input 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.[43] When the database is created, MOVES records the selections in the RunSpec at that moment and uses this information to determine which table rows 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.

In Emissions Rates runs, entering reasonable activity inputs in the CDM is important even though activity data will be applied outside of MOVES to calculate an inventory. Vehicle activity inputs are important because MOVES uses them to calculate the relative amounts of running and resting activity, which in turn affects the rates for start and hotelling. As a general matter, users should input accurate activity for the scenario being modeled regardless of whether MOVES is being used in Inventory or Emissions Rates mode.

[42] The latest version of the MOVES "Hands-on Training Course" is available on EPA's MOVES training website.

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

4.3 Importing Local Data When Using the Default Scale

The Data Importer can be accessed from the Create Input Database Panel. EPA recommends that this database name end with "_in" to indicate it is a user input database. Once an input database has been created, data can be edited by clicking the "Enter/Edit Data" button.

As described in Section 2, the Default Scale can be used for GHG analyses, and using local data at this scale increases accuracy compared to the default data. At the Default Scale, local data can be imported to an input database for a MOVES run using the Data Importer, which has the same set of importers as the CDM, and an additional Zone importer. As of MOVES4.0.1, the Zone Importer allows the modeler to allocate local VMT and vehicle population data within the Default Scale.[44]

At the Default Scale, MOVES calculates VMT and vehicle populations for each county in the RunSpec by applying the corresponding ZoneRoadType and Zone fractions to the VMT and vehicle population values. Previously, it was impractical to use user-supplied VMT and vehicle populations at the Default Scale because there was no way to supply the ZoneRoadType and Zone Tables, which reflected the nation as a whole. Therefore, VMT and vehicle population values, whether national default or user-supplied, were always assumed to apply to the entire U.S. rather than the geographic area chosen in the RunSpec.

EPA added the Zone Tab to the Data Manager in MOVES4.0.1. This tab can be used to supply custom ZoneRoadType and Zone tables at the Default Scale, which can be used in conjunction with user-supplied VMT and vehicle population values.

If a modeler chooses to use the Default Scale and wants to supply VMT for one or more counties or states, they must also supply data for the Zone tab, the Source Type Population tab, and the Vehicle Type VMT tab. Modelers cannot supply data for just one or two tabs (i.e., just Zone/ZoneRoadType and VMT, for example; in this case, vehicle populations must also be supplied).

When using this new MOVES4.0.1 feature when a single county is selected in the RunSpec, within the Zone tab, the modeler needs to:

- Edit the ZoneRoadType table to include a SHOAllocFactor of 1.0 for each road type, and
- Edit the Zone table to include 1.0 for all of the "AllocFactor" columns.

This will, in effect, allocate 100% of the VMT and vehicle population (supplied through the Vehicle Type VMT and Source Type Population tabs, respectively) to the selected county.

If more than one county is selected in the RunSpec:

1. Supply VMT and vehicle population inputs that reflect the combined VMT and vehicle populations for all selected counties.
2. Calculate each individual county's proportion of the combined VMT.

[44] In MOVES versions earlier than MOVES4.0.1, local VMT and vehicle populations cannot be added through the Data Importer.

3. In ZoneRoadType, supply these values for each county's SHOAllocFactor, using the same value for each road type.
4. In Zone, supply these values for each county's "AllocFactor" columns.[45]

If state preaggregation is used, the ZoneRoadType and Zone tables should be populated following the instructions above, providing the AllocFactors for every county in the run.

Once a Default Scale run with local VMT and vehicle populations has been setup, the Input Data Sets section in the Advanced Features Panel can be used to confirm the correct database is listed.

> ***The remainder of Section 4 describes the panels to create an input database file in terms of the County Data Manager. Because of the similarities between the County Data Manager and the Data Importer, this information applies to the Data Importer except where otherwise noted.***

4.4 Meteorology Data

Ambient temperature and relative humidity data are important inputs for estimating onroad GHG emissions with MOVES. These meteorology data inputs affect air conditioner use and electric vehicle (EV) energy consumption. Local meteorology data cannot be used in the Default Scale.

MOVES requires a temperature (in degrees Fahrenheit) and relative humidity (in terms of a percentage, on a scale from 0 to 100) for each hour selected in the RunSpec. For example, MOVES requires a 24-hour temperature and humidity profile to model a full day of emissions on an hourly basis. EPA recommends that users input the average daily temperature profile for each month if they are modeling all 12 months, but only need to input the average annual temperature for an annual inventory.

Temperature assumptions used for estimating onroad GHG emissions should be based on the latest available information. The MOVES database includes default monthly temperature and humidity data for every county in the country. These default data are based on average monthly temperatures for each county from the National Climatic Data Center for the period from 2001 to 2011. These national defaults can be used for a GHG inventory, or more recent data should be used. Based on national trends, more recent temperature data is likely to be warmer, which tends to increase GHG emissions because MOVES estimates vehicle air conditioner use based on temperature. Detailed local meteorological data are available from the National Climatic Data Center. EPA recommends documenting the sources of temperature data and any methods used to adjust them to fit the requirements of MOVES, as a means of keeping track of the inputs to the analysis and to ensure that the same method can be replicated over time.

[45] If a county's share of start and hotelling activity is not expected to be proportional to the share of VMT, consider other approaches. The simplest approach might be to model each county separately.

4.4.1 Meteorology Data in Emission Rate Calculations

Users can develop Emission Rates for a single county in MOVES. If the Emission Rates calculation type is chosen in the RunSpec, users can enter a different temperature and humidity for each hour of the day to create an emission rate table that varies by temperature for running emissions processes. Emission rates for all running processes that vary by temperature can be post-processed outside of MOVES to calculate emissions for any mix of temperatures that can occur during a day. This creates the potential to create a lookup table of emission rates by temperature for the range of temperatures that can occur over a longer period of time such as a month or year from a single MOVES run.

However, for emissions from any non-running processes that occur on the "off-network" road type, i.e., start and hotelling emissions, it is still necessary to define a temperature profile for each hour of the day. Unlike running emissions that depend entirely on temperature, off-network emissions depend on both temperature and hour of day. It is possible to model both running and off-network emission rates in one run to create a lookup table that can be post-processed into an inventory. As discussed in Section 3.3.5, creating a lookup table of emissions rates is an advanced approach and recommended only when necessary. See the MOVES Technical Guidance for further information.[46] The MOVES training materials also provides more details. [47]

4.5 Source Type Population

The CDM and Data Importer process Source Type Population differently. Please refer to Section 4.3 for specifics on how to include local source type population in the Default Scale.

In MOVES, start and hotelling activity is estimated based on the number of vehicles in an area rather than the VMT. Like running emissions, GHGs are emitted from starts (methane, N_2O, and elemental carbon) and hotelling (long-haul truck idling) emissions (all GHGs except N_2O). Thus, a good estimate of local vehicle populations is important. As noted in Section 2.3, local vehicle population data is likely to be more accurate than vehicle populations generated from MOVES default values, so EPA recommends developing appropriate vehicle population inputs for your area.

MOVES categorizes vehicles into 13 source types, which are subsets of five HPMS vehicle types, as shown in Table 4-1: MOVES Source Types and HPMS Vehicle Type.[48] Modelers should be able to develop population data for many of these source type categories from state motor vehicle registration data (e.g., passenger cars, passenger trucks, light commercial trucks, motorcycles). Where MOVES is used for Clean Air Act regulatory purposes, modelers may be able to get this information from agencies that are responsible for meeting those requirements, such as the state air quality agency or a metropolitan planning organization. Modelers may be

[46] MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, August 2023, EPA-420-B-23-011.
[47] The latest MOVES training materials can be downloaded from EPA's MOVES training website.
[48] There are actually 6 HPMS vehicle Type IDs, but MOVES uses Vehicle Type ID 25 to substitute for HPMS Type IDs 20 (short wheelbase light-duty) and 30 (long wheelbase light-duty) for VMT input only. For more information, see the Federal Highway Administration's website for Highway Performance Monitoring System (HPMS).

able to obtain population data for other types of vehicles from their owners or operators: population data for intercity buses may be available from bus companies, data for transit buses may be available from local transit agencies, data for school buses may be available from school districts, and data for refuse trucks may be available from refuse haulers or local governments.

Estimating population for other source types, particularly long-haul trucks, may be more difficult. If population data is not available for a particular source type, users could estimate population for that source type 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 base population estimates on 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 very 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).[49] Local VMT multiplied by the ratio of default population to default VMT will give an estimate of local population based on local VMT.

Table 4-1: MOVES Source Types and HPMS Vehicle Type

MOVES		**HPMS**	
Source Type ID	Source Types	Vehicle Type ID	Vehicle Type
11	Motorcycle	10	Motorcycles
21	Passenger Car	25	Light Duty Vehicles
31	Passenger Truck		
32	Light Commercial Truck		
41	Other Buses	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		

[49] Population isn't available in the Summary Reporter, which is not covered in this document. See the MOVES training materials for more information.

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

4.5.1 Source Type Population in Emission Rate Calculations

Users can develop emission rates for a single county in MOVES. If the Emission Rates option is used at the County Scale and Source Type is selected in the Output Emission Detail Panel, MOVES will produce emission rates for start emissions and hotelling emissions by source type in terms of unit of mass (e.g., grams) per vehicle. Total start and/or hotelling 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 data using the Source Type Population Importer that represents the population of vehicles in the total area where the lookup 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 lookup table results will be applied to more than one county, 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 Table by vehicle population. Alternatively, for start emission processes, use the rateperstart Table, which requires multiplying by the number of vehicle starts. For hotelling processes, use the rateperhour Table, which requires multiplying by the number of hotelling hours. All of these rate tables are found in the output database, see also Section 3.7.2.

4.6 Age Distribution

The age distribution of vehicle fleets can vary significantly from area to area. Fleets with a higher percentage of older vehicles will have higher emissions for two reasons:

1. Older vehicles have typically been driven more miles and have experienced more deterioration in emission control systems.
2. A higher percentage of older vehicles means that there are more vehicles in the fleet that were designed to meet older, less stringent emission standards.

Surveys of registration data indicate considerable local variability in vehicle age distributions, which is not reflected in the default age distributions in MOVES. The default database in MOVES has the same national default age distribution for each vehicle type in each year for every county, which is the national average.

Therefore, for estimating onroad GHG emissions, EPA recommends that states develop age distributions for the area being analyzed (e.g., for one or more individual counties, a state as a whole, etc.). Only one age distribution can be entered for the area being modeled, so if you had age distribution information that varies by county, you would have to do a separate run for each county to utilize it. An age distribution may have already been developed for SIP and conformity purposes and if so, could also be used for estimating onroad GHG emissions. EPA has made available MOVES4 tools for creating and converting age distributions.

A typical vehicle fleet includes a mix of vehicles of different ages. MOVES covers a 31-year range of vehicle ages, with vehicles 30 years and older grouped together. MOVES allows the user to specify the fraction of vehicles in each of 30 vehicle ages for each of the 13 source types in the model.

While the MOVES Age Distribution input asks for an age distribution by source type, EPA does not expect that detailed local age distribution data will 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 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. A set of these national default age distributions for all source types and all calendar years is available on EPA's website. 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, users have two choices when modeling future years:

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 (e.g., major recessions, the COVID pandemic) on the future fleet age distribution.

EPA has created the Age Distribution Projection Tool for MOVES4 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. 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 the recession, since the effect of the recession persists in the affected model years but diminishes in amplitude over time.

EPA recommends that users fully document the sources of data and methods used to develop local age distributions as a means of keeping track of the inputs to the analysis and to ensure that the same method can be replicated over time.

4.7 Vehicle Type Vehicle Miles Traveled (VMT)

The CDM and Data Importer process user input of VMT differently. Please refer to Section 4.3 for specifics on how to include local VMT in the Default Scale.

VMT inputs often have the greatest impact on the results of a state or local transportation GHG or energy consumption analysis. Regardless of calculation type, MOVES requires VMT as an input for onroad inventories. MOVES estimates emissions based on travel activity multiplied by emission factors. MOVES will multiply the VMT from each vehicle source type, on each road type, by the corresponding emission factors to generate an emissions inventory.[50] MPOs or state DOTs may have VMT estimates that can be used in MOVES. If reliable VMT data are not available locally, other sources of VMT and vehicle population data are available. The Federal Highway Administration (FHWA) also has resources that may be useful for local VMT data when not available.[51] For a future year, travel activity information for a GHG analysis can be estimated using a variety of methods. Future VMT can be estimated by applying a growth rate to historical VMT, or with a commercially available sketch planning tool, or a traditional four-step travel demand model. For example, in EPA's Travel Efficiency Assessment Method, a sketch planning tool is used to estimate changes in travel activity resulting from various emission reduction strategies. Then MOVES is applied to estimate the changes in criteria pollutant and GHG emissions.[52]

MOVES allows the option of entering either annual VMT or daily VMT. EPA recommends that users with average annual daily VMT (AADVMT) take advantage of the daily VMT input option. As another option, EPA has created a spreadsheet-based tool, the AADVMT Converter for MOVES4, 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 MOVES4.[53]

MOVES also 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, but results are likely to differ.

[50] This is true even when the calculation type is Emission Rates.

[51] For a historical year, one source of VMT data is the Federal Highway Administration's Highway Performance Monitoring System (HPMS). Another source of consistent local VMT information for the entire U.S. is FHWA's Database for Air Quality and Noise Analysis (DANA) tool, which also provides other traffic-based MOVES county-level inputs in the format required by MOVES (see FHWA's DANA tool page).

[52] For more information, see the "Travel Efficiency Assessment Method (TEAM) User Guide: Analyzing Passenger Travel Impacts and Emission Reductions from Travel Efficiency Strategies" "EPA-420-B-21-036, September 2021, and EPA's related documents to EPA's Travel Efficiency Assessment Method found on EPA's Estimating Emission Reductions from Travel Efficiency Strategies website.

[53] The AADVMT Converter can be found on EPA's Tools to Develop or Convert MOVES Inputs website. Instructions for use of the converter can be found within the spreadsheet.

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.[54] 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. 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 future year in a GHG 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.

4.7.1 Vehicle Type VMT in Emission Rate Calculations

If the Emission Rates option is used, and Source 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 mass 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 lookup 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 lookup 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.

4.8 Average Speed Distribution

Vehicle power, speed, and acceleration have a significant effect on vehicle emissions, including GHG 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 guidance in this section concerning the use of local speed distribution data applies whether local average speed distributions are applied within MOVES using the Inventory mode or outside of MOVES using the Emission Rates mode.

4.8.1 Average Speed Distribution: Guidance for Inventory Mode

When estimating onroad GHG emissions, a local speed distribution by road type and source type is useful to include if available. States could develop and use local estimates of average speed.

[54] For more information, see FHWA's Highway Statistics Series website.

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 information 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 FHWA also has free resources that may be useful for developing a speed distribution for MOVES.[55]

In cases where onroad emissions modeling has been done to meet SIP and conformity requirements for criteria pollutants, areas may already have developed this information. Users may want to find the latest average speed distribution used in onroad emissions modeling for a SIP or conformity determination in the area.

Table 4-2 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. This is particularly important for GHG analysis, since GHG emission rates are highest at low speeds and very high speeds. A single average speed will tend to be in the middle of the speed range where emission rates are lower, leading the analysis to underestimate GHG emissions.

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[55] See FHWA's National Performance Management Research Data Set (NPMRDS) and FHWA's Database for Air Quality and Noise Analysis (DANA).

Table 4-2: 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

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 4-1). 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.

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.

4.8.1.1 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 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.

4.8.1.2 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.

4.8.2 Average Speed Distributions in Emission Rates Calculations

If the Emission Rates option 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 for each source type in each speed bin. However, the CDM still requires a complete speed distribution to work, and the information provided in this input is used by MOVES to calculate the relative amounts of running and non-running activity, which in turn affects the rates for these processes and off-network idling. Therefore, speed inputs for Emission Rates runs must reflect realistic activity for the area.

4.9 Road Type Distribution

The fraction of VMT by road type varies from area to area and can have a significant effect on GHG emissions from onroad mobile sources. EPA expects states to develop and use their own specific estimates of VMT by road type for SIP and conformity analyses, so if your GHG analysis is for one of these areas, you may be able to obtain this information from the agency that does the MOVES modeling for those purposes. The VMT fractions by road type used for estimating onroad GHG emissions should be consistent with the most recent information used for transportation planning. 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.

If this information is not available or easily obtained, then modelers could use the Default Scale. Default information for this input is not available at the County Scale.

4.9.1 Road Type Distribution: Guidance for Inventory Mode

As in the case for other MOVES inputs, EPA does not expect that users will be able to develop local distributions of VMT by road type for all 13 vehicle source types. If local road type distributions are available for some, but not all source types, the same road type distribution can be used for all source types within an HPMS vehicle class. For example, users could apply 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. Users could also apply the same road type distribution across multiple HPMS vehicle classes if more detailed information is not available.

4.9.2 Road Type Distribution: Guidance for Emission Rates Mode

If the Emission Rates option 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 4.14.2 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 must 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.

4.10 Fuel (Supply, Formulation, Usage Fraction, and AVFT)

MOVES has four tables – called FuelFormulation, FuelSupply, FuelUsageFraction, and AVFT (Alternative Vehicle Fuels and Technology) – that interact to define the fuels used in the area being modeled.

- The FuelSupply Table identifies the fuels used in a region by a 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. conventional 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.

In general, users should rely on the default county-level fuel information in MOVES in a GHG analysis. The default fuel tables in MOVES have been revised and reflect EPA's latest information about fuel use in the United States.

The following subsections of this document specify situations where changes to the MOVES default fuel data are appropriate. This guidance will apply for a single county, and for Emission Rates and Inventory runs.

For new major MOVES versions, EPA develops updated fuel properties by region based on averages of survey data as well as data provided to EPA as part of EPA fuel compliance programs. These updated data provide consistent and maintainable fuel defaults that account for fuel production and distribution networks, natural borders, and regional/state/local variations in fuel policy.

The default fuel properties in MOVES4 are described in the MOVES technical report, *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES4*.

4.10.1 Fuel Formulation and Fuel Supply Guidance

MOVES has default gasoline, E-85, and diesel fuel formulation and supply information for every county-year-month combination that can be selected. These default tables are based on volume-weighted fuel property data for thousands of batches of fuel produced in or distributed to each of the fuel regions. EPA recommends using the default fuel supply and fuel formulation data for GHG analyses. If you have reason to believe the default data do not reflect the fuel used in the modeled area, see the MOVES Technical Guidance for more information about how to change these inputs.[56]

MOVES includes the GHG emissions from biofuels, such as ethanol and biodiesel, in its in-use mobile source inventories.[57] Users that want information about the biofuels included in MOVES should consult the MOVES Onroad Technical Reports.

Fuel Formulation

The FuelFormulation Table defines the attributes (such as RVP, sulfur level, ethanol volume, etc.) of each fuel. Users who would like more information about fuel formulation portion of the Fuel Tab in MOVES can refer to the MOVES Technical Guidance.[58] The Technical Guidance provides detail about each field in the FuelFormulation Table and highlights the characteristics users should be able to provide and where default data can be used.

Fuel Supply

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[56] Default fuel information in MOVES4 is based on the information in the fuel supply report for MOVES4, *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES4*, available at https://www.epa.gov/moves/moves-onroad-technical-reports. It does not necessarily reflect later changes made to local fuel requirements.

[57] In MOVES, ethanol and biodiesel have comparable CO_2 emission rates to their conventional fuel counterparts. For more information, see Table 4-1 of the Onroad Technical Report: *Greenhouse Gas and Energy Consumption Rates for Onroad Vehicles in MOVES4.*

[58] MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, August 2023, EPA-420-B-23-011.

The FuelSupply Table identifies the fuel formulations used in an area and each formulation's respective market share. After the fuel formulations for the area being modeled have been reviewed and/or modified, the FuelSupply Table can be populated. There are six fields in this table. The fuelregionID field identifies the area being modeled. 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 described in detail below.

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 below in Table 4-3:

Table 4-3: MOVES Fuel Types

fueltypeID	Description
1	Gasoline
2	Diesel Fuel
3	Compressed Natural Gas (CNG)
5	Ethanol (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.

4.10.2 Fuel Usage Fraction

E-85 capable vehicles, also known as flex-fuel vehicles (FFVs) exist throughout the country and are capable of using either conventional gasoline or E-85 fuel, which is a blend of 85% ethanol and 15% gasoline. E85 has a slightly different carbon content than either E10 or E0 gasoline, so the E85 usage fraction can have a small impact on CO_2 emissions.[59] It will also have a small effect methane and EC emissions.[60] 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 means gasoline only
- sourceBinFuelTypeID = 2 means diesel
- sourceBinFuelTypeID = 3 means CNG
- sourceBinFuelTypeID = 5 means FFV
- sourceBinFuelTypeID = 9 means 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

[59] See Table 4-1 in the report Greenhouse Gas and Energy Consumption Rates for Onroad Vehicles in MOVES4.
[60] See the report Speciation of Total Organic Gas and Particulate Matter Emissions from Onroad Vehicles in MOVES4.

either 1 (gasoline) or 5 (E-85). The usageFraction column of this table defines the distribution of how much E-85 compared to gasoline being burned by FFVs.

MOVES contains default estimates of E-85 fuel usage for each county in the U.S. 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.

Please note that this table defines the fraction of E-85 use among E-85 capable vehicles, not the fraction of 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 4-4: 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 0.0 for fuelSupplyFuelType ID 5
Exclusively E-85	0.0 for fuelSupplyFuelType ID 1 1.0 for fuelSupplyFuelType ID 5
On average, 75% gasoline and 25% E-85	0.75 for fuelSupplyFuelType ID 1 0.25 for fuelSupplyFuelType ID 5

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

4.10.3 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 and is one of the most important tables to customize for a GHG analysis. 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,[61]
- CNG,
- battery electric (BEV), and

[61] The E-85 fraction represents the fraction of flexible fuel vehicles (FFVs), 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 4.10.2.

- fuel cell electric (FCEV).[62]

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, these vehicles are included in the gasoline vehicle category, consistent with EPA's regulations for these vehicles as they are subject to the gasoline vehicle standards. 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).[63]

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.

Sources of vehicle registration data, which can be used to create fuel type distributions, include:

1. Where available, modelers 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 AVFT information that EPA has compiled as inputs for the National Emissions Inventory (NEI) data for 2020. This information is a combination of state submitted data and EPA information and is available from EPA's Onroad NEI Data website. Modelers would need to download and

[62] 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. MOVES4 adds BEV and FCEV as options for all heavy-duty source types, as well as CNG long-haul combination trucks.

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

"unzip" their state's file, locate the county of interest, and save the AVFT input file.[64] This would then be the starting point for the AVFT Tool described below.[65]

The one situation where it may make sense to use 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 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, 2023, would include some model year 2023 vehicles and may even include some model year 2024 vehicles. However, since both model year 2023 and 2024 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 2023 and 2024. In this example, sales of model year 2022 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.

4.10.3.1 AVFT Tool

The AVFT Tool, included with MOVES starting with MOVES4, is found in the Tools drop-down menu in the MOVES GUI. The AVFT Tool 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 CDM.

This tool has two functions:

- It can project future fuel type distributions based on the combination of local historic data and projected national trends.

[64] Please see the NEI 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," available on EPA's MOVES training website, 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.

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

- It can gap-fill local historic fuel type distribution data if necessary. Since MOVES models vehicles from ages 0 to 30 years in each run, the AVFT Tool will gap-fill (as needed) model years between the last complete model year data that the modeler inputs to the tool and 30 years *prior* to that model year.

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.[66] The tool also requires the modeler to identify the last complete model year (see description in Section 4.10.3, above) and the analysis year to be specified in the tool's GUI. The tool will gap-fill data 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.[67] Detailed instructions can be found within the tool itself ("AVFT Tool Help").

This tool presents two 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 to use varies by source type and depends on the types of gaps present in the source data for local fuel type distributions. Note that if the input data do not contain gaps, neither method will affect the input data. The AVFT Tool's gap-filling methods are *Fill with 0s* and *Use defaults and renormalize*:

- <u>Fill with 0s</u>:
    - This method identifies the source type and fuel type combinations that MOVES is capable of modelling that are missing in the input fuel type distributions and fills them with 0s.
    - EPA recommends using this method when no model years are missing completely in the input data and 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, and it will not change the local data values.
    - However, if any model years are completely missing for a source type in the input data between the last complete model year and 30 years prior to that model year, this method will produce 0s for all fuel types and result in a tool error. (This

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[66] The AVFT Tool is not applicable for motorcycles (sourceTypeID 11) because MOVES models only gasoline motorcycles. The tool will produce the right number of rows for motorcycles but there are no methods for them.
[67] If you need to model an earlier calendar year than the year selected as the "last complete model year," the AVFT Tool will not provide all the model years needed in its output. In this case, you will need to run the tool a separate time specifically for the earlier calendar year run. For this separate run, enter the earliest calendar year as the "last complete model year" input.

could be the case, for example, if the fleet in the area is relatively new and vehicles older than, for example, 20 years, are so few and far between that model years are completely missing for some source types.) To correct this error, either manually enter a reasonable fuel type distribution for those model years in the input data or select the "Use defaults and renormalize" method instead.
    - Note that if the input data do not have missing values, this method will not change the input data.
    - This is the default method for all source types other than long-haul vehicles.
- Use defaults and renormalize:
    - 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.
    - For model years and source types with no input data, i.e., model years of a source type that are completely missing, this method copies the MOVES national default fuel type distributions.
    - EPA 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 "use defaults and renormalize" selected for these source types, the output of the tool will include the national default fuel type distributions for these vehicles.
    - EPA also 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).
    - If the input data do not have missing values, this method will not change the input data.
    - This is the default method for Single Unit Long-haul and Combination Long-haul trucks.

Table 4-5: AVFT Gap-Filling Methods Summary Table

AVFT Gap Filling Method	Default Recommended Use	Considerations
Fill with 0s	All source types except long-haul vehicles	Use when no model years are completely missing, and input data contain all model year and fuel type combinations in the local fleet
Use defaults and renormalize	Single-unit long haul trucks Combination long-haul trucks	Use for additional source types: • Where local data are not available or applicable; • When model years are completely missing; • When data is missing a specific fuel type altogether that is present in the field

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, which will apply 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.

Table 4-6: 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 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 MOVES training materials or 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.

4.11 Inspection and Maintenance Programs

Guidance for this tab depends on whether an area has an inspection and maintenance program, and which pollutants need to be modeled:

- When modeling an area where no I/M program applies, the user can check "No I/M Program" on this tab.
- When modeling an area with an I/M program, if CO_2, N_2O, and/or elemental carbon emissions are the only pollutants selected, the user can check "No I/M Program" on this tab because the only GHG affected is methane.
- When modeling an area with an I/M program, if methane, volatile organic compounds, or carbon monoxide is selected, the user should include the same I/M program inputs used for SIP and conformity analyses; refer to Section 4.9 of the MOVES Technical Guidance for more information.[68]

When modeling a state or other geographic area at the Default Scale that has areas both with and without I/M programs, modelers can rely on the MOVES default information for this input. If methane, volatile organic compounds, or carbon monoxide is selected, the user should include the same I/M program inputs used for SIP and conformity analyses for the county(-ies) with I/M; refer to Section 4.9 of the MOVES Technical Guidance for more information.

4.12 Starts

The Starts Tab is used to import local information on vehicle start activity. **This input is optional and should be used only if local data are available.** There are several sources for vehicle start information, but typically this is derived from origin/destination surveys used for travel demand modeling. If no starts information is available, this importer should not be used, and MOVES will calculate start activity based on user-supplied vehicle populations (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.

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[68] MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, August 2023, EPA-420-B-23-011.

Table 4-5 below summarizes the tables available in the Starts tab.

Table 4-7: 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 importers available under the Starts Tab include:

- Starts,
- StartsPerDayPerVehicle
- StartsPerDay,
- StartsHourFraction,
- StartsSourceTypeFraction,
- StartsAgeAdjust
- StartsMonthAdjust, and
- StartsOpModeDistribution

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 Output Emissions Detail 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 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. Information on starts must be provided by monthID, hourDayID, sourceTypeID, and vehicle ageID. To use this input, vehicle starts information must be available for all fields. 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 4.5). 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 20-30 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 4.5) 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." Longer periods of soak typically result in higher start emission rates. 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.

4.13 Hotelling

The Hotelling Tab is used to import information on combination truck hotelling activity. All hotelling processes only apply to long-haul combination trucks (sourcetype = 62). **This input is optional and should be used only if local data are available.** 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.

4.14 Idle Data

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

- *Extended 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 4.13 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 4.8 and 4.9, 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, on the shoulder of a road, in a parking lot, or in a driveway. 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 Idle Tab is used to import optional information on total idle activity, which is the sum of idling associated with driving as well as off-network idling (idling that is not related to combination truck hotelling activity). **This user input is optional and should be used only 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.[69] Survey data, limited observations, or assumptions about efficacy of idle restrictions should not be used to replace the default data in MOVES.

Section 4.14.1 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 4.14.2. Including the ONI emissions is a necessary step in calculating a complete emissions inventory when using the Emission Rates mode.

4.14.1 Off-network Idle: Guidance for Inventory Mode

The Idle Tab contains four importers. 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.

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[69] 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 MOVES4* (EPA-420-R-23-005), available on EPA's MOVES Onroad Technical Reports website.

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 4.13 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.

4.14.2 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.

4.15 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.

4.16 Generic

The Generic Tab can be used to export, modify, and re-import any of the default MOVES tables not covered by the CDM. Users should note that there are complex interactions between tables in MOVES, and there may be unintended consequences from changing any table. Generally, other than the Stage II vehicle refueling controls – which are not needed in a GHG or energy consumption analysis – most tables should never be changed; results would be compromised if such tables are modified. [70] EPA recommends that users consult with their EPA Regional Office before modifying any of the default MOVES tables accessible through the Generic Tab.

[70] See the MOVES Technical Guidance and the MOVES User Guide (Section 1.4 indicates web locations for these documents) for further information about Stage II vehicle refueling in MOVES.

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. This section covers using MOVES (MOVES-Nonroad) for developing transportation sector nonroad GHG inventories other than locomotives, commercial marine vessels and engines, and aircraft.[71]

The basic nonroad emission rates and population and activity estimates in MOVES, including estimates of population growth, have not changed from prior releases of the model. However, the latest version of MOVES should be used because it includes updated fuel information which does affect estimates of nonroad GHG emissions.

MOVES-Nonroad allows for the estimation of 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.[72] 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.[73] 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, as well as GHG emissions estimates.

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.

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, the Default Scale is the only option for domain/scale. The 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 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.

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[71] Information about developing emissions inventories for locomotives, commercial marine vessels and engines, and aircraft, can be found on EPA's Emissions Models and Other Methods to Produce Emission Inventories website.

[72] See *Nonroad Engine Population Growth Estimates in MOVES2014b*, EPA-420-R-18-010 for more information.

[73] See *Geographic Allocation of Nonroad Engine Population Data to the State and County Level*, *NR-014d* for more details.

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. To develop an annual inventory, all months should be selected. Both day types, weekday and weekend, should also be selected as well.

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. Much like the onroad Default Scale's Data Importer, local data entered through the Nonroad Data Importer will be applied to all counties, so it is recommended to run counties individually for which a user has local data.

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 metropolitan statistical 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 A. 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.[74] Note that MOVES-Nonroad does not model emissions from locomotives, commercial marine vessels, or aircraft.[75]

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. To estimate nonroad GHGs, a user should select Atmospheric CO_2 and Methane (CH_4). Note that MOVES does not model Nitrous Oxide (N_2O) for nonroad equipment.

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. Refer to Section 5.3 for suggestions on reducing the size of outputs. 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.

[74] See also the nonroad equipment portion of EPA's FAQ about modeling electric vehicles and equipment. For more information on quantifying emissions reductions from onroad and nonroad vehicle retrofit and replacements, see EPA's retrofit and replacement guidance.

[75] 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 the Methods to Produce Emissions Inventories portion of EPA's MOVES website.

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:

- 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 user 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 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 changes, the user then imports that data into MOVES. Details of the mechanics of using the data importers are provided in the MOVES training materials.[76] Guidance for the use of the data importers for GHG inventories is given below.

5.2.1 Meteorology

MOVES-Nonroad uses the same default meteorology data as MOVES-Onroad. For GHG inventories, the nonroad inventory should be based on the same meteorology data used for the onroad inventory – see Section 4.4 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)

Fuel properties are not likely to have a significant impact on GHG emissions. If updated fuel formulations and fuel supply are not already available, EPA recommends using default data for GHG analyses.

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 4.10.1 of this document.

[76] The latest MOVES training materials can be downloaded from EPA's MOVES training website.

In MOVES4, the default values in the FuelFormulation and NRFuelsupply tables are based on the information in the fuel supply report for MOVES4,[77] 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.[78] 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.[79] 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. 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, diesel, CNG, and LPG fuels for all relevant years.

Fuel properties are not likely to have a significant impact on GHG emissions. Ethanol does not have an impact on estimates of CO_2 emissions in MOVES, but users may want to quantify

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[77] See *Fuel Supply Defaults: Regional Fuels and the Fuel Wizard in MOVES4*, available on EPA's MOVES Onroad Technical Reports website.

[78] With the exception of Denver: at the time MOVES4 was initially released (i.e., version MOVES4.0.0), EPA did not have certainty about future fuel properties for the Denver area (i.e., MOVES4.0.0 continues to reflect fuel properties consistent with the implementation of the Federal 7.8 psi Reid Vapor Pressure requirement in the area). Therefore, until EPA releases a MOVES4 version that updates fuels for this area (i.e., reflects the fuel properties associated with the implementation of Federal reformulated gasoline (RFG) in the area), when modeling Denver counties, modelers will need to update the fuel tables in MOVES to reflect the local fuel in use. Counties in the Denver RFG implementation area include Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer (part), and Weld (part).

[79] The Fuels Wizard is not used for E-85, Diesel, or CNG fuels.

ethanol used when preparing a GHG inventory because ethanol is a renewable fuel. Users that want information about the biofuels included in MOVES should consult the most recent versions of MOVES user materials on the web (see Section 1.4 of this document).

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

For more information about fuel formulations, see Section 4.10.1. 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.

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. 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 users 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 GHG 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 11 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 summarizes what each of the scripts does and what kind of local activity data the results should be multiplied by. 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:

$$hp\ hours = rated\ horsepower \times load\ factor \times total\ hours\ of\ operation\ per\ equipment \times number\ of\ equipment\ operating$$

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:

$$vehicle\ days = number\ of\ equipment\ operating \times number\ of\ days\ of\ operation$$

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 of the MOVES Technical Guidance.

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_OperatingHour _by_SCC_and_ModelYear.sql	Emission factors in g/hour for each *SCC* and *model year*	SCC, Model Year	Total hours of operation for appropriate SCC and model year
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: Nonroad Equipment Types

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

Table A-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