MOVES4
Hands-on Training

May 2024 Update for MOVES4.0.1

Course Goals

- Provide an overview of MOVES
  - Understanding capabilities and input data needs
  - Deciding on a modeling strategy
  - Using MOVES to estimate both onroad and nonroad emissions
  - Applying relevant EPA guidance
- A detailed look at MOVES at the County Scale for SIPs and regional conformity analyses based on EPA's MOVES4 Technical Guidance
  - Setting up a RunSpec
  - Creating a county input database using the County Data Manager
  - Developing MOVES inputs
  - Using MOVES in both inventory and rates mode
  - Reviewing MOVES output
- Hands-on experience using the MOVES model

Course Prerequisites

- Before you begin the class, you should:
  1. Download and install MOVES from the Latest MOVES Model page
  2. Download and unzip the training files for the class available at the MOVES Training page
- This course includes editing spreadsheets and running macros
  - The latest version of Excel is recommended to utilize all features of MOVES' spreadsheet-based tools

Course Outline (1)

- Module 1: Introduction to MOVES
  - General MOVES overview and strategies for running MOVES
  - Introduction to the MOVES GUI
- Module 2: Default Scale
  - Explanation of the MOVES RunSpec
  - Hands-on exercise building a Default Scale RunSpec
- Module 3: Generating Inventories at the County Scale
  - Relevant guidance for County Scale runs
  - Explanation of MOVES inputs at the County Scale
  - Hands-on exercise using the County Data Manager to create an input database and running MOVES

Course Outline (2)

- Module 4: Processing MOVES Output
  - Discuss MOVES output tables
  - Post Processing menu
  - Hands-on exercise writing SQL scripts and using HeidiSQL
- Module 5: Review and Best Practices
  - Best practices for managing files
  - What to look for when reviewing MOVES runs
- Module 6: Emission Rates for County Scale Analyses
  - Discuss differences between rates/inventory
  - Considerations for input files
  - Hands-on exercise using emission rates output to build an inventory

Course Outline (3)

- Module 7: Project Scale Analyses
  - Overview and relevant guidance for Project Scale analyses
  - Explanation of MOVES inputs at the Project Scale
  - Hands-on exercise using Project Scale to model a small transportation project
- Module 8: Capstone Exercise
  - Develop a county level inventory for a given scenario
- Module 9: Modeling Nonroad Emissions
  - Options for modeling nonroad emissions
  - Hands-on exercise using a post-processing script to estimate a nonroad inventory

Course Outline (4)

- Module 10: Modeling Greenhouse Gases
  - Options for using MOVES to model greenhouse gas (GHG) emissions
  - Hands-on exercise using Default Scale with local VMT and vehicle population
- Module 11: Special Cases and Additional Examples
  - An optional module in the MOVES training
  - We may cover sections of this module if questions come up that are answered by this module
  - Otherwise, this is a good resource if you have additional questions after the training has concluded

Note on Hands-On Exercises

- The hands-on exercises are an essential part of this class
- Plan to spend several hours on the exercises
- While the class slides and answer key files demonstrate exactly how to complete each step, we recommend that you work though the exercises on your own, then use the supporting materials to check your work or to help if you get stuck

Module 1:
Introduction to MOVES

MOVES
Motor Vehicle Emission Simulator

EPA

Module 1 Overview

- Overview of MOVES
- Available documents
- Modeling options
- Introduction to MOVES Graphical User Interface

What is MOVES?

- The MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-art modeling framework for onroad and nonroad emissions inventory development
- EPA's official model for state implementation plans (SIPs) and transportation conformity analyses
- Current version is MOVES4
  - Most recent version on web for download is here. Patches and minor updates for MOVES4 are described in the update log

What can you use MOVES for? (1)

- MOVES can help you estimate emissions:
  - From **onroad vehicles** or **nonroad vehicles/equipment**
    - All mobile sources except locomotive engines, large marine engines, and aircraft
  - For many pollutants
    - Including criteria pollutants, greenhouse gases, and mobile source air toxics
  - For any year or shorter timeframe
    - Including the past, present, and future (1990 and any calendar year 1999-2060)
  - For any geographic area in the U.S.

What can you use MOVES for? (2)

- MOVES could be used to answer these types of questions:
  - Nationwide, how much CO_2 do freight trucks emit?
  - How much CO_2 will be emitted from the onroad vehicle sector in my state, in 2035?
  - How much NOx and VOC will the onroad transportation sector generate, in an ozone nonattainment area, in the attainment year?
  - How much PM_{10} is associated with construction equipment in my county?
  - What would be the emission effects of:
    - replacing my city's diesel bus fleet with electric buses?
    - adding a new highway interchange?
    - replacing a traffic signal with a roundabout?

MOVES4

- Major release, available August 2023
- Incorporates several important updates, including:
  - Recent EPA rule makings:
    - Heavy-duty (HD) low NOx rule for model years 2027 and later (HD2027 rule)
    - Light-duty (LD) greenhouse gas rule for model years 2023 and later (LD GHG 2023 rule)
  - The ability to model HD battery electric (BEV) and fuel cell vehicles (FCEV), as well as compressed natural gas (CNG) long-haul combination trucks
  - Improved modeling of LD electric vehicles
  - New tools to make the model easier to use
  - Updated 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
  - The latest data on ammonia emission rates for light-duty and heavy-duty vehicles
  - Other limited-impact updates to specific emissions rates and adjustments

MOVES4 Builds on Previous Models

- EPA has been refining our mobile source emissions models since 1978
- As standards and technology have changed—and as we've learned more about air pollution—the models have become more detailed and more complex
- They now cover more pollutants, more emissions processes, and more emissions sources
- Over time, we have also made improvements to help the user

Public Releases	Release Years
MOBILE thru MOBILE6.2	1978-2004
NONROAD	1998-2010
MOVES2010	2010
MOVES2010a	2010
MOVES2010b	2012
MOVES2014	2014
MOVES2014a	2015
MOVES2014b	2018
MOVES3.0	2020
MOVES3.1	2022
MOVES4	2023

When do I use MOVES?

- See:
  - EPA's MOVES4 Policy Guidance: Use of MOVES for State Implementation Plan Development, Transportation Conformity, General Conformity and Other Purposes (EPA-420-B-23-009), August 2023
  - EPA's Federal Register notice of September 12, 2023 (88 FR 62567), which announced the availability of MOVES4
- Next slides summarize information primarily from the Policy Guidance and the FR notice

State Implementation Plans

- MOVES4 must be used to develop new SIPs after its release. There is no grace period
- However, if a state has done significant work on a SIP using MOVES3, it may continue with that model
- In general, incorporating MOVES4 into the SIP now could be useful in some areas; MOVES4 will have to be used for transportation conformity at the end of the grace period

Transportation Conformity

- EPA's September 12, 2023 *Federal Register* notice announces the availability of MOVES4 and establishes a two-year grace period for using MOVES4 for:
  - Regional emissions analyses (unless MOVES4-based SIP budgets become applicable sooner)
  - Project-level conformity $PM_{2.5}$, PM_{10}, and CO hot-spot analyses
- Grace period will end **September 12, 2025**
- Analyses that are started during the grace period may use either MOVES4 or MOVES3
- Analyses started after the grace period must use MOVES4

Using MOVES4 for Other Purposes

- The Policy Guidance also discusses:
  - I/M performance standard modeling
  - General conformity
  - Greenhouse gas analyses
  - Mobile source air toxics analyses
  - EPA's National Emissions Inventory (NEI)
- See the guidance for more information

MOVES4 Technical Guidance (1)

- MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA-420-B-23-011), August 2023
- Detailed guidance on appropriate inputs for MOVES in SIPs and transportation conformity regional emissions analyses, in states other than California
  - Onroad at the County Scale and Nonroad
  - Defaults vs. local information
  - Developing appropriate local inputs
  - Information on available tools
- Often useful when using MOVES for other purposes

MOVES4 Technical Guidance (2)

- Main changes in MOVES4 guidance compared to previous version:
  - How to document a MOVES run (new section 2.6)
    - Good documentation is necessary to meet requirements for interagency consultation and public review, and serves as a reference for future MOVES runs
  - New guidance for the fuels Alternate Vehicle Fuel and Technology (AVFT) input
    - Covered later in the training
  - How states that have adopted California emission standards, consistent with CAA section 177, can use MOVES to model them (new section 2.5)
    - Either using one of the available MOVES tools, or via updating information in an input database table

Other MOVES Guidance Documents (1)

- Guidance documents done for earlier versions of MOVES generally continue to apply
- *Using MOVES for Estimating State and Local Inventories of On-Road GHG Emissions and Energy Consumption*
  - See EPA's Estimating Greenhouse Gas Emissions webpage for latest version
- *PM Hot-Spot Guidance: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas*
  - See EPA's Project-Level Conformity and Hot-Spot Analyses webpage for latest version
- *Using MOVES in Project-Level Carbon Monoxide Analyses*
  - See EPA's Project-Level Conformity and Hot-Spot Analyses webpage for latest version

Other MOVES Guidance Documents (2)

- *Performance Standard Modeling for New and Existing Vehicle Inspection and Maintenance (I/M) Programs Using MOVES*
  - See EPA's Vehicle Emissions Inspection and Maintenance (I/M): Policy and Technical Guidance webpage for latest version

- *Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions*
  - See EPA's Port Emissions Inventory Guidance webpage for latest version

Other MOVES Information (1)

- Cheat Sheets and help for user tools are integrated into the model itself
- The MOVES GitHub site provides access to the MOVES source code and additional documentation
- MOVES4 Q&A document, EPA Releases MOVES4 Mobile Source Emissions Model, highlights the differences between MOVES4 and earlier versions of MOVES
- Overview of EPA's MOtor Vehicle Emission Simulator (MOVES4) provides detailed references to technical documentation and other MOVES information
- Detailed technical reports are available that describe the default inputs and algorithms in MOVES

Other MOVES Information (2)

- If you need additional MOVES resources after this class, see our website for documentation, frequently asked questions, and more:
  - www.epa.gov/moves
- If you have questions, contact us: mobile@epa.gov
- To get MOVES updates, join the MOVES listserv by sending a blank email to join-epa-mobilenews@lists.epa.gov
  - For more information about the MOVES listserv, see www.epa.gov/moves/forms/epa-mobilenews-listserv

MOVES Basics

MOVES

Motor Vehicle Emission Simulator

How does MOVES work?

- In this course, we will focus on the **onroad** portion of MOVES
  - Information on the **nonroad** model is covered in Module 9
- Next few slides will cover:
  - Processes that yield emissions
  - Pollutants
  - Vehicle types
  - Emission rate components

Emissions Processes in MOVES

- Running Exhaust
- Start Exhaust
- Extended Idle Exhaust
  - (trucks "hotelling" under load)

Emissions from the tailpipe and from the crankcase are estimated separately

- Evaporative
  - Permeation, Vapor Venting, Fuel Leaks
- Refueling
  - Displacement Vapor Loss, Spillage Loss
- Tire Wear
- Brake Wear

Pollutants in MOVES

- HC
    - THC, NMHC, NMOG, TOG, VOC
- CO
- NO_x (NO, NO_2)
- NH_3
- SO_2
- PM_{10}, $PM_{2.5}$
    - Multiple exhaust species plus brakewear and tirewear
- GHG
    - CO_2, CH_4, N_2O
    - "CO_2 equivalent", which combines all GHGs selected in terms of CO_2
- Toxics
    - Over 50 different exhaust and evap species
- Energy
- See the onroad cheat sheet (available in the MOVES Help menu) for the full names of all pollutants

Source Types in MOVES

- Vehicles are categorized into "Source Use Types" in MOVES, which are distinguished by vehicle type as well as activity
- For example, passenger trucks and light commercial trucks can be the same type of trucks, but their activity differs
- The 13 source types in MOVES are:

  - Passenger Car
  - Passenger Truck
  - Motorcycle
  - Light Commercial Truck
  - Other Buses
  - Transit Bus
  - School Bus
  - Refuse Truck
  - Single Unit Short-haul Truck
  - Single Unit Long-haul Truck
  - Motor Home
  - Combination Short-haul Truck
  - Combination Long-haul Truck

Fuel Types in MOVES

- There are 5 fuel types in MOVES:
  - Gasoline
  - Diesel
  - Ethanol (E-85)
  - Compressed Natural Gas (CNG)
  - Electricity
- Not all source types can be modeled with all fuel types. For example:
  - E-85 is only modeled in light-duty vehicles
  - CNG is only modeled in heavy-duty vehicles

Regulatory Classes in MOVES

ID	Name	Description
10	MC	Motorcycles
20	LDV	Light Duty Vehicles
30	LDT	Light Duty Trucks
41	LHD2b3	Chassis-certified Class 2b and 3 Trucks (8,500 lbs < GVWR ≤ 14,000 lbs)
42	LHD45	Class 4 and 5 Trucks (14,000 lbs < GVWR ≤ 19,500 lbs) & “incomplete” Class 3 Trucks
46	MHD67	Class 6 and 7 Trucks (19,500 lbs < GVWR ≤ 33,000 lbs)
47	HHD8	Class 8a and 8b Trucks (GVWR > 33,000 lbs)
48	Urban Bus	Urban Bus (see CFR Sec 86.091_2)
49	Gliders	Glider Vehicles (see EPA-420-F-15-904)

- While source type defines vehicle types by their activity, “Regulatory Class” or “RegClass” defines vehicles by their emissions
- Generally, emissions standards are set according to a vehicle’s Gross Vehicle Weight Rating (GVWR)
- Only a few RegClasses have 1:1 correspondence with SourceType

MOVES Emission Rates

- Base emission rates in MOVES vary for each combination of…

Fuel, RegClass, and Model Year	Age Group	Operating Mode
Gas-LDV-MY2021	0-3 years	low speed coast; 20 mph, VSP 0-3 kW/tonne
Gas-LDT-MY2015	6-7 years	accelerating; 55 mph, VSP 12-15 kW/tonne

- **Fuel type:** different rates for gasoline, diesel, electricity, E85, & CNG vehicles
- **Regulatory class:** different rates for different emission standards
- **Model year:** standards change over time
- **Vehicle Age:** age of vehicle affects deterioration of emission controls

- **Operating mode:** speed and acceleration for running, soak time for start and evap emissions
  - Road type and speed distribution inputs determine fraction of time in different operating modes
  - "Soak time" refers to how long a vehicle has parked with the engine off

MOVES Calculations

- At runtime, MOVES selects the relevant base emission rates, then:
  - Applies relevant adjustments for various modeling conditions:
    - Temperature and humidity
    - Differences in fuel composition
    - I/M programs
    - Etc.
  - Weights emission rates using relevant vehicle activity values
  - Generates the output in the format and at the level of detail requested by the user

What output does MOVES provide?

- MOVES can provide either:
  - Emission inventories, calculated for you by MOVES using fleet and activity inputs
  - Emission rates, which you can multiply by appropriate activity factors outside of MOVES to manually calculate emission inventories – this is covered in Module 6

- Output is stored in a database
  - Output tables have "ID" columns and a "value" column
  - ID columns are used to identify what the value represents, and the value column contains the actual MOVES output (i.e., emission inventory or rate)
  - MOVES output can contain more or less detail, based on selections you make when setting up the run
    - More detail means more ID columns will be populated in the output and the output will include more rows

Example MOVES Output

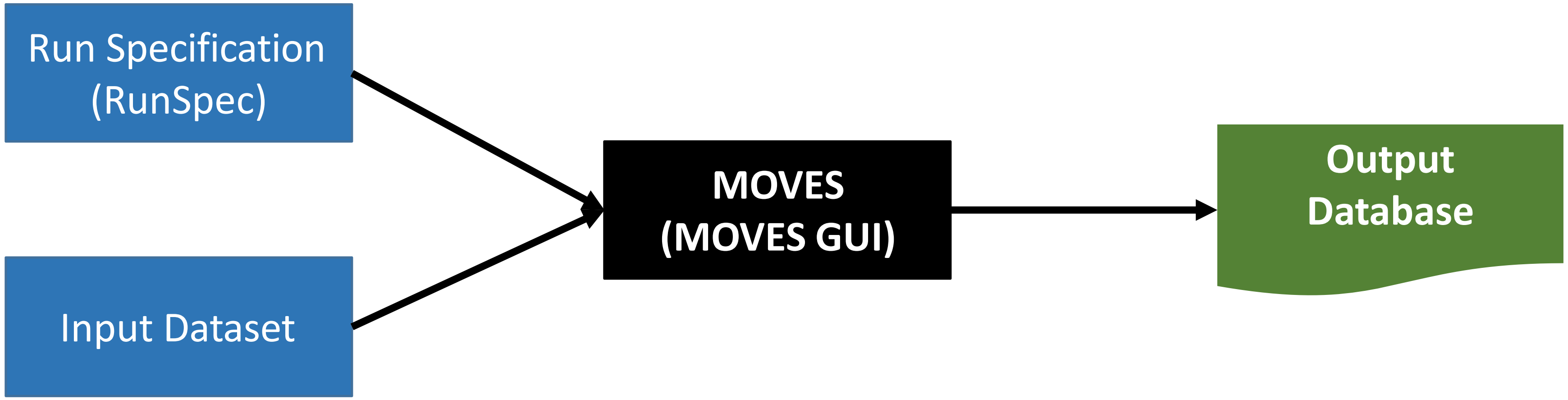
yearID	monthID	dayID	hourID	countyID	pollutantID	sourceTypeID	fuelTypeID	emissionQuant
2023	7	5	1	26163	1	21	1	**105.3**
2023	7	5	1	26163	1	21	2	**7.8**

- The first row shows that there are **105.3** grams of hydrocarbons emitted from gasoline passenger cars operating in a specific county between midnight and 1 AM on a typical weekday in July of 2023
  - "EmissionQuant" is the value column, and the ID columns specify the other information listed about the **105.3** grams
  - Don't worry about figuring out how to decode or "translate" the ID fields at this point. This will be explained this later
- Module 4 is dedicated to processing MOVES outputs

MOVES Files

- To run MOVES, you must provide or create:
  - A run specification, a.k.a. “RunSpec” and
  - An input database at the County and Project Scales

- MOVES creates an output database



Databases

- A database can be thought of as a set of tables
  - Databases are not “files” with an extension
  - You create them through the MOVES GUI, but you don’t “save” them
  - Data can be viewed and manipulated in HeidiSQL, or they can also be exported to another program (e.g., Excel)

- You name all three items (RunSpec file, input database, and output database), and names should relate to one another

For example, a MOVES run for CO emissions in Clark County, NV (Las Vegas) for the year 2023, could have the following components & names:

Item	Name
RunSpec	ClarkCounty_CO_2023**.mrs**
Input database	ClarkCounty_CO_2023**_in**
Output database	ClarkCounty_CO_2023**_out**

Summary: Files and Databases

Item	Purpose	Where does it come from?
RunSpec	Describes what is being modeled, where, and when	You making selections in the MOVES GUI and then save the resulting file Ex.: ClarkCounty_CO_2023.mrs
Input Database	Provides data necessary for the run	At County & Project scales: You create it through the MOVES GUI and fill it with local information Ex. ClarkCounty_CO_2023_in At Default scale: MOVES relies on the default database (no action needed)
Output Database	Stores results of the run	You create it through the MOVES GUI, and MOVES stores results in it Ex. ClarkCounty_CO_2023_out

Locating Your MariaDB Data Folder

- The data folder stores the MOVES default database, as well as input and output databases
- The MOVES Installer may have put a shortcut on your desktop

- If not, it usually can be found in C:\ProgramData
  - For example: C:\ProgramData\MariaDB\MariaDB 10.11\data
    - C:\ProgramData is hidden, but if you type it into Windows Explorer, you can see it
    - Also, you may have a different MariaDB version number, and that's OK
  - Once you locate it, create a shortcut to it on your desktop (press the ALT key and drag-and-drop the folder to your desktop; you will see "Create Link in desktop" appear)

Modeling Options Overview

- MOVES has an array of input & output options
- You need to consider your modeling approach, e.g.,
  - Scale/Domain
  - Inventory vs. Emission Rates
- Your modeling approach will affect
  - Number of runs
  - Amount of post-processing necessary
  - Input data required
- Next few slides give an overview
- See also Section 2 in the Technical Guidance

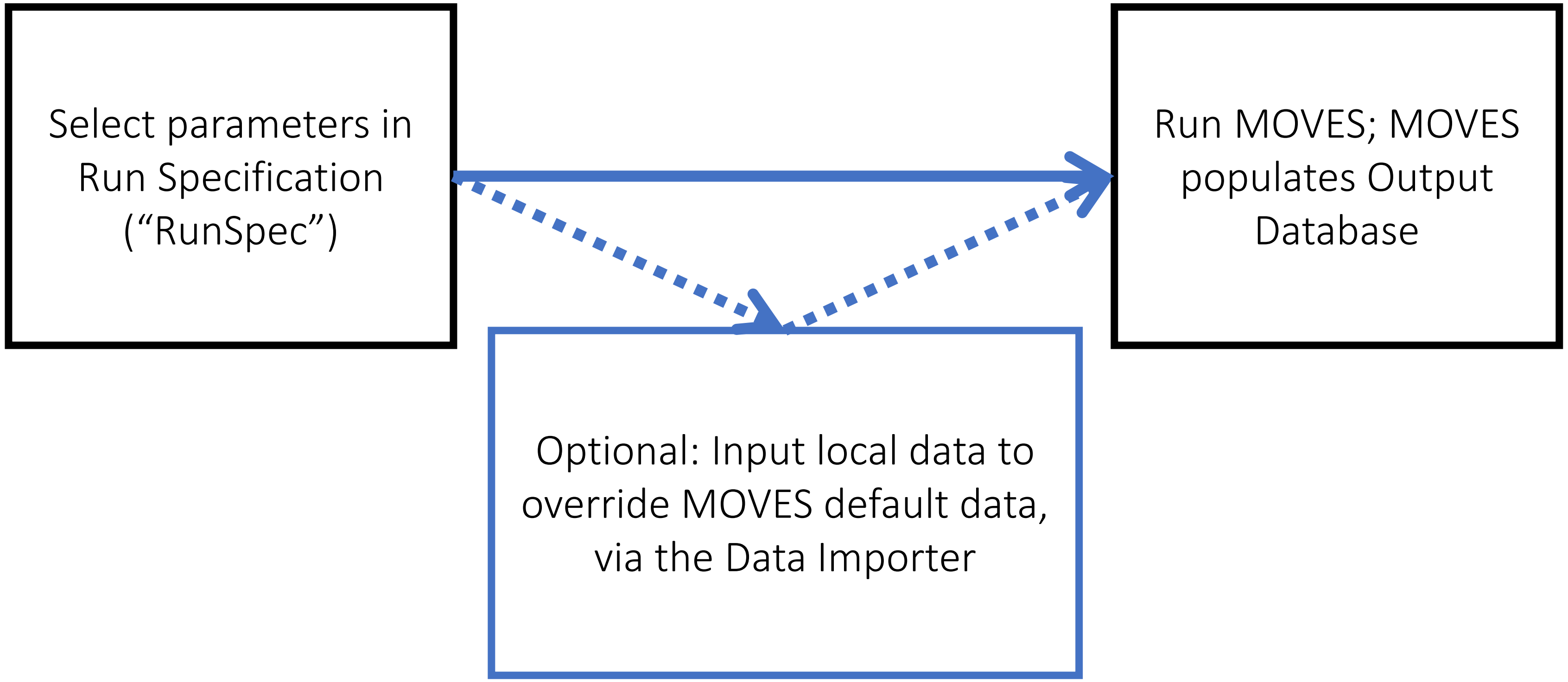
MOVES: Three Scales of Analysis

- Three scales: Default, County, or Project
- All three scales have the same underlying MOVES emission rates and adjustment factors
- RunSpec file is needed for all three scales
- An input database is optional for Default scale, needed for County and Project Scales
- An output database is needed for all three scales

Default Scale Overview

- Can be used to model:
  - The entire country
  - One or more states, also DC, Puerto Rico, and U.S. Virgin Islands
  - One or more counties
- *Cannot* be used for SIP or transportation conformity purposes
- With Default Scale, MOVES uses information in the MOVES default database, unless user includes local or scenario-specific data (optional)
- Caution: the MOVES default database does not always have the most current or best available for any specific county or state
  - Some defaults are national but applied as-is to the geographic area chosen (e.g., vehicle age distribution)
  - Some defaults are national and are "downscaled" for geographic area chosen (e.g., VMT)
  - Some defaults are for specific areas (e.g., type of I/M program)

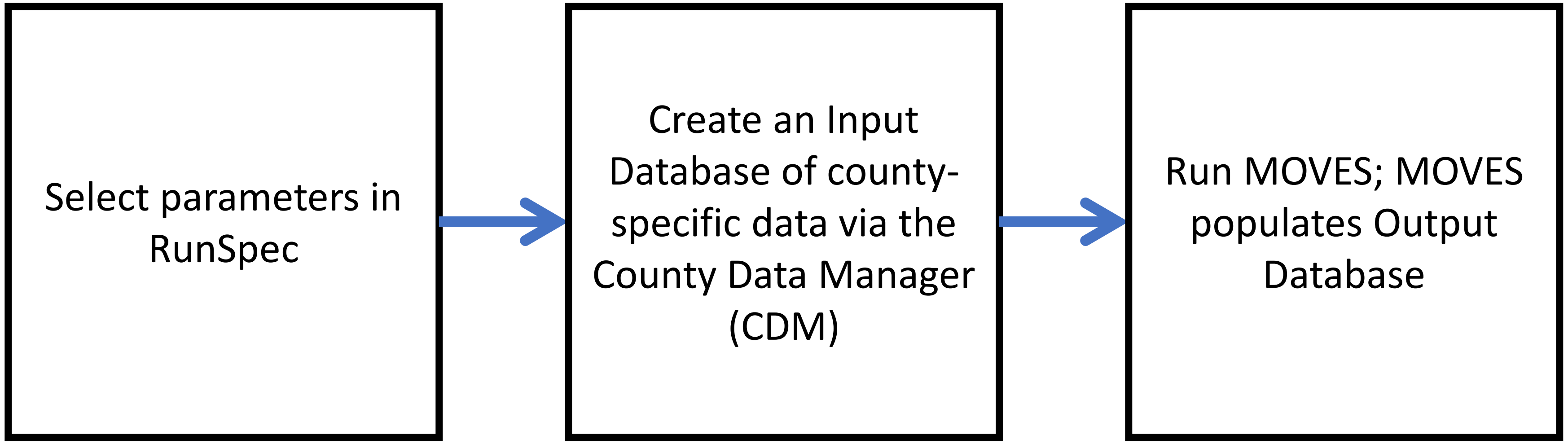
Default Scale Process



County Scale Overview

- Can be used to model an individual county or a partial county
- *Required* for SIP and transportation conformity regional emissions analyses
- You must enter county-specific data, via the County Data Manager (CDM), for the input database. The CDM is used to:
  - Export templates, which you complete with local data and then import
  - Export MOVES default data
- Use of local data are necessary for some inputs and recommended for most
  - However, there are some inputs where the default data is preferred (e.g., fuels)

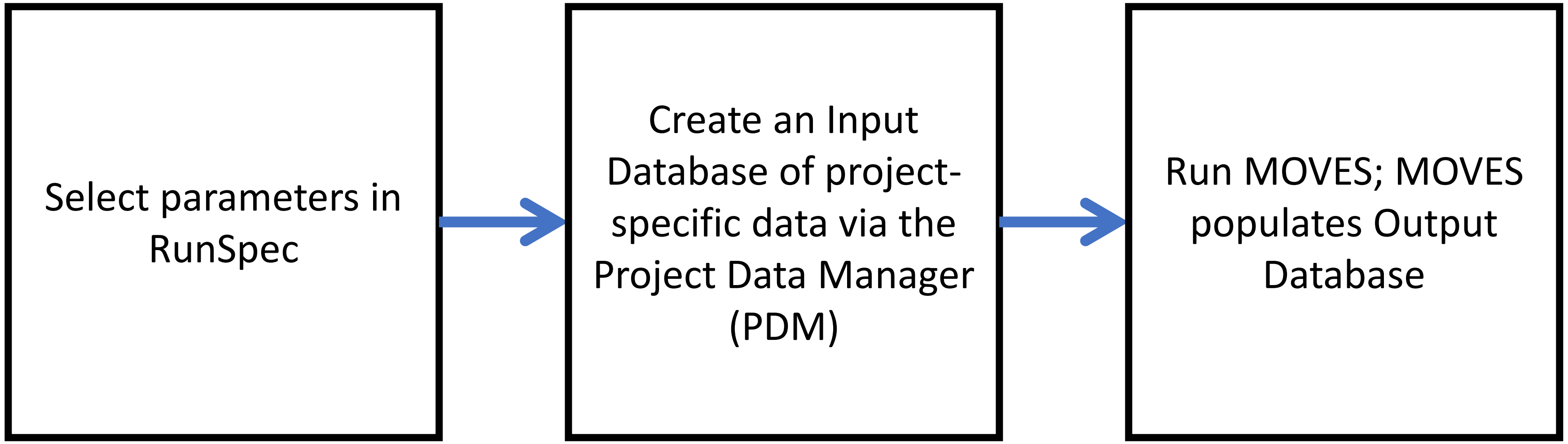
County Scale Process



Project Scale Overview

- Link level modeling of specific transportation projects
  - Highways, intersections, interchanges, transit projects, parking lots
- Required for transportation conformity $PM_{2.5}$, PM_{10}, or CO hot-spot analyses
- You must enter project-specific data, via the Project Data Manager (PDM), for the input database
- Also covered in EPA's 3-day quantitative PM hot-spot analysis course

Project Scale Process



Summary: The Three Scales of MOVES

	Default	County	Project

Geographic area covered	• Entire nation
	• One or more states
	• One or more counties
		• One county
		• A multi-county area
		  • modeled with a representative single county, or
		  • each modeled separately and summed
		• A partial county
			An individual transportation project (e.g., a highway, intersection, or transit project)

Purpose	Non-regulatory only	Required for SIP and regional conformity analyses	Required for project-level conformity analyses
Input database	User does not need to create; use of Data Importer is optional	User creates with local data, through the County Data Manager	User creates with local data, through the Project Data Manager
Default data	Used unless overridden	Access to default data is limited	Access to default data is limited

Calculation Type

- Two types: Inventory or Emission Rates
  - Either are acceptable for SIP and regional conformity analyses
  - Either option can be used with any of the three scales
- Advantages and trade-offs in both approaches
- Choice depends on the area and purpose
  - In many cases, Inventory is the appropriate calculation type
- Additional detail on these options will be discussed in
  - Module 3 for County Scale
  - Module 6 for Emission Rates

Calculation Type: Inventory

- Inventory: Output is emissions in units of mass (e.g., grams, kg, lbs, tons) for the time and place specified
  - Shorter run times and smaller output files than Emission Rates
  - MOVES does the processing of [rates × activity] to yield total mass of emissions
    - Minimizes post-processing and therefore inadvertent errors
  - Results are specific to county and time period
    - A run can produce a county inventory, e.g., for one day with a specific 24-hour temperature profile

- Inventory typically used when modeling a small number of counties over a limited time period

Calculation Type: Emission Rates

- Emission Rates: Output is a set of emission rates, e.g., rate per mile, rate per vehicle
  - Longer run times and larger output files than Inventory
  - You must process MOVES results by multiplying rates by appropriate vehicle activity data to get inventory
  - Could cover wide range of conditions with fewer runs than Inventory
- Emission Rates typically used to:
  - Model a multi-state domain over multiple seasons
  - Create inventories with travel model post-processing software
  - Develop emission rates for a representative county and then apply them to other counties
  - Used with the SMOKE-MOVES interface tool for air quality modeling
    - More information on SMOKE-MOVES at https://github.com/CEMPD/SMOKE-MOVES
  - Develop rates for FHWA's CMAQ calculators and tools

Introduction to the MOVES Graphical User Interface (GUI)

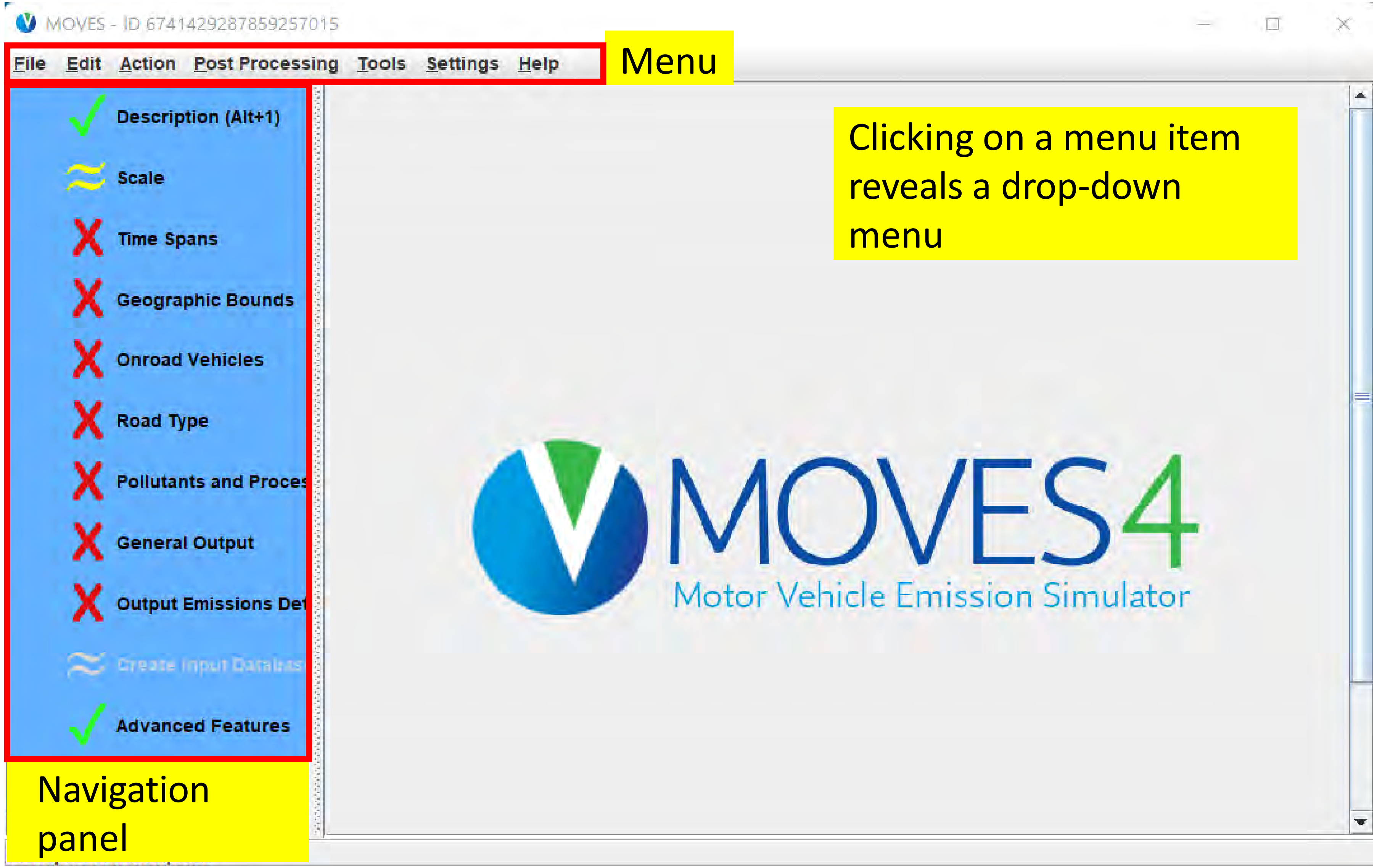
MOVES
Motor Vehicle Emission Simulator

Start MOVES

- Begin by opening MOVES4
- On your desktop, double-click the “MOVES4” icon
- Make sure it’s MOVES4, if you have multiple versions

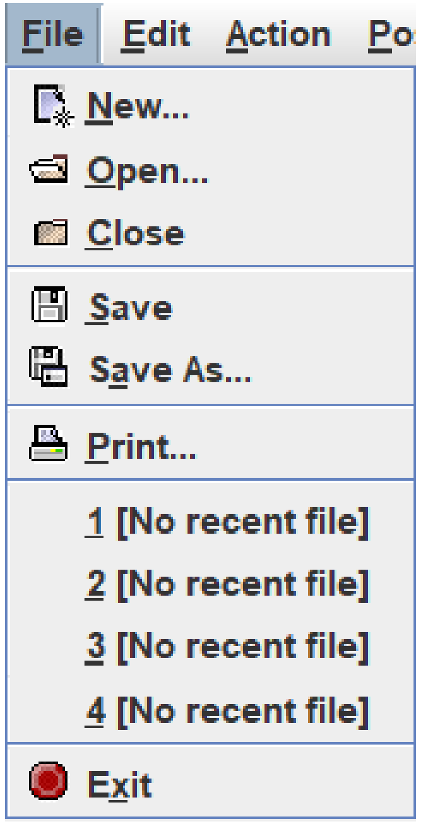
MOVES4.0

MOVES Graphical User Interface (GUI)



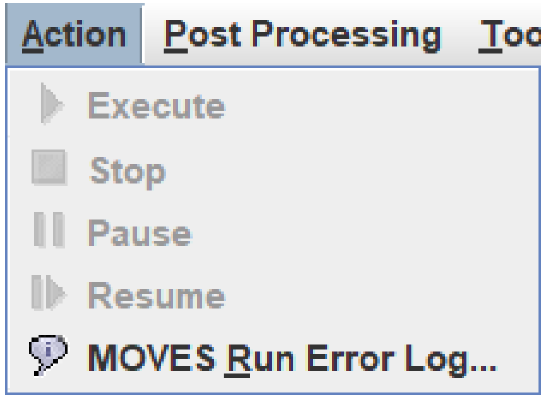
File Menu

- Choices refer to the RunSpec
  - Print will print the XML version of the RunSpec, not a screen shot
  - Your latest saved RunSpecs are also listed
- Tips for RunSpec filename conventions
  - Use ".mrs" extension, for "MOVES RunSpec"
  - Use only letters, numbers and underscores (_) in the file name so that RunSpec file names can be related to input and output database names
  - Including details like location, year, or other brief descriptions can help distinguish similar RunSpecs. For example:
    - "NewYorkState_2009_GHG.mrs"
    - "Washtenaw_2025_ozone.mrs"



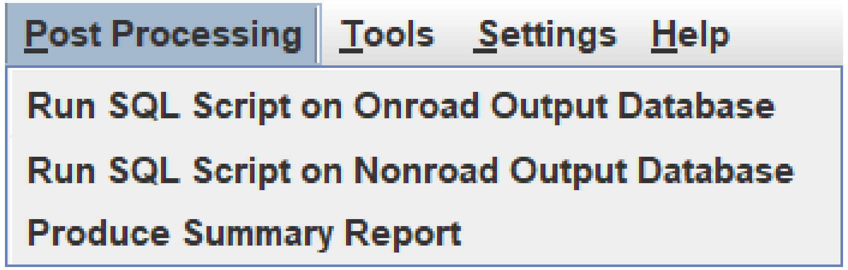
Action Menu

- Execute: Runs MOVES
  - Only available if RunSpec is complete
- Stop: Terminates an in-progress MOVES run
  - It may take a while for MOVES to notice this command
  - After using, if MOVES doesn't seem to be responding, you may need to close the CMD window and/or terminate the java.exe processes via Windows Task Manager
- Pause/Resume: Pauses or Resumes a MOVES run
  - It may take a while for MOVES to notice this command
  - Useful if you need to put your computer to sleep in the middle of a run
- MOVES Run Error Log: Displays the error log for the selected output database



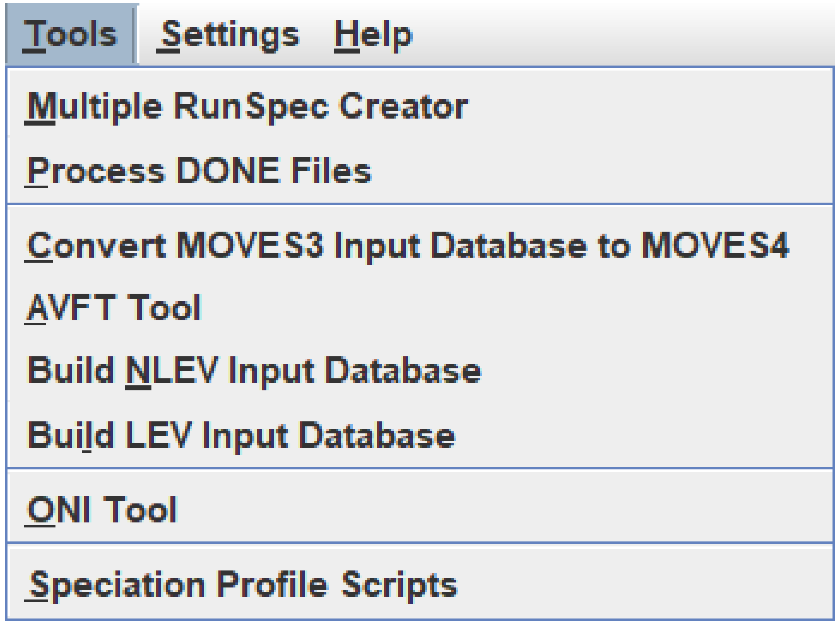
Post Processing Menu

- Run SQL Script on Onroad Output Database
  - Provides access to built-in SQL scripts intended to post process **onroad** output
  - Discussed in Module 4
- Run SQL Script on Nonroad Output Database
  - Provides access to built-in SQL scripts to intended to post process **nonroad** output
  - Discussed in Module 9
- Produce Summary Report
  - Discussed in Module 2



Tools Menu

- EPA provides a number of tools to help develop user inputs
- Most tools are included with MOVES (shown here), but some are available for download from the MOVES website



GUI Tools (1)

- Multiple RunSpec Creator
  - An advanced tool that may be useful when you need to create and execute a batch of similar MOVES runs
- Process DONE Files
  - A tool that may be useful when MOVES is run asynchronously over a network
  - Not necessary for most users and MOVES configurations
- Convert MOVES3 Input Database to MOVES4
  - This tool can convert MOVES3 County or Project input DBs into MOVES4-compatible input DBs
  - You would only convert a MOVES3 input database for MOVES4 if it still includes the latest available information
  - See the Tool help file, especially for fuels and I/M inputs

GUI Tools (2)

- AVFT Tool
  - The AVFT (Alternate Vehicle Fuel and Technology) input allows you to modify the fraction of vehicles capable of using different fuels and technologies
  - The AVFT Tool can be used to develop a completed AVFT table based on available information
  - See the Tool help file and the MOVES Technical Guidance
  - More on this tool in Module 3

- Build NLEV database
  - This tool builds an input database to be used by Ozone Transport Commission (OTC) states to model the early introduction of NLEV standards in those states
  - This tool creates a special input database which contains a set of alternate HC, CO, and NOx start and running emission rates based on EPA analysis of the NLEV program

- Build LEV database
  - This tool builds an input database to be used by states that chose to adopt California LEV standards in place of federal standards
  - This tool creates a special input database which contains a set of alternate HC, CO, NOx, and PM start and running emission rates based on EPA and CARB analysis of the LEV programs

GUI Tools (3)

- ONI (Off-network Idle) Tool
  - This tool calculates ONI activity from a County Scale input database (more detail about ONI in Module 3 and Module 6)
  - This tool is only needed when using MOVES at the County Scale in Emission Rates mode, and only when you do not have your own ONI activity that is granular enough to use with the MOVES rates output (such as by hour of day)
  - Inventory mode users do not need to use this tool, as MOVES will calculate hours of ONI activity during runtime in this mode

- Speciation Profile Scripts Tool
  - This tool is used when MOVES results will be input to air quality models like CMAQ
  - The scripts in the tool associate MOVES output with appropriate "speciation profiles," which allows modelers to allocate residual organic gases, total organic matter and residual particulate matter to the pollutant categories ("chemical mechanisms") that are needed for air quality modeling

Other Tools Available (1)

There are other tools designed to help develop MOVES inputs available at https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs

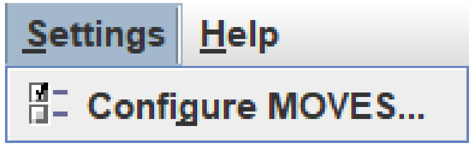
- Age Distribution Projection Tool (Excel Macro)
  - This tool creates projections of future year age distributions based on current local age distributions. It uses the same underlying age distribution projection algorithm as MOVES
  - More on this tool in Module 3
- AADVMT Converter Tool (Excel)
  - This tool uses Annual Average Daily Vehicle Miles Travelled (AADVMT) at the HPMS level to calculate type of day, monthly and yearly VMT by HPMS class
  - More on this tool in Module 3

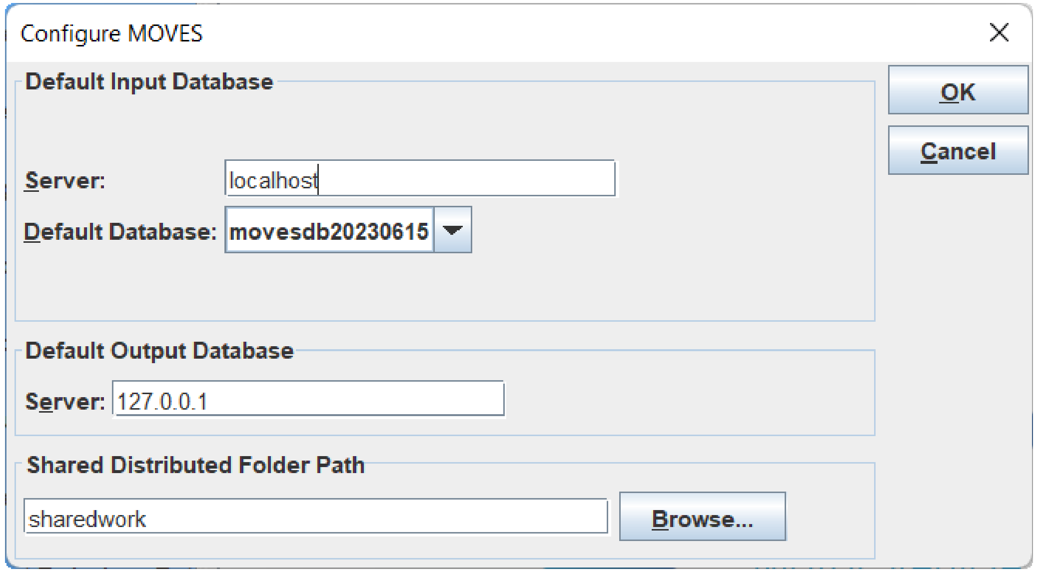
Other Tools Available (2)

- VMT Offset Tool (zip)
  - This tool is used when states need to perform two of the calculations as described in the VMT Offset Demonstration guidance. It "freezes" control measures in place as they existed in the 2011 base year for the 2008 ozone NAAQS
  - See the README.pdf file in the download package for instructions on how to install and use this tool
- Nonroad Retrofit Tool (Excel Macro)
  - This tool is used to help quantify emission reductions from nonroad retrofit projects
  - See Diesel Retrofit and Replacement Projects: Quantifying and Using Their Emission Benefits in SIPs and Conformity - Guidance for State and Local Air and Transportation Agencies
- MOVES2AERMOD (zip)
  - This tool can help automate the process of generating the EMISFACT portion of an AERMOD input file using MOVES output
  - See EPA's Quantitative PM Hot-Spot Analysis training for more information

Settings Menu

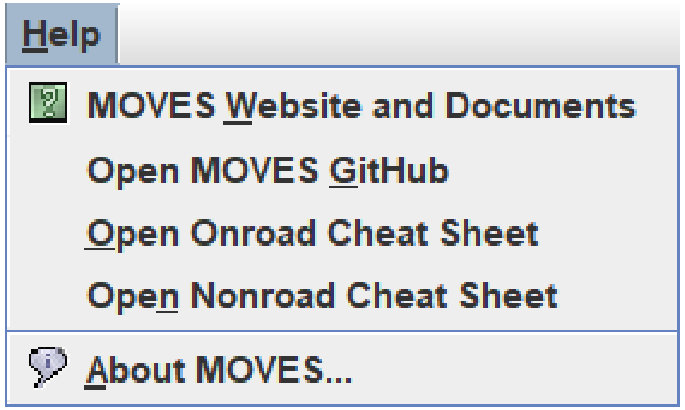
- Configure MOVES
  - Allows you to specify the default database
    - This setting should only be changed when using the VMT Offset Tool
  - Allows you to specify the Shared Distributed Folder Path
    - Useful when running MOVES in a networked configuration
    - This is not covered in this course, but more information is available on GitHub





Help Menu

- MOVES Website and Documents
  - Opens the MOVES website, where you can find tools, technical reports, FAQs, etc.
- Open MOVES GitHub
  - View MOVES source code
  - Documentation and help files (in the docs folder), including:
    - Command line MOVES
    - Tips for faster MOVES runs
    - MOVES input/output database changes
- Open Onroad/Nonroad Cheat Sheet
  - Opens a handy PDF for decoding MOVES ID fields
- About MOVES…
  - Clicking will provide the specific version of the model and the license agreement



Navigation Panel

- The Navigation Panel is used to navigate through your RunSpec
- The RunSpec specifies the scale, location, time period, alternate data and output preferences of a MOVES run
- To set up a RunSpec, complete each item on the Navigation Panel by making selections on the sub-panels
  - Items marked with ≈ must be viewed to be assessed for completeness
  - Items marked with X are required and not yet complete
  - All items on the Navigation Panel must show ✓ or ≈ to run
- We will build a RunSpec in Module 2: Default Scale

Module 1 Questions?

Module 2:
Default Scale

MOVES
Motor Vehicle Emission Simulator

EPA

Module 2 Overview

- Overview of Default Scale
- Description of each component in the MOVES RunSpec
- Exercise: Create a RunSpec using Default Scale inputs
  - Review results using the Summary Reporter
  - Purpose is to become familiar with MOVES, rather than demonstrate a recommended method for inventory analysis

Module 2 Key References

- *Using MOVES for Estimating State and Local Inventories of On-Road GHG Emissions and Energy Consumption*
  - Section 2 is useful for considering different approaches when emissions are estimated for a non-regulatory purpose
  - See EPA's Estimating Greenhouse Gas Emissions webpage for latest version
- *MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity*
  - Section 3 describes setting up a RunSpec with MOVES4
  - Available at: https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

Summary: The Three Scales of MOVES (Default)

	Default	County	Project

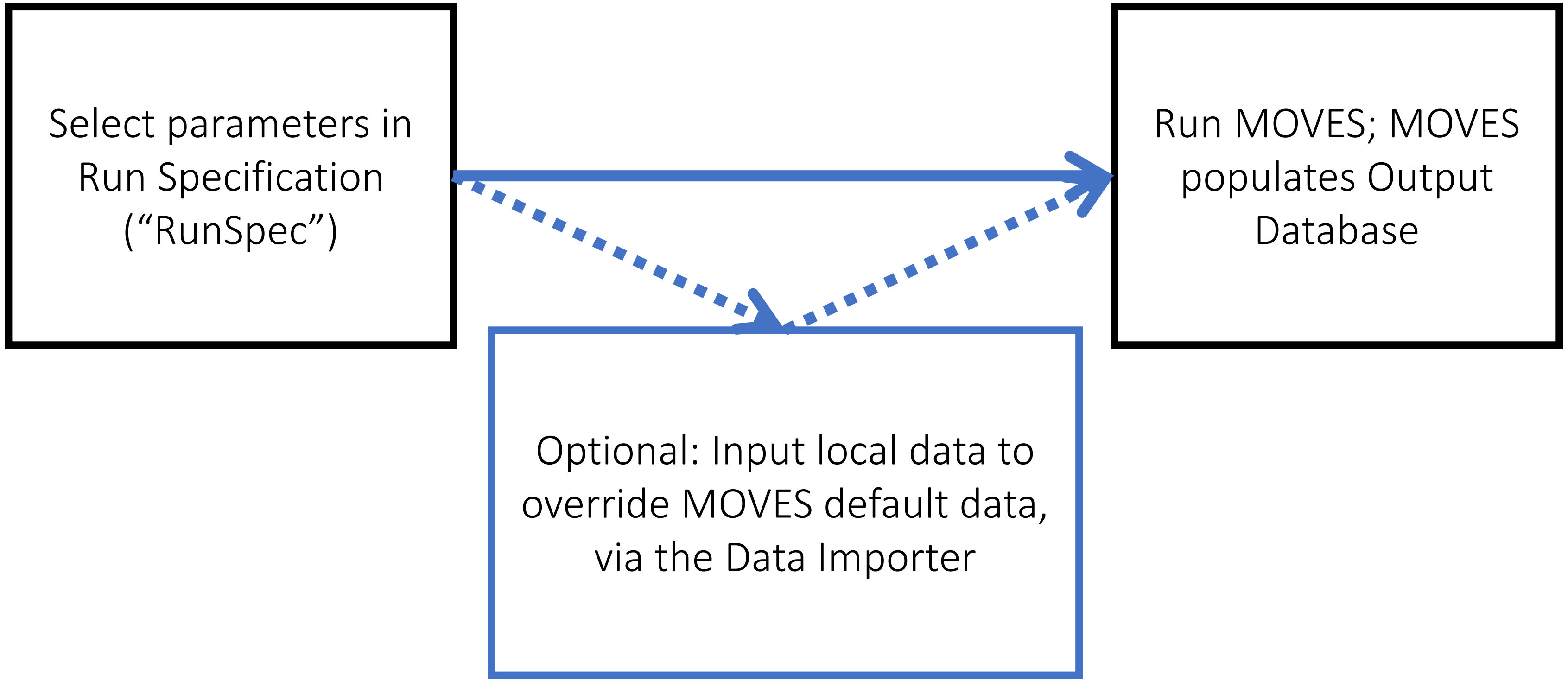
Geographic area covered	• Entire nation
	• One or more states
	• One or more counties
		• One county
		• A multi-county area
		  • modeled with a representative single county, or
		  • each modeled separately and summed
		• A partial county
			An individual transportation project (e.g., a highway, intersection, or transit project)

Purpose	Non-regulatory only	Required for SIP and regional conformity analyses	Required for project-level conformity analyses
Input database	User does not need to create; use of Data Importer is optional	User creates with local data, through the County Data Manager	User creates with local data, through the Project Data Manager
Default data	Used unless overridden	Access to default data is limited	Access to default data is limited

Default Scale Summary (Reminder)

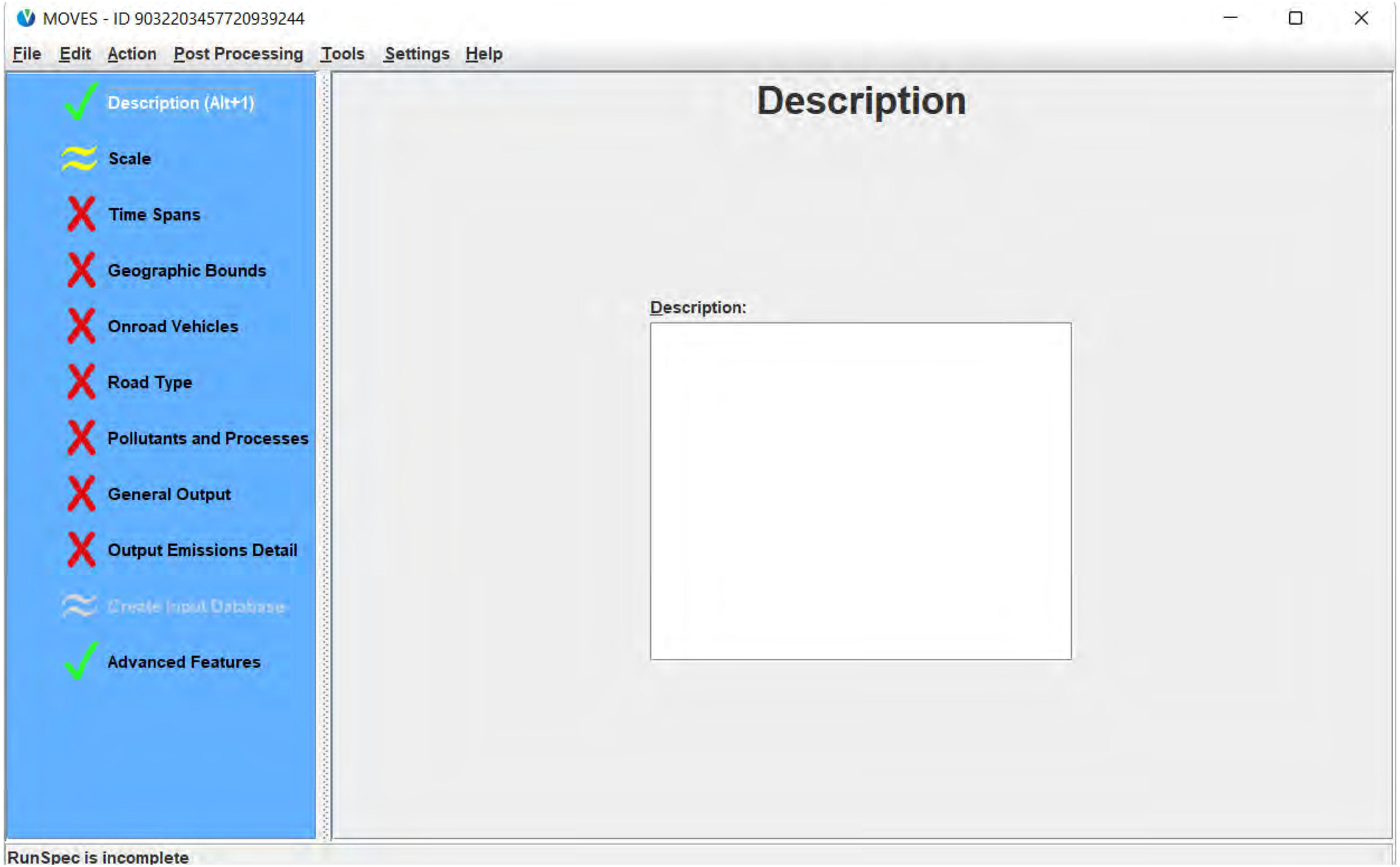
- Can be used to model:
  - The entire country
  - One or more states, also DC, Puerto Rico, and U.S. Virgin Islands
  - One or more counties
- *Cannot* be used for SIP or transportation conformity purposes
  - With the default scale, MOVES uses information in the MOVES default database, unless user includes local or scenario-specific data (optional)
- Caution: the MOVES default database does not always have the most current or best available for any specific county or state:
  - Some defaults are national and applied as-is to the geographic area chosen (e.g., vehicle age distribution)
  - Some defaults are national and are apportioned to the geographic area chosen (e.g., VMT)
  - Some defaults are for specific areas (e.g., type of I/M program)
  - More information on default data in Module 3; default data fully documented in the MOVES technical reports

Default Scale Process (Reminder)



Overview of RunSpec Elements

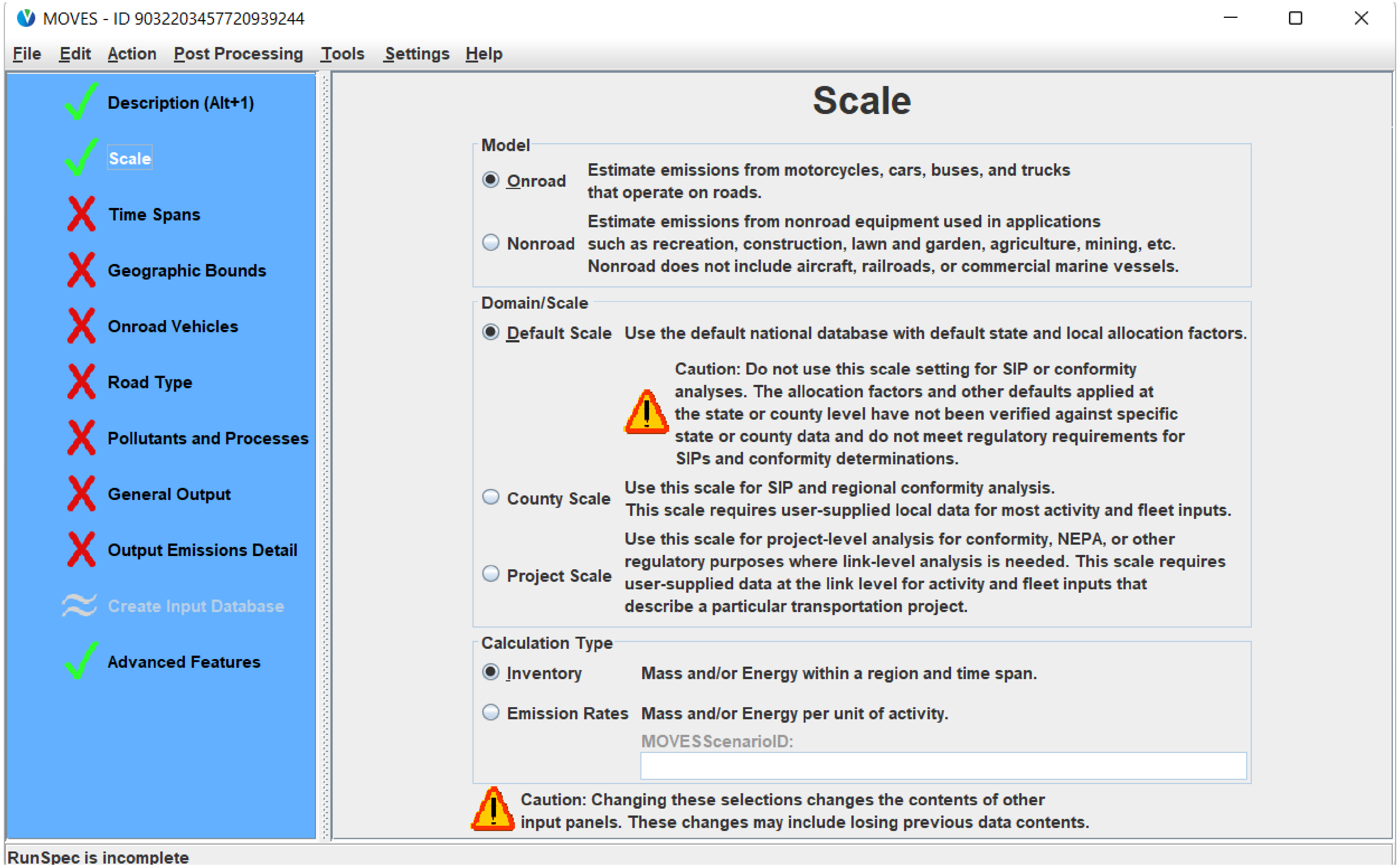
Description Panel



Description Panel Discussion

- Saves a description the RunSpec (what is being modeled)
- Text entered here appears in the MOVESRun table of the output database
- Description is optional but useful to keep track of runs
- Best practice is to include a high-level overview of the run’s scenario
  - If performing multiple related runs, include whatever elements are unique about this particular run
  - May be helpful to also include details like location, time period, and pollutant types

Scale Panel


MOVES - ID 9032203457720939244
File Edit Action Post Processing Tools Settings Help
Description (Alt+1)
Scale
Time Spans
Geographic Bounds
Onroad Vehicles
Road Type
Pollutants and Processes
General Output
Output Emissions Detail
Create Input Database
Advanced Features
Scale
Model
Onroad
Estimate emissions from motorcycles, cars, buses, and trucks that operate on roads.
Nonroad
Estimate emissions from nonroad equipment used in applications such as recreation, construction, lawn and garden, agriculture, mining, etc. Nonroad does not include aircraft, railroads, or commercial marine vessels.
Domain/Scale
Default Scale
Use the default national database with default state and local allocation factors.
Caution: Do not use this scale setting for SIP or conformity analyses. The allocation factors and other defaults applied at the state or county level have not been verified against specific state or county data and do not meet regulatory requirements for SIPs and conformity determinations.
County Scale
Use this scale for SIP and regional conformity analysis. This scale requires user-supplied local data for most activity and fleet inputs.
Project Scale
Use this scale for project-level analysis for conformity, NEPA, or other regulatory purposes where link-level analysis is needed. This scale requires user-supplied data at the link level for activity and fleet inputs that describe a particular transportation project.
Calculation Type
Inventory
Mass and/or Energy within a region and time span.
Emission Rates
Mass and/or Energy per unit of activity.
MOVESScenarioID:
Caution: Changing these selections changes the contents of other input panels. These changes may include losing previous data contents.
RunSpec is incomplete

Scale Panel Discussion

- Model Type
  - Onroad or Nonroad
- Domain/Scale
  - Default
  - County
  - Project
- Calculation type
  - Inventory
  - Emission Rates

	Default	County	Project

Geographic area covered	• Entire nation
	• One or more states
	• One or more counties
		• One county
		• A multi-county area
		  • modeled with a representative single county, or
		  • each modeled separately and summed
		• A partial county
			An individual transportation project (e.g., a highway, intersection, or transit project)

Purpose	Non-regulatory only	Required for SIP and regional conformity analyses	Required for project-level conformity analyses
Input database	User does not need to create; use of Data Importer is optional*	User creates with local data, through the County Data Manager	User creates with local data, through the Project Data Manager
Default data	Used unless overridden	Access to default data is limited	Access to default data is limited

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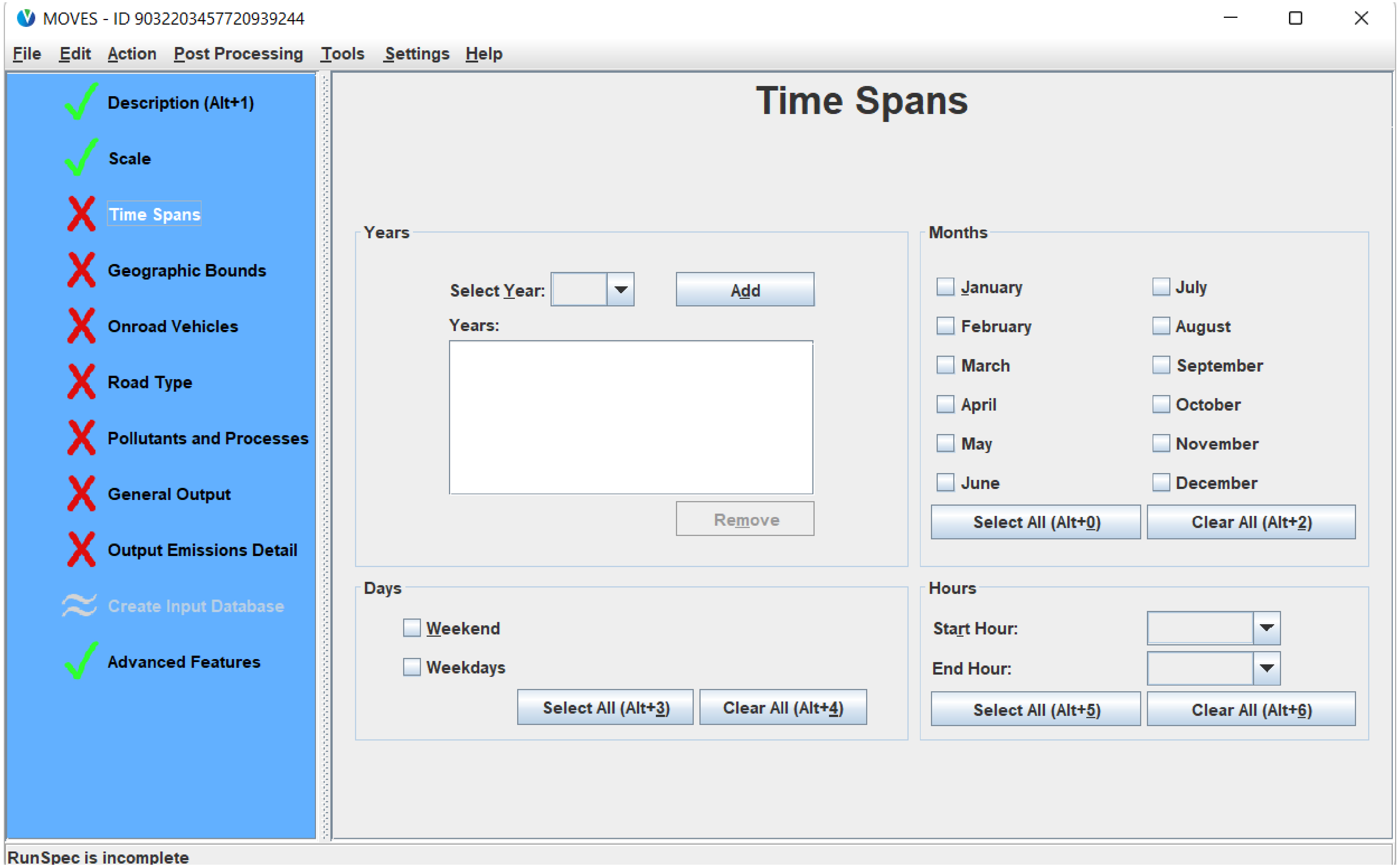
Time Spans Panel



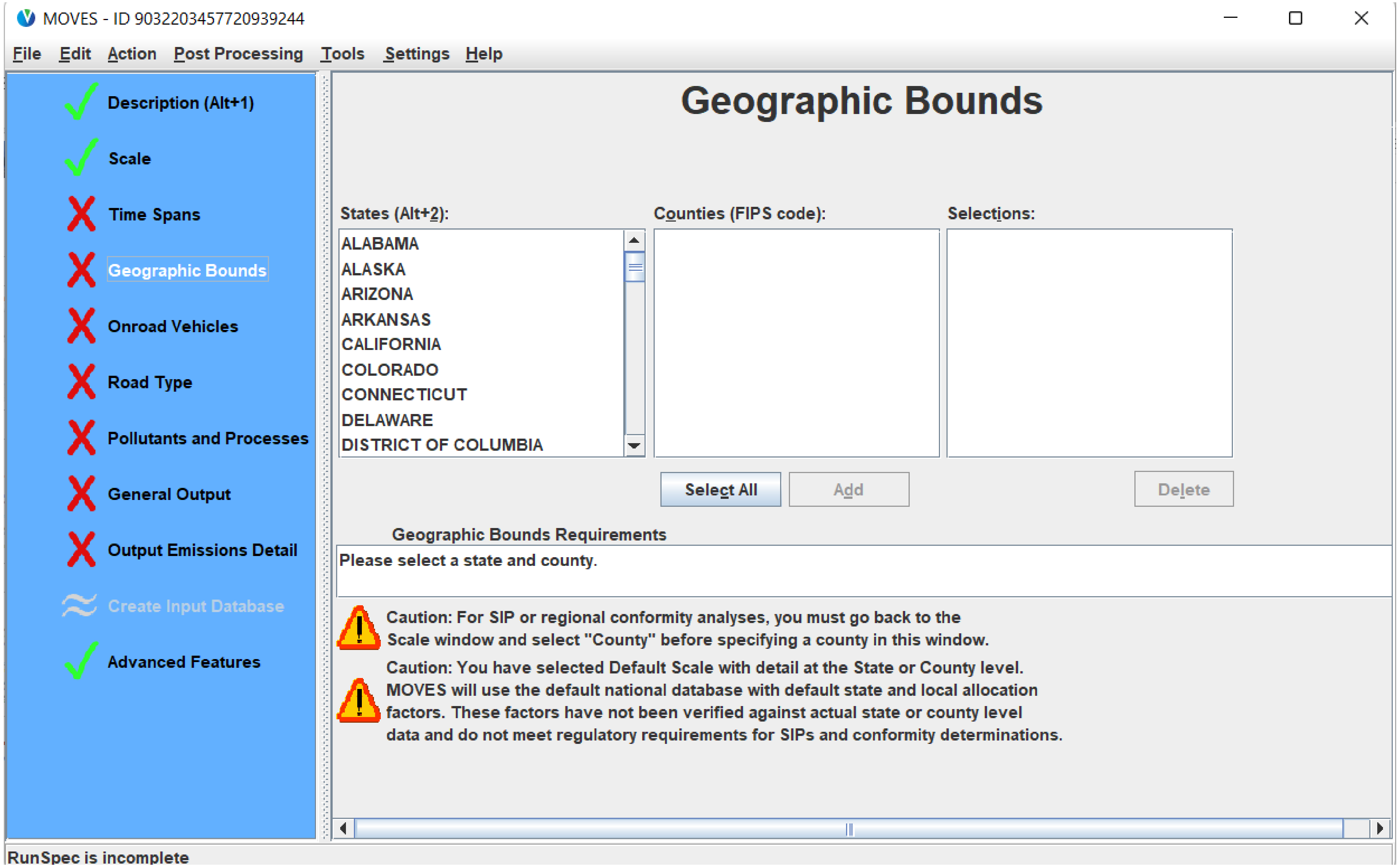
Time Spans Panel Discussion (1)

- What time period does the model run cover?
- All four sections on this panel must be completed:
  1. Year:
     - Select one or more years at Default Scale. Note: recommend only one for performance
     - Only one year per run at County or Project Scale
  2. Months:
     - Select one or more months (including all)
  3. Days:
     - MOVES doesn’t model specific days like “Monday”, but instead models two different types of days: weekdays and weekend days. Select one or both day types
  4. Hours:
     - Select one or more hours (including all)

Time Spans Panel Discussion (2)

- To model an entire day, select all hours
- To model an entire month, select all hours and both day types
- To model an entire year, select all hours, both day types, and all months
- An “Advanced Feature” allows for temporal preaggregation:
  - On the Advanced Features Panel, if you select a Time Aggregation of Day, Hour, or Year, MOVES will make automatic selections on the Time Spans Panel
  - Preaggregation of time will speed up runtime at the expense of modeling precision
  - Evaporative emissions and Project Scale cannot be modeled this way
  - Temporal preaggregation does not meet the regulatory requirements for SIPs and conformity determinations

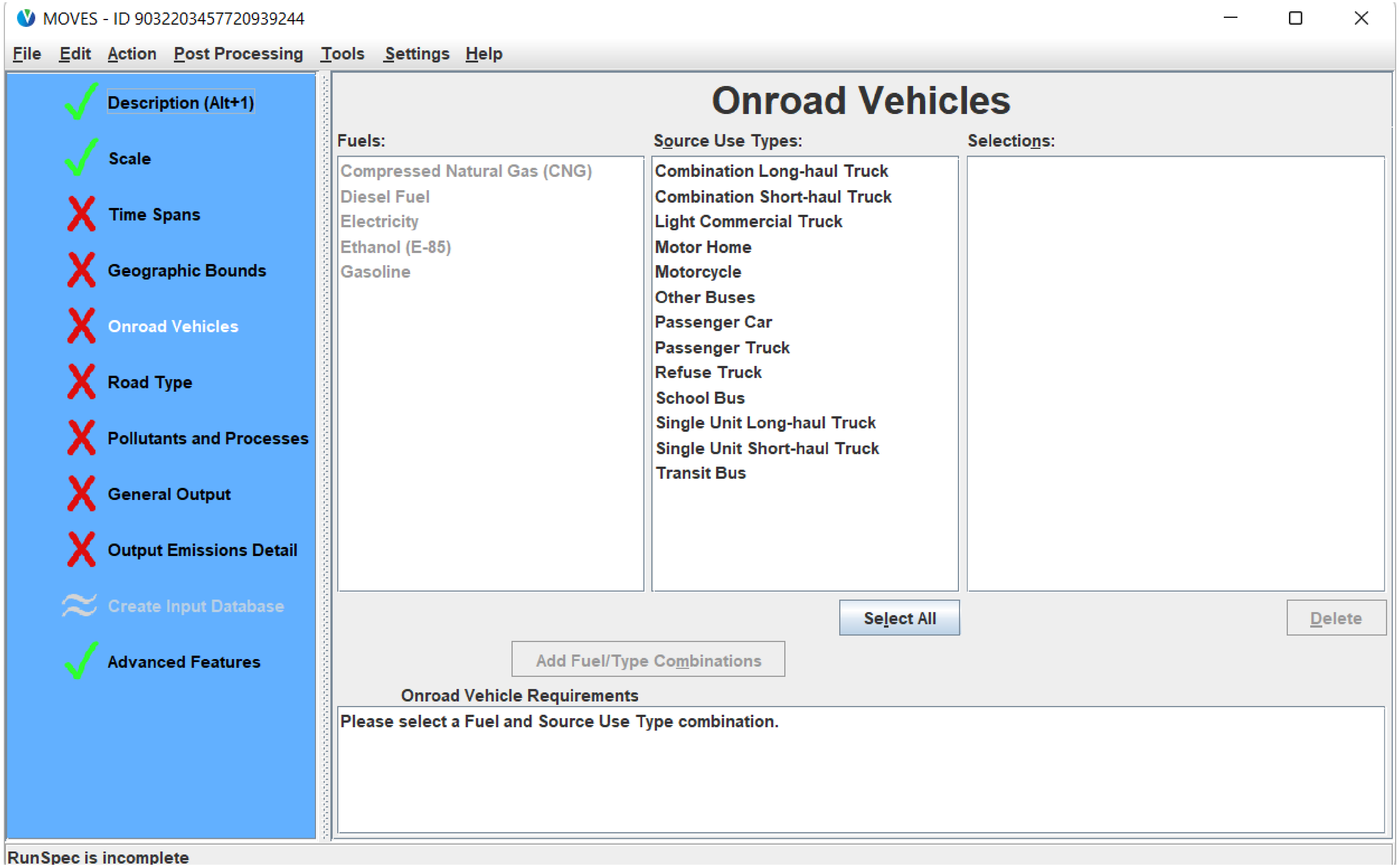
Geographic Bounds Panel



Geographic Bounds Panel Discussion

- What geographic area does the model run cover?
- In the standard configuration, this panel lets you select individual counties by state
  - At County or Project scale, you can select only one county
  - At Default scale, you can select one or more, and they can be in different states
- An "Advanced Feature" allows geographic pre-aggregation at Default Scale only
  - On the Advanced Features Panel, if you set Region Preaggregation to:
    - State, then the Geographic Bounds Panel will allow you to select one or more states (and not counties)
    - Nation, then the Geographic Bounds Panel doesn't have any options

Onroad Vehicles Panel



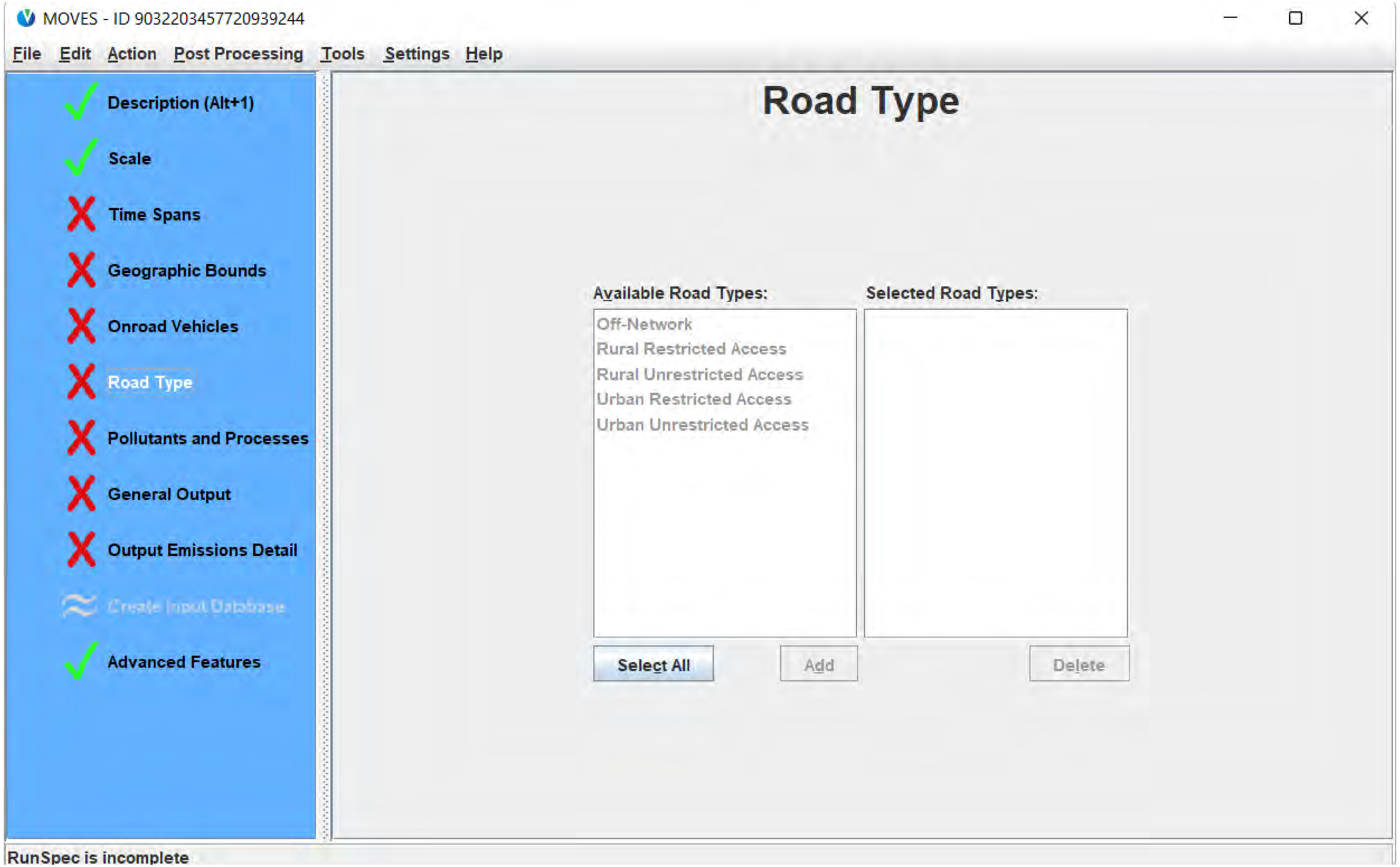
MOVES Source Types & HPMS Vehicle Types

Source Type ID	MOVES Source Types	Vehicle Type ID	HPMS 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		

Onroad Vehicles Panel Discussion

- What types of vehicles do you want to model?
- For most analyses, all source types should be selected
- All applicable fuel types will be automatically added for you
  - Note: On this panel, “Ethanol (E-85)” specifically refers to flexible fuel vehicles, regardless of what fuel they actually use

Road Type Panel



Road Type Panel Discussion (1)

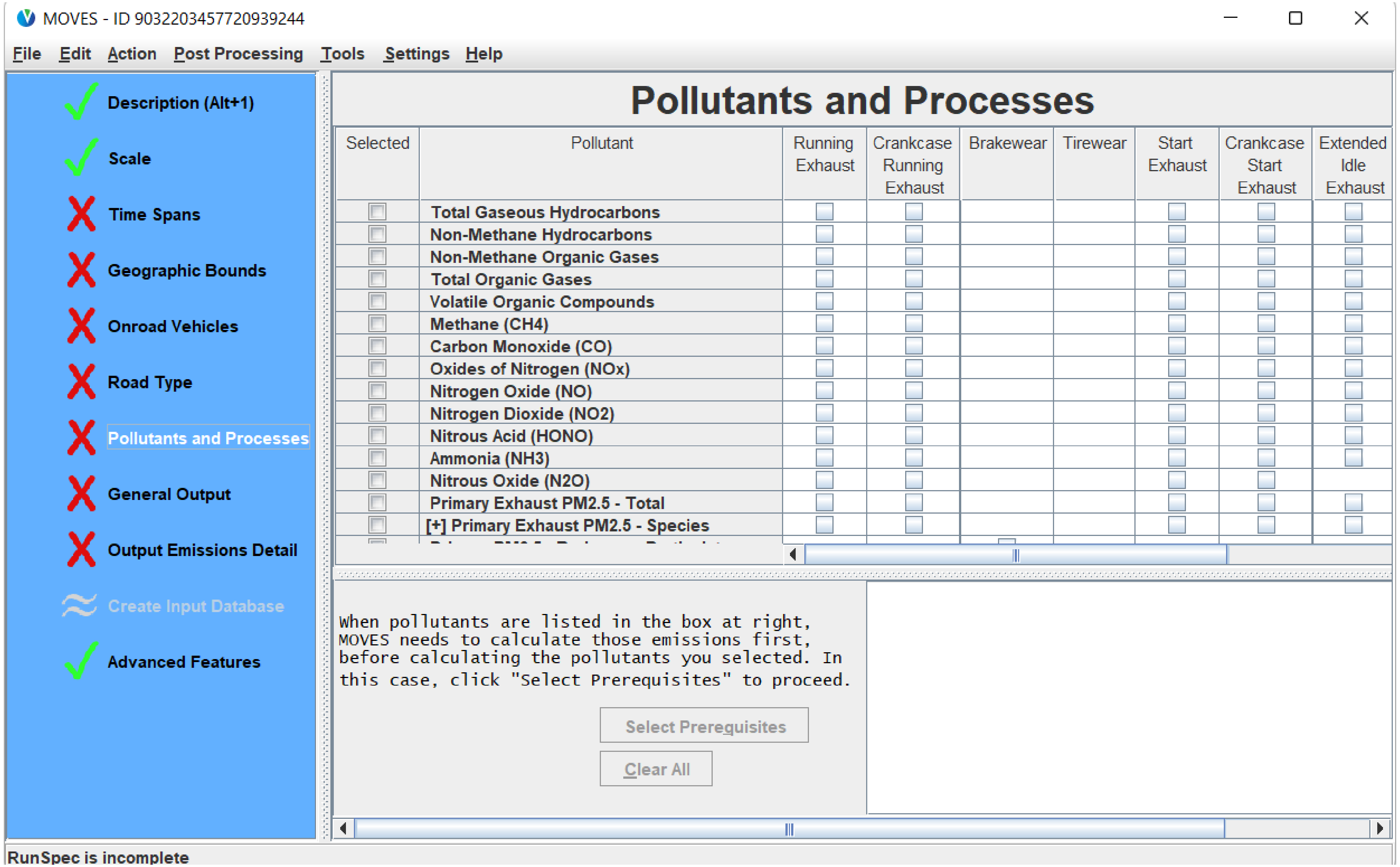
- What road types are you including?

MOVES Road Types	Use to Represent	Emission Processes Occurring on Road Type:
1: Off-Network	Parking areas	Start, hotelling, off-network idle, and resting evaporative emissions
2: Rural Restricted	Controlled-access highway (i.e., entrance/exit via ramps): freeways and interstates	All running emissions, including running evaporative
3: Rural Unrestricted	All other roads (arterials, local, collector, etc.)	
4: Urban Restricted	See row 2 – but urban	
5: Urban Unrestricted	See row 3 – but urban	

Road Type Panel Discussion (2)

- Generally, select all road types
- If you are modeling only starts and/or hotelling processes, you can select the Off-Network road type by itself
- If you are modeling any other process, select all road types

Pollutants and Processes Panel



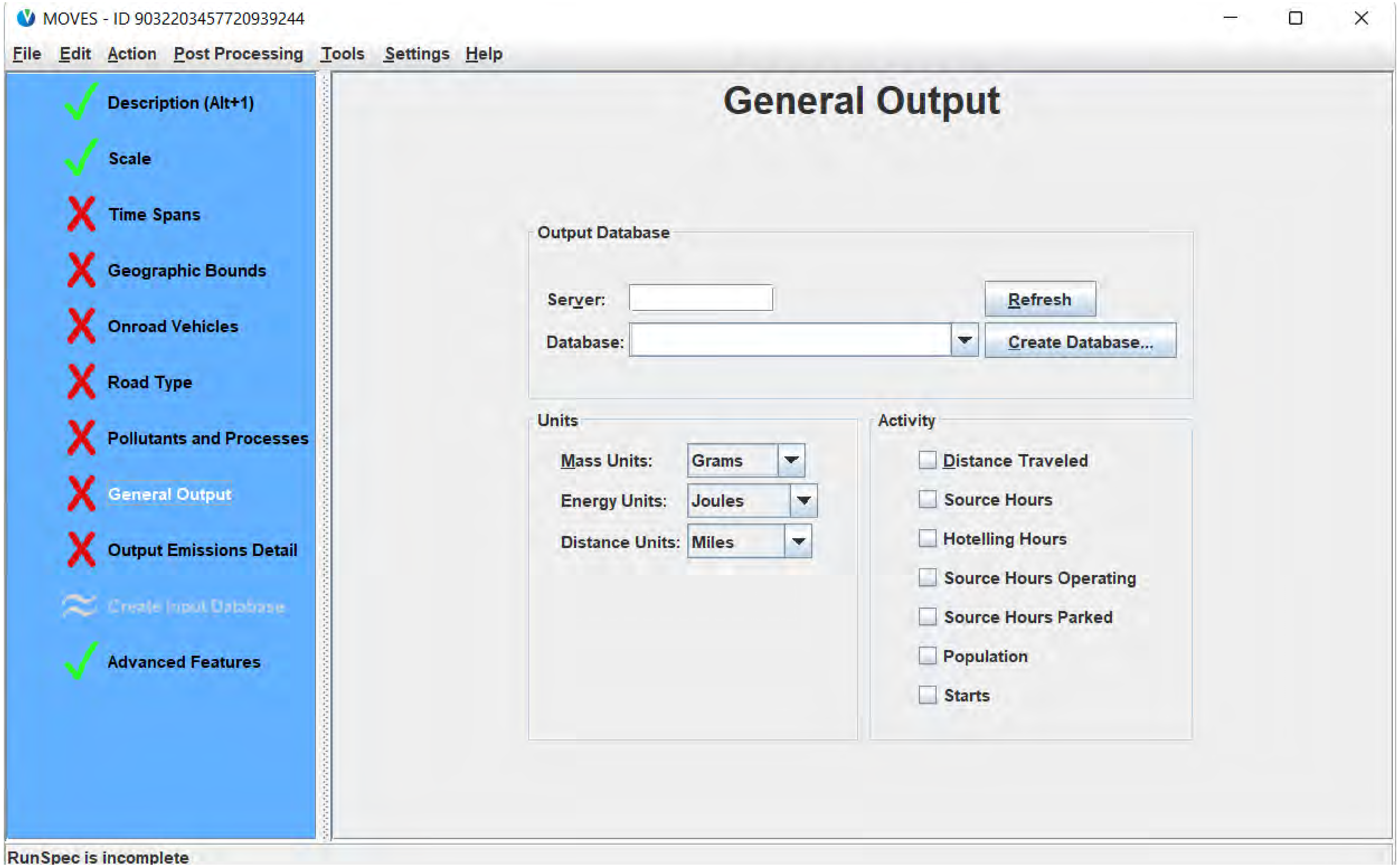
Pollutants and Processes Panel Discussion (1)

- Which pollutants and which emissions processes are you modeling?
- In general, select all processes for a pollutant to ensure a full inventory
- Checkbox to the left of the pollutant name has two uses:
- Selects or unselects all chosen processes for a pollutant
- Indicates at least one process for this pollutant has been selected
- NOTE: Table may extend beyond what's shown on the screen; use scroll bars at bottom & left side of table

Pollutants and Processes Panel Discussion (2)

- Some pollutant/process selections automatically select certain road types
- Some pollutants and processes are “chained”
  - MOVES indicates what additional pollutants or processes are needed
  - Clicking “Select Prerequisites” will automatically select required pollutants/processes
- Only select the pollutants/processes needed for your analysis, as more selections will increase runtime

General Output Panel



General Output Panel Discussion (1)

- The only required input on this panel is the name of the output database
  - Tip: end output database names with "_out" to clearly indicate they contain output
  - Enter a unique name to have MOVES make a new output database, unless you want to use one already made
- You can store output from multiple MOVES runs (i.e., multiple RunSpecs) in the same database
  - Output from each RunSpec will be identified by a different MOVES run ID
  - Only recommended when there's a reason to do so, e.g.:
    - Each run is for a county in a nonattainment area and the results will later be summed, or
    - Two or more runs that will be compared

General Output Panel Discussion (2)

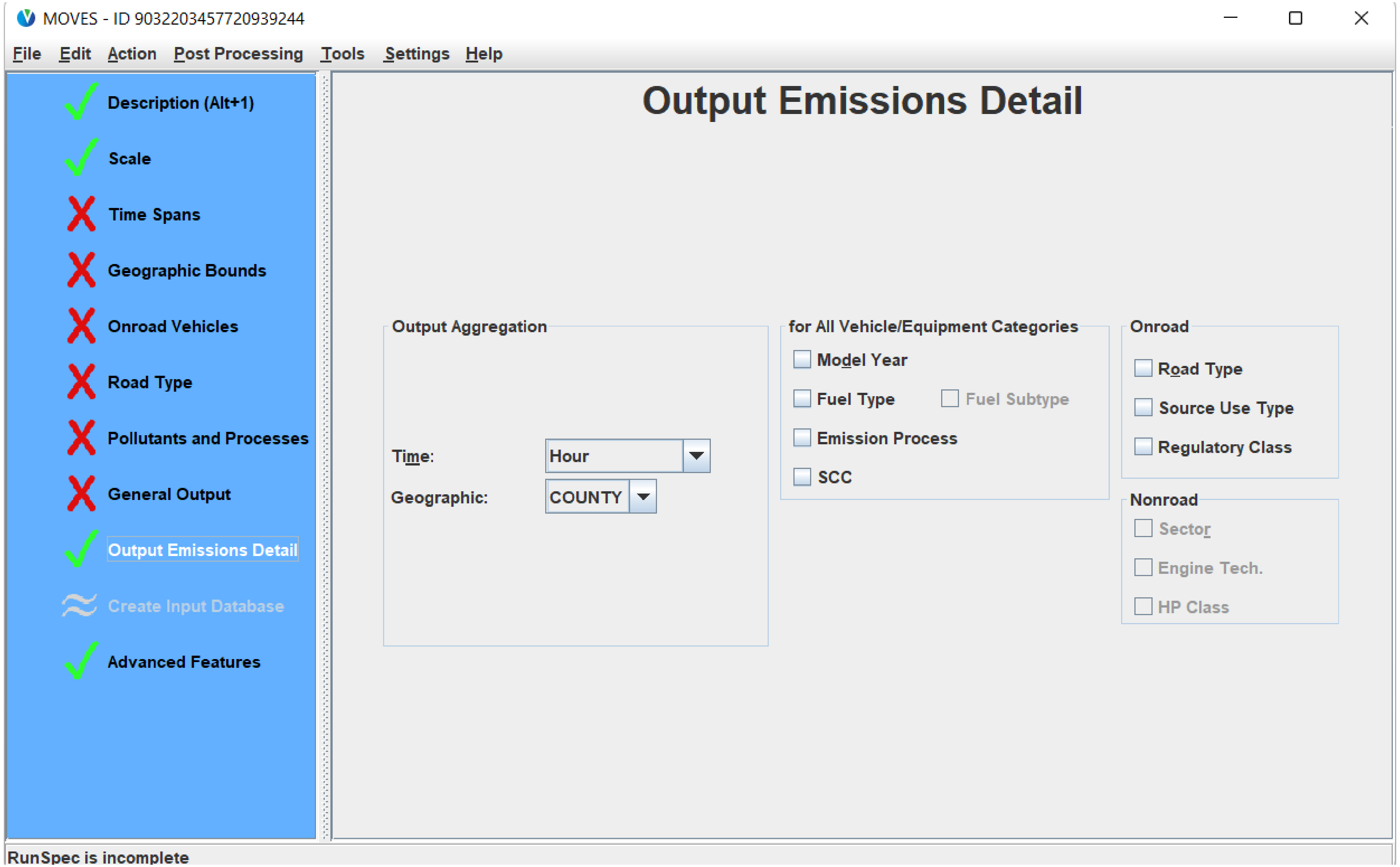
- Units must be selected for:
  - Mass (Kilograms, Grams, Pounds, U.S. Ton)
    - Grams may be the best choice for criteria pollutants/precursors and air toxics
    - Tons is recommended for CO_2
  - Energy (Joules, KiloJoules, Million BTU)
  - Distance (Kilometers, Miles)
  - **Grams, Joules, and Miles are selected by default**

General Output Panel Discussion (3)

- Activity (vehicle activity) selections are optional, but may be important
- Reported only for the selections made (geographic area, time period, vehicles, etc.) and only when relevant for the run

Activity Output Options	Notes
Distance Traveled	Vehicle miles travelled. Can be used as a check against inputs to ensure all VMT is accounted for
Source Hours	Combines source hours operating and source hours parked
Hotelling Hours	Reports hours of: Extended Idle, Auxiliary Power Units use, Shore Power, and Battery/Off
Source Hours Operating	Total hours of vehicle running operation
Source Hours Parked	Total hours of vehicle parking
Population	Number of vehicles (not people)
Starts	Number of vehicle starts

Output Emissions Detail Panel



Output Emissions Detail Panel Decisions

- What is the level of detail that you want in your emissions output?
- You can choose to aggregate emission *results* (different from preaggregating inputs):
  - Do you want emission results aggregated temporally?
  - Do you want emission results aggregated geographically?
    - Only relevant when multiple counties/states are selected
- Do you want emissions by additional detail (e.g., fuel type)?

Time Output Aggregation

- "Output Aggregation" options for Time:
  - Hour
  - 24-Hour Day
    - Results are for one weekday and one weekend day
  - Portion of Week
    - Weekday results are for a total of 5 weekdays
    - Weekend results are for a total of 2 weekend days
  - Month
  - Year

  - CAUTION: Once a longer time period is selected, you cannot get information for shorter time periods without re-running MOVES

Time Output Aggregation: Hour

- If "Hour" is selected:
  - The emissions will be reported for each hour, day type, month, and year selected in the RunSpec
  - Because MOVES does not model specific days, these will be hourly emissions for a "typical day" of the indicated type
  - If all hours are run:
    - Summing across all hours will result in **daily** emissions.
    - Summing across both day types will **NOT** result in weekly or monthly emissions

Time Output Aggregation: 24-Hour Day

- If "24-Hour Day" is selected:
  - All hours must be selected
  - The emissions will be reported as daily emissions for each day type, month, and year selected in the RunSpec
  - These are "typical days"
  - If both day types are run:
    - Summing across both day types will **NOT** result in weekly or monthly emissions
    - You must multiply the daily emissions by the number of times those day types occur to calculate weekly or monthly emissions

Time Output Aggregation: Portion of Week

- If "Portion of Week" is selected:
  - All hours must be selected
  - The emissions will be reported for each day type, month, and year selected in the RunSpec
  - The emissions for "weekdays" represent emissions occuring on all weekdays in a typical week
    - I.e., "24-Hour Day" emissions for a typical weekday x5
  - The emissions for "weekend days" represent emissions occuring on all weekend days for a typical week
    - I.e., "24-Hour Day" emissions for a typical weekend day x2
  - If both day types are run:
    - Summing across both day types will result in **weekly** emissions
    - Summing across all months will **NOT** result in annual emissions

Time Output Aggregation: Month and Year

- If “Month” is selected:
  - All hours and day types must be selected
  - The emissions will be reported as monthly emissions for each month and year selected in the RunSpec
  - If all months are run:
    - Summing across all months will result in **annual** emissions
- If “Year” is selected:
  - All hours, day types, and months must be selected
  - The emissions will be reported as annual emissions for each year selected in the RunSpec

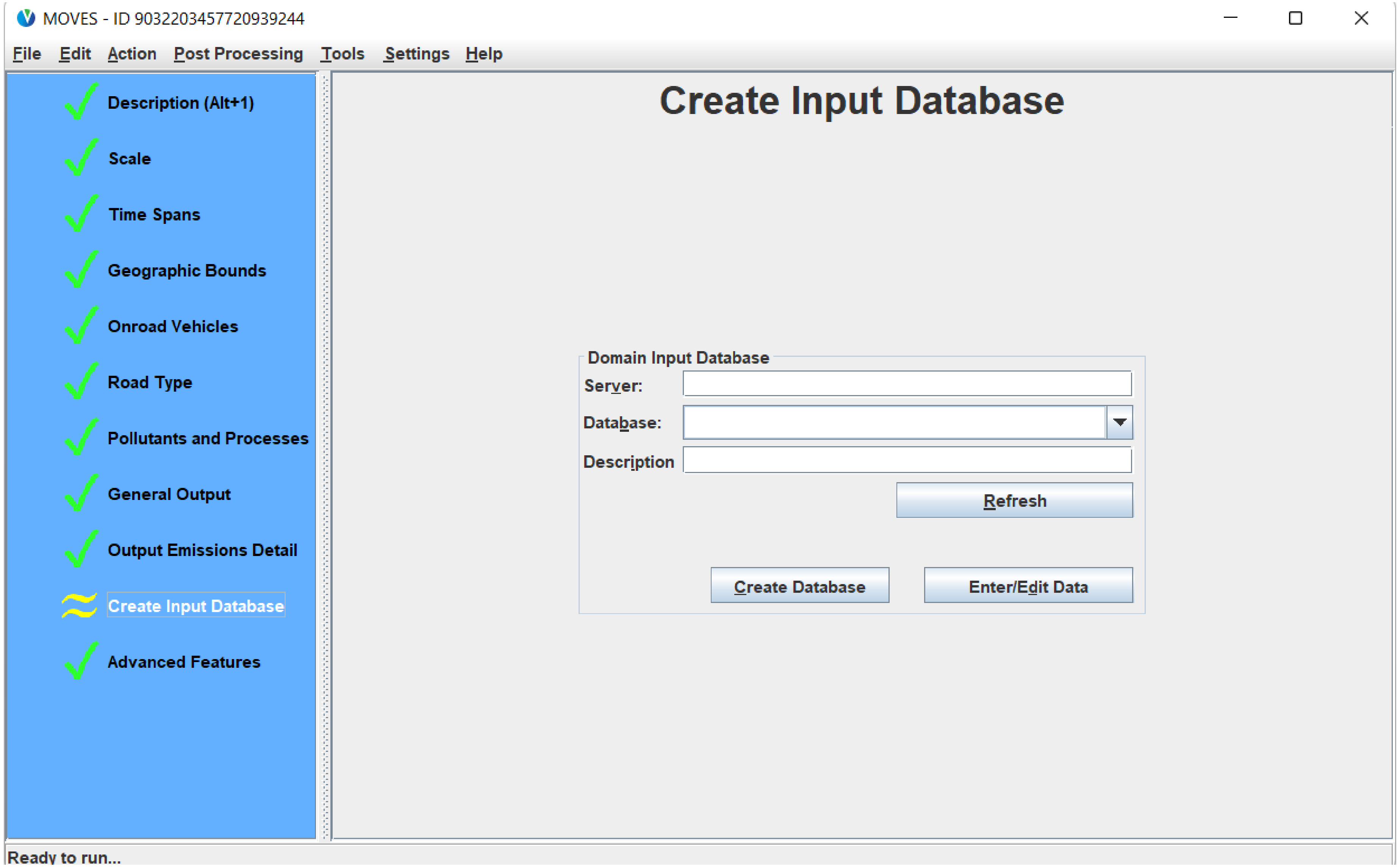
Geographic Output Aggregation

- “Output Aggregation” options for Geographic:
  - County
  - State (only for Default Scale)
  - Nation (only for Default Scale)
- You can change it to a larger geographic area in Default Scale
  - E.g., if modeling counties in a two-state metro-area, you can choose State for emissions grouped by each state’s portion
  - CAUTION: Once a larger area is selected, you cannot get information for smaller geographic areas without re-running MOVES

Output Emissions Detail Panel Discussion

- Other output detail is optional
  - More selections here result in more detail (rows of output data)
- MOVES can report emissions by:
  - Source use type (type of vehicle, <u>perhaps the most useful</u>)
  - Model year (CAUTION: will increase output x31)
  - Fuel type
  - Emissions process (e.g., starts, running emissions, etc.)
  - Source Classification Code (SCC), an EPA reporting code
  - Road type
  - Regulatory Class (maps roughly to some vehicle weight classes)

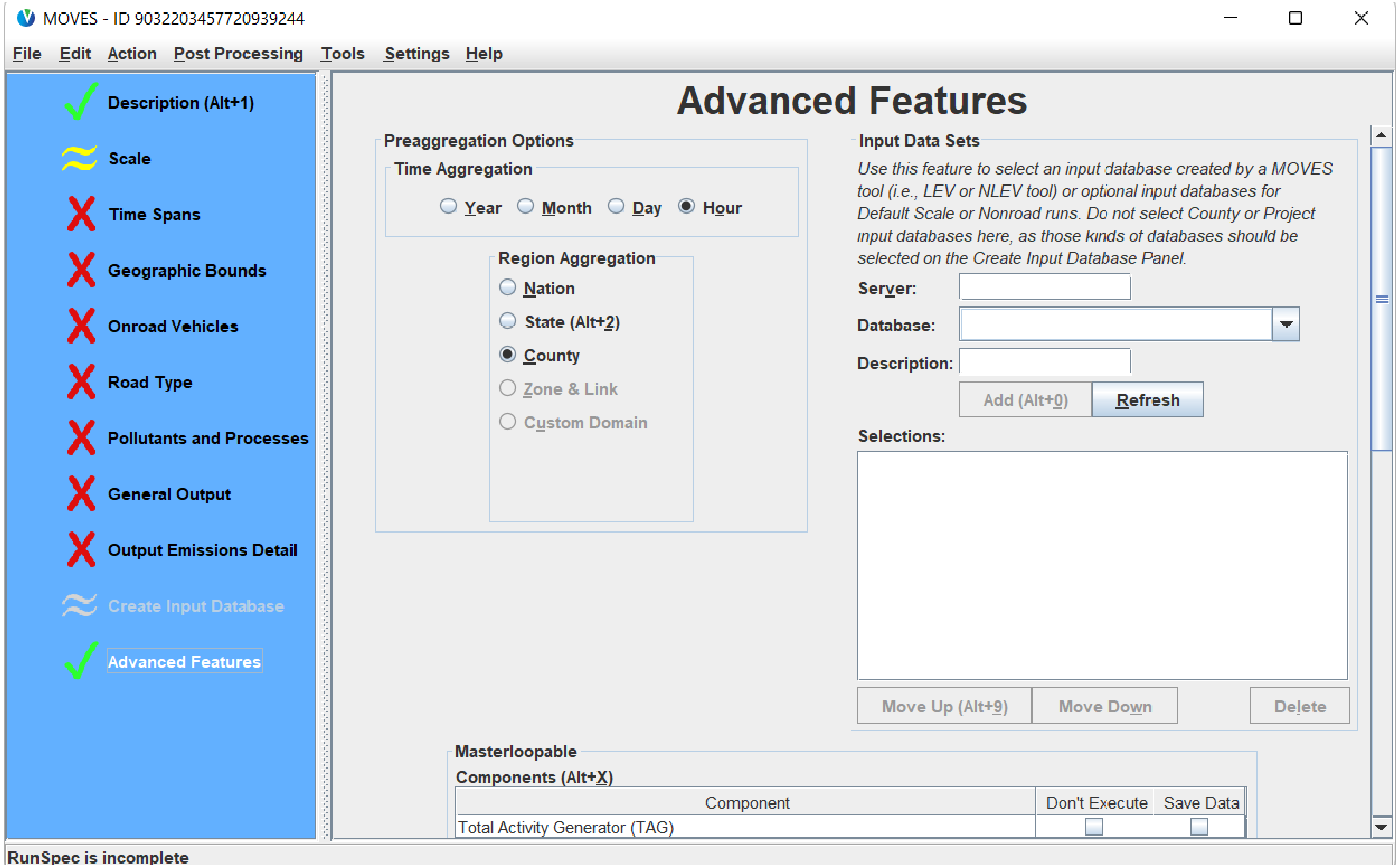
Create Input Database



Create Input Database Discussion

- Required for County and Project Scale – but optional for Default Scale
- Only available once all other panels have green checks
- Used to input local information on fleet mix, fuels, meteorology, etc.
  - We will discuss input databases in Module 3

Advanced Features Panel



Advanced Features Panel Discussion

- This panel will not be used in most cases, however:
  - Pre-aggregation selections may speed up runs by averaging some input parameters
  - If you want to do a national run, indicate that here
  - Input Data Sets selection can be used to import LEV or NLEV supplementary databases (if applicable), as well as specify optional input databases at Default Scale
    - Optional input databases for Default Scale can be created on the previous panel, but are automatically specified here
- Note:
  - County and Project scale input databases should not be defined here
    - Should be defined in "Create Input Database" panel instead
  - "Masterloopable", aggregation, and default database options toward the bottom of the panel are for EPA diagnostic work only. We recommend you do not use

Hands-on Exercise:
Create a Default Scale RunSpec

Module 2 Exercise Files

- The zip file of course materials contains a folder called Module 2 – Default Scale Exercise
- If you have not done so, unzip the course materials to a convenient location, such as your desktop
- If you get lost or have technical difficulties, the course files for this module contain an *Answer Key* folder, where you can find the completed RunSpec and resulting output database

Hands-on Exercise: Default Scale Scenario

- Purpose: Learn to use the MOVES GUI and create a RunSpec
- Let's create a RunSpec to answer the question:

  How much NOx was emitted from passenger cars in Washtenaw County, Michigan on a weekday and on a weekend day, during the summer in 2023?

- We will do the same run in Module 3 at the County Scale and compare results
- Note:
  - This exercise scenario is intentionally simplified to facilitate learning, limit complexity, and reduce MOVES run time
  - You cannot use the Default Scale for SIP or conformity purposes. This is for comparison only

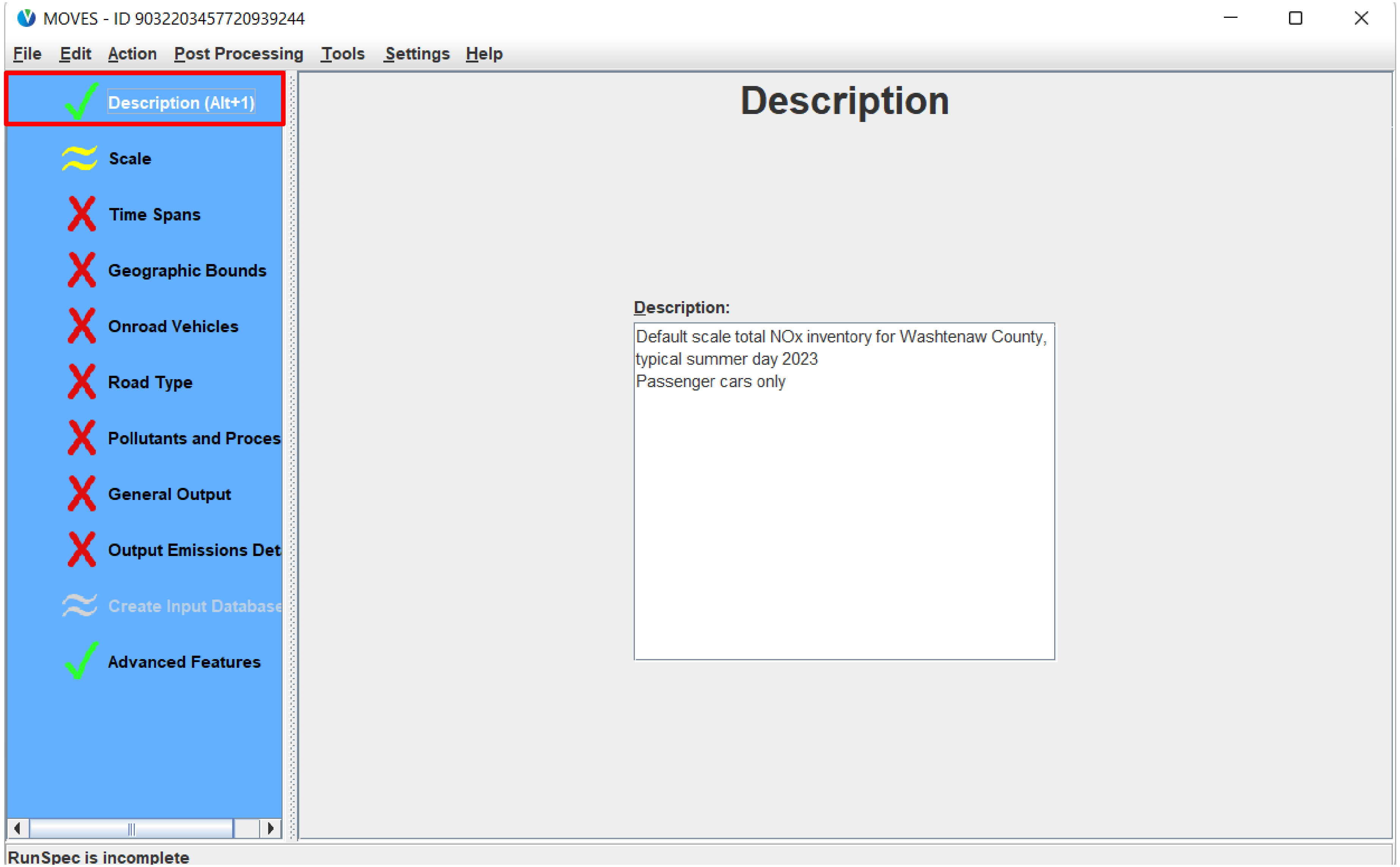
Default Scale Exercise Overview

Component	Description
Type and Location	Inventory run for Washtenaw County, Michigan • This is where EPA's National Vehicle and Fuel Emissions Laboratory is located
Time	Summer weekday and weekend day, 2023 • Select July, both day types, and all hours
Vehicles	Passenger Cars only • Normally, all vehicle types would be selected
Roads	All road types
Pollutants	Oxides of Nitrogen, all processes • Normally, more pollutants would be required for a SIP or conformity run
Output Detail	Name your output database **washtenaw_2023_training_out** • Include the following activity output: Vehicle Miles Travelled, Population • Include the following emissions details: Source Type, Fuel Type, and Emission Process

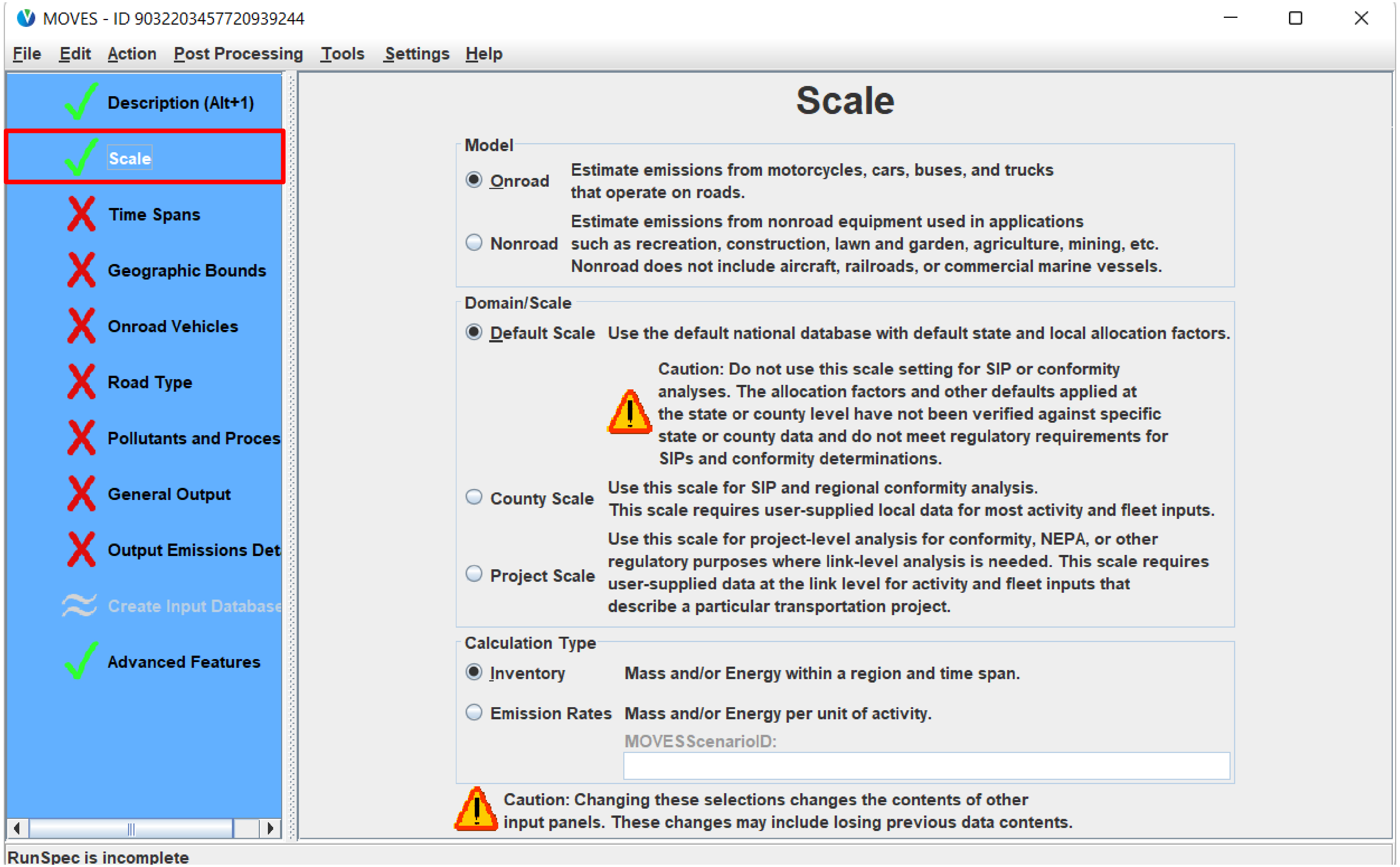
Build the RunSpec on your own

How much NOx was emitted from passenger cars in Washtenaw County, Michigan on a weekday and weekend day in summer 2023?

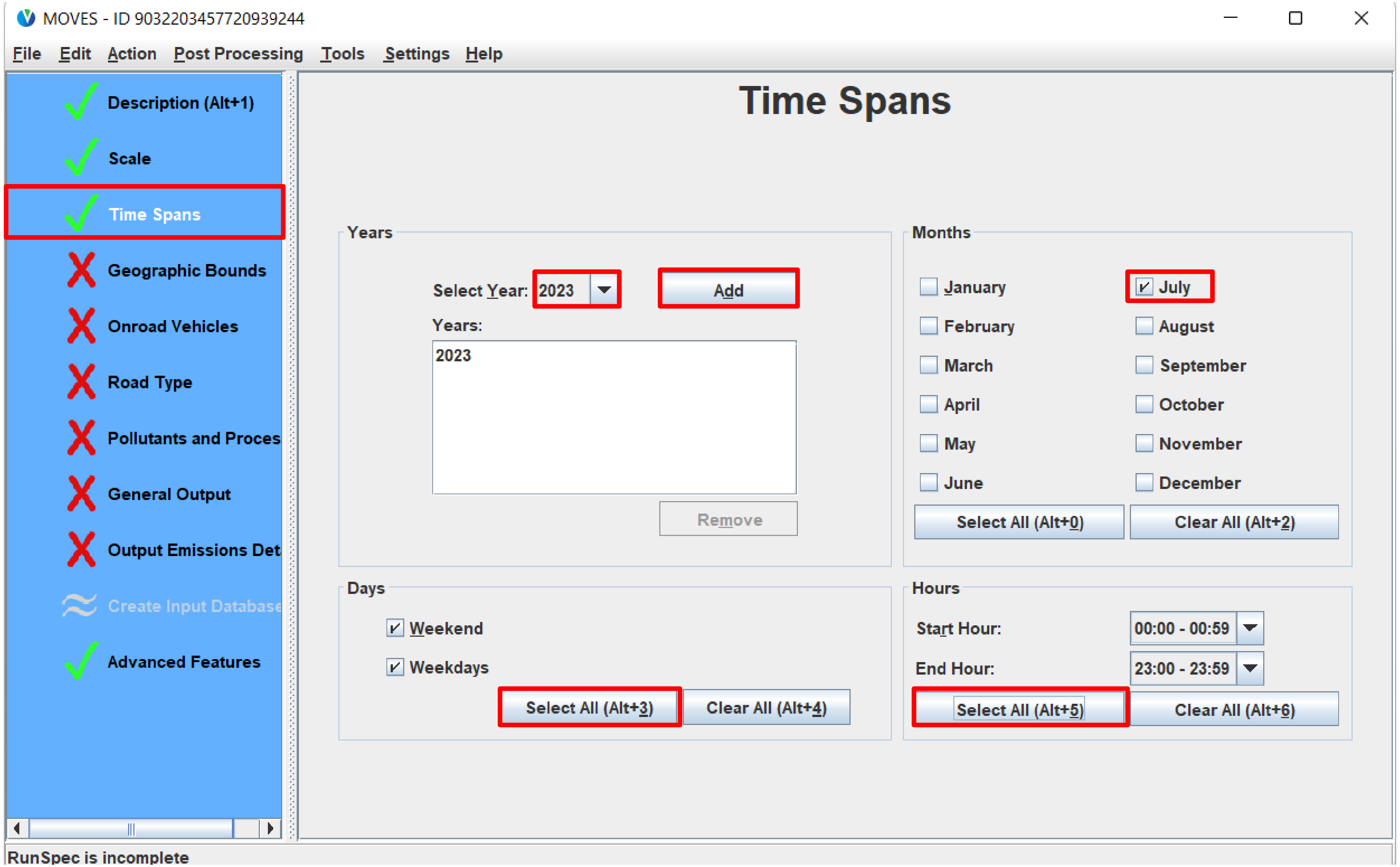
Default Scale Exercise: Description Panel



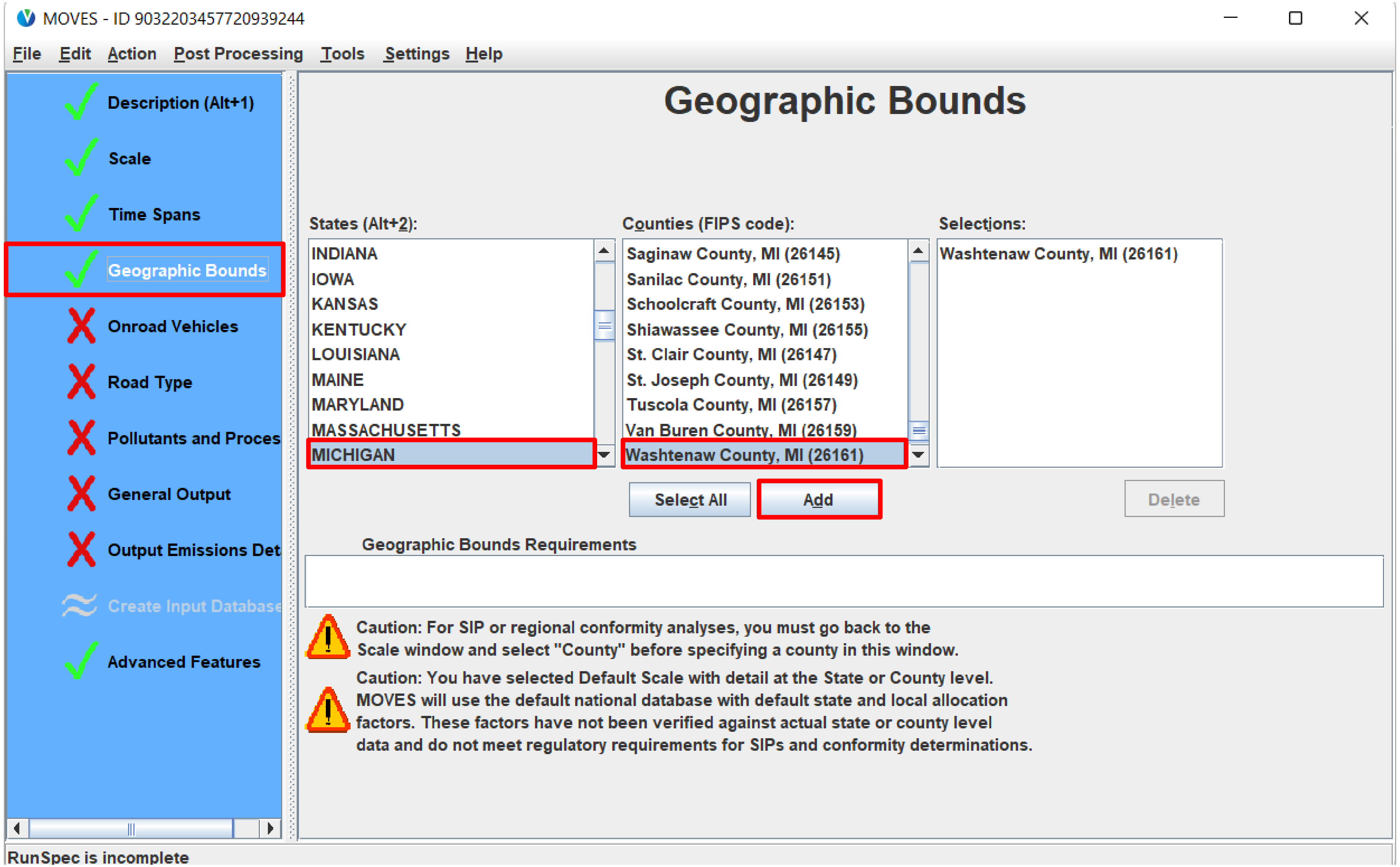
Default Scale Exercise: Scale Panel



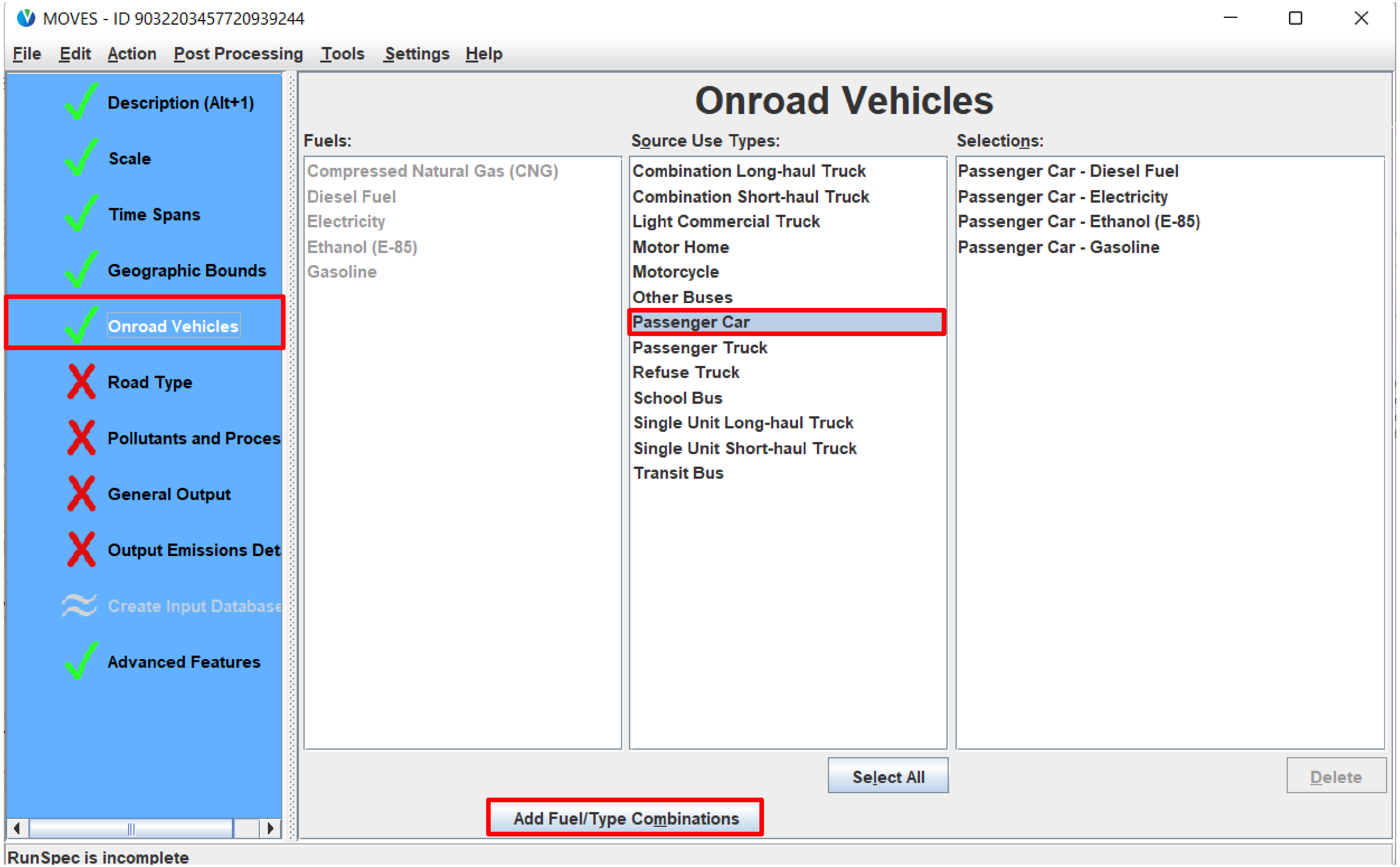
Default Scale Exercise: Time Spans Panel



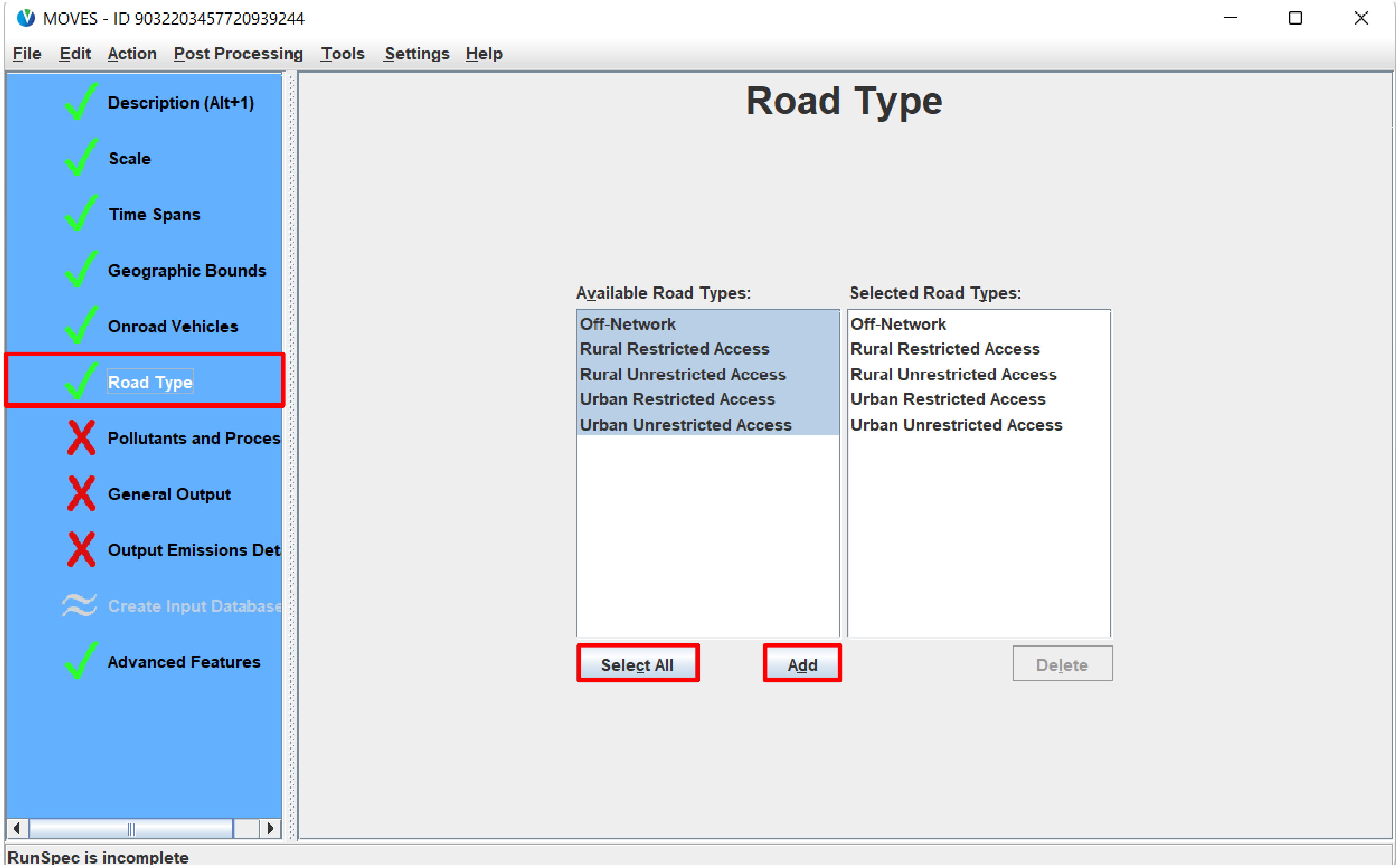
Default Scale Exercise: Geographic Bounds Panel



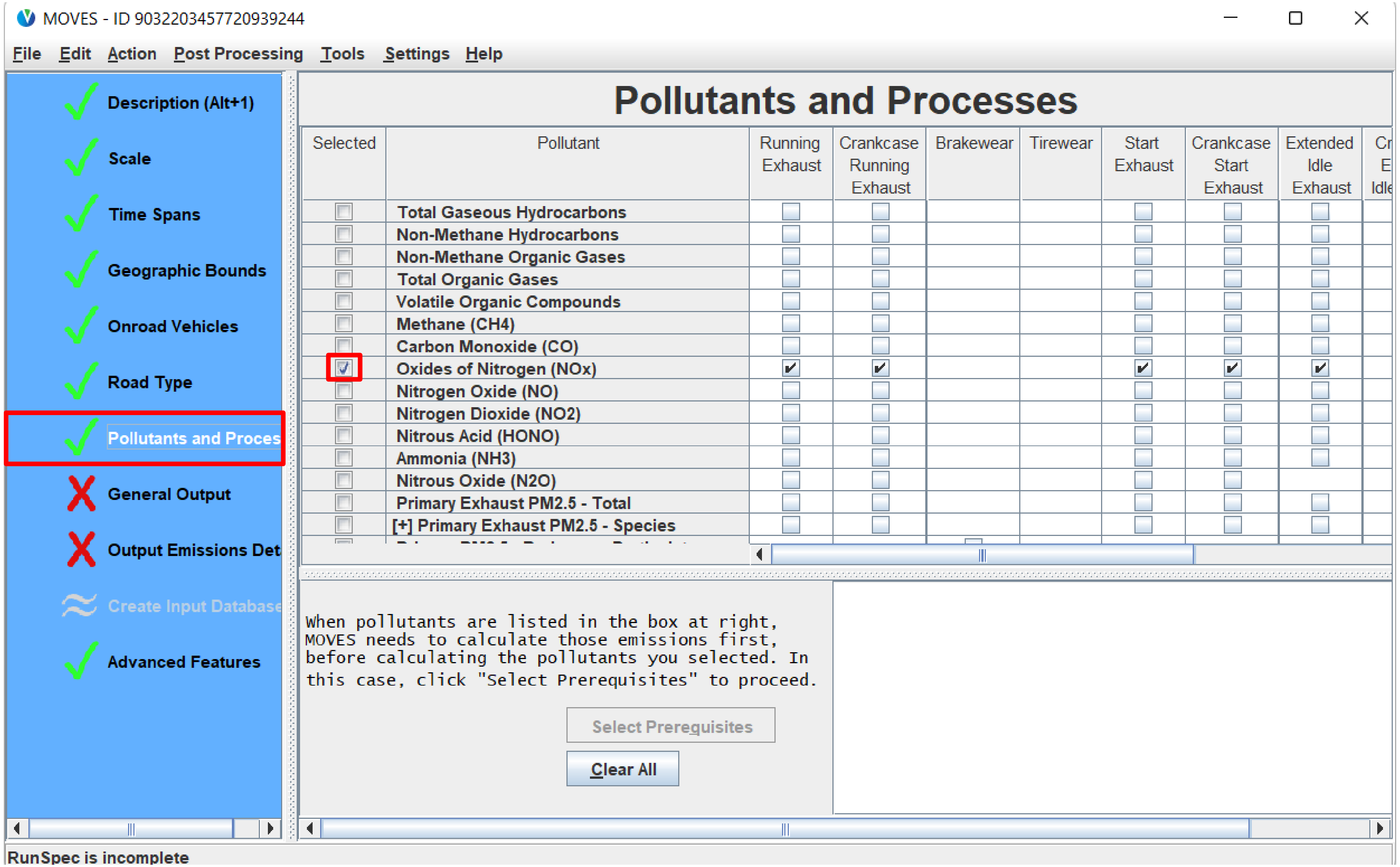
Default Scale Exercise: Onroad Vehicles Panel



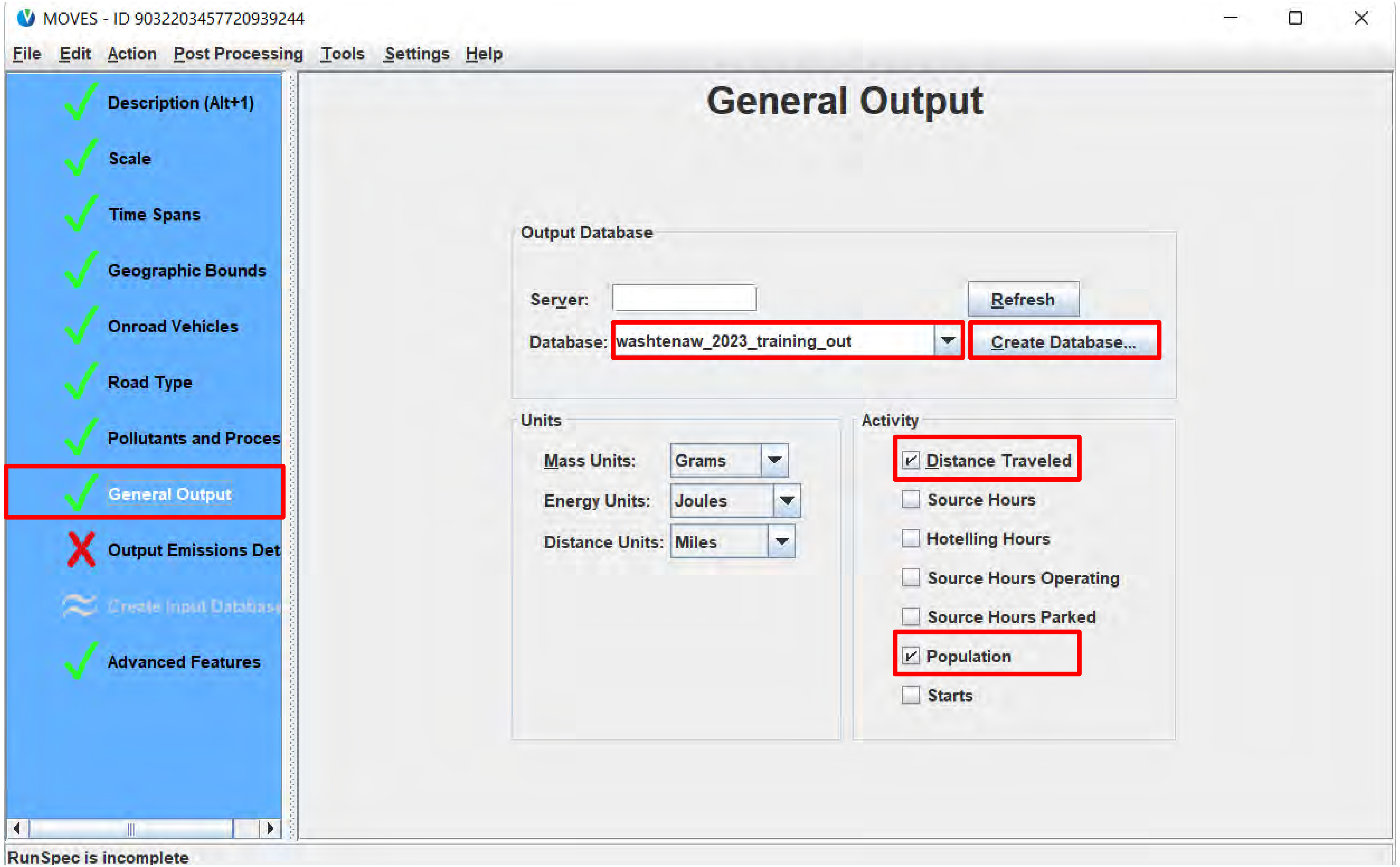
Default Scale Exercise: Road Type Panel



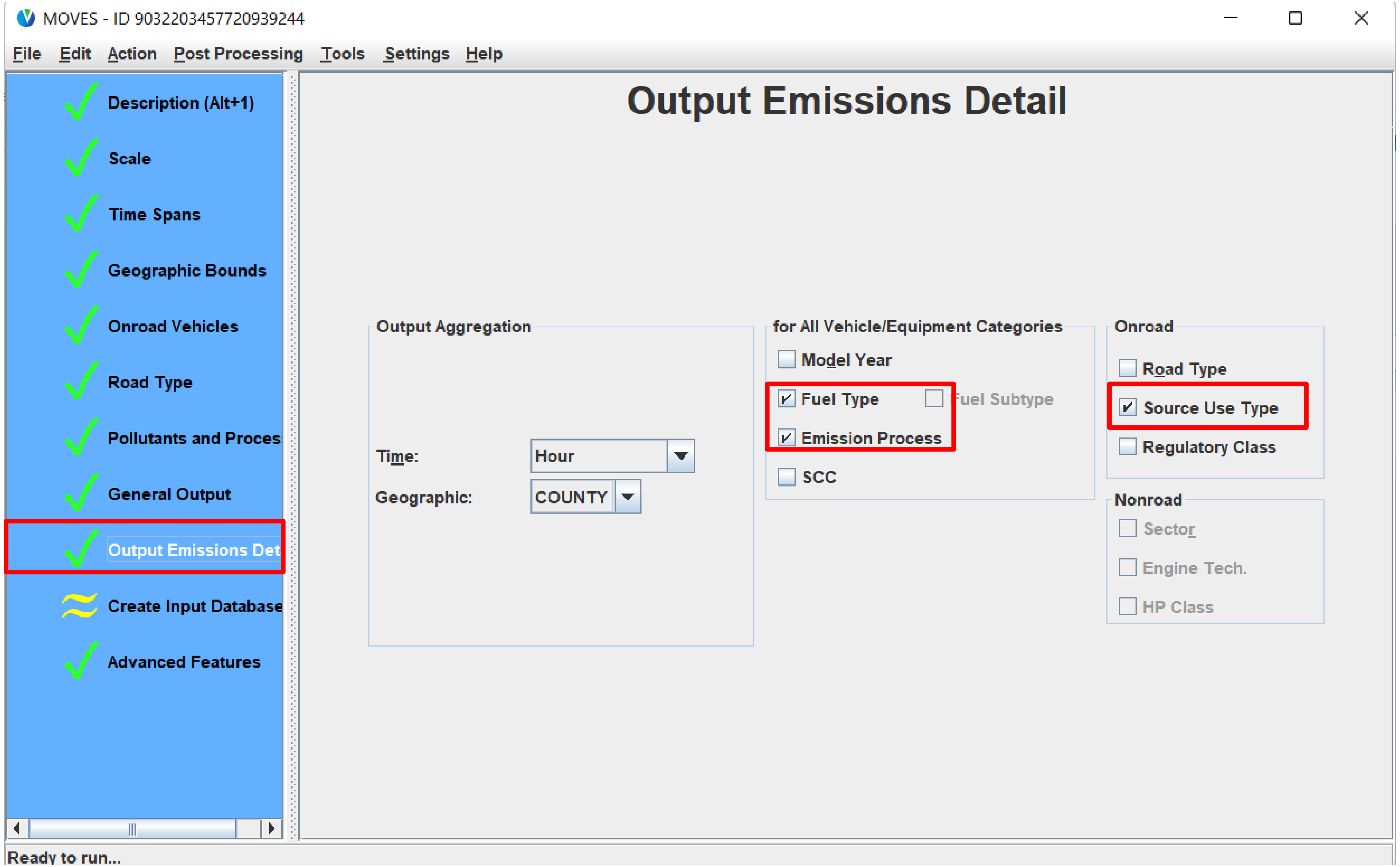
Default Scale Exercise: Pollutants and Processes



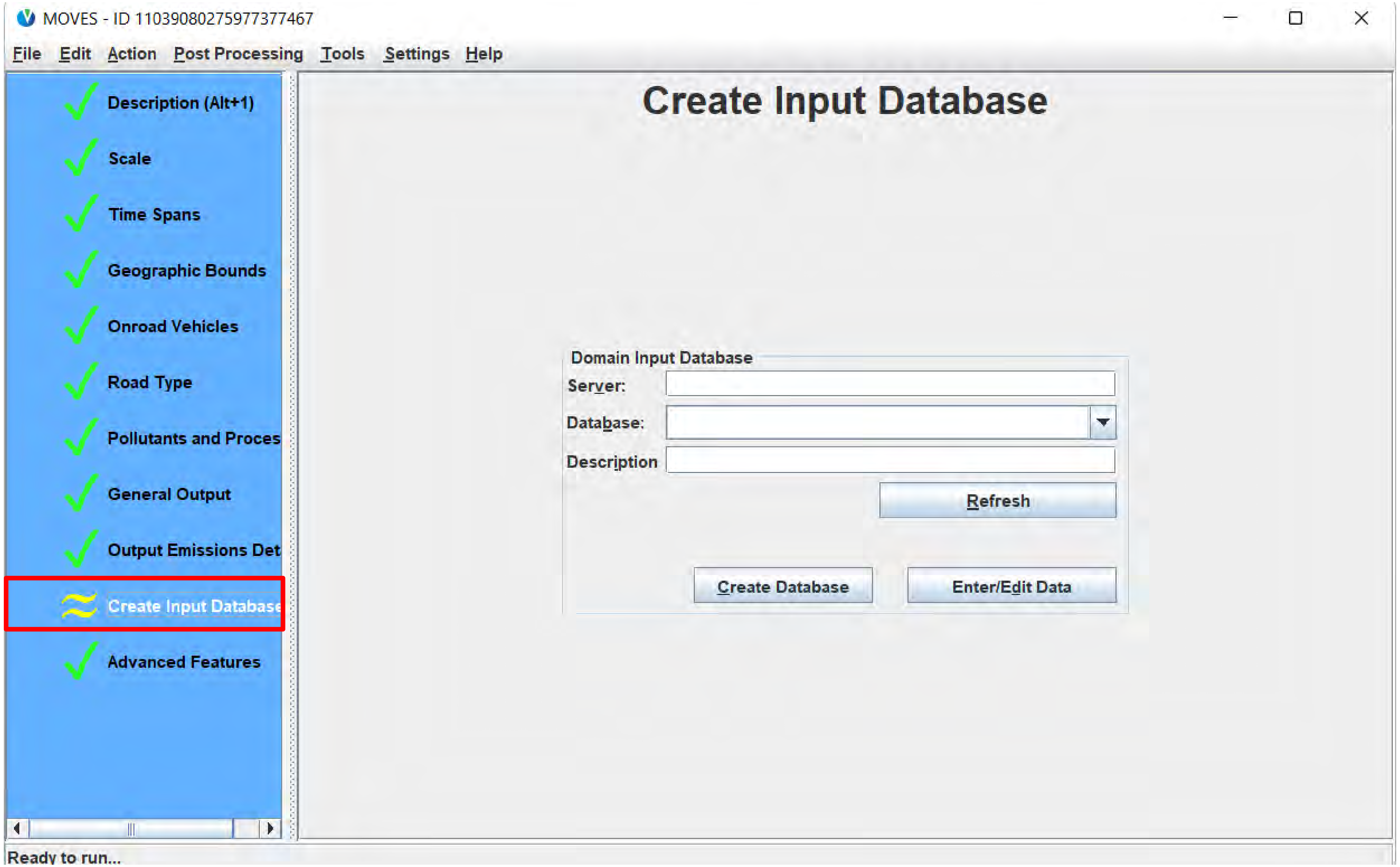
Default Scale Exercise: General Output Panel



Default Scale Exercise: Output Emissions Detail



Default Scale Exercise: Create Input Database



Default Scale Exercise: Saving the RunSpec

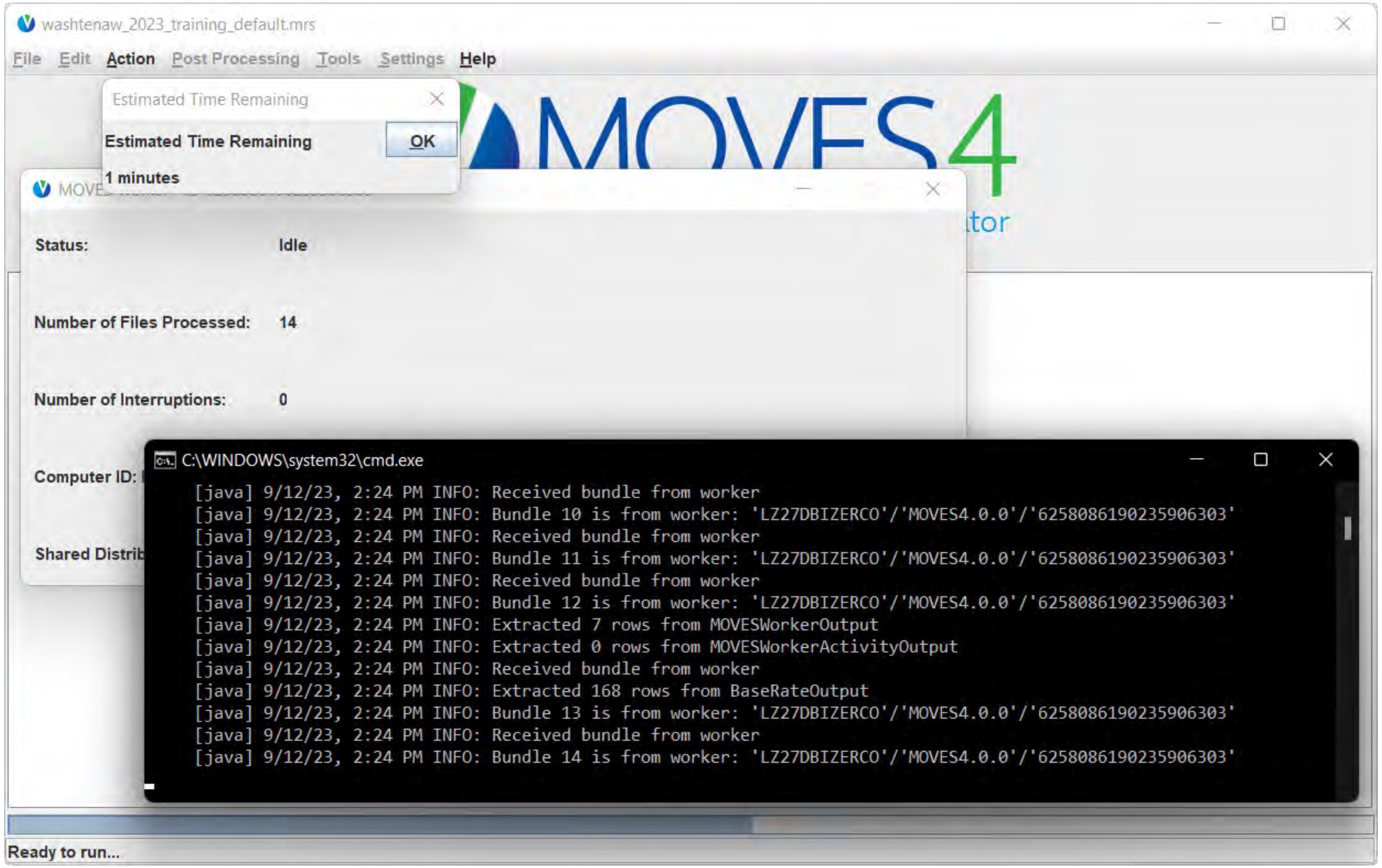
- Best Practice
  - Relate the RunSpec name to input/output database names
  - Save the RunSpec in its own folder, alongside any input files or output post-processing scripts

- Saving our Default Scale Run Exercise:
  - No input database created
  - We named the output database “washtenaw_2023_training_out”
  - Save the RunSpec as: “washtenaw_2023_training_default.mrs” in a new folder:
    - From File menu, select Save As…
    - Create a new folder (somewhere easy to find, such as on your Desktop) called “MOVES4 Default Scale Training Exercise”
    - Name the RunSpec file “washtenaw_2023_training_default_default.mrs”
    - Click Save

Default Scale Exercise: Running MOVES

- MOVES needs your action to begin the run
- Instructions for our Default Scale Run Exercise:
  - Click the Action Menu
  - Click "▶ Execute" menu item
    - Note: this option is only available when your RunSpec has all green checks
  - When prompted to save the run specification, click "No" as we have already saved the RunSpec
  - NOTE: Executing the RunSpec will open a new window. This window will display any warning or error messages MOVES encounters, along with a status bar and a dialog box that estimates time remaining
    - This run should take around 2 minutes to run

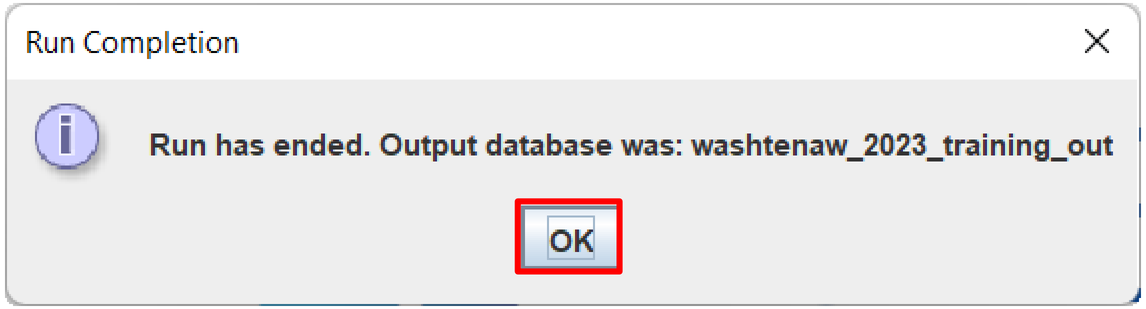
Default Scale Exercise: MOVES is Running



- NOTE: If errors occur, the messages may help identify problems. They get saved to moveslog.txt along with more information.

Default Scale Exercise: Run Complete

- A run is complete when you see the following popup:



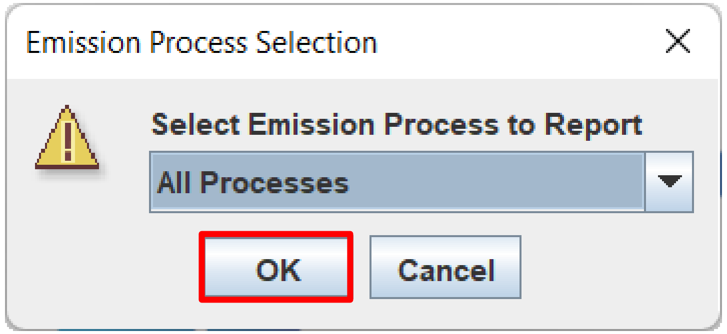
- Click OK

Accessing MOVES Results

- HeidiSQL
  - A flexible and powerful analysis tool, covered in Module 4
  - Recommend using HeidiSQL for most analyses
- MOVES Post Processing Summary Reporter
  - Reports can be viewed onscreen, printed, or saved to import in Excel
  - For the Summary Reporter to operate properly, the RunSpec that produced the output needs to be loaded in MOVES
  - Only works for Inventory runs

Default Scale Exercise: Summary Reporter

- Instructions for our Default Scale Run Exercise:
  - From the Post Processing menu, select Produce Summary Report
    - A pop-up appears, Select Emissions Processes to Report
    - Select "All Processes"
    - Click OK



Default Scale Exercise: Summary Reporter Selections

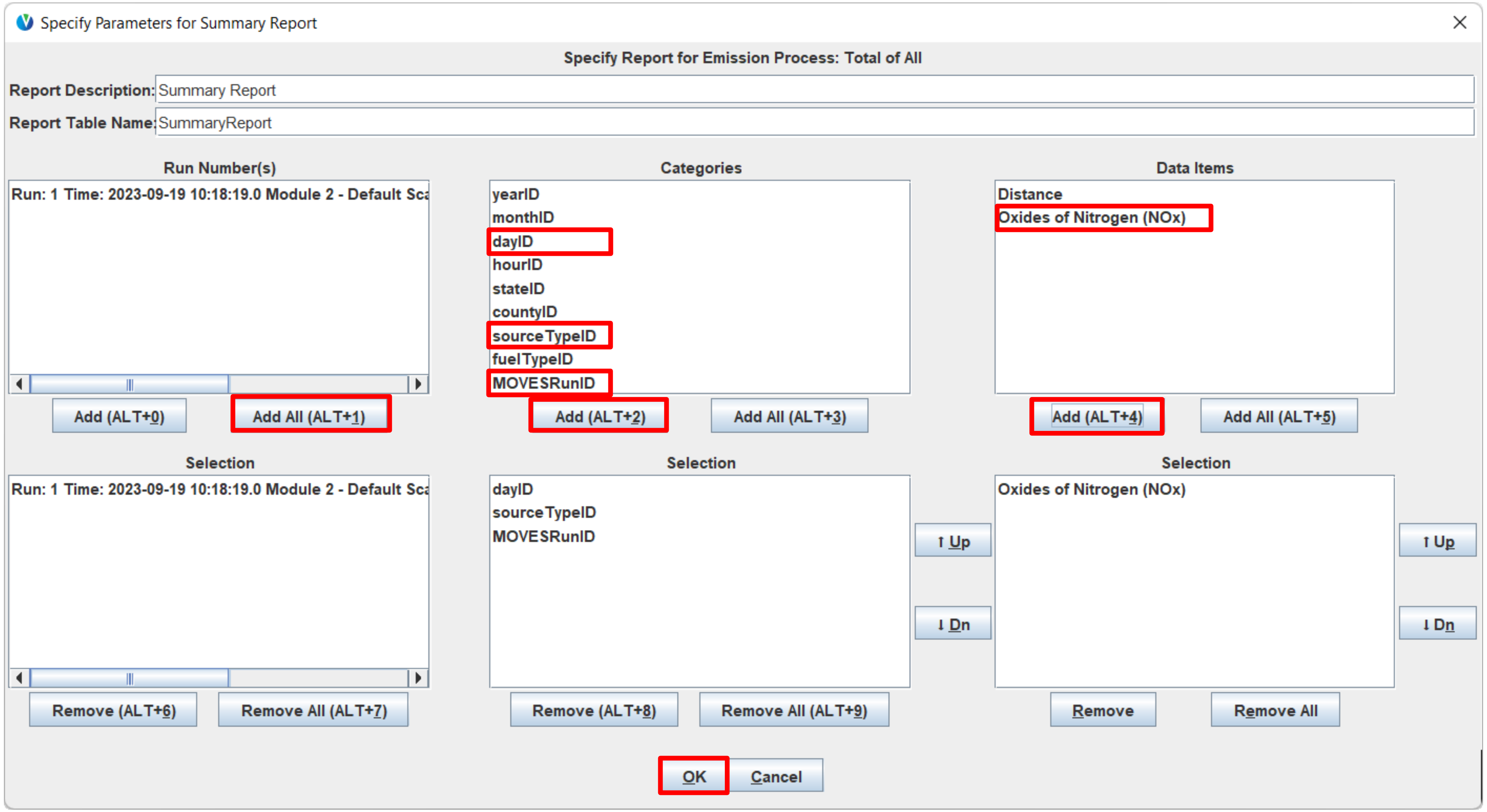
- Use the next screen to:
  - Give the report a title (optional)
  - Specify the base portion of table names used to store various portions of the report (optional, but if not changed, the report will be overwritten next time)
  - Select run number, categories, and data items reported
    - Use the Add, Add All, Remove, Remove all buttons to make selections
  - Choose the categories to be distinguished in the report

- Instructions for our Default Scale Run Exercise:
  - Click *Add All* under Run Number(s)
  - Under Categories, select `dayID`, `sourceTypeID`, and `MOVESRunID` and click *Add*
  - Under Data Items, select `Oxides of Nitrogen` and click *Add*
  - Click *OK*

Selecting Parameters for the Summary Report

Best practice is to always select MOVESRunID and dayID in Categories:

- If you re-run the RunSpec or run a different RunSpec with the same output database, you can end up with duplicate rows and potential double-counting
- The Summary Reporter doesn't know how to weight emissions for weekdays and weekend days, so you don't want to combine those in this tool



The Summary Report – Header Tab

Screen Report

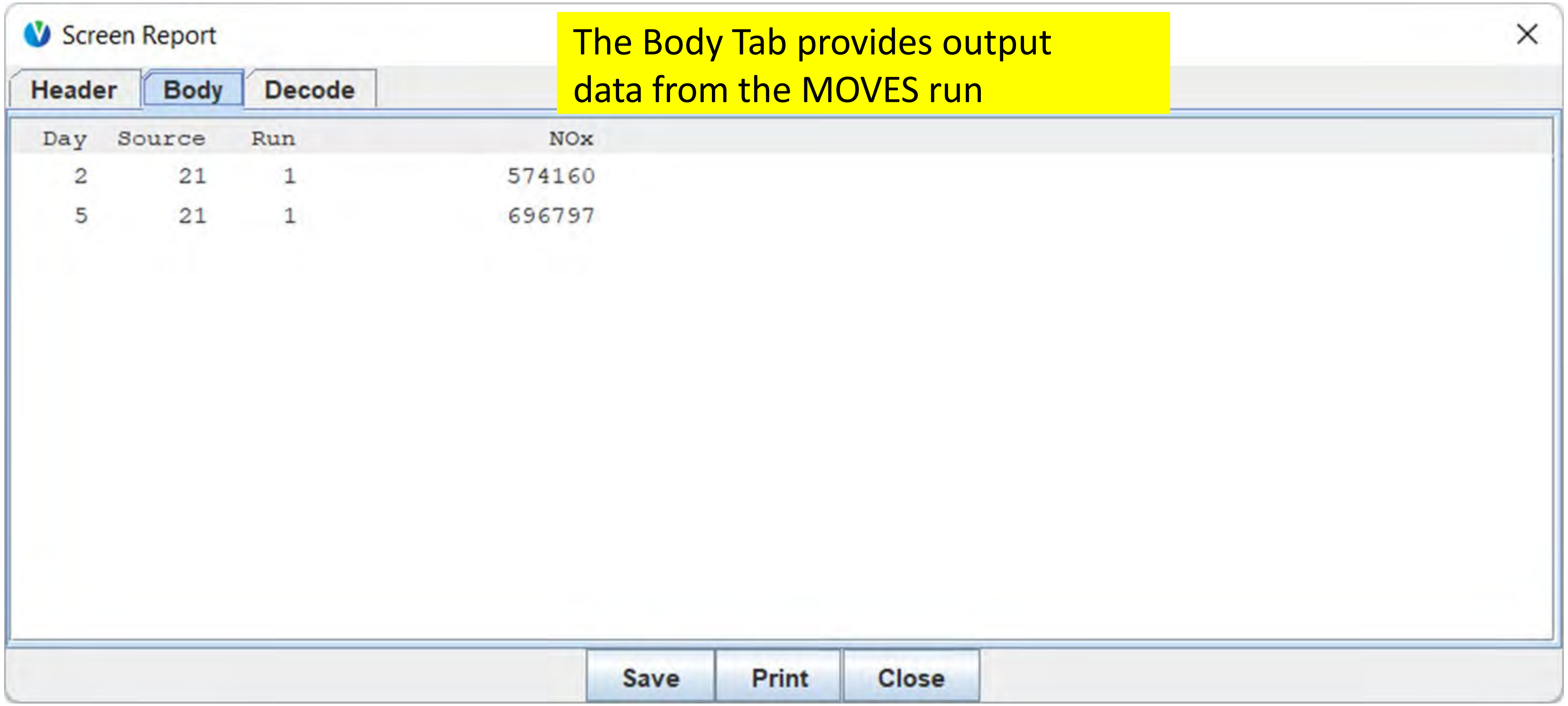
The Header Tab provides general information about the MOVES run

Header | **Body** | **Decode**

Run	Header Item:	Item Value
	Report Description:	Summary Report
	Report Date/Time:	2023-9-19 11:32:36
	MOVES Output Database:	washtenaw_2023_training_out
	Emission Process:	All
1	Run Date/Time:	2023-09-19 10:18:19.0
1	Run Specification:	Module 2 - Default Scale Exercise\washtenaw_2023_training_default.mrs
1	Run Spec File Date/Time:	2023-09-19 10:13:31.0
1	Run Spec Description:	Default scale total NOx inventory for Washtenaw County, typical summe
1	Mass Units:	g
1	Energy Units:	J
1	Distance Units:	mi
1	Time Units:	hour

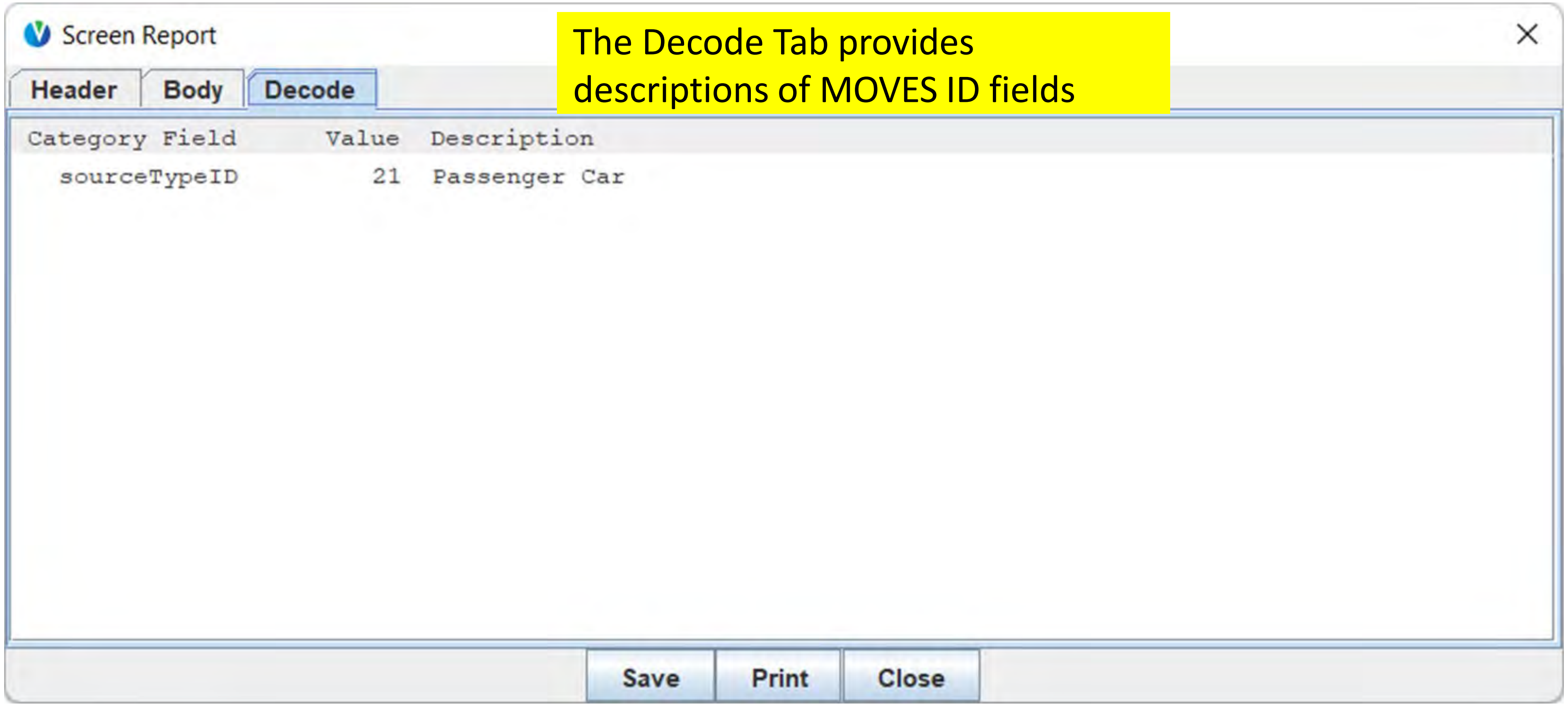
Save **Print** **Close**

The Summary Report – Body Tab



The Body Tab provides output data from the MOVES run

The Summary Report – Decode Tab

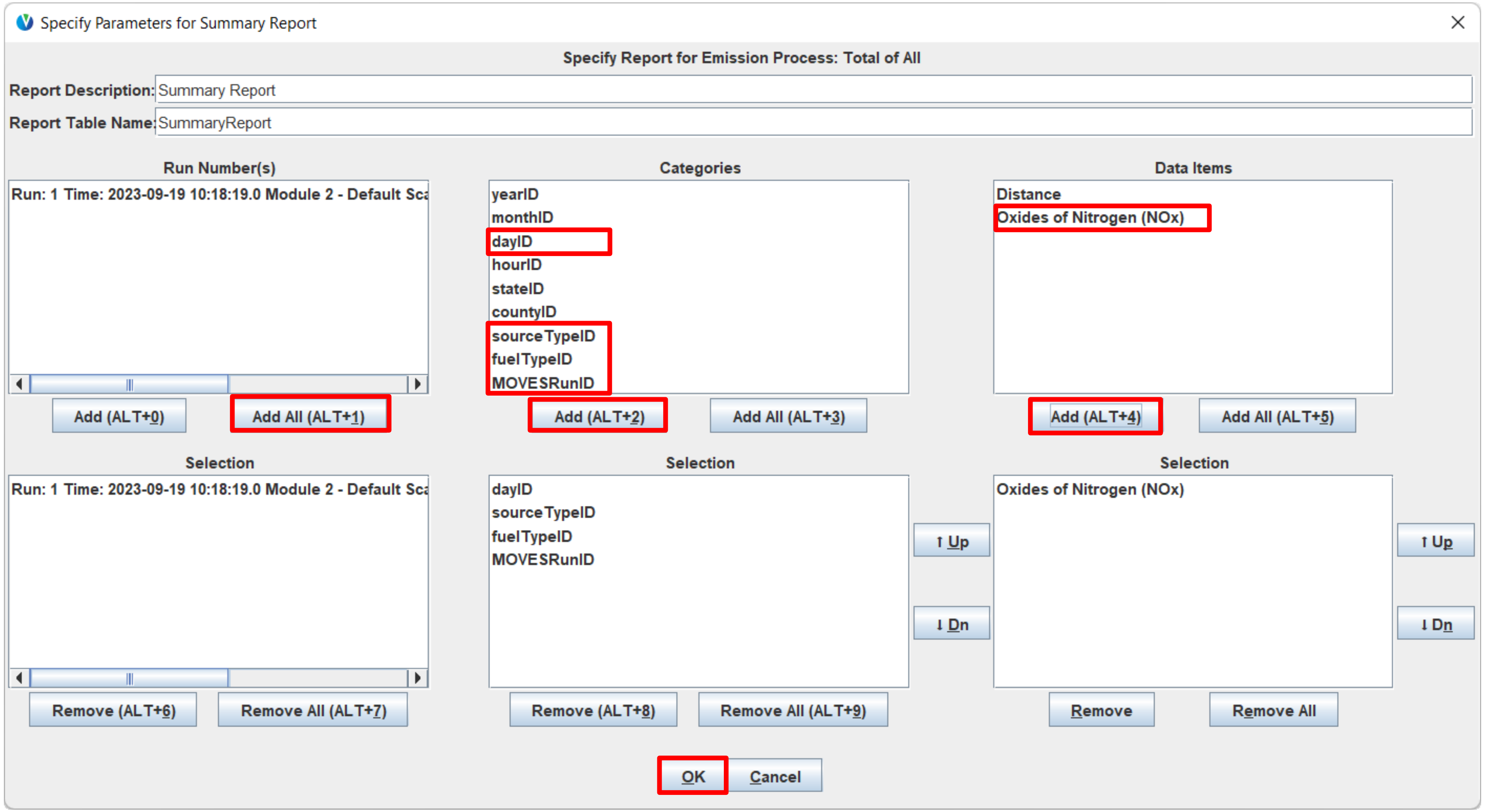


What if you want NOx split by fuel type?

- Rerun the summary report, but select `fuelTypeID` in addition to `dayID`, `sourceTypeID`, and `MOVESRunID` from Categories

- Instructions for our Default Scale Run Exercise:
  - Click *Add All* under Run Number(s)
  - Under Categories, select `dayID`, `sourceTypeID`, `fuelTypeID`, and `MOVESRunID` and click *Add*
  - Under Data Items, select `Oxides of Nitrogen` and click *Add*
  - Click *OK*

Adding fuelTypeID to the Summary Report



Total NOx is reported by fuel type

Screen Report

Header | Body | Decode

Day	Source	Fuel	Run	NOx
2	21	1	1	571666
2	21	2	1	2356
2	21	5	1	138
2	21	9	1	0
5	21	1	1	693787
5	21	2	1	2842
5	21	5	1	168
5	21	9	1	0

Save | Print | Close

Module 2 Questions?

Module 3: Generating Inventories at the County Scale

MOVES
Motor Vehicle Emission Simulator

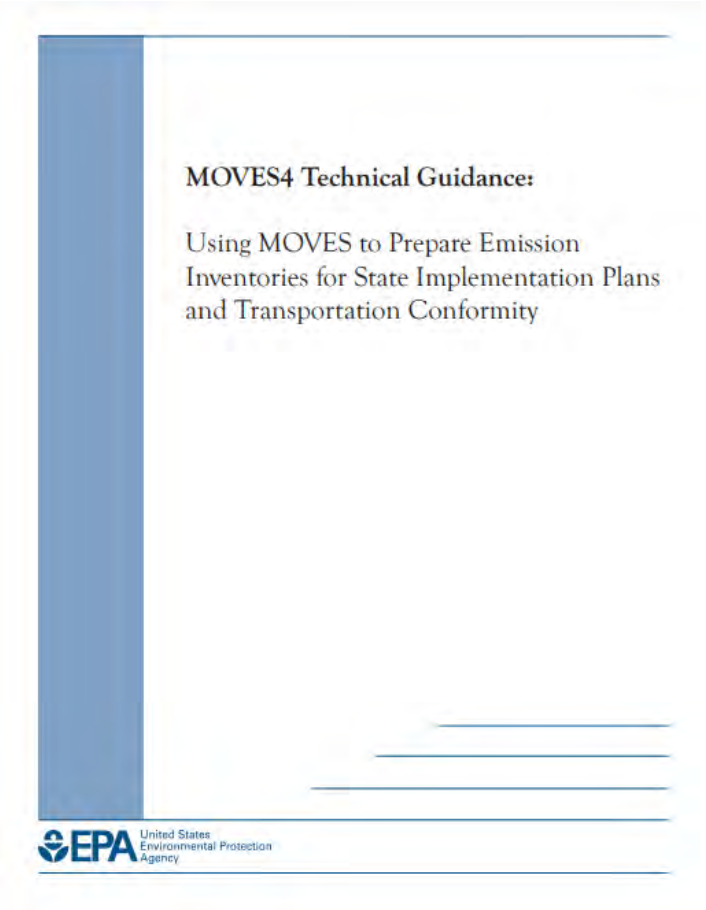
EPA

Module 3 Overview

- Overview of County Scale
- RunSpec guidance specific to County Scale runs for SIPs or transportation conformity analyses
- Introduction to the County Data Manager (CDM)
- Description and guidance for County Scale user inputs
- Exercise: Create a County Scale Input Database (CDB)
  - Purpose is to become familiar with County Scale inputs, rather than demonstrate a recommended inventory analysis

Module 3 Key References

- The MOVES Technical Guidance provides guidance on use of local inputs and defaults
- Some input guidance is presented in this course, but refer to Technical Guidance for more detail


MOVES4 Technical Guidance:

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

EPA United States Environmental Protection Agency

Summary: The Three Scales of MOVES (County)

	Default	County	Project

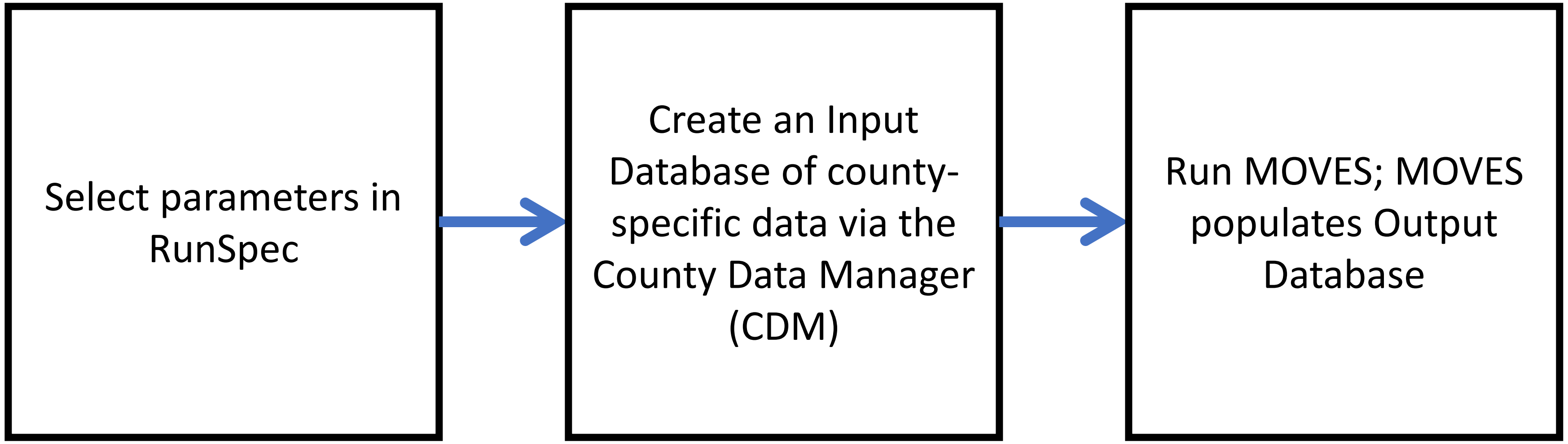
Geographic area covered	• Entire nation
	• One or more states
	• One or more counties
		• One county
		• A multi-county area
		  • modeled with a representative single county, or
		  • each modeled separately and summed
		• A partial county
			An individual transportation project (e.g., a highway, intersection, or transit project)

Purpose	Non-regulatory only	Required for SIP and regional conformity analyses	Required for project-level conformity analyses
Input database	User does not need to create; use of Data Importer is optional	User creates with local data, through the County Data Manager	User creates with local data, through the Project Data Manager
Default data	Used unless overridden	Access to default data is limited	Access to default data is limited

County Scale

- Can be used to model an individual county or a partial county
- Required for SIP and conformity analyses
- You must enter county-specific data, via the County Data Manager (CDM), for the input database
  - The CDM is used to either:
    - export MOVES default data, which you review (and potentially edit, then import), or
    - export templates, which you fill out with local data, then import
  - Use of local data are necessary for some inputs and recommended for most
    - However, there are some inputs where the default data is preferred (e.g., fuels)
    - Other inputs are optional (e.g., starts)

County Scale Process Review



County Scale RunSpec Guidance

Description Panel Guidance

- Saves a description the RunSpec (what is being modeled)
- Text entered here appears in the MOVESRun table of the output database
- Description is optional but useful to keep track of runs
- Best practice is to include a high-level overview of the run’s scenario
  - If performing multiple related runs, include whatever elements are unique about this particular run
  - May be helpful to also include details like location, time period, and pollutant types

Scale Panel Guidance

- Domain/Scale
  - County scale must be used for SIPs or transportation conformity analyses
  - NOTE: Default scale relies on national defaults and allocation factors that are not appropriate for regulatory purposes
- Calculation Type
  - Either Inventory or Emission Rates options may be used for SIPs or transportation conformity analyses
  - Both methods can give the equivalent results, but post-processing errors are more common when using Emission Rates
  - Use the same approach when comparing two or more cases:
    - Base year and attainment year
    - Budget and regional conformity analysis
  - Use interagency consultation process to agree upon a common approach or to minimize differences in results if different approaches are used

Time Spans Panel Guidance

- For all regulatory purposes
  - Select all hours
  - Select only one calendar year
- Consult with EPA and the MOVES Technical Guidance to determine the appropriate year, month(s), and type of day(s)

Geographic Bounds Panel Guidance

- At County Scale, you can only select one county
  - First select the appropriate state
  - Then select the county
    - The county's FIPS code is also displayed for reference
- Choosing a county accesses the available default data stored for that county

Onroad Vehicles Panel Guidance

- For most analyses, select all vehicle types
- MOVES will automatically add all valid gasoline, diesel, CNG, E-85 (flexible fuel), and electric vehicle combinations to the RunSpec
  - VMT is allocated to the various fuel types associated with each source type using the AVFT input table, discussed later in the data management section

Road Type Panel Guidance

- For SIP/conformity analyses, select all road types in RunSpec
  - VMT is allocated to each road type using the RoadTypeDistribution input table, discussed later in the data management section

Pollutants and Processes Panel Guidance

- Consult the MOVES Technical Guidance to determine the pollutants and processes that should be modeled
  - Varies by purpose of modeling (e.g.: What public health standard has been violated? What demonstration is being made?)
  - For SIP/conformity analyses, select all processes associated with a given pollutant
  - Extra pollutants/processes will increase run time
- Some pollutants and processes are “chained”, so click “Select Prerequisites” if the button is enabled

General Output Panel Guidance

- The only required input on this panel is the name of the output database
  - Best practice is to name output databases ending with "_out"
  - Manually create the database if it doesn't already exist
  - You can store the output of multiple RunSpecs in the same database
    - Different RunSpecs will be identified by different MOVESrunID numbers
    - Generally, there should be a reason to have multiple RunSpecs in the same output database (e.g., each run is a county in a nonattainment area and the results will later be summed)
- Activity output selections are optional
  - Selecting "Distance Traveled" and "Population" is recommended
  - Selecting any of the other options is entirely up to you

Output Emission Detail Panel Guidance

- The Output Aggregation of the Time level is up to you
  - Generally *Hour* or *24-Hour Day* are recommended
    - However, note that results must be properly weighted if emissions for longer timeframes are needed (see Module 2)
  - If you select *24-Hour Day*, detail at the hour level will be lost
- Keep *County* selected for the Geographic aggregation option because we are at County Scale
- The other options on this panel depend on the detail that you need
  - More selections means more detail
  - Differentiation by Source (vehicle) Type is likely most useful

Create Input Database Guidance

- This panel is used to specify your County Scale Input Database, also known as a CDB
- It is also the entry point for the County Database Manager (CDM)
- We will dive into this in a few slides

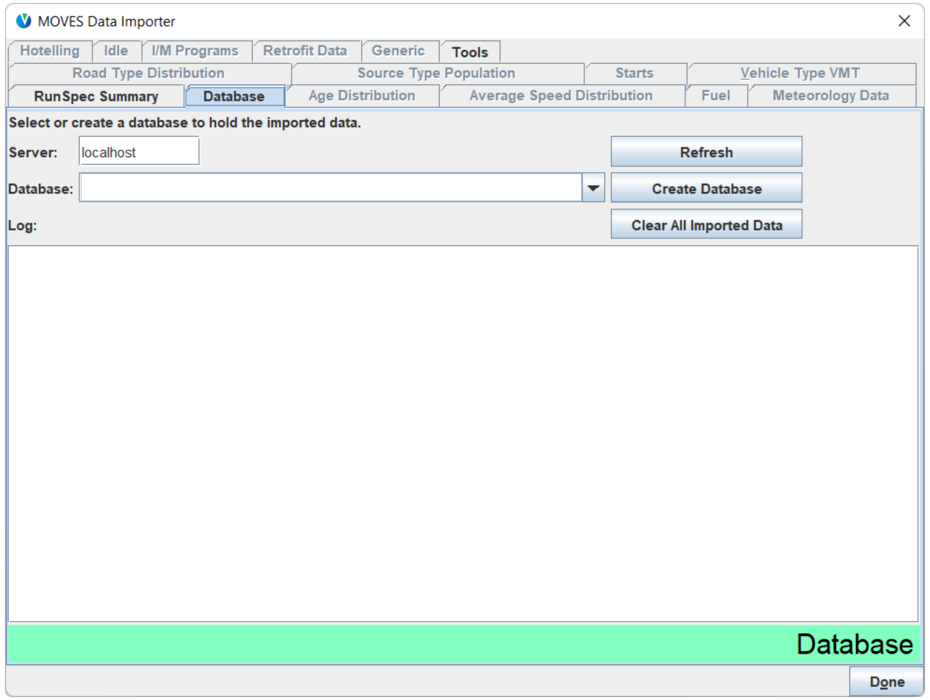
Advanced Features Panel Guidance

- This panel is only used if you need to specify a LEV or NLEV supplementary input database
  - These are created using the Build LEV or Build NLEV Input Database tool
- Note:
  - Time and Region Preaggregation are not acceptable for regulatory applications
  - The “Do Not Perform Final Aggregation” and “Do Not Perform Domain Database Validation” options are not acceptable for regulatory applications

Introduction to the County Data Manager

What is the County Data Manager?

- The County Data Manager (CDM) is a tool that facilitates the process of entering data into a county input database
  - The data in the input database is used by MOVES when executing the run
- CDM takes the form of a separate Graphical User Interface (GUI) that is used in conjunction with the MOVES Main GUI
  - When the CDM is open, the MOVES Main GUI is frozen and no changes can be made to the RunSpec
  - Nothing done in the CDM will affect the selections in the RunSpec



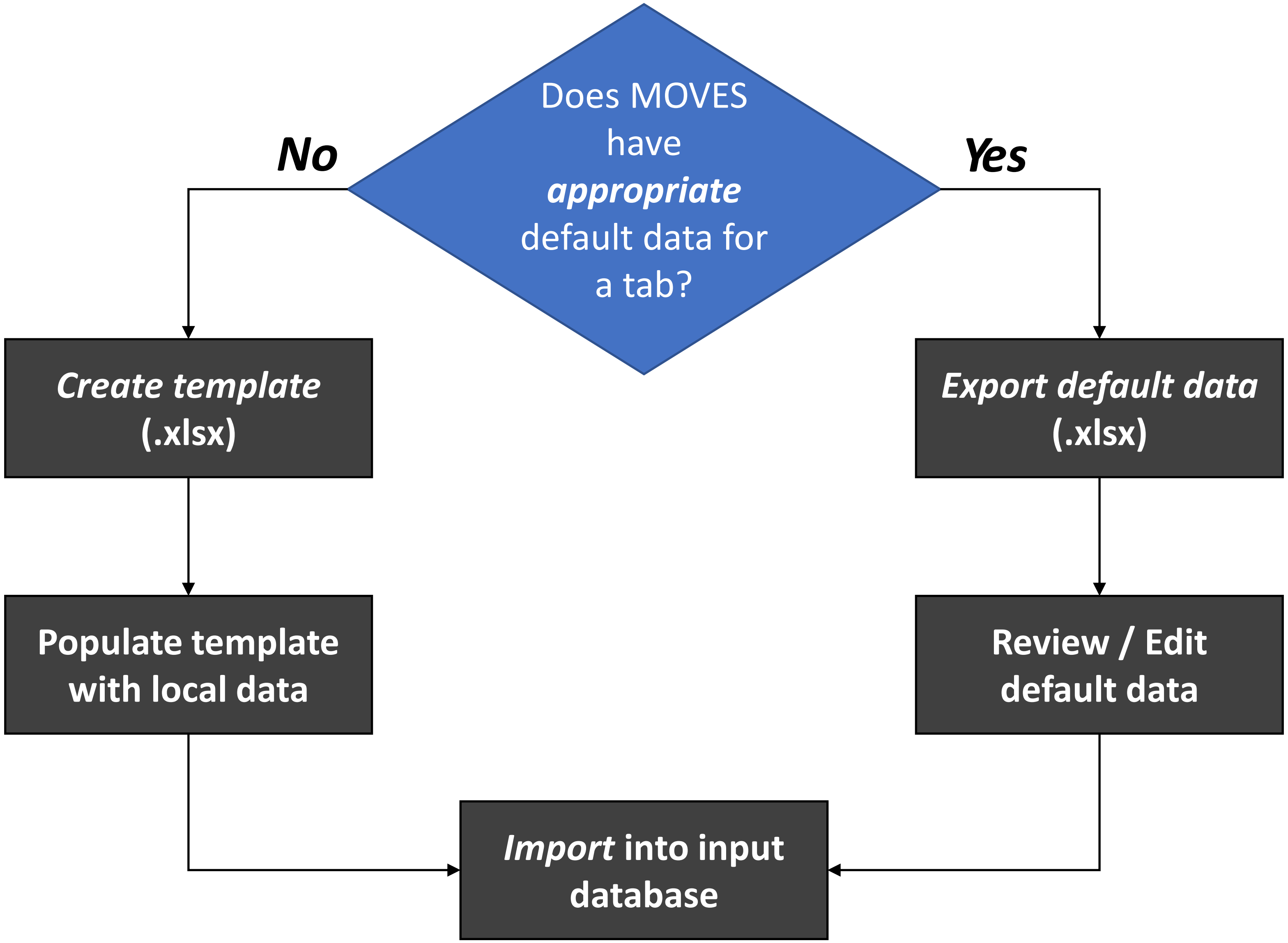
County Data Manager Functions

- Use the CDM to create an input database, one tab at a time, by either:
  - Creating a table template, in which you will enter local data, or
  - Exporting default data (when available) to a table in order to review and/or modify with local data
- Work with the resulting file in Excel, then "Import" worksheets into the CDM
  - Data are not entered directly in the CDM
  - You can add descriptions in the CDM of data being imported to document data sources
- Using the CDM ensures the input tables are properly formatted and error-free, necessary for MOVES to run properly
- Imported data can be cleared for each tab or the entire database can be emptied
  - You should always clear previously-imported data before importing new data for the same input to prevent execution errors

Using the CDM: A Tab for Each Input

- The ✓ and X symbols for each tab are determined by the relationship between the selections you made in the RunSpec and the data you provided
- The ✓ appears when you have provided data that is sufficient and passes error checks for all parameters in the RunSpec
  - Note that several tabs begin with a green check (these are optional inputs)
  - The X appears if you have not provided enough information or if there is an error with the data provided

Flowchart for Tabs with a X



Using the CDM: Creating a Template

- All tabs provide the option of creating a template spreadsheet of the appropriate MOVES table
  - Save with .xlsx extension to get a spreadsheet format
- Templates contain the proper fields/column headings, but have blank cells for user-specified data
- The template will be pre-populated with some data based on entries made in the RunSpec
- Templates contain extra worksheets that will help you decipher MOVES codes

Using the CDM: Exporting Default Data

- Some tabs have default data available:
  - Average Speed Distribution
  - Fuel (Fuel Supply, Fuel Formulation, Fuel Usage, AVFT)
  - Meteorology Data
  - Vehicle Type VMT (only Month, Day, and Hour VMT Fractions)
  - I/M Programs
  - Idle
  - Hotelling (only Hotelling Activity Distribution)
  - Starts (for certain starts tables)
  - Age Distribution
- Tabs with default data have a “Export Default Data” button in the lower left corner

What do the default data represent?

Default Data Available:	What that information represents:
Age Distribution Average Speed Distribution Idle Starts	National average
Fuel: Fuel Supply, Fuel Formulation	Area chosen in the RunSpec, based on EPA's fuel studies
Fuel: Fuel Usage, AVFT (fraction of vehicles using gas, diesel, electricity, CNG)	National average
Meteorology Data	Area chosen in the RunSpec
Vehicle Type VMT Vehicle (SourceType) Population	Area chosen in the RunSpec: MOVES starts with a national estimate and apportions some amount of it to the area
I/M Programs	Area chosen in the RunSpec: information may not be the latest
Hotelling (long-haul combination trucks only)	National rate applied based on rural and urban restricted access (highway) VMT by long-haul combination trucks

Using the CDM: Importing Data (1)

- Data must be imported back into the CDM from Excel for each tab with a red X (even when using default data for a tab)
- Imported data are read from an Excel worksheet that has been properly formatted with the correct columns
- General steps:
    1. Recommended: Add a description of the data you are about to import (e.g., the data source or file name)
    2. Browse to find the correct Excel file
    3. Select the appropriate worksheet (name should match the Data Source name)
    4. Click the “Import” button
- Tip: Some tabs require multiple worksheets to be imported. MOVES will notify you if it can import all tabs at once

Using the CDM: Importing Data (2)

- Check to see if you get an “Import Complete” message
- When the import is successfully completed the X will change to a ✓ on the County Data Manager tab
  - If message says “Import Complete” but the X remains, there was an error detected during import (e.g., there might be missing data)
  - For many tables, unused data can be imported (e.g., extra months, hours, source types, etc.) with no adverse impacts; however, data for additional counties and years should NOT be imported as this can cause errors when attempting to execute the RunSpec
- The description you entered will appear in the log, which can be viewed on the Database tab

A word about file management…

- As you complete an input database, you will be creating, modifying, and saving Excel files, and then importing them
- Being organized will make this process easier
- EPA recommends creating a folder for your MOVES work, e.g., on your desktop
  - Within that folder, create a new folder for each separate analysis, where you can save the RunSpec and Excel files for that analysis
  - See how we organized the course files for this class as an example

County Scale Data Manager Guidance with a Hands-on Exercise

MOVES
Motor Vehicle Emission Simulator

Module 3 Exercise Files

- The zip file of course materials contains a folder called Module 3 - County Scale Exercise
  - This folder contains input data that we will use throughout the exercise, as well as an almost-complete RunSpec for you to use
- If you have not done so, unzip the course materials to a convenient location, such as your desktop
- If you get lost or have technical difficulties, the course files for this module contain an *Answer Key* folder, where you can find the completed RunSpec and resulting output database

County Data Manager Guidance Overview

- We will go through each data input (MOVES table) that can be accessed through the tabs in the CDM
- We will look at the fields in each input table and go over EPA's MOVES Technical Guidance for that input
- After discussing each input, we will enter the appropriate data for our County Scale inventory exercise
- This exercise will include exporting defaults and creating templates. Keep all Excel files for this exercise organized together in an analysis folder. For example, you can use the Module 3 - County Scale Exercise folder

Summary of Data Inputs (1)

- Source Type Population
  - Number (i.e., population) of local vehicles operating in the area
  - No defaults available in CDM
  - MOVES table: SourceTypeYear
- Vehicle Type VMT
  - Annual <u>or</u> daily VMT, by HPMS vehicle type <u>or</u> MOVES source type
    - No defaults available for annual or daily VMT
    - MOVES tables: HPMSVTypeYear <u>or</u> HPMSVTypeDay <u>or</u> SourceTypeDayVMT <u>or</u> SourceTypeYearVMT
  - VMT distributions by month, day, and hour
    - National defaults available for these distributions if needed
    - MOVES tables: MonthVMTFraction, DayVMTFraction, HourVMTFraction

The AADVMT Converter Tool, available on the MOVES website, can help prepare the VMT input

Summary of Data Inputs (2)

- Meteorology Data tab
  - Temperature and humidity inputs
  - County-level defaults available in CDM
  - MOVES table: ZoneMonthHour
- Average Speed Distribution
  - Speed distributions by road type, hour and source (vehicle) type
  - National defaults available in CDM
  - MOVES table: AvgSpeedDistribution
- Road Type Distribution
  - Fraction of source type VMT on different road types
  - No defaults available in CDM
  - MOVES table: RoadTypeDistribution

Summary of Data Inputs (3)

- Age Distribution
  - Fleet age fractions by source type
  - National defaults available in CDM
  - MOVES table: SourceTypeAgeDistribution
- Fuel
  - Market share and composition of fuel blends
    - County-level defaults available in CDM for these
  - Flexible fuel vehicle fuel usage and fuel type distributions
    - National defaults available in CDM for these
  - MOVES tables: FuelSupply, FuelFormulation, FuelUsage, and AVFT

The Age Distribution Projection Tool, available on the MOVES website, can help prepare future age distributions

The AVFT Tool, available on the Fuel tab of the CDM as well as in the MOVES Tools dropdown menu, can help prepare the AVFT table

Summary of Data Inputs (4)

- I/M Programs
  - Data on I/M program(s), if any
  - County-level defaults available in CDM
  - MOVES table: IMCoverage
- Starts
  - Information on vehicle starts
  - Optional input; default start activity is determined by vehicle population
  - Some national default data are available in CDM
  - MOVES table: Starts (and others)

Summary of Data Inputs (5)

- Hotelling
  - Information on hours and type of hotelling activity
  - Optional input; default hotelling activity is determined by local road type distribution and long-haul combination truck VMT
  - Default national distribution of hoteling activity types available in CDM
  - MOVES tables: HotellingActivityDistribution, HotellingHours, and others

Summary of Data Inputs (6)

- Idle
  - Allows you to provide information on Total Idle Fraction
  - This information is used to calculate “off-network idle” (e.g., idling not associated with a drive cycle – idling outside grocery store, or school)
  - Optional input
  - Regional defaults available in CDM
  - MOVES tables: TotalIdleFraction and others

- Retrofit Data
  - Defines retrofit programs
  - Optional input
  - No defaults available in CDM
  - MOVES table: OnRoadRetrofit

County Scale Hands-on Exercise

- Purpose:
  - Provide hands-on practice using the CDM
  - Will create templates, review default data, use tools, and import data for a County Scale emissions inventory run
  - Explain guidance for using MOVES at the County Scale for official purposes
- NOTE: This exercise scenario is intentionally simplified to facilitate learning, limit complexity, and reduce MOVES run time. Therefore, it should NOT be used as an example of an official County Scale run using MOVES
  - A RunSpec constructed to calculate an inventory for a SIP or conformity analysis would have to completely address all variables as described in EPA guidance

County Scale Exercise Overview

- The County Scale exercise scenario is identical to the Default Scale scenario from Module 2:
  - Modeling NOx emissions from passenger cars in Washtenaw County on a weekday and weekend day during the summer of 2023
- Since building the RunSpec is very similar between Default and County Scale, we will save time by simply loading a preconfigured County Scale RunSpec
  - This RunSpec is identical to the RunSpec we built in Module 2, except it has County Scale selected on the Scale Panel

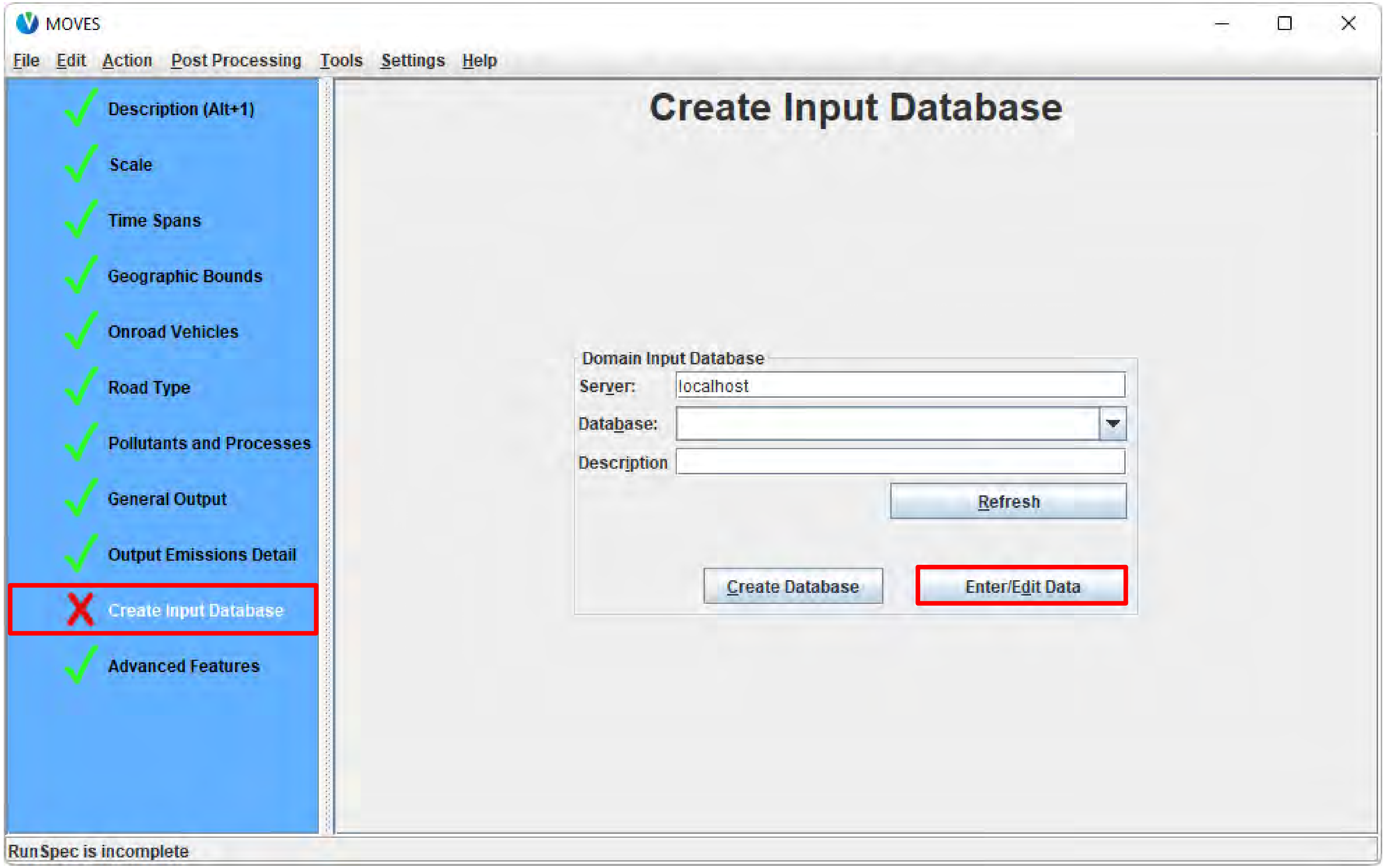
Loading the County Scale RunSpec

- Instructions for Loading the County Scale RunSpec:
  - If you’ve closed MOVES, open it by double-clicking the “MOVES4” icon
  - Once MOVES is open, select the File menu and click Open…
    - Click No when prompted to save the existing RunSpec
    - Navigate to your course files, and select *washtenaw_2023_training_county.mrs* in the Module 3 - County Scale Exercise folder
    - Click Open
  - Note that since we have not created the input database yet, the Create Input Database Panel has a red X

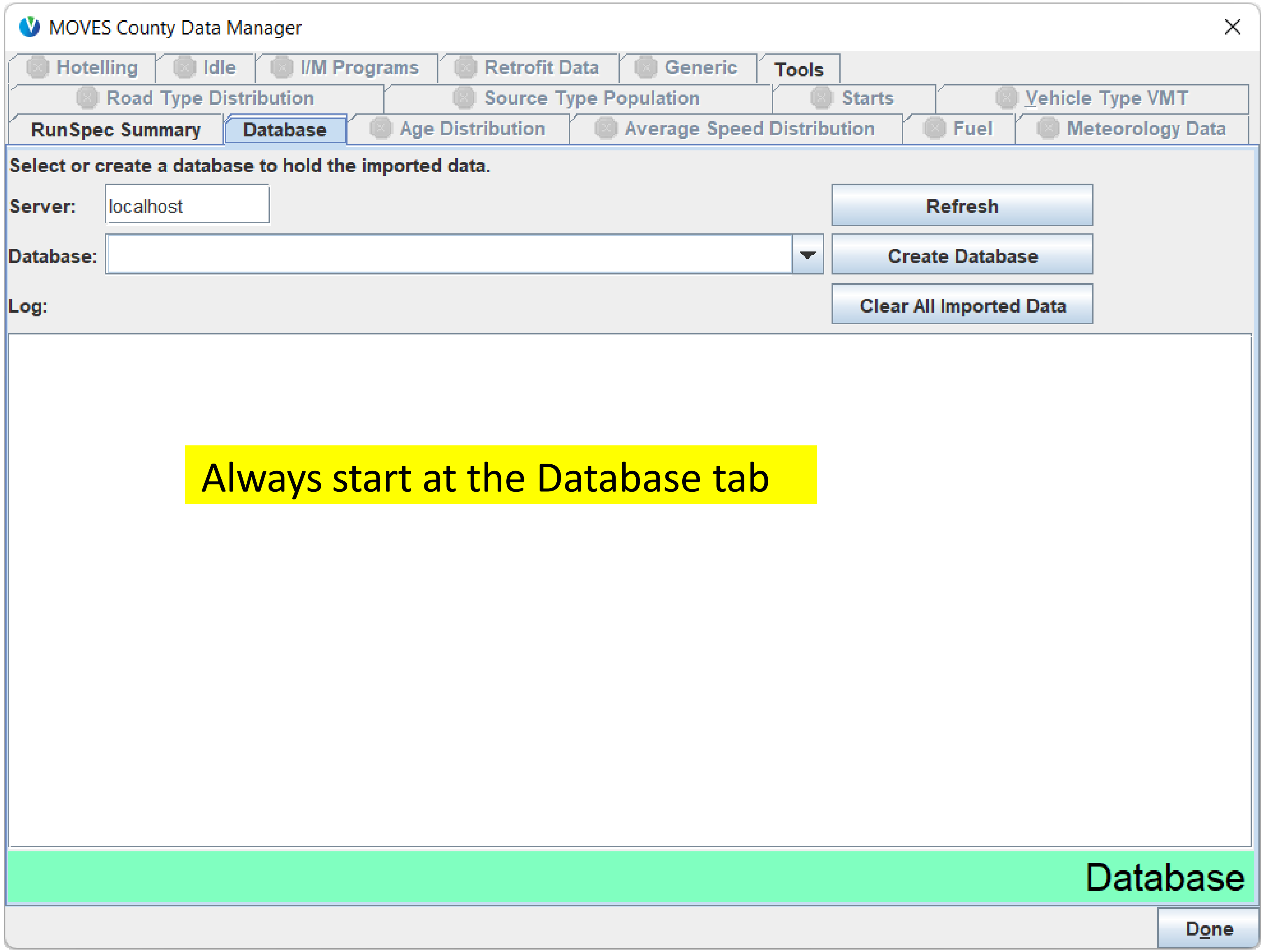
Open the County Data Manager

- To open the CDM:
  - Navigate to the Create Input Database Panel
    - Note: this panel is only available once all other panels have green checks
  - Click "Enter/Edit Data" button on Create Input Database panel
- Note: The "Create Database" button creates the input database schema (all the tables, but without any of your local data)
  - You can use this button either within the CDM, or directly on the Create Input Database Panel. Either way works the same. In this example, we will do it within the CDM

Open the CDM from Create Input Database



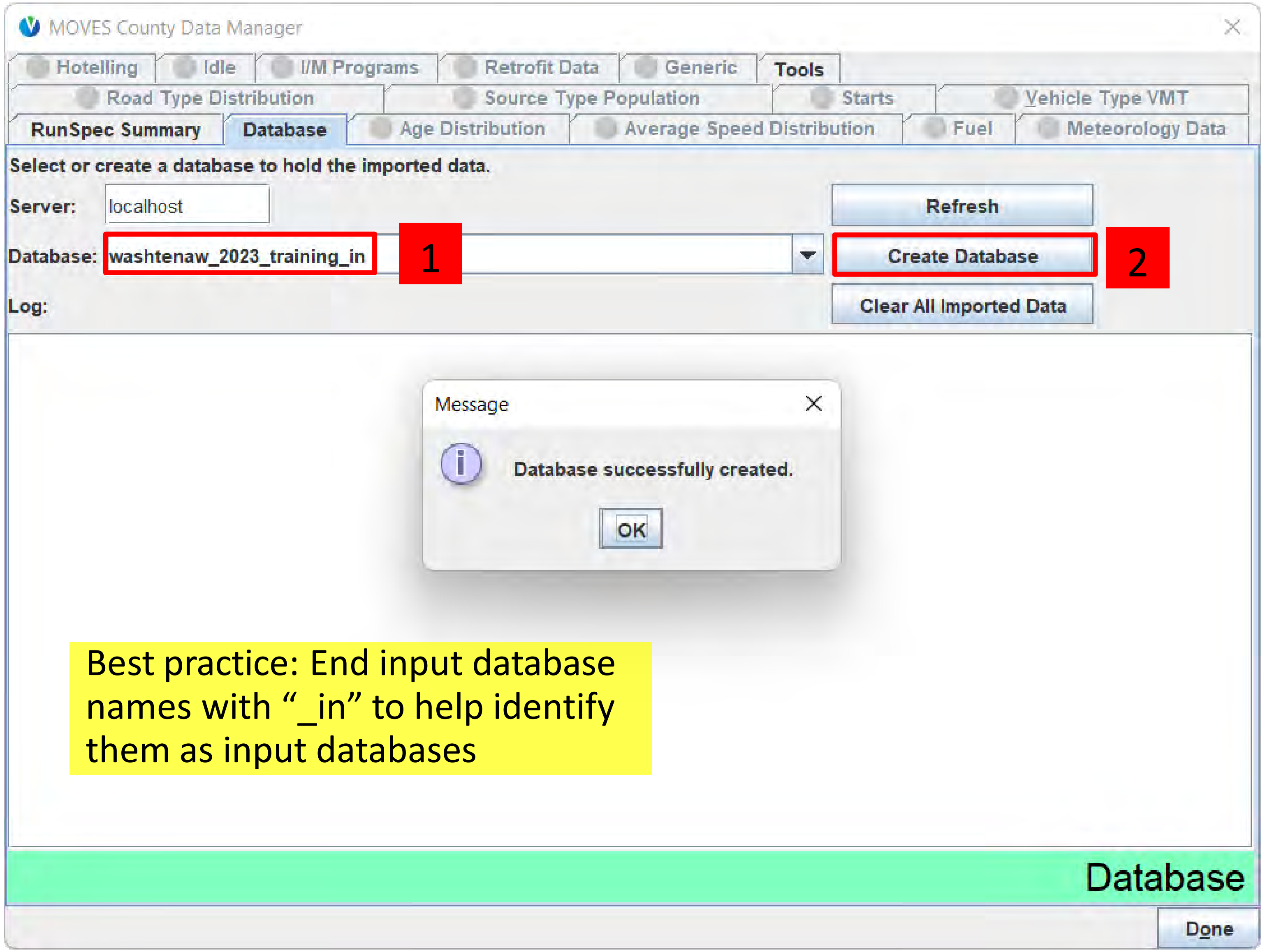
A Newly Opened CDM



Using the CDM: Database Tab

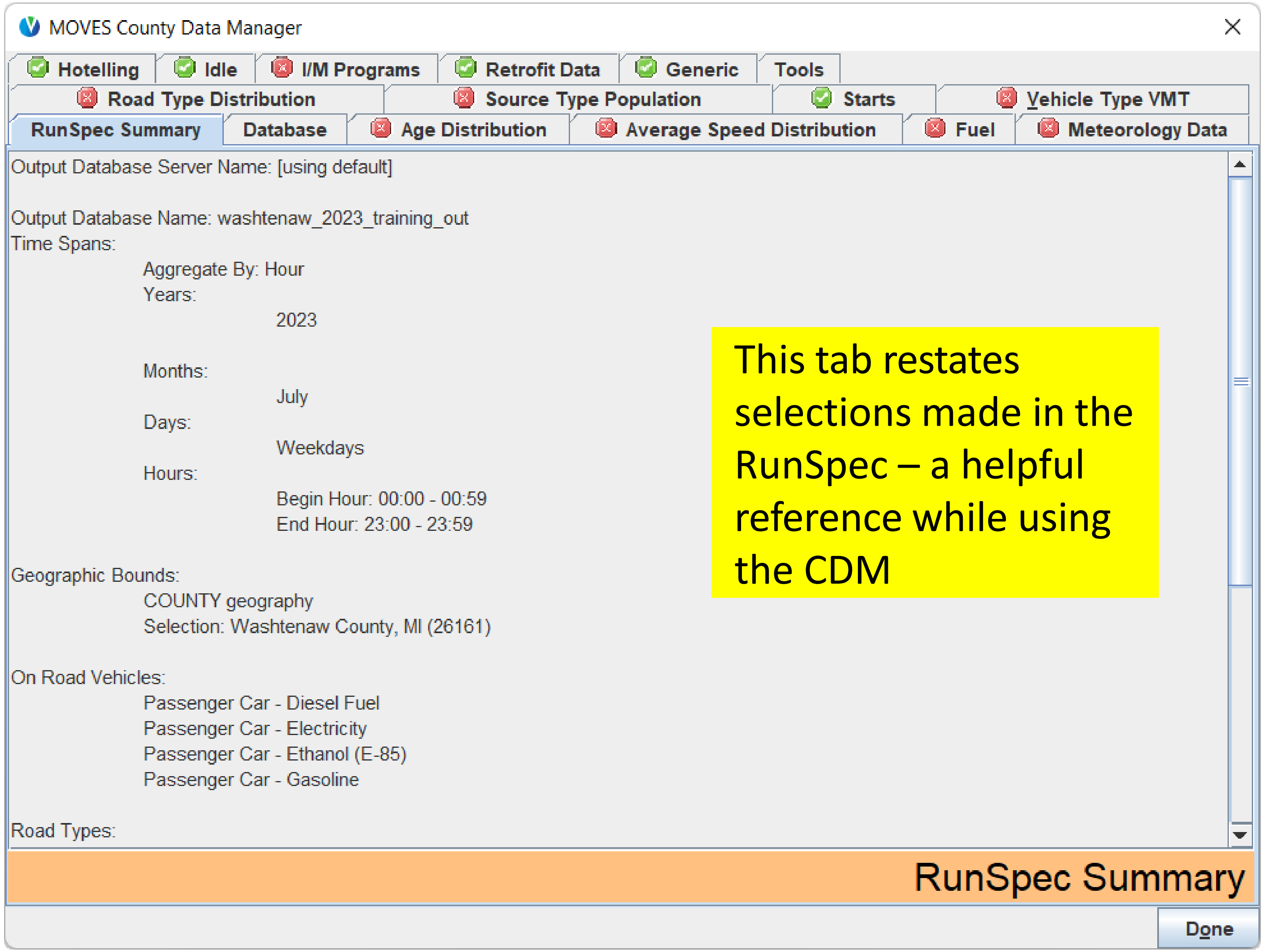
- Use this tab to create or select your county input database
- Existing county input databases can be selected from the dropdown menu
- Once a county input database has been created or selected, the tables within it can be edited with the other CDM tabs
  - All the tables in the database can be cleared of data with the “Clear All Imported Data” button
- The tab also displays a log of changes

Creating a New Input Database



Best practice: End input database names with "_in" to help identify them as input databases

Using the CDM: RunSpec Summary Tab



This tab restates selections made in the RunSpec – a helpful reference while using the CDM

Source Type Population Tab

Source Type Population

- The Source Type Population tab has one table to populate: *SourceTypeYear*
- This table needs the number of vehicles of each “source type” (vehicle type) in the county being modeled
- MOVES uses vehicle population when estimating start and evaporative emissions
- There is no default data for this input, so you need to create a template and fill it out

Source Type Population: Template

- Creating a template for Source Type Population gives you a template for the *SourceTypeYear* table:
  - This template has one row for each source type in the RunSpec
  - YearID is automatically filled out for you based on the year selected in the RunSpec
  - The population for each source type is entered in the SourceTypePopulation column

yearID	sourceTypeID	sourceTypePopulation
2023	11	
2023	21	
2023	31	
2023	32	

sourceTypeYear SourceUseType

- Use the SourceUseType tab in the template file (or use the cheat sheet) to decode the sourceTypeID field

Source Type Population: Guidance (1)

- Section 4.3 of MOVES Technical Guidance
- Historic local population data are recommended
  - Based on vehicle registration data or I/M data, for instance
- Vehicle population growth must be handled outside the model since MOVES only runs one year at County Scale
  - Vehicle population for future years can be scaled in proportion to expected VMT or human population growth

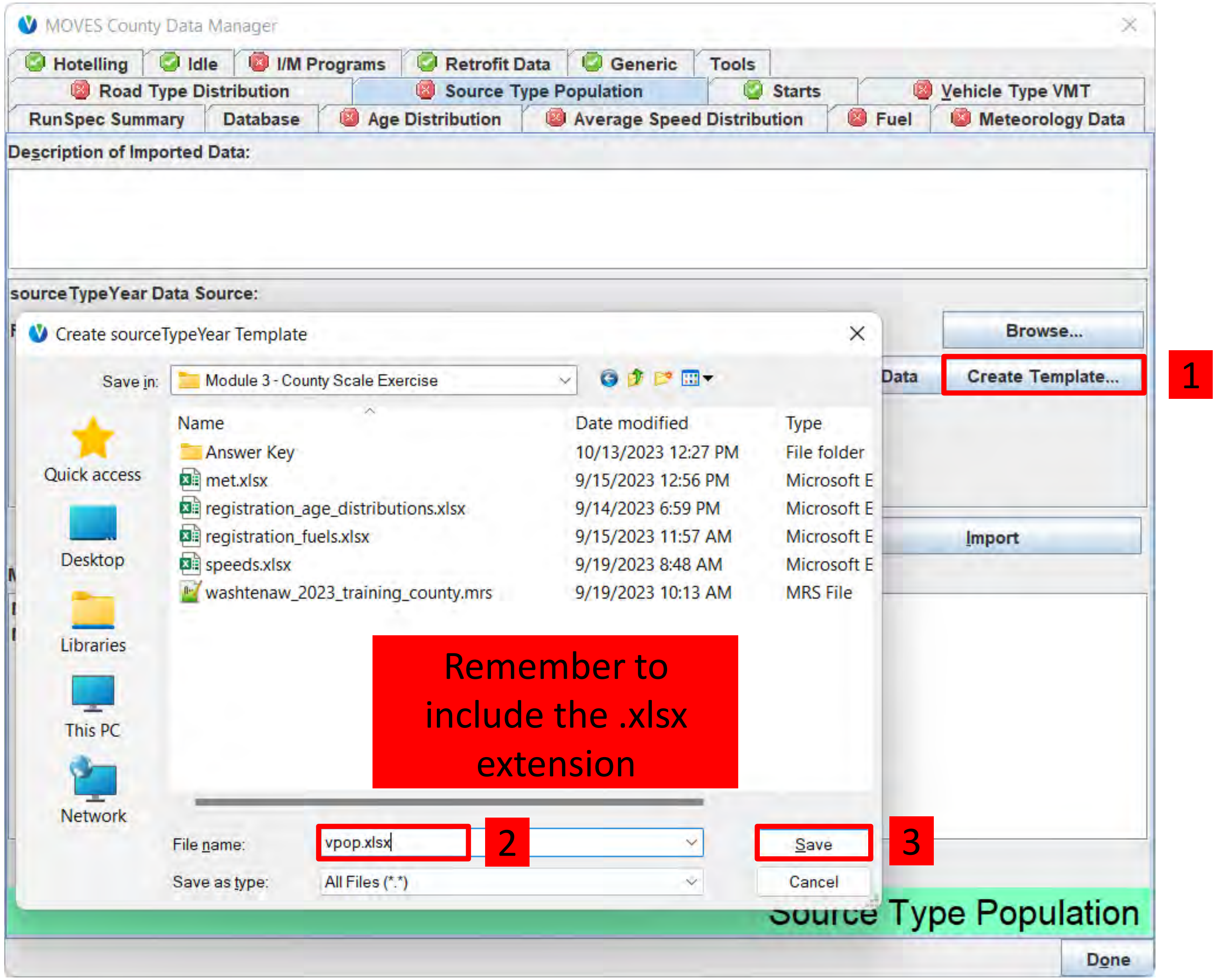
Source Type Population: Guidance (2)

- Only local vehicles need to be included in population
  - Local vehicles are those that have a significant portion of their starts and parked hours in the county
  - Vehicles that only pass through the county (do not park or start) do not have to be included in population, but their VMT must be included in the Vehicle Type VMT tab
- Sources of population data
  - Use local registration data for motorcycles, passenger cars, and light trucks
  - Use data from transit agencies, school districts, and refuse haulers for buses and refuse trucks
  - If information is not available for other vehicle classes, their local population can be estimated by using the ratio of MOVES national default population to MOVES national default VMT and then applying that same ratio to local VMT

Source Type Population: Exercise

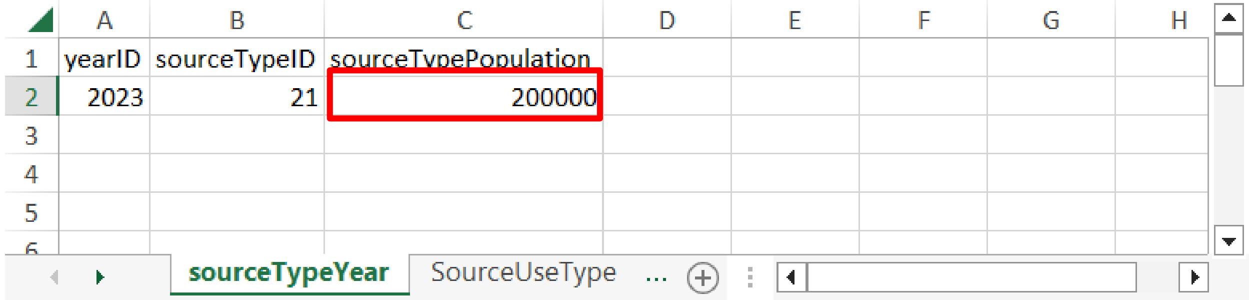
- Let’s enter source type population data into the CDM for our County Scale exercise
- We have passenger car populations from local registration data:
  - 200,000 passenger cars
- Instructions for importing road type distribution into the CDM:
  1. Create a template from the Source Type Population tab
  2. Enter and save our local population data in Excel
  3. Browse for the data file in the CDM
  4. Select the correct worksheet
  5. Import the worksheet into the CDM
  6. Check for errors

Create Source Type Population Template



Fill out Source Type Population Template

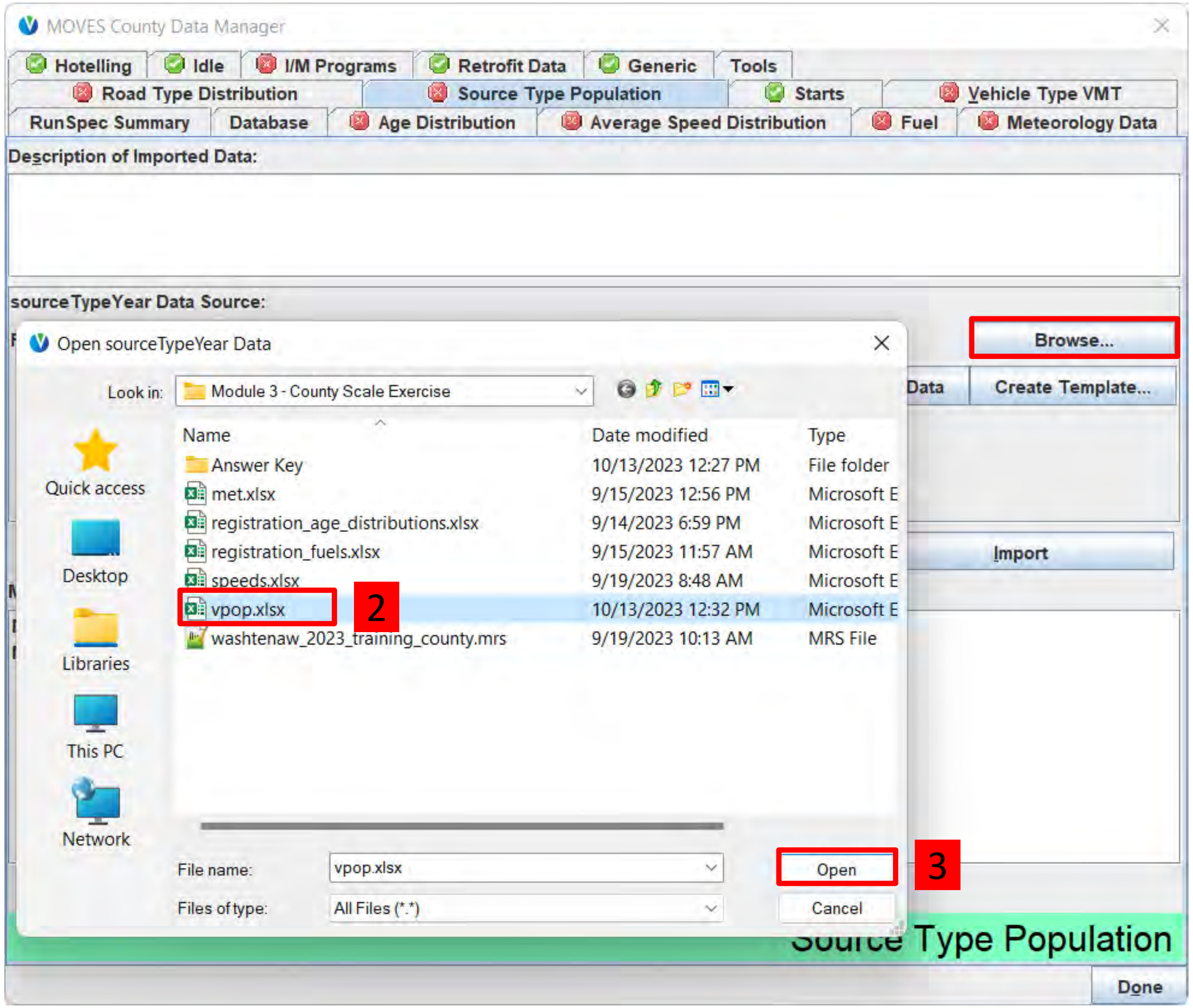
- In Windows Explorer, find the template you just created and open it
- Enter a vehicle population of 200,000 as the “sourceTypePopulation” next to the sourceTypeID 21 to indicate how many passenger cars are in this scenario



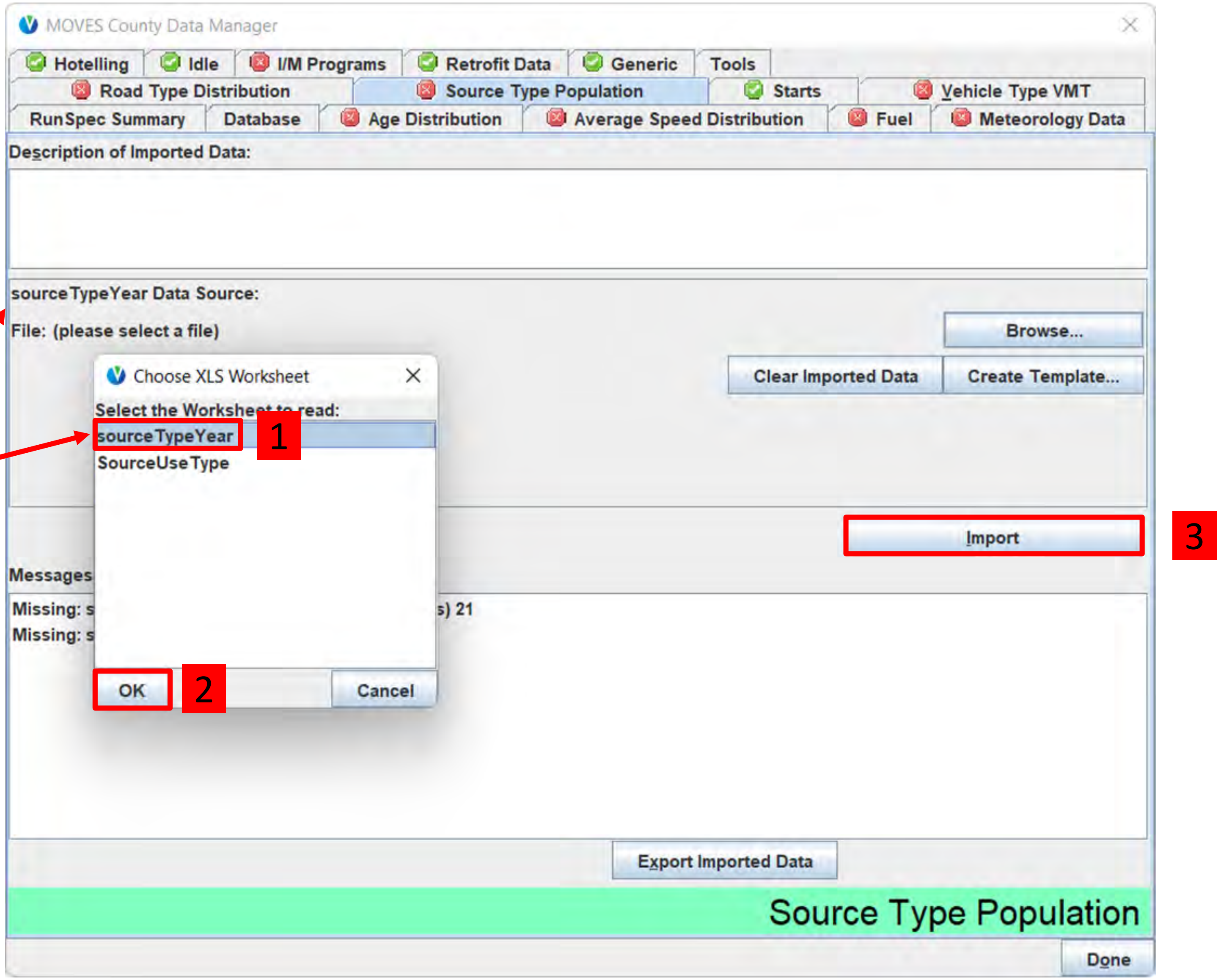
yearID	sourceTypeID	sourceTypePopulation
2023	21	200000

- Save and close when done

Import the Source Type Population (1)

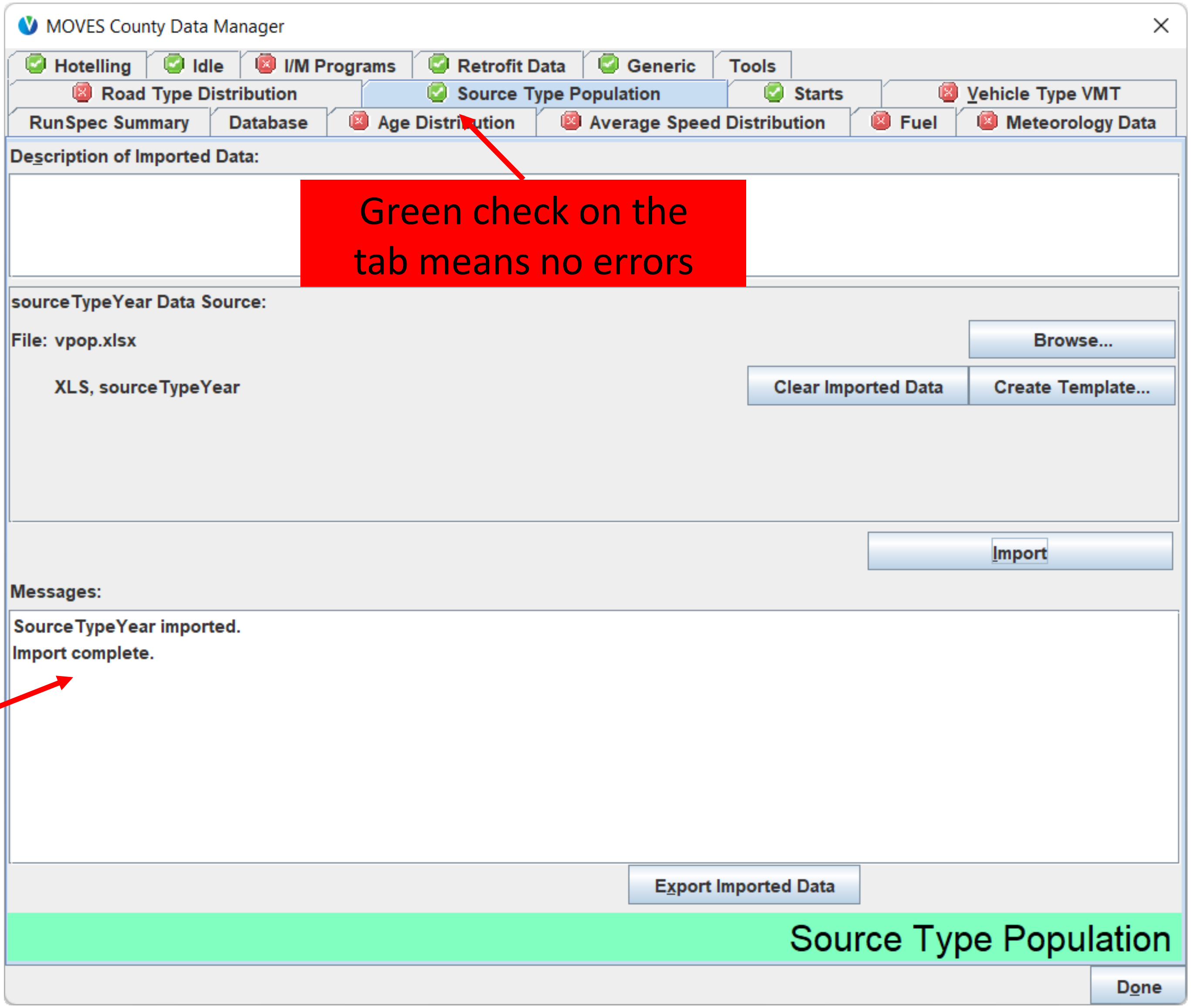


Import the Source Type Population (2)



Match the worksheet name to the Data Source name

Check for Source Type Population Errors



Any errors will appear in the messages list

Vehicle Type VMT Tab

Vehicle Type VMT

- MOVES uses VMT to calculate emissions for all running and refueling processes
- VMT input is also used to allocate emissions by month, day type (weekday or weekend), and hour
- MOVES allows VMT to be entered in different forms:
  - VMT by HPMS class or VMT by MOVES source type
  - Annual VMT or daily VMT

Vehicle Type VMT: HPMS Class or Source Type

- HPMS class
  - Enter VMT by the 5 HPMS classes
    - The most common form for local data
    - Relies on default data in MOVES to allocate VMT from HPMS class to source type
- MOVES Source Type
  - Enter VMT by the 13 MOVES source types
    - Allows more control over how VMT is allocated, e.g., between passenger cars and light trucks
    - Requires more pre-processing if raw data are by HPMS class

Source Types and HPMS Classes

Source Type ID	MOVES Source Types	Vehicle Type ID	HPMS 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		

Vehicle Type VMT: Annual or Daily

- Annual VMT
  - MOVES can accept annual VMT, along with VMT fractions by month, day type, and hour
  - Entering annual VMT and the correct month and daily VMT fractions for the entire year allows the same files to be used to model any month or day
  - Best choice if you want to model multiple months and day types in a single run
- Daily VMT
  - MOVES can accept daily VMT along with VMT fractions by hour
  - MOVES applies same VMT to each month if running multiple months
  - MOVES applies same VMT to weekdays and weekend days if running both day types, however, you can enter different hourly fractions for weekdays and weekend days
- No defaults available for either Annual or Daily VMT

Vehicle Type VMT: Allocation Fractions

- Month VMT Fractions:
  - Fraction of annual VMT occuring per month. Required input for Annual VMT input only
- Day VMT Fractions:
  - Fraction of monthly VMT occuring on each day type (weekday or weekend). Required input for Annual VMT input only
- Hour VMT Fractions:
  - Fraction of daily VMT occuring per hour. Required input for both Annual and Daily VMT inputs
- Notes:
  - Even when VMT is entered based on HPMS vehicle class, temporal allocation factors always vary by MOVES source types (e.g., month VMT fractions by source type)
  - Defaults are available for each of this allocation fractions

Vehicle Type VMT: Month VMT Fraction

- MonthVMTFraction must sum to 1 within each source type over a 12-month period

This shows example default data available for MonthVMTFraction

sourceTypeID	monthID	monthVMTFraction
21	1	0.0730856
21	2	0.0697126
21	3	0.0817315
21	4	0.0823022
21	5	0.0875028
21	6	0.0882716
21	7	0.0923251
21	8	0.0934297
21	9	0.0846806
21	10	0.086516
21	11	0.0802282
21	12	0.0802141

MonthVMTFraction

Vehicle Type VMT: Day VMT Fraction

- DayVMTFraction must sum to 1 within each source type, month, and road type combination
- DayVMTFraction is the fraction of VMT occurring on each day, by road type and day type, throughout a month

This shows example default data available for DayVMTFraction

	A	B	C	D	E	F
1	sourceTypeID	monthID	roadTypeID	dayID	dayVMTFraction	
2	21	7	2	2	0.27882	
3	21	7	2	5	0.72118	
4	21	7	3	2	0.27882	
5	21	7	3	5	0.72118	
6	21	7	4	2	0.237635	
7	21	7	4	5	0.762365	
8	21	7	5	2	0.237635	
9	21	7	5	5	0.762365	
10						

DayVMTFraction

Vehicle Type VMT: Hour VMT Fraction

- HourVMTFraction must sum to 1 within each source type, road type, type of day combination
- HourVMTFraction is applied to all months
  - If data varies for different months, you must use different RunSpecs for each

This shows example default data available for HourVMTFraction

sourceTypeID	roadTypeID	dayID	hourID	hourVMTFraction
21	2	2	1	0.0164213
21	2	2	2	0.0111921
21	2	2	3	0.0085415
21	2	2	4	0.00679328
21	2	2	5	0.00721894
21	2	2	6	0.0107619
21	2	2	7	0.01768
21	2	2	8	0.0268751
21	2	2	9	0.0386587

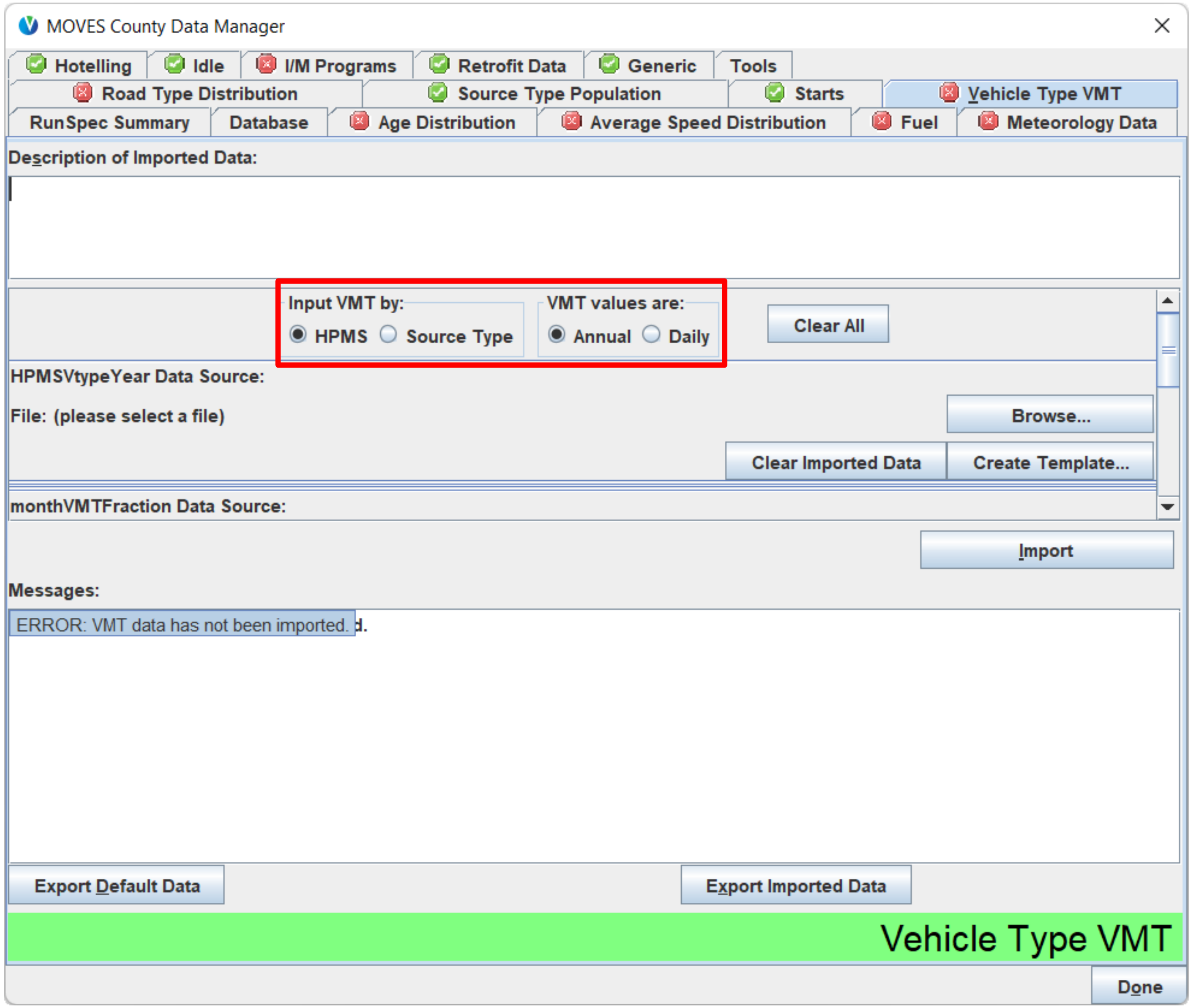
HourVMTFraction

VMT Input Tables Summary

- This table shows which tables are used based on the choice of:
  - Daily VMT or Annual VMT
  - HPMS or Source Type

	HPMS	Source Type	What will you need to import into MOVES?
Annual VMT	HPMSVtypeYear monthVMTFraction dayVMTFraction hourVMTFraction	sourceTypeYearVMT monthVMTFraction dayVMTFraction hourVMTFraction	1 VMT table 3 allocation fraction tables required with Annual VMT
Daily VMT	HPMSVtypeDay hourVMTFraction	sourceTypeDayVMT hourVMTFraction	1 VMT table 1 allocation fraction table required with Daily VMT

Entering Vehicle Type VMT Data



VMT and temporal fractions are all imported on this tab.

Before doing anything else on this tab, use the radio buttons to select:

- HPMS or Source Type
- Annual or Daily

Vehicle Type VMT: Templates

- When you create a template on this tab, MOVES will prompt you for a file name for the template, and then ask you if you want to create templates for all tables on this tab
  - If you plan to use default data for the month/day/hour allocation fractions, answer “No” because you only need one template for the VMT table and no other templates
  - If you plan to use local data for one or more of the allocation fractions, answer “Yes” to make templates for all tables at once

Vehicle Type VMT: HPMS Templates

- HPMSVtypeYear:
  - Has one row for each HPMS vehicle type (HPMSVtypeID) based on the source types selected in the RunSpec
  - You enter VMT values in the HPMSBaseYearVMT column

HPMSVtypeID	yearID	HPMSBaseYearVMT
10	2023	
25	2023	
40	2023	
50	2023	
60	2023	

- HPMSVtypeDay:
  - Has rows for each combination of HPMS vehicle type, month, and day type selected in the RunSpec
  - You enter VMT values in the VMT column

HPMSVtypeID	yearID	monthID	dayID	VMT
10	2023	7	2	
10	2023	7	5	
25	2023	7	2	
25	2023	7	5	
40	2023	7	2	
40	2023	7	5	
50	2023	7	2	
50	2023	7	5	
60	2023	7	2	
60	2023	7	5	

HPMS ...

HPMSVtypeDa ...

Vehicle Type VMT: Source Type Templates

	A	B	C
1	sourceTypeID	yearID	VMT
2	11	2023	
3	21	2023	
4	31	2023	
5	32	2023	
6	41	2023	
7	42	2023	
8	43	2023	
9	51	2023	
10	52	2023	

	A	B	C	D	E
1	sourceTypeID	yearID	monthID	dayID	VMT
2	11	2023	7	2	
3	11	2023	7	5	
4	21	2023	7	2	
5	21	2023	7	5	
6	31	2023	7	2	
7	31	2023	7	5	
8	32	2023	7	2	
9	32	2023	7	5	
10	41	2023	7	2	
11	41	2023	7	5	
12	42	2023	7	2	

SourceTy| ...

- SourceTypeYearVMT:
  - Has one row for each source type selected in the RunSpec
  - You enter VMT in the VMT column
- SourceTypeDayVMT:
  - Has rows for each combination of source type, month, and day type selected in the RunSpec
  - You enter VMT in the VMT column

Vehicle Type VMT: Allocation Templates

- MonthVMTFraction:
  - One row for each source type and month combination in the RunSpec
- DayVMTFraction:
  - One row for each source type, month, road type, and day type combination in the RunSpec
    - RoadTypeID 1 is not relevant, but must be included to get a green check. You can provide the same values for this road type as any other road type
- HourVMTFraction:
  - One row for each source type, road type, day type, and hour combination in the RunSpec
    - RoadTypeID 1 is not relevant, but must be included to get a green check. You can provide the same values for this road type as any other road type

monthVMTFraction

	A	B	C
1	sourceTypeID	monthID	monthVMTFraction
2	11	7	
3	21	7	
4	31	7	
5	32	7	

dayVMTFraction

	A	B	C	D	E
1	sourceTypeID	monthID	roadTypeID	dayID	dayVMTFraction
2	21	7	1	2	
3	21	7	1	5	
4	21	7	2	2	
5	21	7	2	5	

hourVMTFraction

	A	B	C	D	E
1	sourceTypeID	roadTypeID	dayID	hourID	hourVMTFraction
2	21	1	2	1	
3	21	1	2	2	
4	21	1	2	3	
5	21	1	2	4	

Vehicle Type VMT: Guidance (1)

- Section 4.5 of MOVES Technical Guidance
- Local VMT data are necessary
- Can enter by HPMS Class or by Source Type
  - Use HPMS Class if you don’t have enough detail to disaggregate to Source Type
  - Use Source Type if you have that data and want more control over how MOVES allocates VMT

Vehicle Type VMT: Guidance (2)

- Can use either Annual or Daily VMT
- Use Annual if you want to model multiple months and day types with different VMT fractions in a single run
  - Local VMT, month, day, and hour fractions should be used if available; otherwise, defaults are acceptable
  - Entering annual VMT and the correct month and daily VMT fractions for the entire year allows the same files to be used to model any month or day
  - Use EPA's AADVMT Converter Tool to convert local Daily VMT to Annual VMT if necessary (must have VMT by HPMS class to use the tool)
- Use Daily if that is the form your VMT is in and the VMT is appropriate for the month and day type you are modeling

Vehicle Type VMT: Guidance (3)

- Recommend using the same approach (HPMS or source type, annual or daily VMT) for any analysis that compares two or more cases
  - Avoid causing differences in results due to differences in the way VMT is allocated
  - Use interagency consultation process to agree on a common approach or to minimize differences caused by different approaches

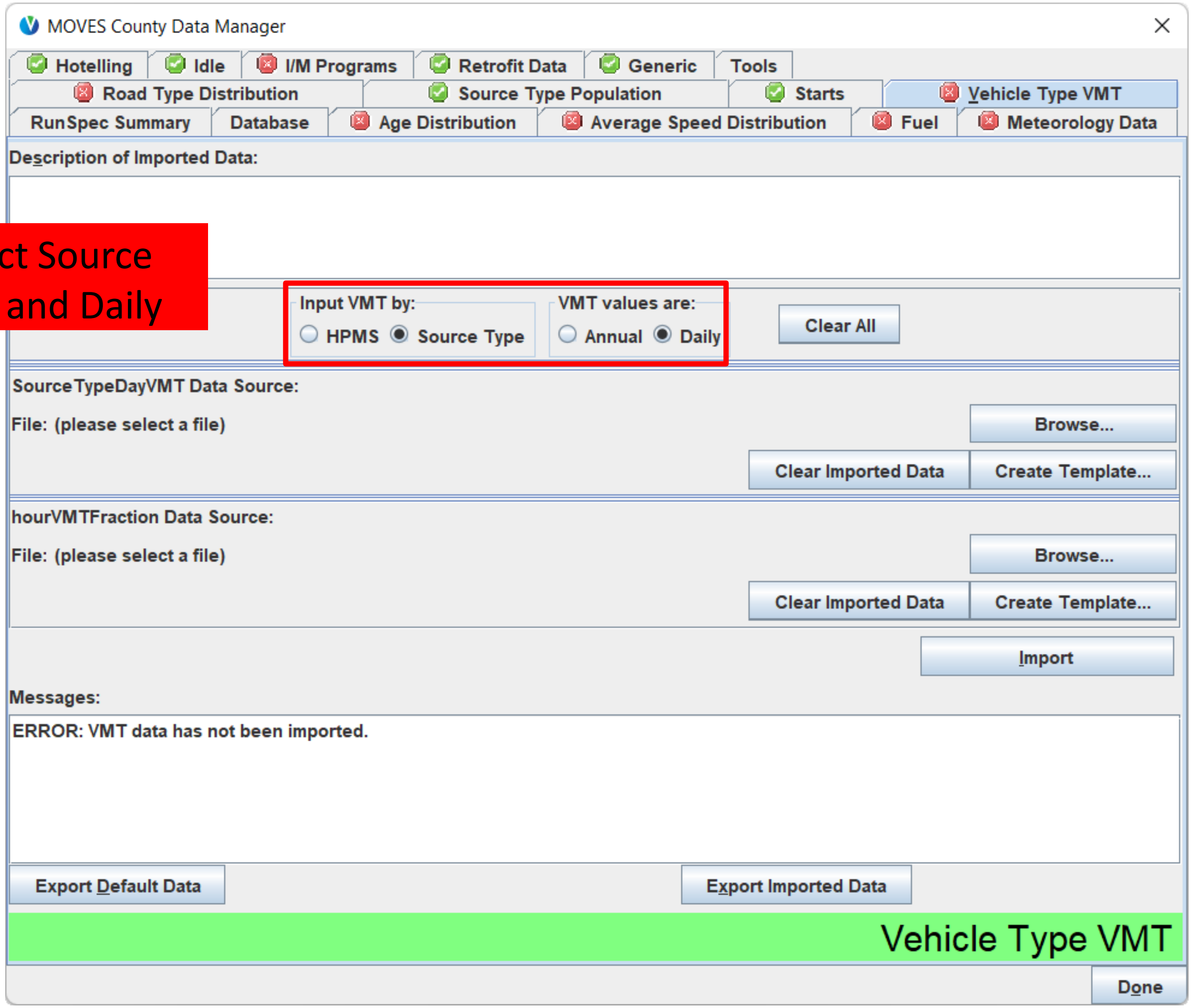
Vehicle Type VMT: Exercise Overview

- We know daily VMT for July weekdays and weekend days in Washtenaw County and will enter VMT by source type for each day type:
  - Passenger cars (sourceTypeID 21)
  - Weekday (dayID 5) = 5,000,000
  - Weekend day (dayID 2) = 4,000,000
- We will create a template <u>and</u> export defaults on this tab:
  - We will create a template to import the daily VMT
  - We will use the default hourly VMT distribution for this example

Vehicle Type VMT: Exercise Instructions

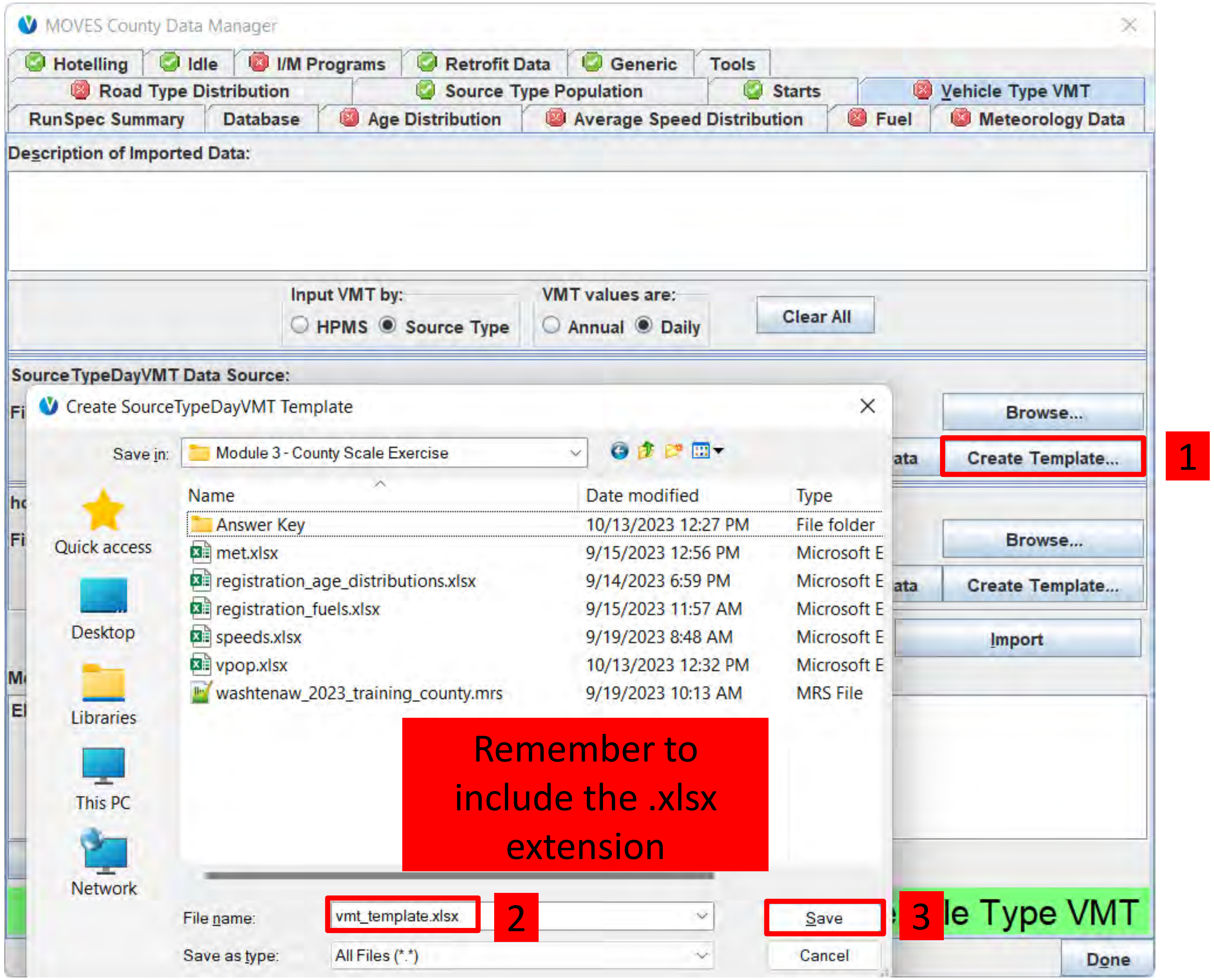
- Instructions for importing Vehicle Type VMT into the CDM:
  1. Select "Source Type" and "Daily" buttons on the Vehicle Type VMT tab
  2. Click "Create Template…" for SourceTypeDayVMT and save as vmt_template.xlsx
  3. Open vmt_template.xlsx and enter 4,000,000 for dayID 2 and 5,000,000 for dayID 5
  4. In the CDM, click "Export Default Data" and save as vmt_default.xlsx
  5. Open vmt_default.xlsx and review the hourVMTFraction tab
  6. In the CDM, click "Browse…" for SourceTypeDayVMT
     - Select vmt_template.xlsx. If MOVES asks if it should automatically import all 7 tabs – click "no" because we are only using one tab in this file. Then choose the SourceTypeDayVMT tab.
  7. In the CDM, click "Browse…" for HourVMTFraction
     - Select vmt_default.xlsx. MOVES will ask if it should automatically import all 7 tabs – click "no" because we are only using one tab in this file. Then choose the HourVMTFraction tab.
  8. Import both tables by clicking "Import"
  9. Check for errors

Select Source Type and Daily



Select Source Type and Daily

Create a template for SourceTypeDayVMT



Choose "No" in this example because we only need a template for SourceTypeDayVMT. However, if you are also planning to provide data for the distribution tables (like HourVMTFraction), choose yes to save time.

Edit the SourceTypeDayVMT template

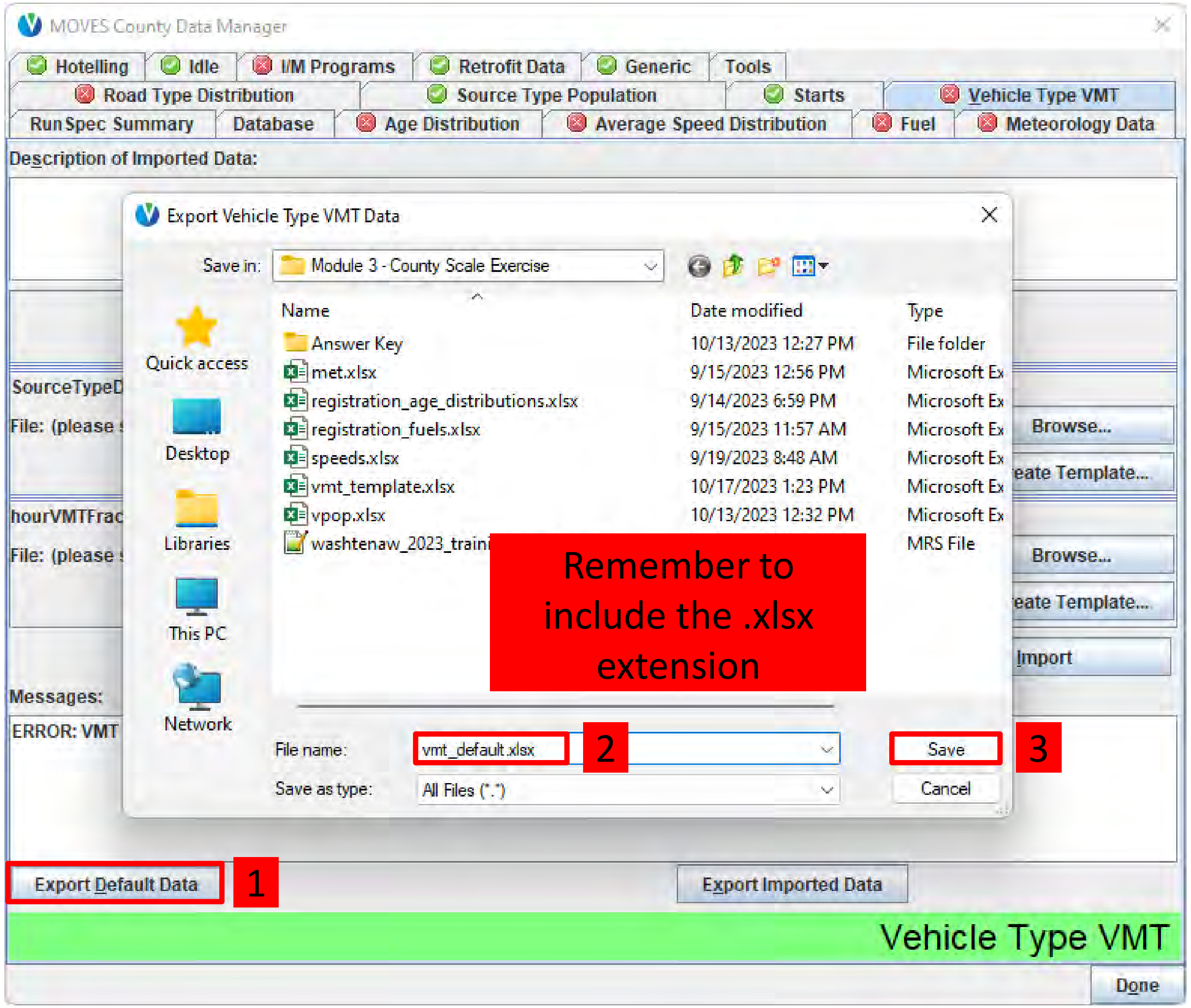
- In Windows Explorer, find the template you just created and open it
- Enter the 4,000,000 for the VMT for typical weekend days (dayID 2) and 5,000,000 for the VMT for typical weekday days (dayID 5)

sourceTypeID	yearID	monthID	dayID	VMT
21	2023	7	2	4000000
21	2023	7	5	5000000

SourceTypeDayVMT

- Save and close when done

Export default VMT data



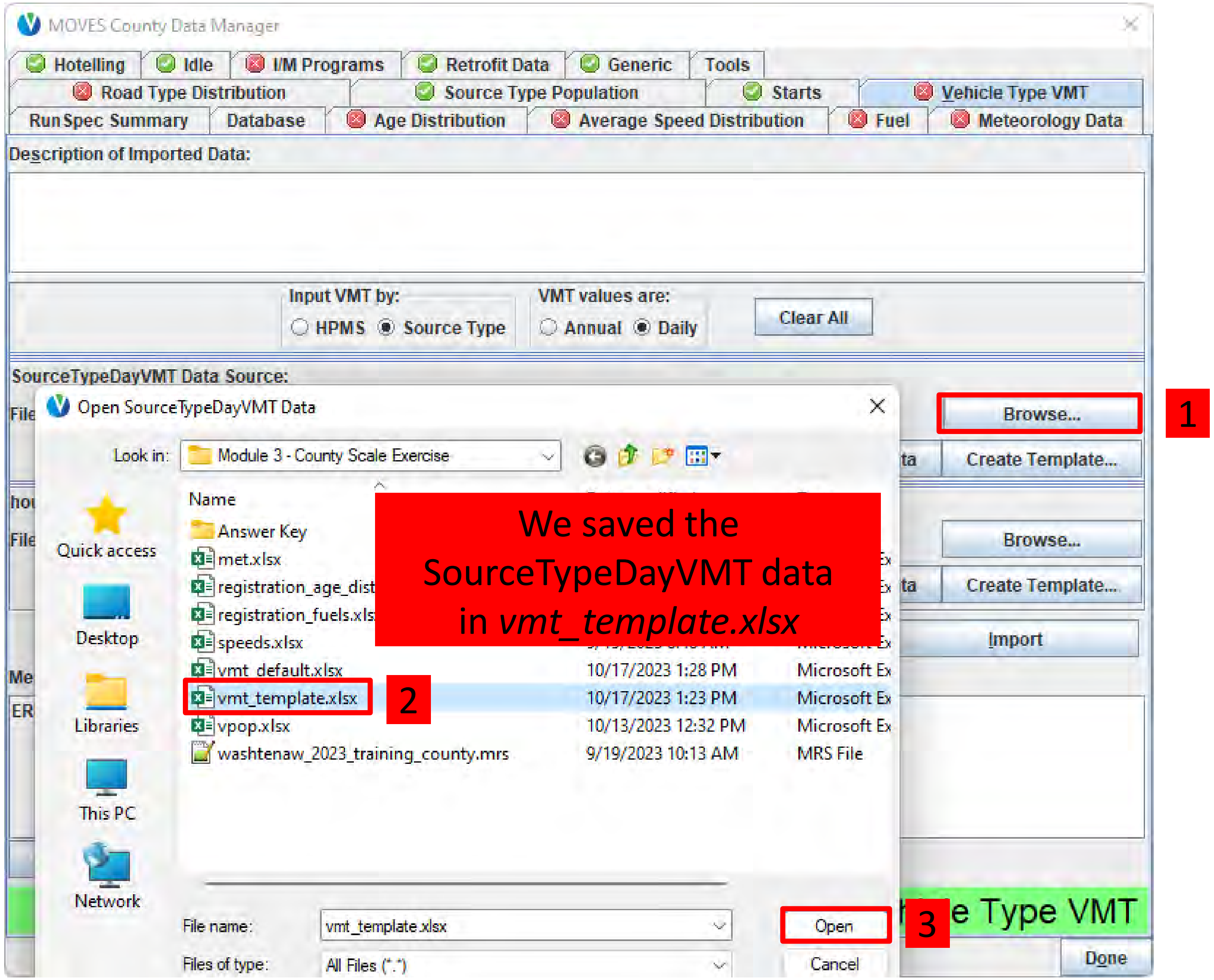
Review the default data

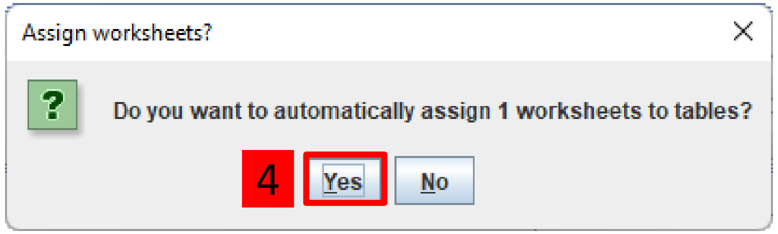
- Best practice is to always review default data before using it
- In Windows Explorer, find the file you just created and open it
- Review the data on the HourVMTFraction tab. No changes are necessary
- Close when done

sourceTypeID	roadTypeID	dayID	hourID	hourVMTFraction
21	1	2	1	0.0214739
21	1	2	2	0.0144428
21	1	2	3	0.0109684
21	1	2	4	0.00749451
21	1	2	5	0.00683855
21	1	2	6	0.0103588

HourVMTFraction

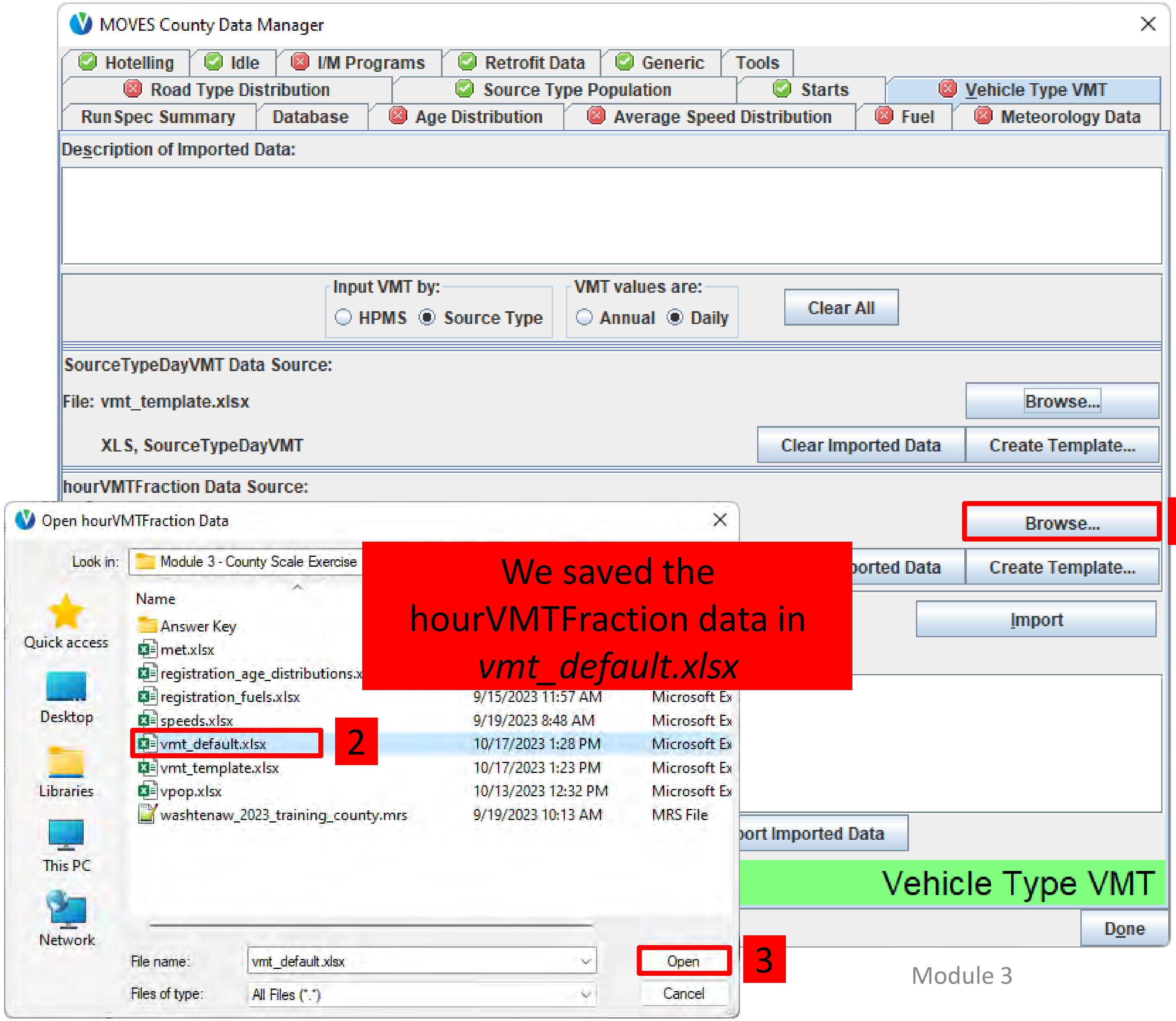
Importing SourceTypeDayVMT

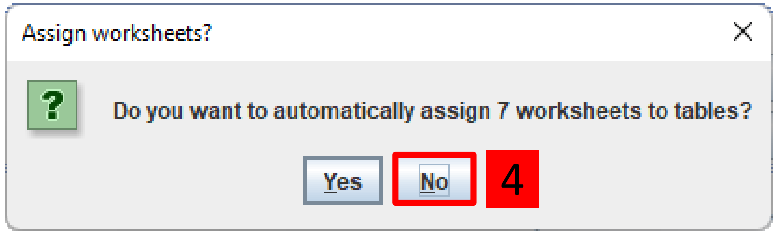




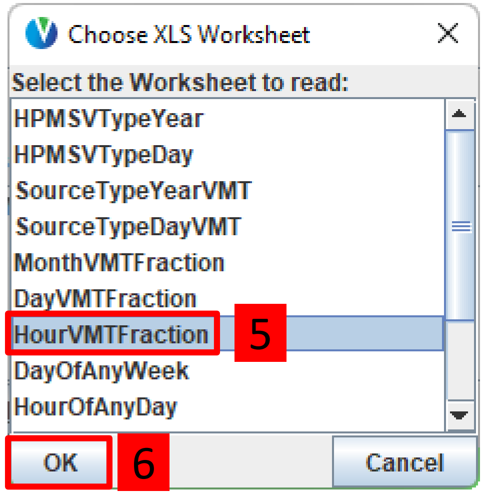
Choosing "Yes" will have MOVES automatically match tab names in the spreadsheet to "data sources" on this tab of the CDM. There is only one data tab in this spreadsheet in this example.

Importing HourVMTFraction

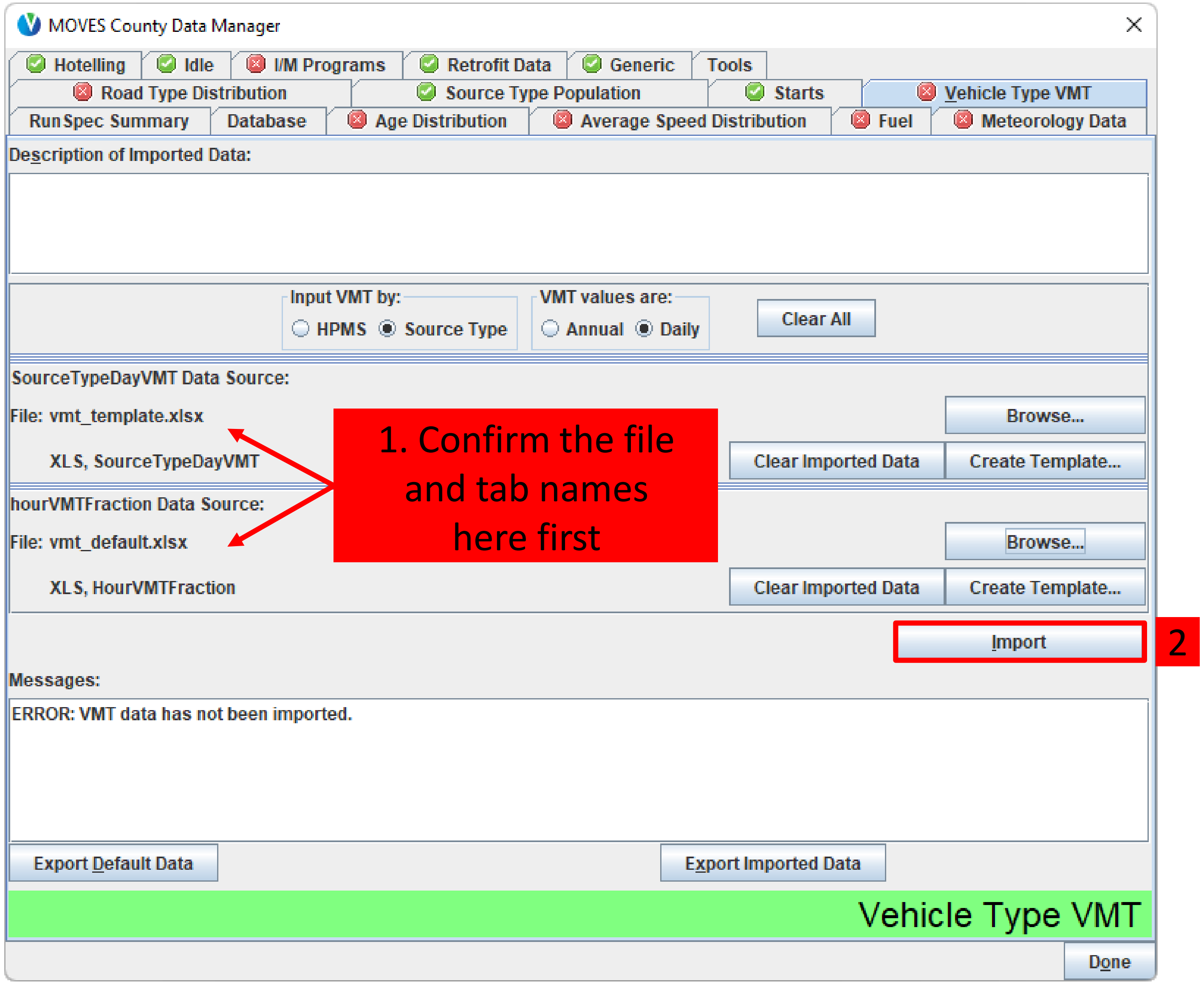




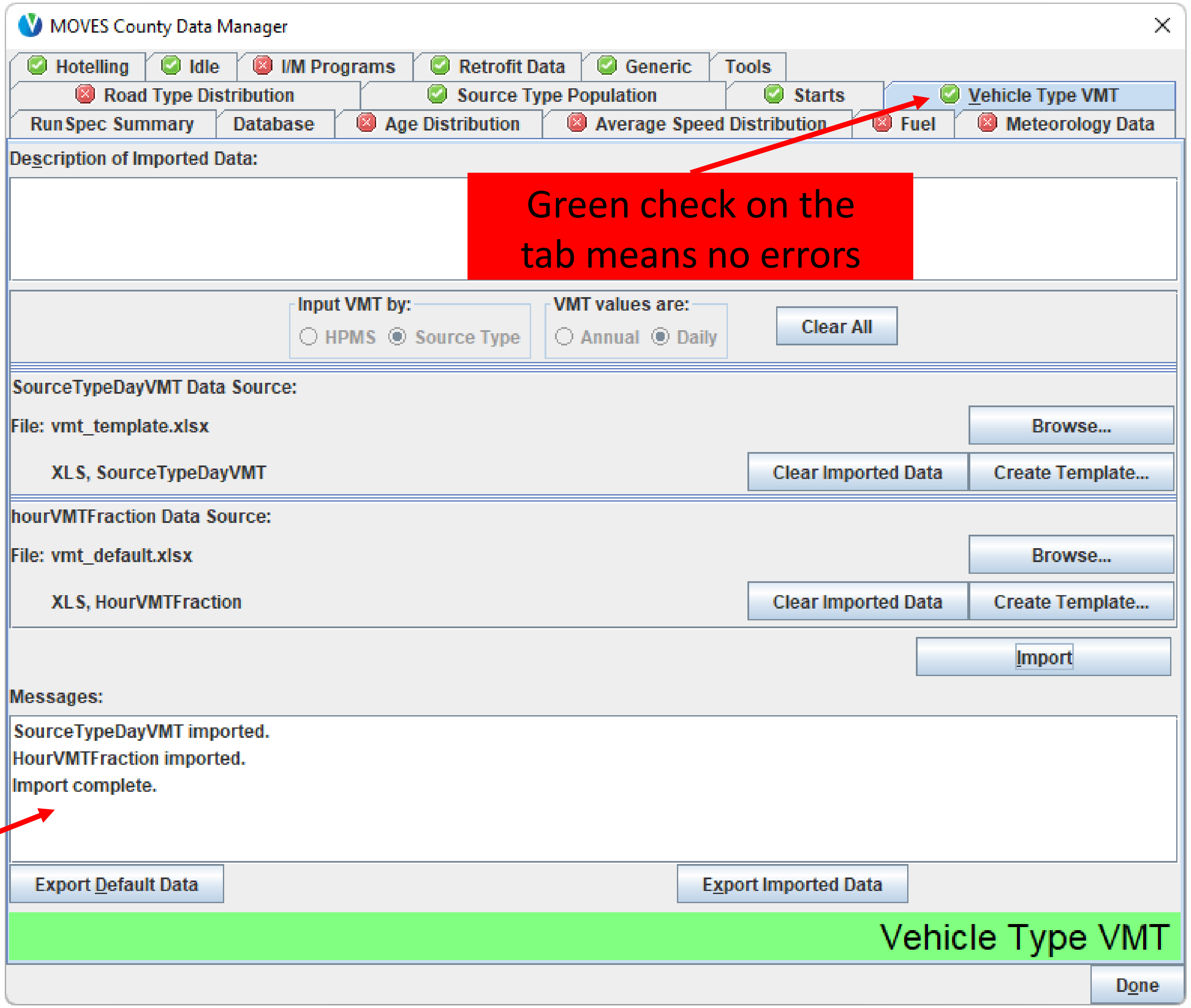
Choosing "Yes" will overwrite the file we already specified for SourceTypeDayVMT, which we don't want. Instead, choose "No", and MOVES will prompt you to select what tab to import for the HourVMTFraction data source.



Importing data for Vehicle Type VMT



Check for Vehicle Type VMT Errors



Any errors will appear in the messages list

Meteorology Tab

Meteorology

- Meteorology data must be entered for every month and hour selected in the RunSpec
  - Additional months and hours are OK
- Temperatures are in degrees Fahrenheit
- Relative humidity must be between 0 and 100
- ZoneID is simply the countyID + a zero

	A	B	C	D	E
1	monthID	zoneID	hourID	temperature	relHumidity
2	7	261610	1	66.4	80.4
3	7	261610	2	64.8	82.4
4	7	261610	3	63.7	83.9
5	7	261610	4	62.8	85
6	7	261610	5	62	85.9
7	7	261610	6	61.4	86.7
8	7	261610	7	61.9	86.8
9	7	261610	8	66.3	81.7
10	7	261610	9	70.9	73.5
11	7	261610	10	74.9	66.2
12	7	261610	11	78	60.8
13	7	261610	12	80.5	56.4
14	7	261610	13	82.4	53.2
15	7	261610	14	83.7	51
16	7	261610	15	84.5	49.4
17	7	261610	16	84.9	48.7
18	7	261610	17	84.7	48.8
19	7	261610	18	84	49.7
20	7	261610	19	82.7	51.4
21	7	261610	20	80.4	55.4
22	7	261610	21	76.3	62.6
23	7	261610	22	72.1	70.3
24	7	261610	23	69.5	75.3
25	7	261610	24	67.8	78.1

ZoneMont ...

Example default data

Meteorology: Template

- Creating a template on the Meteorology tab creates gives you a template for the ZoneMonthHour table:
  - This template has one row for each month and hour combination in the RunSpec
  - ZoneID is automatically filled out for you based on the county selected in the RunSpec
  - Temperature and relHumidity must be filled out for every row

	A	B	C	D	E
1	monthID	zoneID	hourID	temperature	relHumidity
2	7	261610	1		
3	7	261610	2		
4	7	261610	3		
5	7	261610	4		
6	7	261610	5		
7	7	261610	6		

zoneMonthHour | HourOfAnyDay

- Use the HourOfAnyDay tab in the template file to decode the hourID field

Meteorology: Guidance

- Section 4.2 of MOVES Technical Guidance
- Local temperature and humidity data are required inputs for SIP and regional conformity analysis with MOVES
- Default data based on historic 10-year averages – these may not be appropriate for all types of analysis
- Temperatures for conformity analysis must be consistent with temperatures used to develop SIP emissions budgets

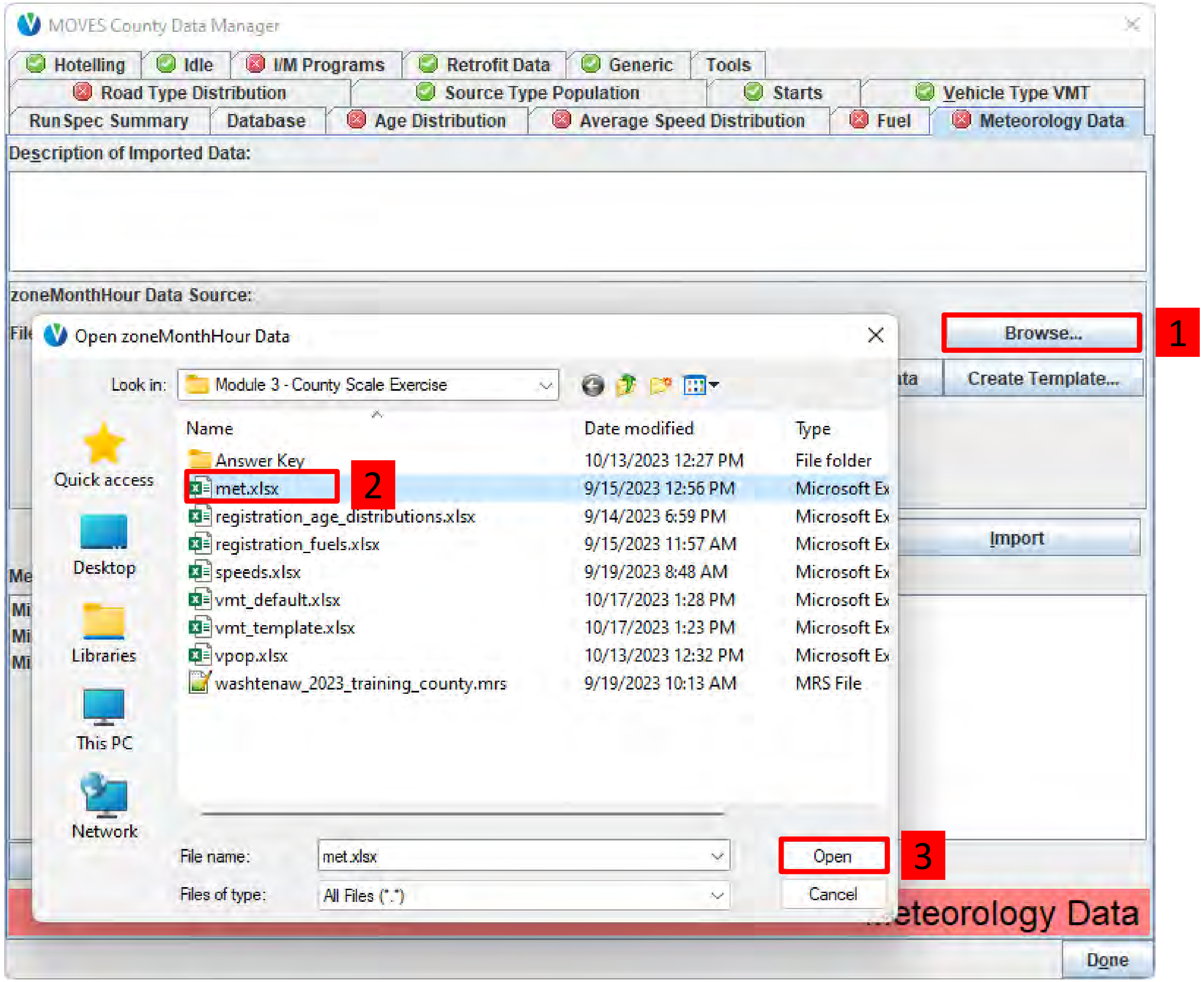
Meteorology: Exercise Overview

- Let's enter meteorology data into the CDM for our County Scale exercise
- The template with specific local meteorology for Washtenaw County has already been filled out and saved in the Module 3 - County Scale Exercise folder
- You can open the file *met.xlsx* in Excel to review the data
- Always review your input files before entering in MOVES to ensure accuracy and avoid run errors

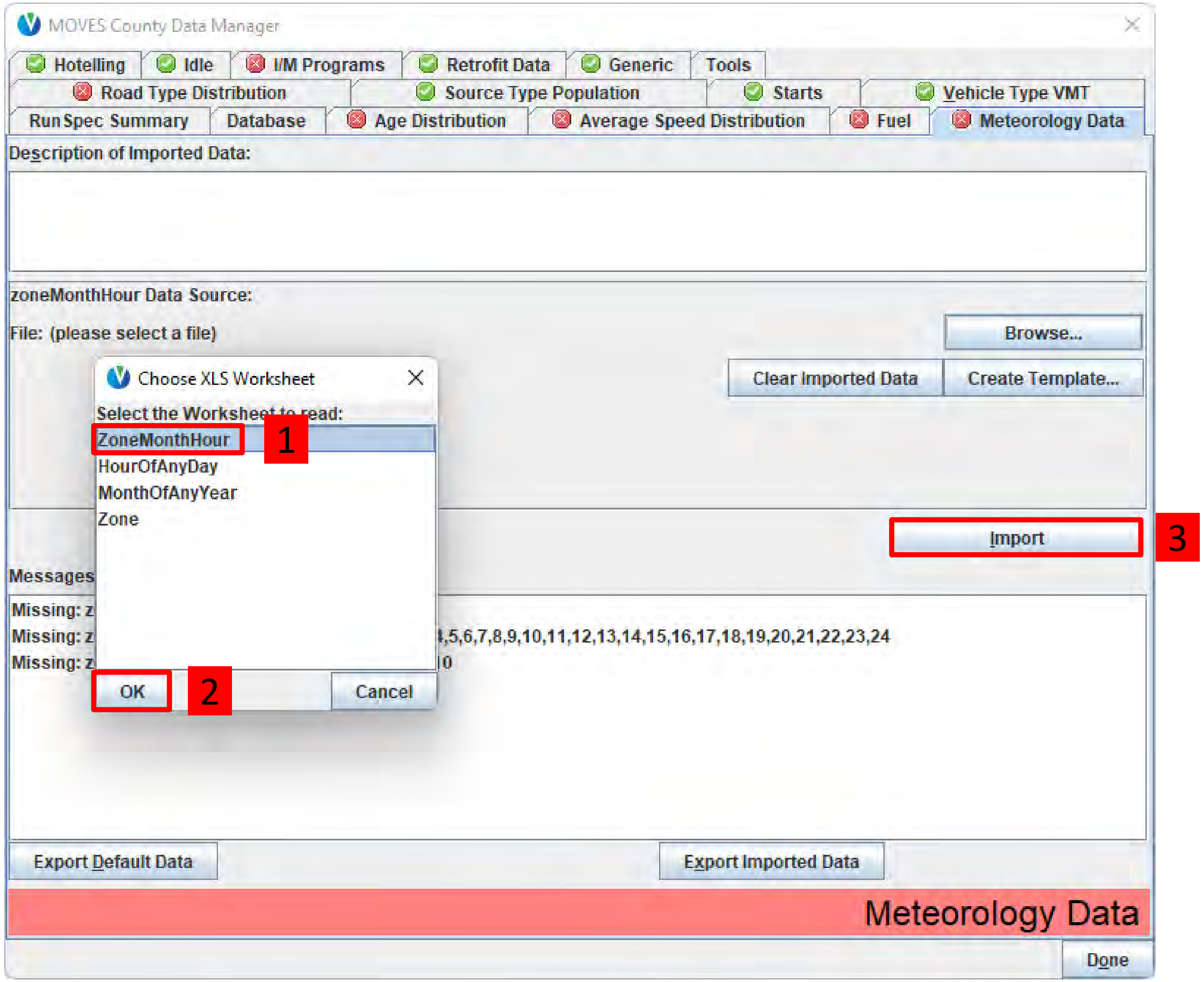
Meteorology: Exercise Instructions

- Instructions for importing met data into the CDM:
  1. Go to the Meteorology tab
  2. Click Browse, select *met.xlsx* from Module 3 - County Scale Exercise folder, and click Open
  3. Select the worksheet called “ZoneMonthHour” and click OK
  4. Click Import
  5. Check:
     - Proper file name and worksheet are listed
     - No error messages
     - Green check on Meteorology tab

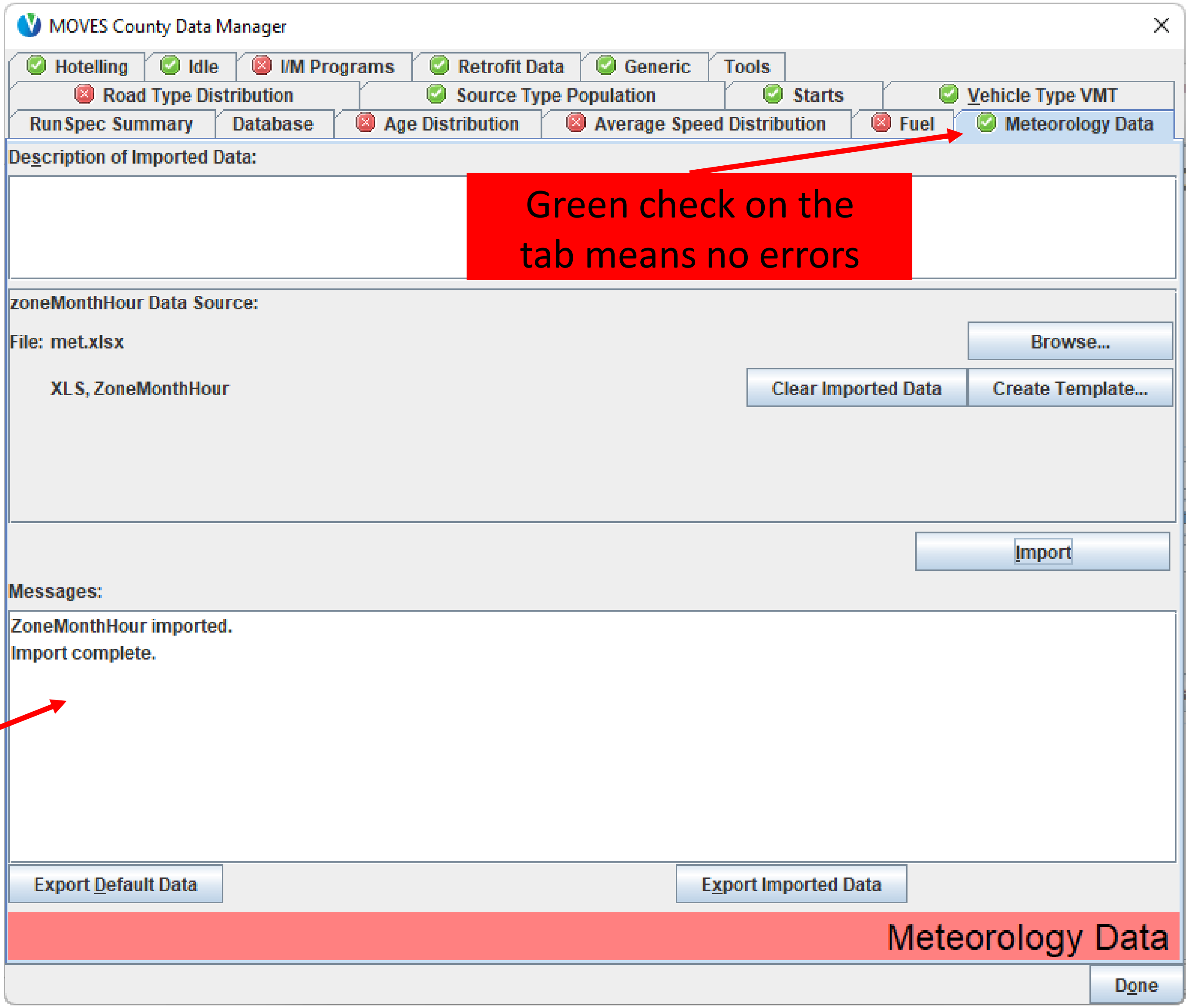
Importing Meteorology Data (1)



Importing Meteorology Data (2)



Check for Meteorology Errors



Any errors will appear in the messages list

Average Speed Distribution Tab

MOVES

Motor Vehicle Emission Simulator

Average Speed Distribution (1)

- Avg. Speed Distribution is fraction of **time** spent in each speed bin for every source type, road type, and hour/day
  - AvgSpeedFraction should sum to 1 within these fields
  - This is the fraction of "vehicle hours travelled" (VHT), also known as "source hours operating" (SHO), in each speed bin – not fraction of VMT
- MOVES has 16 speed bins ranging from 2.5 to 75+ mph
- AvgSpeedDistribution table can be very long (~50,000+ rows) if RunSpec covers all source types, road types, day types, and hours

avgSpeedBinID	Description
1	Speed < 2.5mph
2	2.5mph <= speed < 7.5mph
3	7.5mph <= speed < 12.5mph
4	12.5mph <= speed < 17.5mph
5	17.5mph <= speed < 22.5mph
6	22.5mph <= speed < 27.5mph
7	27.5mph <= speed < 32.5mph
8	32.5mph <= speed < 37.5mph
9	37.5mph <= speed < 42.5mph
10	42.5mph <= speed < 47.5mph
11	47.5mph <= speed < 52.5mph
12	52.5mph <= speed < 57.5mph
13	57.5mph <= speed < 62.5mph
14	62.5mph <= speed < 67.5mph
15	67.5mph <= speed < 72.5mph
16	speed >= 72.5

Average Speed Distribution (2)

- Emissions vary by speed and road type. They can be an indicator of:
  - Level of congestion
  - How much acceleration / deceleration activity is happening vs. cruise activity
- Default data are available on this tab

sourceTypeID	roadTypeID	hourDayID	avgSpeedBinID	avgSpeedFraction
21	2	15	1	0.00101877
21	2	15	2	0.00251428
21	2	15	3	0.00326095
21	2	15	4	0.00263183
21	2	15	5	0.0011668
21	2	15	6	0.000862039
21	2	15	7	0.00321305
21	2	15	8	0.00220081
21	2	15	9	0.00645005
21	2	15	10	0.0071706
21	2	15	11	0.0184119
21	2	15	12	0.0416805
21	2	15	13	0.101803
21	2	15	14	0.200026
21	2	15	15	0.237479
21	2	15	16	0.370111

avgSpeedDistribution

Example default data

Average Speed Distribution: Template

- Creating a template on the Average Speed Distribution tab gives you a template for the AvgSpeedDistribution table:
  - This template has 16 rows for each source type, road type, hour, and day combination in the RunSpec, one for each speed bin
  - hourDayID is the combination of hourID and dayID

	A	B	C	D	E	F	G	H
1	sourceTypeID	roadTypeID	hourDayID	avgSpeedBinID	avgSpeedFraction			
2	21	2	15	1				
3	21	2	15	2				
4	21	2	15	3				
5	21	2	15	4				
6	21	2	15	5				

avgSpeedDistribution | AvgSpeedBin | ...

- Use the AvgSpeedBin tab in the template file to decode the avgSpeedBinID field

Average Speed Distribution: Guidance (1)

- Section 4.6 of MOVES Technical Guidance
- Local speed distribution data are recommended
  - The more detail that can be obtained, the better
  - Speed distribution data can be applied to all source types within an HPMS class (e.g., same distribution for 31 and 32) or for more general categories (e.g., same distribution for all light-duty vehicles) if more detailed information is not available
  - For temporal aspects, speed distribution data can be entered at the hourly level, but varying the speed distribution only for peak and off-peak hours is also acceptable
  - Freeway speeds should reflect mainline freeway speeds and ramps combined

Average Speed Distribution: Guidance (2)

- MOVES has four road types that need the average speed distribution input:
  - Urban restricted and rural restricted road types are generally interstates and freeways
  - Urban unrestricted and rural unrestricted road types are generally arterials, collectors, and local roads
- If separate speed distributions are known for arterials, collectors, and local roads, either:
  - Calculate a weighted speed distribution that applies to all urban or rural unrestricted roads, or
  - Do multiple MOVES runs using the appropriate speed and VMT information for arterials, collectors, and local roads separately and combine the results

Average Speed Distribution: Working with Travel Model Data

- MPO travel demand forecasting models typically produce link-level output that can be used to develop speed distributions and road type distributions
- Depending on model capabilities, speeds may need to be post-processed
- Output will need to be “mapped” to MOVES format
  - Map travel model road types to MOVES road types
  - Map travel model time periods to MOVES hours
  - If different vehicle types are modeled, map vehicle types to MOVES source types
  - If different geographic areas modeled (e.g., central business district (CBD), urban, suburban, etc.), map to MOVES urban and rural groups

Average Speed Distribution: Example Travel Model Output

- Type: link type (highway, transit, etc.)
- Area: area type (CBD, urban, suburban, etc.)
- FacType: roadway type (freeway, major arterial, etc.)
- AB_AM1VOL: traffic volume in the A to B direction during the first a.m. time period (BA_AM1VOL = volume in the B to A direction)
- AB_AM1SPD: speed in the A to B direction during the first a.m. time period (BA_AM1SPD = speed in the B to A direction)
- This example continues for 9 more time periods and ~ 19,000 more links

Copy of links.txt - Notepad

File Edit Format View Help

Link ID	Length	Type	Area	FacType	AB_AM1VOL	BA_AM1VOL	AB_AM1SPD	BA_AM1SPD
3975	0.620000	1	4	5	25.248997	21.887457	24.999958	24.999980
4666	2.350000	1	5	1	1820.314055	0	73.939564	0
4681	1.790000	1	5	5	0.527671	109.884528	35.999999	35.846250
4684	0.200000	1	3	3	453.636272	637.764953	35.946277	35.750598
5499	0.240000	1	3	5	17.822716	40.974265	21.999990	21.999173
5651	0.300000	1	3	4	200.434152	38.935625	30.962177	30.999996
5741	0.240000	1	3	3	610.997617	427.611556	35.811902	35.970377
5742	0.250000	1	3	3	675.074401	367.797467	33.382355	35.875447
5771	0.230000	1	4	5	18.784017	14.096248	24.999993	24.999998
5773	0.250000	1	3	5	29.657767	17.989278	21.999863	21.999990
6291	1.127189	1	4	1	954.390479	0	74.984542	0
7984	0.510638	1	2	5	14.430858	22.951666	19.999986	19.999861
7986	0.131238	1	2	3	125.881050	216.377628	25.999209	25.988763

Average Speed Distribution: Steps in Developing Speed Inputs from Travel Models (1)

- Map to the four relevant MOVES road types
  - No VMT or VHT on roadTypeID = 1 (“off-network”)
  - Use only roadway links, not rail, bike, or walk links
- Sort by speed bin
- Calculate VHT by speed bin and road type:
  - For each link: length × volume / speed = VHT
- Sum total VHT by road type and then calculate bin fractions

Average Speed Distribution: Steps in Developing Speed Inputs from Travel Models (2)

- Repeat for each time period; map to MOVES hours
- If multiple vehicle types are modeled, repeat for each vehicle group and map to MOVES source type
  - Some areas do separate traffic assignment for cars, trucks, and other classes
  - If bus transit links are modeled separately, calculate speeds separately and use these speeds for the transit bus source type
- If multiple area types, then map each to either rural or urban road types

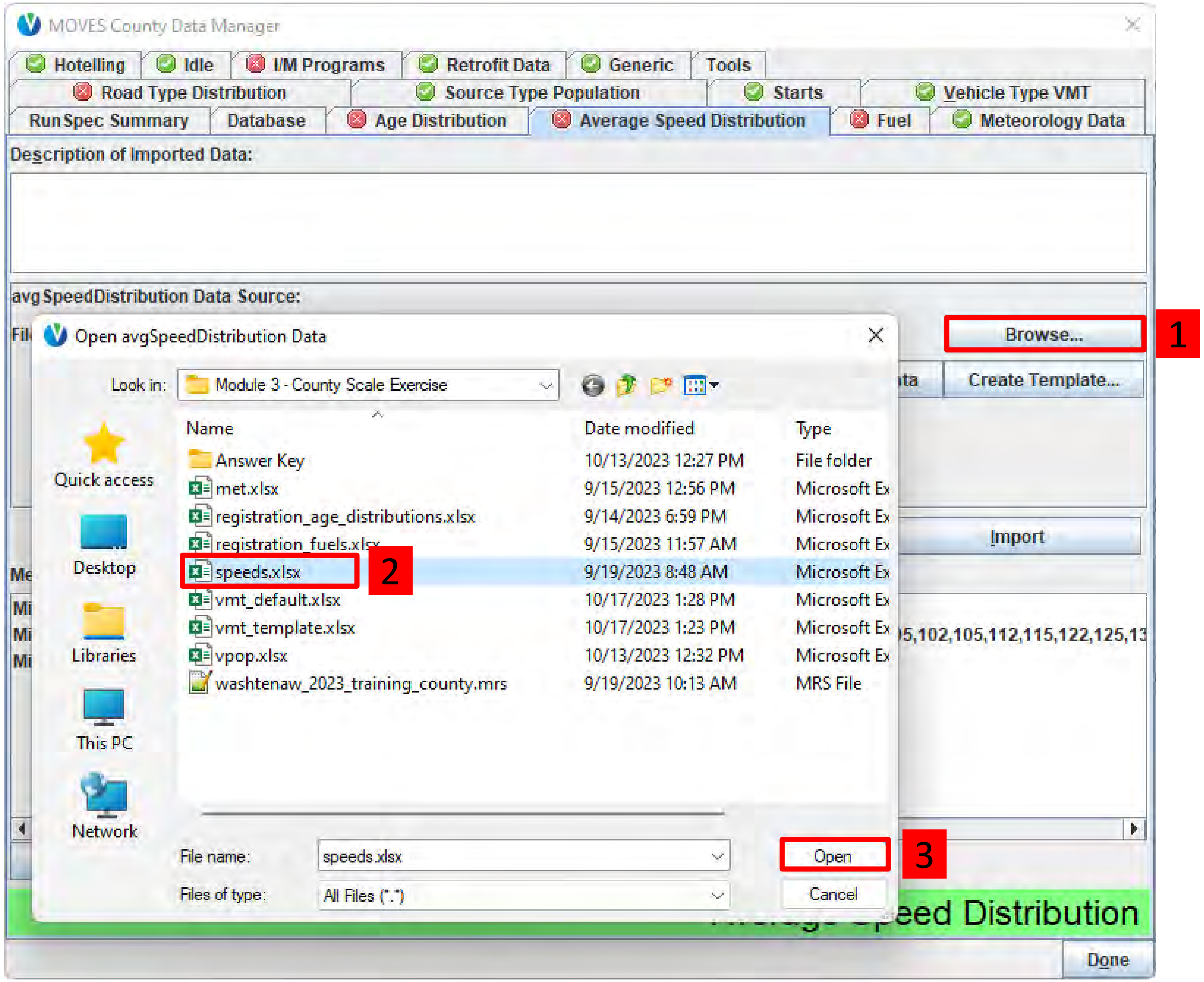
Average Speed Distribution: Exercise Overview

- Let's enter average speed distribution data into the CDM for our county-level exercise
- The template has already been filled out and saved in the Module 3 - County Scale Exercise folder
- Open the file *speeds.xlsx* in Excel to review the data
- Always review your input files before entering in MOVES to ensure accuracy and avoid run errors

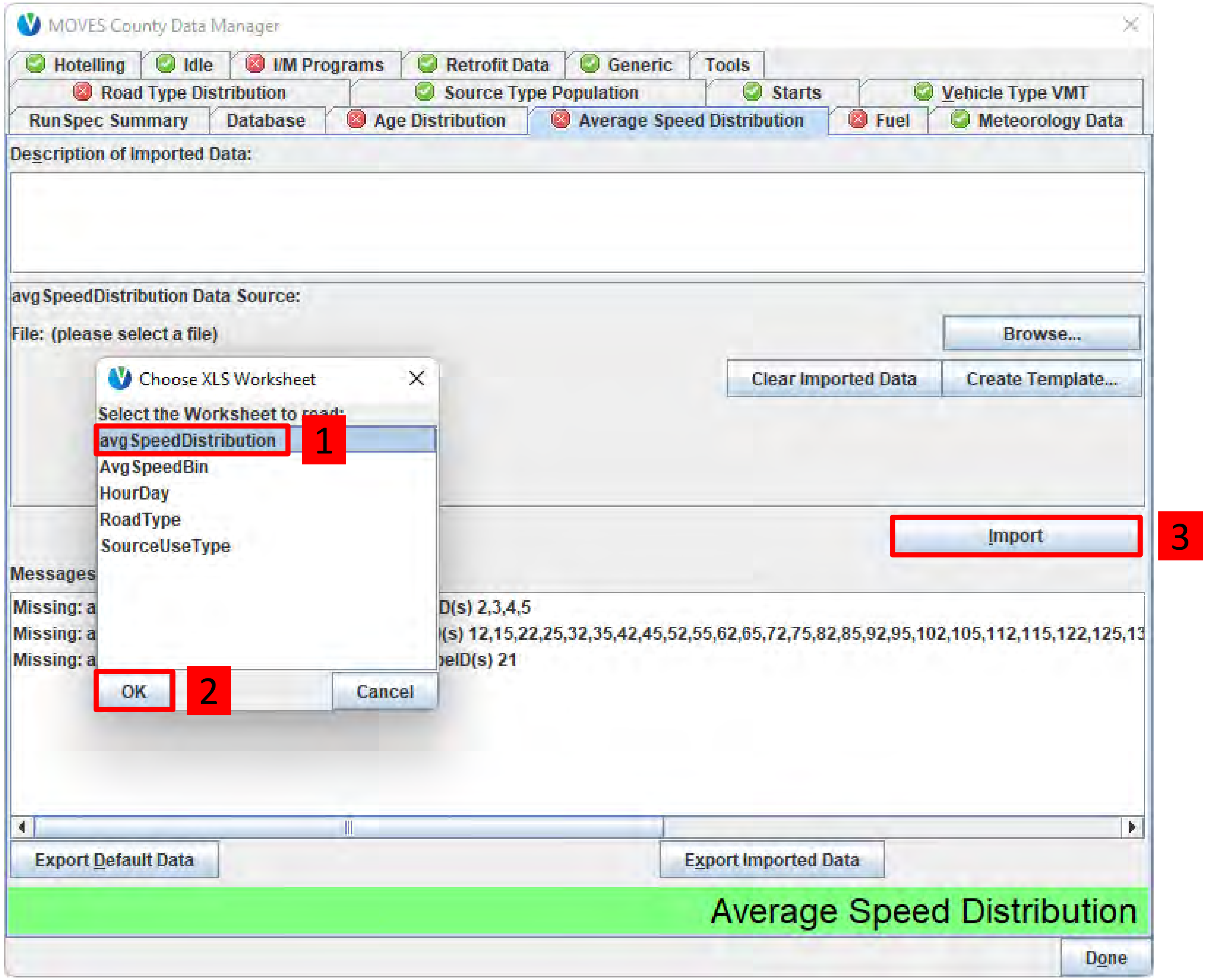
Average Speed Distribution: Exercise Instructions

- Instructions for importing average speed distribution into the CDM:
  1. Go to the Average Speed Distribution tab
  2. Click Browse, select speeds.xlsx from the Module 3 - County Scale Exercise folder, and click Open
  3. Select the worksheet called “AvgSpeedDistribution” and click OK
  4. Click Import
  5. Check:
     - Proper file name and worksheet are listed
     - No error messages
     - Green check on Average Speed Distribution tab

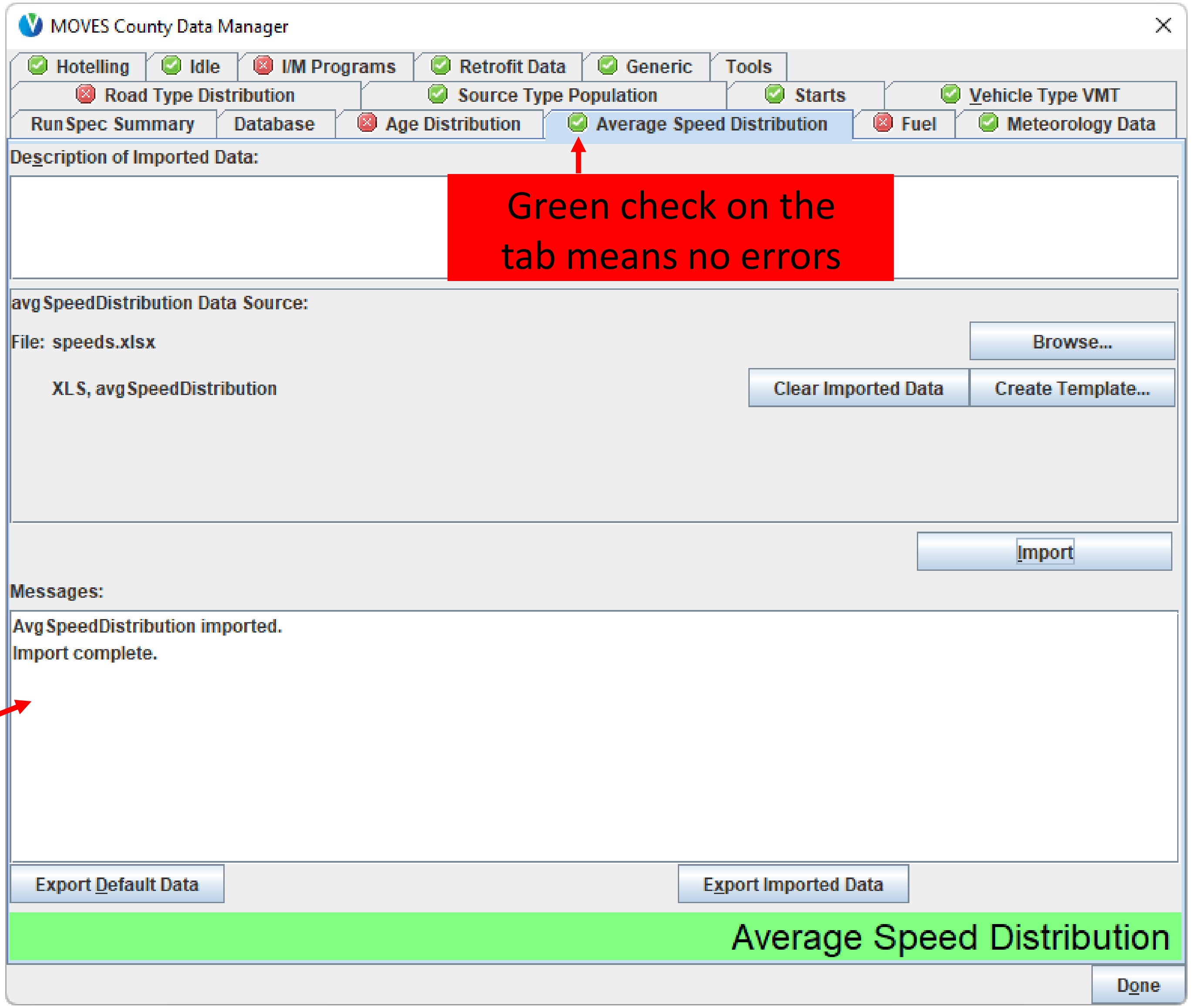
Importing Speed Distribution Data (1)



Importing Speed Distribution Data (2)



Check for Average Speed Distribution Errors



Any errors will appear in the messages list

Road Type Distribution Tab

MOVES
Motor Vehicle Emission Simulator

Road Type Distribution

- RoadTypeVMTFraction is the fraction of VMT (**distance**, not time) on each road type by source type
  - Values must sum to 1.0 across all road types for each source type
  - There is no default data for this input
- If a running process is selected in the RunSpec, all road types must be selected
  - If a road type does not exist in a county, use this input with 0s for all applicable source types to indicate this

roadTypeID	Description
2	Rural Restricted Access
3	Rural Unrestricted Access
4	Urban Restricted Access
5	Urban Unrestricted Access

Road Type Distribution: Template

- Creating a template on the Road Type Distribution tab gives you a template for the RoadTypeDistribution table:
  - This template has rows for each source type and road type combination in the RunSpec

	A	B	C
1	sourceTypeID	roadTypeID	roadTypeVMTFraction
2	21	2	
3	21	3	
4	21	4	
5	21	5	

roadTypeDistribution | RoadType

- Use the RoadType tab in the template file to decode the roadTypeID field

Road Type Distribution: Using Travel Model Outputs

- Travel model link volumes can be used to develop road type distribution fractions:
  1. Map links to MOVES road types
  2. Calculate VMT by link (length x volume)
  3. Sum by link and road type across all time periods (MOVES inputs for road type distributions do not vary by hour)
  4. Calculate fractions that sum to one
  5. Repeat for each vehicle group, as needed

Road Type Distribution: Guidance

- Section 4.7 of MOVES Technical Guidance
- Road type distribution data should be based on local information
- If data are not available, the same road type distribution can be used for all source types in the same HPMS class
  - However, in many cases, road type distributions vary for source types in the same HPMS class (e.g., transit bus vs. other buses), so source type specific information is encouraged

Road Type Distribution: Exercise Overview

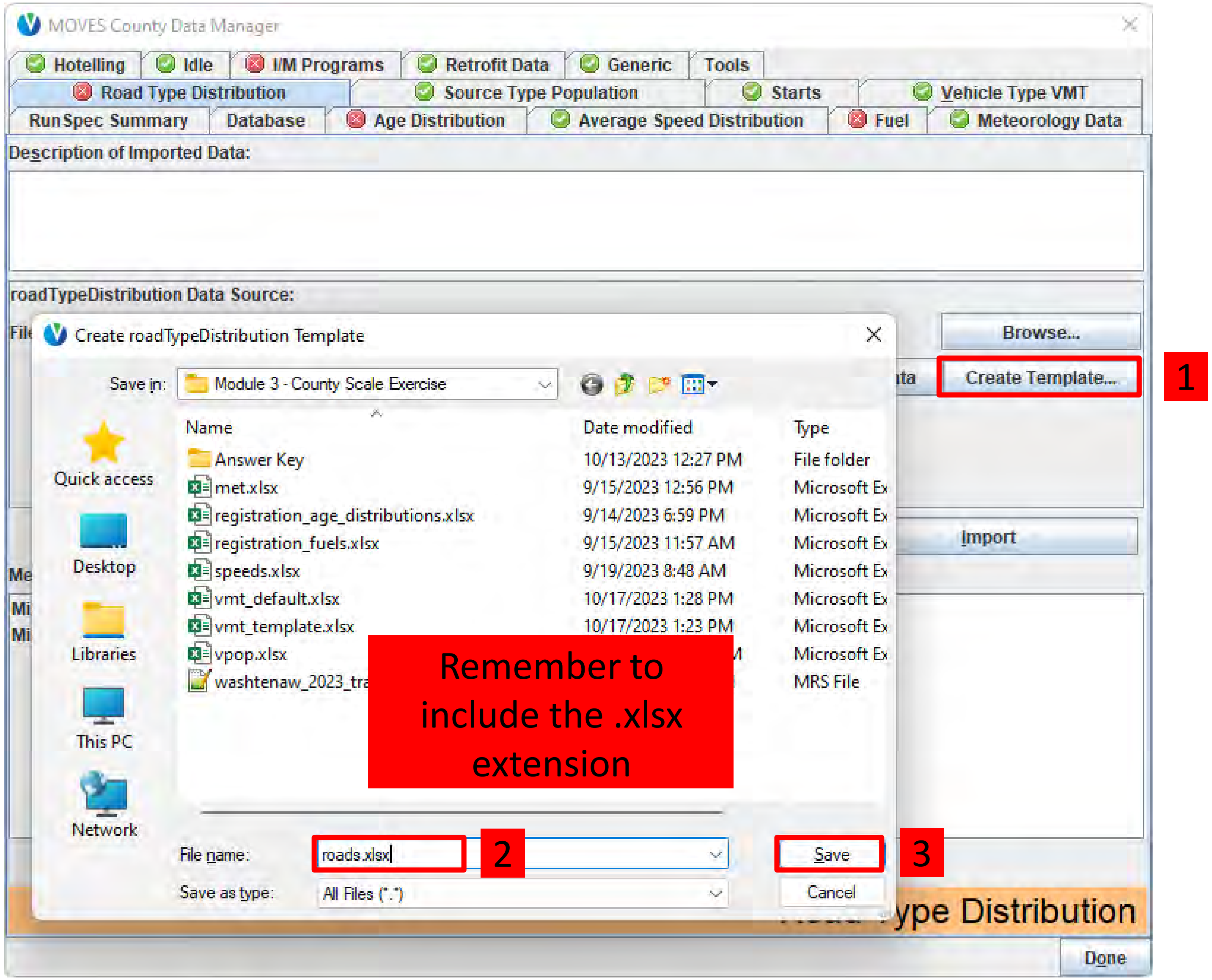
- Let's enter our road type distribution data into the CDM for our County Scale exercise
- We know from our travel demand modeling that Washtenaw County passenger cars have the following road type distribution:

Road Type	Fraction of VMT
Rural Freeways	0.0279
Rural Local & Arterial	0.0281
Urban Freeways	0.3345
Urban Local, Arterial, and Collector	0.6095

Road Type Distribution: Exercise Instructions

- Instructions for importing road type distribution into the CDM:
  1. Go to the Road Type Distribution tab
  2. Click Create Template…, give *roads.xlsx* as the filename, and click Save
  3. Navigate to *roads.xlsx*, enter the distribution from the previous slide and save
     - Use the Road Type decoding tab to help decode the roadTypeIDs
  4. Back in the CDM, click Browse, select *roads.xlsx*, and click Open
  5. Select the worksheet called "roadTypeDistribution" and click OK
  6. Select Import
  7. Check:
     - Proper file name and worksheet are listed
     - No error messages
     - Green check on Road Type Distribution tab

Create Road Type Distribution Template



Fill out Road Type Distribution Template

- In Windows Explorer, find the template you just created and open it
- Enter the distribution values as the “roadTypeVMTFraction” for the appropriate road types to indicate the distribution of passenger car activity on each road type

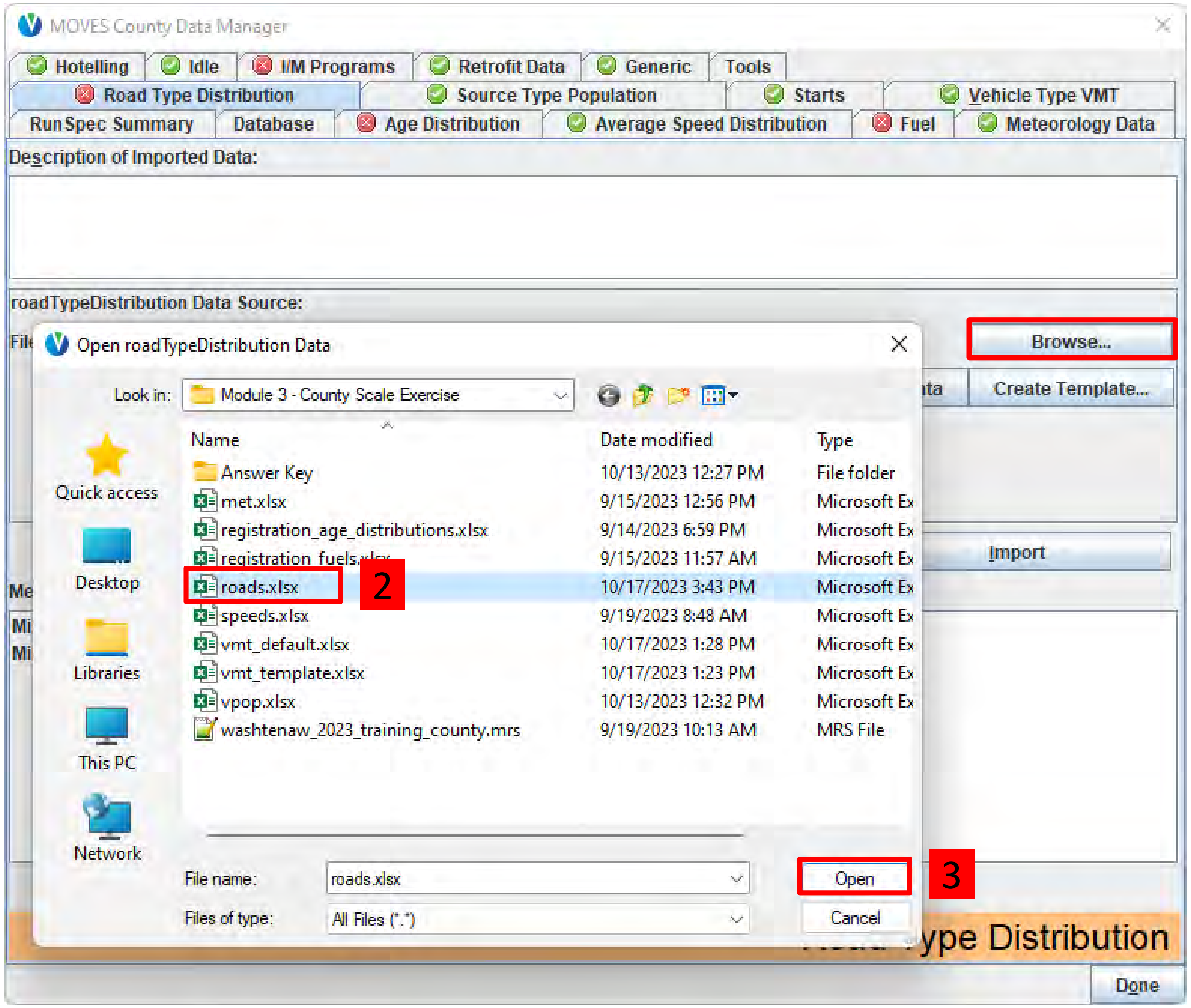
Road Type	Fraction of VMT
Rural Freeways	0.0279
Rural Local & Arterial	0.0281
Urban Freeways	0.3345
Urban Local, Arterial, and Collector	0.6095

	A	B	C
1	sourceTypeID	roadTypeID	roadTypeVMTFraction
2	21	2	0.0279
3	21	3	0.0281
4	21	4	0.3345
5	21	5	0.6095

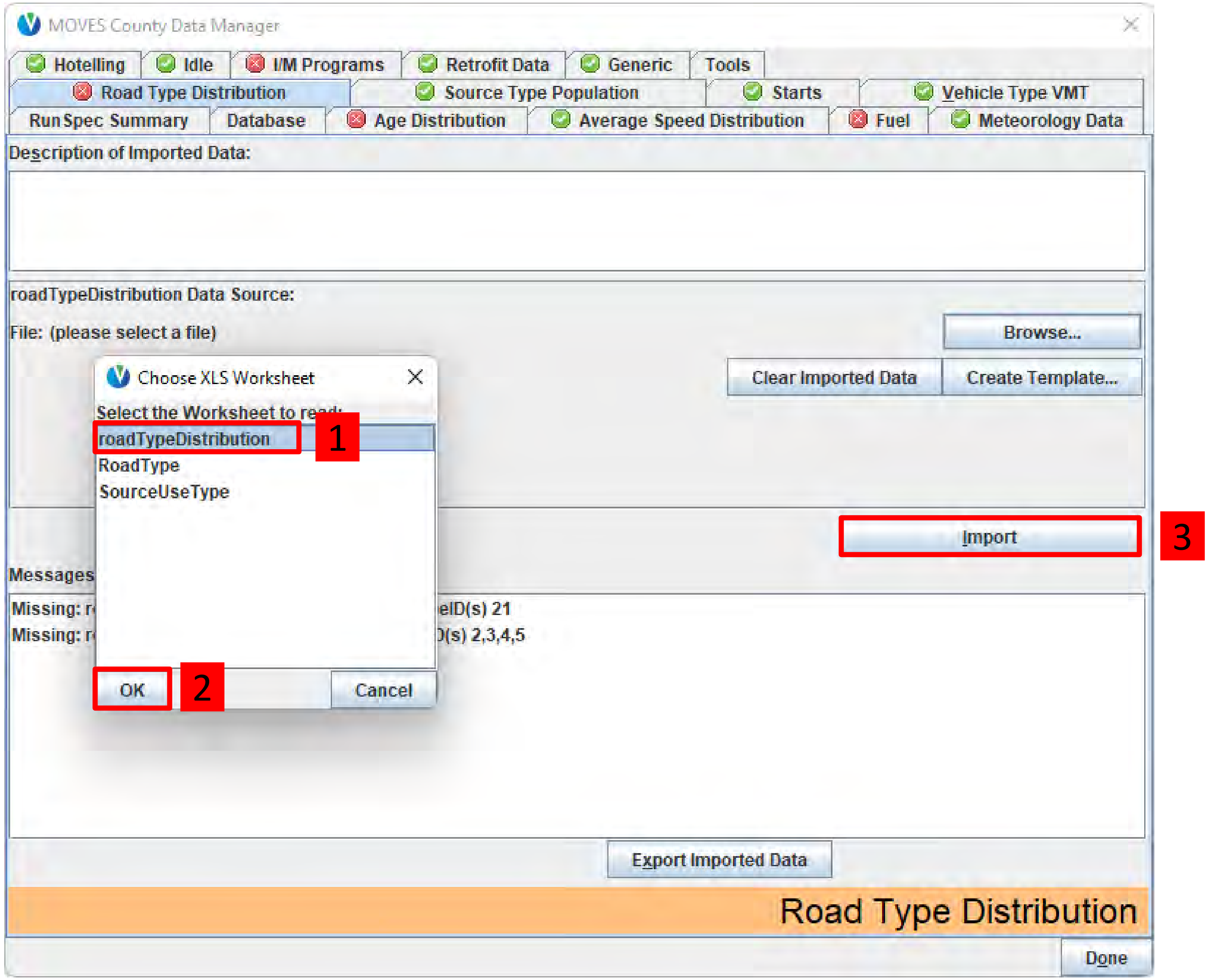
roadTypeDistribution | RoadType

- Use the RoadType decoding tab if needed
- Save and close when done

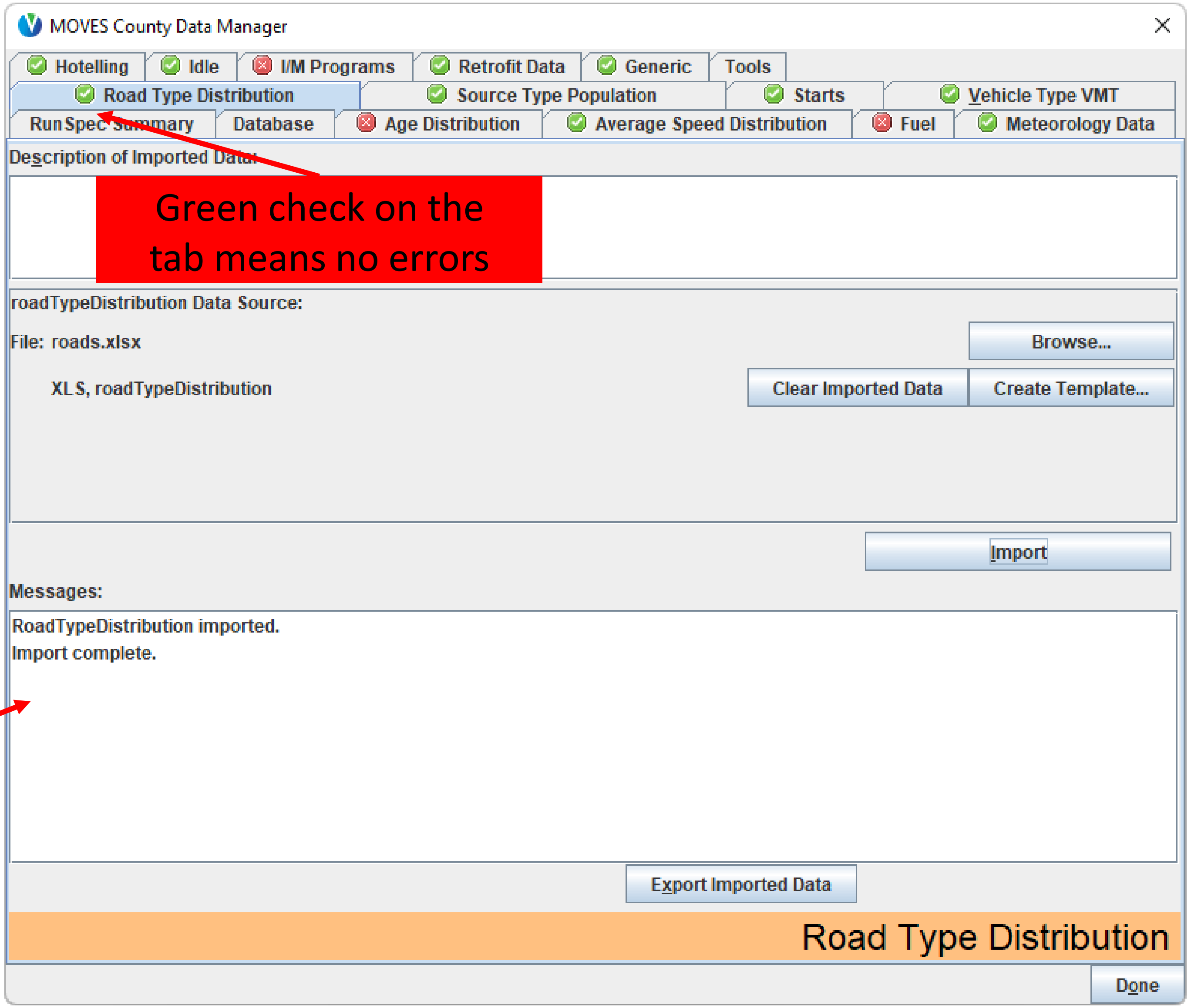
Import the Road Type Distribution (1)



Import the Road Type Distribution (2)



Check for Road Type Distribution Errors



Green check on the tab means no errors

Any errors will appear in the messages list

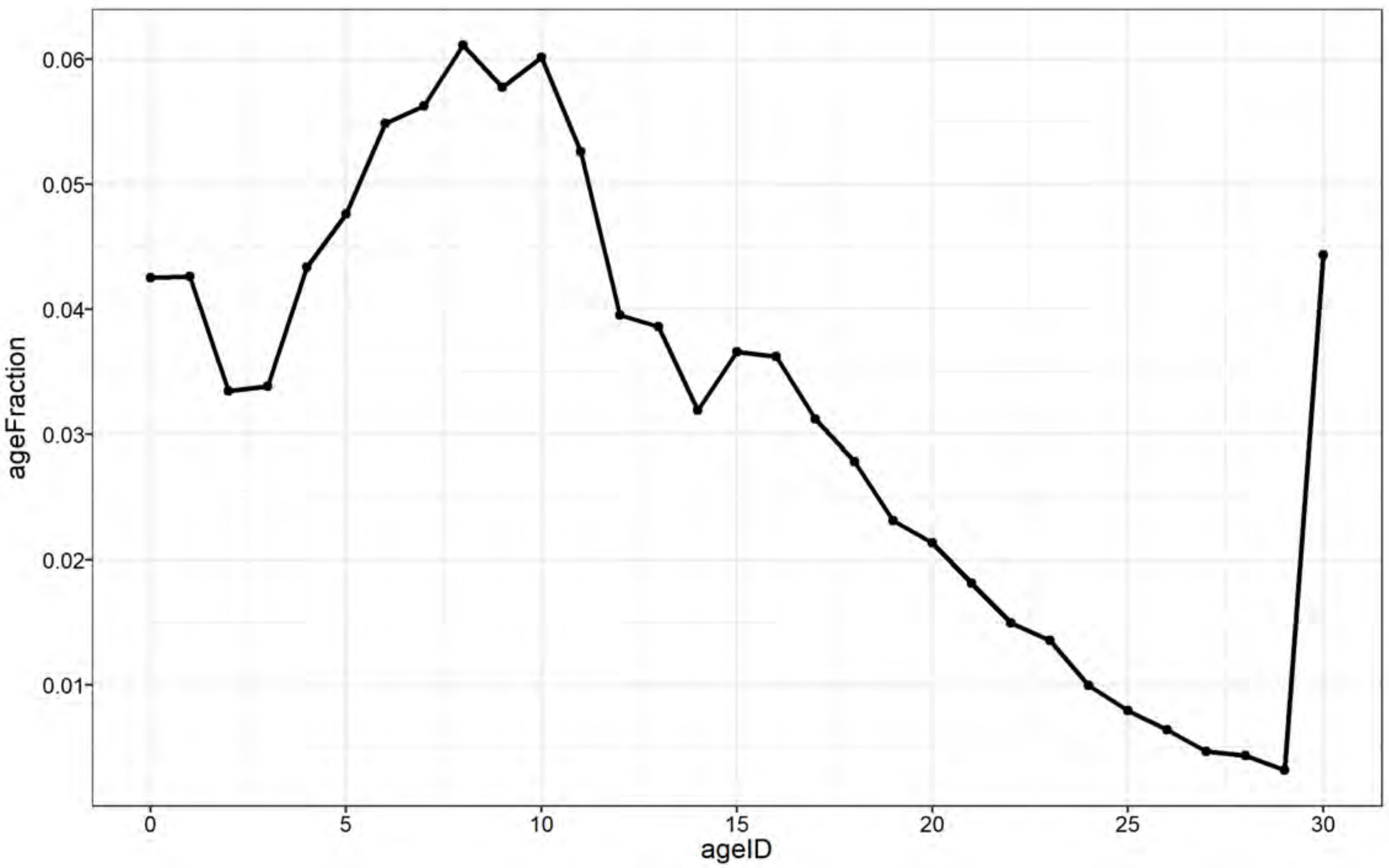
Age Distribution Tab

Age Distribution

- MOVES uses age distributions to allocate vehicle populations by model year
  - Important because vehicle standards vary by model year
- Age distributions are entered by Source Type and calendar year
  - AgeFraction must sum to 1 within these fields
- This covers new (age 0) to 30+ year old vehicles
  - All vehicles ages 30 and older are grouped together and assigned ageID 30
- MOVES does not vary age distributions by month
- Default data are available
  - Generally, only use these for long-haul source types

Example Age Distribution Data

sourceTypeID	yearID	ageID	ageFraction
21	2023	0	0.0425181
21	2023	1	0.0426020
21	2023	2	0.0334677
21	2023	3	0.0338279
21	2023	4	0.0433612
21	2023	5	0.0476467
21	2023	6	0.0548660
21	2023	7	0.0562695
21	2023	8	0.0611211
21	2023	9	0.0577834
21	2023	10	0.0601399
21	2023	11	0.0526379
21	2023	12	0.0395582
21	2023	13	0.0386023
21	2023	14	0.0319130
21	2023	15	0.0365686



Age Distribution: Template

- Creating a template on the Age Distribution tab gives you a template for the SourceTypeAgeDistribution table:
  - This template has 31 rows for each source type in the RunSpec, one for each age (ages 0-30)
  - YearID is populated based on the calendar year selected in the RunSpec
- AgeID = YearID - ModelYearID

	A	B	C	D
1	sourceTypeID	yearID	ageID	ageFraction
2	21	2023	0	
3	21	2023	1	
4	21	2023	2	
5	21	2023	3	
6	21	2023	4	
7	21	2023	5	
8	21	2023	6	
9	21	2023	7	
10	21	2023	8	
11	21	2023	9	
12	21	2023	10	
13	21	2023	11	
14	21	2023	12	
15	21	2023	13	
16	21	2023	14	
17	21	2023	15	
18	21	2023	16	
19	21	2023	17	
20	21	2023	18	
21	21	2023	19	
22	21	2023	20	
23	21	2023	21	
24	21	2023	22	
25	21	2023	23	
26	21	2023	24	
27	21	2023	25	
28	21	2023	26	
29	21	2023	27	
30	21	2023	28	
31	21	2023	29	
32	21	2023	30	

sourceTypeAgeDistribution

Age Distribution: Guidance (1)

- Section 4.4 of MOVES Technical Guidance
- Critical input: emissions are sensitive to age and age distributions vary considerably by locality
- Using local age distribution data are therefore recommended
  - Can be based on vehicle registration or I/M data, for instance
- Needed for 31 age groups (0-29 years, 30 years and older), by source type
  - Age is based on model year relative to calendar year

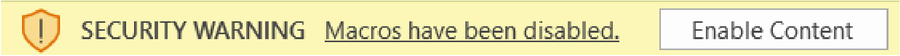
Age Distribution: Guidance (2)

- If data not available for individual source types, can use data for similar HPMS classes
- Use default data for source types where local data are not representative of the operating fleet
  - This is typically the case for single unit and combination long-haul trucks
  - Default age distributions available through MOVES CDM
- When modeling a future year, the Age Distribution Projection Tool can be used to project base year age distributions into the future
  - Available on EPA MOVES tools website
  - Also available in the Tools folder of the training materials folder for your convenience

Age Distribution: Exercise Overview

- Let's enter age distribution data into the CDM for our County Scale exercise
- In our scenario, we have obtained age distribution data for passenger cars from local registration data for calendar year 2020
  - It is saved in the Module 3 - County Scale Exercise folder as *registration_age_distributions.xlsx*
- We need to project the age distribution forward to 2023 for this analysis using the Age Distribution Projection Tool
- Then we will import the results into MOVES

Age Distribution: Exercise Instructions

- Instructions for projecting and importing age distribution data into the CDM:
  1. Open the data file *Module 3 - County Scale Exercise\registration_age_distributions.xlsx*
  2. Open *Tools\moves4-age-distribution-projection-tool-2023-08.xltm*
     If prompted, enable macros: 

  3. Enter 2023 as the analysis year in the tool
  4. Copy and paste the input age distributions into the tool
  5. Click “Run”
  6. Review results and use Save As… to save the results in a macro-free spreadsheet (.xlsx)
  7. In the CDM on the Age Distribution tab, click “Browse…”
  8. Locate the saved file and click “Open”
  9. Select SourceTypeAgeDistribution (the tab that contains the results) and click “OK”
  10. Click “Import”
  11. Check for errors

Using the Age Distribution Projection Tool

Contents of registration_age_distributions.xlsx

	A	B	C	D
1	sourceTypeID	yearID	ageID	ageFraction
2	21	2020	0	0.038316932
3	21	2020	1	0.0397437
4	21	2020	2	0.047708486
5	21	2020	3	0.057688504
6	21	2020	4	0.049109916
7	21	2020	5	0.049869529
8	21	2020	6	0.055617877
9	21	2020	7	0.057369505
10	21	2020	8	0.053481666
11	21	2020	9	0.046301325
12	21	2020	10	0.052811195
13	21	2020	11	0.049172315
14	21	2020	12	0.055406484
15	21	2020	13	0.050884467
16	21	2020	14	0.043032382
17	21	2020	15	0.036593188
18	21	2020	16	0.033343347
19	21	2020	17	0.032017687
20	21	2020	18	0.027779012
21	21	2020	19	0.020313419

source ...

moves4-age-distribution-projection-tool-2023-08.xltm

ollow the numbered steps below and make your selection or input data into the black outlined boxes.

analysis year: 2023 1

2) Enter a base year age distribution by source type below (max 403 rows):

npleted step 2, click "Start"

Start 3

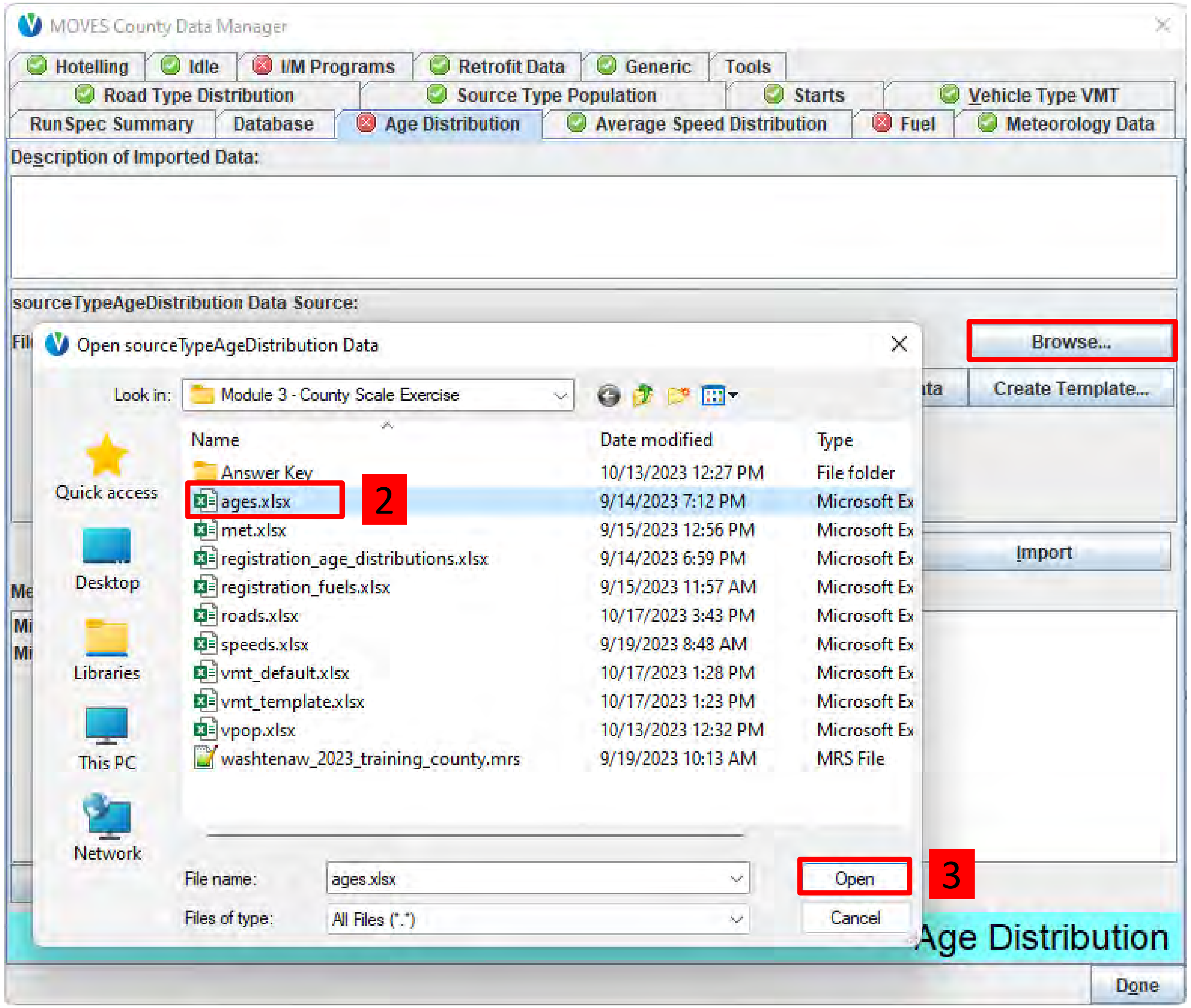
Reset

2. Copy / Paste

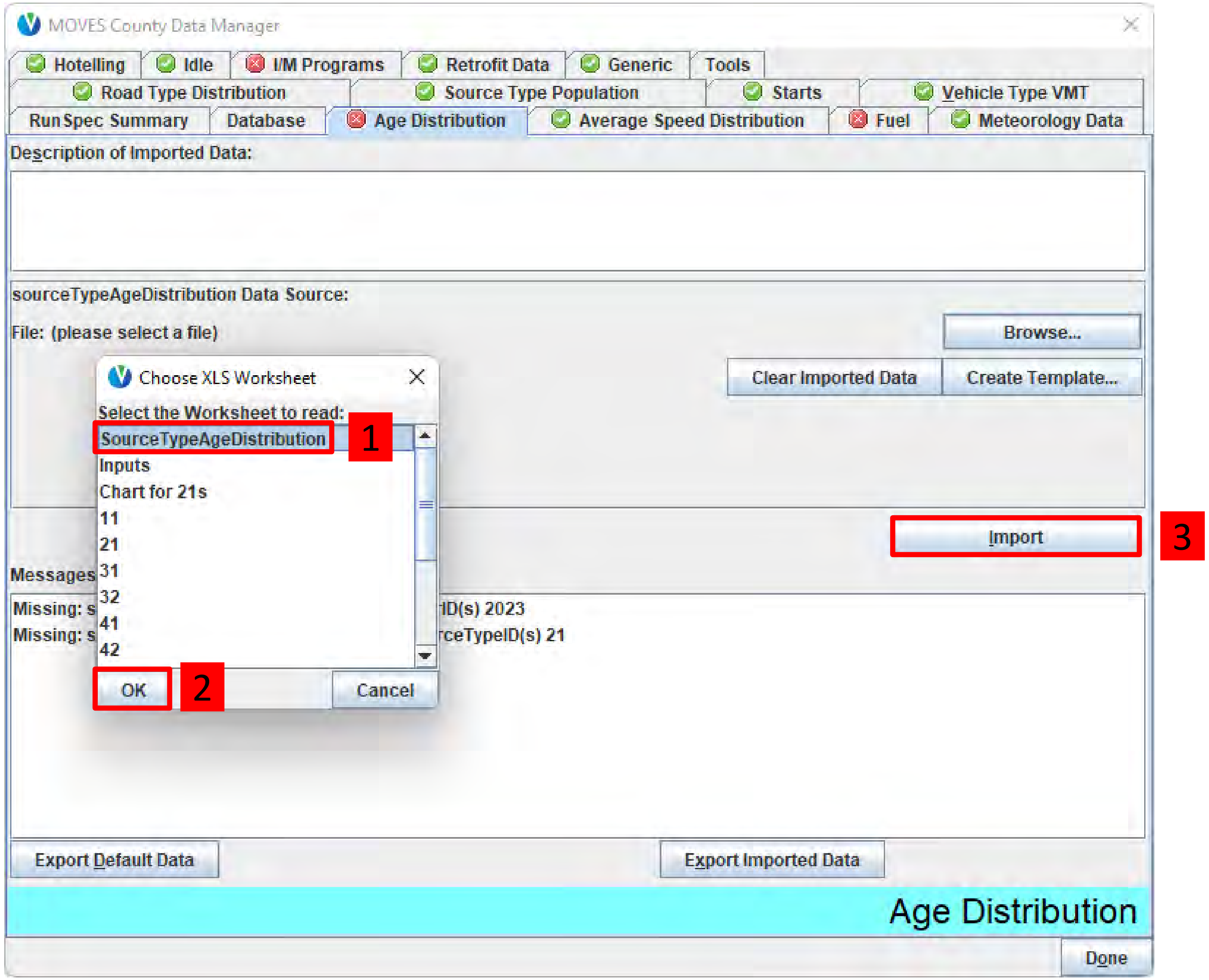
sourceTypeID	yearID	ageID	ageFraction
21	2020	0	0.038316932
21	2020	1	0.0397437
21	2020	2	0.047708486
21	2020	3	0.057688504
21	2020	4	0.049109916
21	2020	5	0.049869529
21	2020	6	0.055617877
21	2020	7	0.057369505
21	2020	8	0.053481666
21	2020	9	0.046301325
21	2020	10	0.052811195
21	2020	11	0.049172315
21	2020	12	0.055406484
21	2020	13	0.050884467
21	2020	14	0.043032382
21	2020	15	0.036593188
21	2020	16	0.033343347

4: Use Save As… to save as ages.xlsx, and click “Yes” when it prompts you to save a macro-free version of the spreadsheet

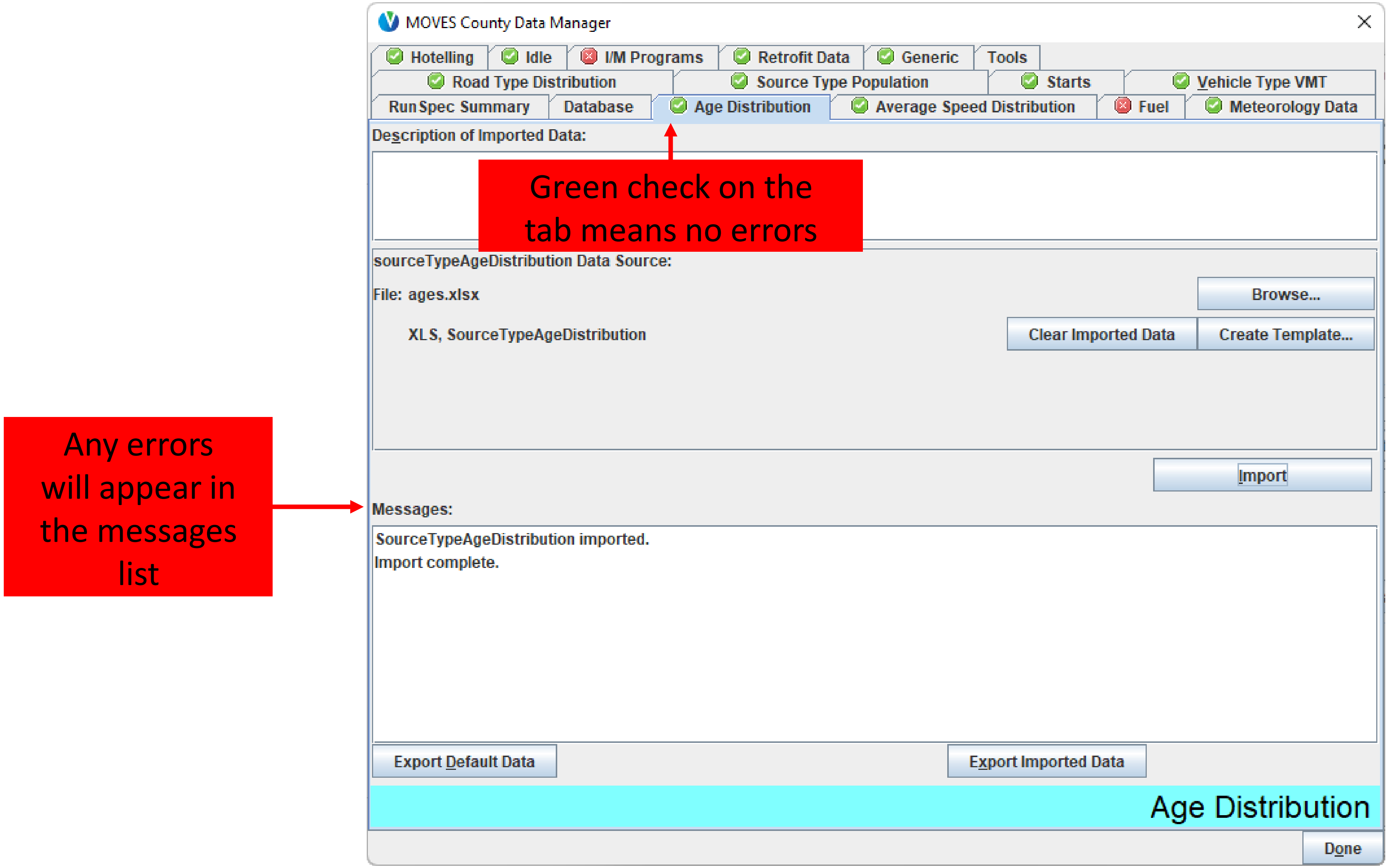
Importing the Age Distribution (1)



Importing the Age Distribution (2)



Check for Age Distribution Errors



Fuel Tab

Fuel

- The Fuel tab contains four data tables:
  - FuelSupply
  - FuelFormulation
  - FuelUsageFraction
  - AVFT
- Data must be provided for each table
  - Default data are available for each
- Tools available on this tab:
  - AVFT Tool, used to develop the AVFT input from local registration data
  - Fuels Wizard, used to modify fuel formulation parameters for gasoline and gasoline/ethanol blends

Fuel: Fuel Supply

- Fuel Supply contains the monthly market share for each fuel formulation
  - FuelRegionID is automatically selected based on the county being modeled
  - FuelYearID and MonthGroupID are automatically selected based on the time spans in the run
  - FuelFormulationID is defined in the FuelFormulation table
    - Market share must sum to 1 for each fuel type
    - Some fuel types have only one fuel formulation, and therefore have a market share of 1
    - Some fuel types have multiple fuel formulations, which have market shares that sum to 1 within that fuel type

	A	B	C	D	E	F	
1	fuelRegionID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV	
2	270000000	2023	7	90	1	0.5	Electricity
3	270000000	2023	7	9114	0.9835	0.5	Gasoline (Sums to 1)
4	270000000	2023	7	9414	0.0165	0.5	Gasoline (Sums to 1)
5	270000000	2023	7	25003	1	0.5	Diesel
6	270000000	2023	7	27002	1	0.5	E-85

FuelSupply | FuelFormulation | ...

Fuel: Fuel Supply Guidance

- Section 4.8.1 of MOVES Technical Guidance
- In general, rely on default county-level information, but review the default data
- MOVES includes two ethanol blend levels for most calendar years: E-10 and E-85
- E-0 and E-15 formulations are included in each region's fuel supply, but set to a default market share of 0
- If local data indicate that E-0 or E-15 are sold in the area, you should apportion market share to these fuels via the Fuel Supply table
- Gasoline with other ethanol volumes below E-15 can be modeled by selecting an existing fuel with the nearest ethanol volume and using the Fuels Wizard to set the ethanol volume to the desired level
  - MOVES should not be used to model gasoline fuels with ethanol concentrations above 15%, other than E-85

Fuel: Fuel Formulation

- Fuel Formulation defines important fuel parameters for all fuels in the Fuel Supply, as well as other available fuels
  - Fuel formulations are assigned a “fuel sub type”. Use the FuelSubType decoding table to look up the associated fuelTypeID for each fuel formulation
  - New FuelFormulationIDs cannot be created, however properties can be changed for existing formulations. Use the Fuels Wizard if changes are needed for gasoline fuels
  - Consult MOVES Technical Guidance for information about the requirements for populating each field

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	fuelFormulationID	fuelSubtypeID	RVP	sulfurLevel	ETOHVolume	MTBEVolume	ETBEVolume	TAMEVolume	aromaticContent	olefinContent	benzeneContent	e200	e300
2	10	10	6.9	30	0	0	0	0	26.1	5.6	1	41.09	83.0
3	20	20	0	11	0	0	0	0	0	0	0	0	[illegible]
4	50	51	7.7	11	85	0	0	0	0	0	0	999	99
5	90	90	0	0	0	0	0	0	0	0	0	0	[illegible]
6	96	10	8.7	338	0	0	0	0	26.4	11.9	1.64	50	8
7	97	10	6.6	150	0	0	0	0	24	11	0.8	52	8
8	98	12	8.8	30	10	0	0	0	25.77	8.44	0.65	47.61	84.8

FuelSupply | **FuelFormulation** | FuelUsageFraction | avft | County | EngineT ...

Fuel: Fuel Formulation Guidance (1)

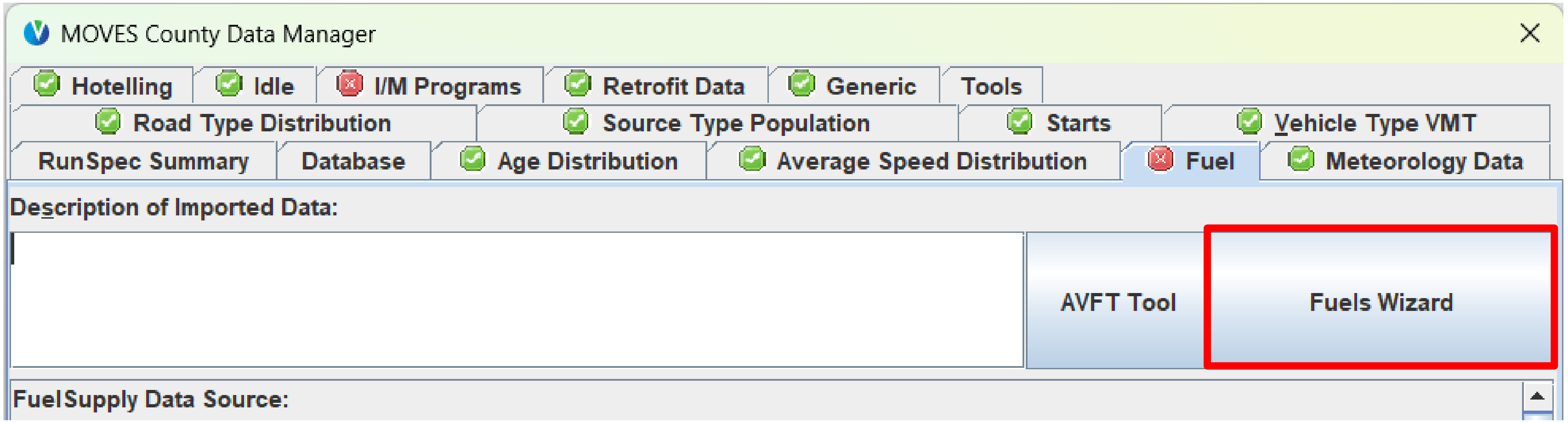
- Section 4.8.1 of MOVES Technical Guidance
- In general, rely on default county-level information
- However, you should review the default data and only make change where:
  - Local fuel requirements have changed, or
  - Precise local volumetric fuel property information is available
    - In this case, use default fuel properties unless a full local fuel property study exists
    - Because fuel properties are quite variable, single or yearly station samples are not adequate for substitution
  - If a full local fuel property study exists, the recommended approach is to modify existing fuel formulations and assign each the appropriate market share

Fuel: Fuel Formulation Guidance (2)

- Important: Always review values for Reid Vapor Pressure (RVP)
  - In some cases, the 1 pound per square inch (psi) ethanol waiver was not taken into account in the default database; in other years, the RVP was interpolated in the default database
  - Therefore, assumptions in the default database may need correcting
  - The RVP should be set to the regulatory limit applicable in the area, making sure RVP reflects whether the 1 psi ethanol waiver is present for 10% ethanol blends
- More details on Federal gasoline regulations are available at: https://www.epa.gov/gasoline-standards/federal-gasoline-regulations
- When adjusting any individual fuel property for gasoline, use the Fuels Wizard instead of modifying the data in Excel (access the Fuels Wizard in the Fuels tab of the CDM)
  - Appropriately adjusts other fuel properties based on known fuel properties (e.g., RVP)

Fuel Tools: Fuels Wizard

- After fuel formulation data are imported, the Fuels Wizard can be used to adjust a gasoline formulation based on a change in a specific property, such as RVP
  - Do not use for E-85, diesel, CNG, or electric fuel types
- Since changing one parameter will affect other parameters due to refinery configuration required to create the fuel, the Fuels Wizard calculates the appropriate fuel parameters consistent with EPA's refinery modeling

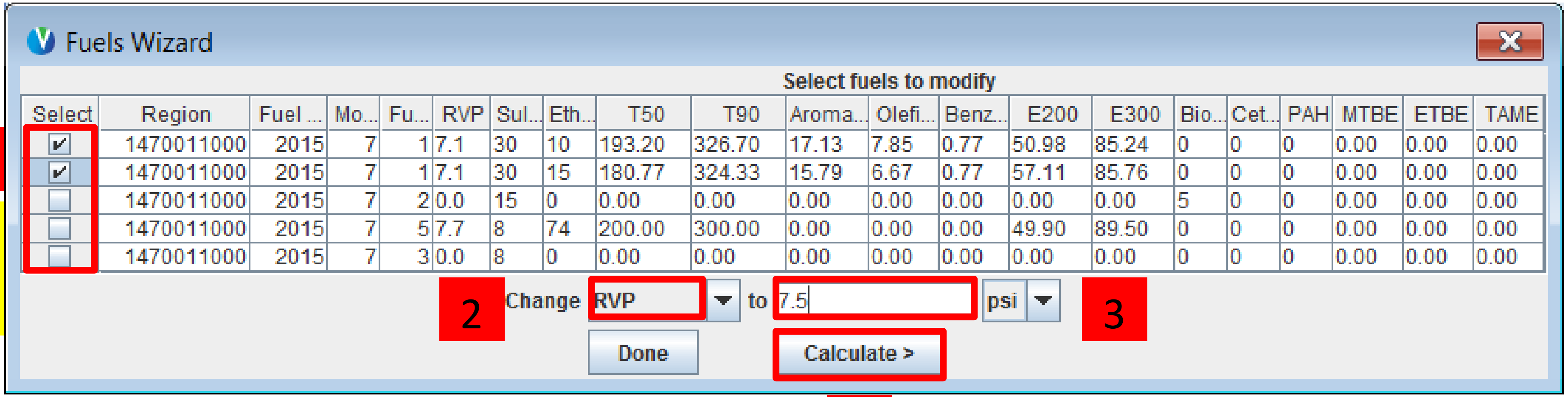


Access via the CDM

Fuels Wizard Example: Change the RVP of Gasoline

1

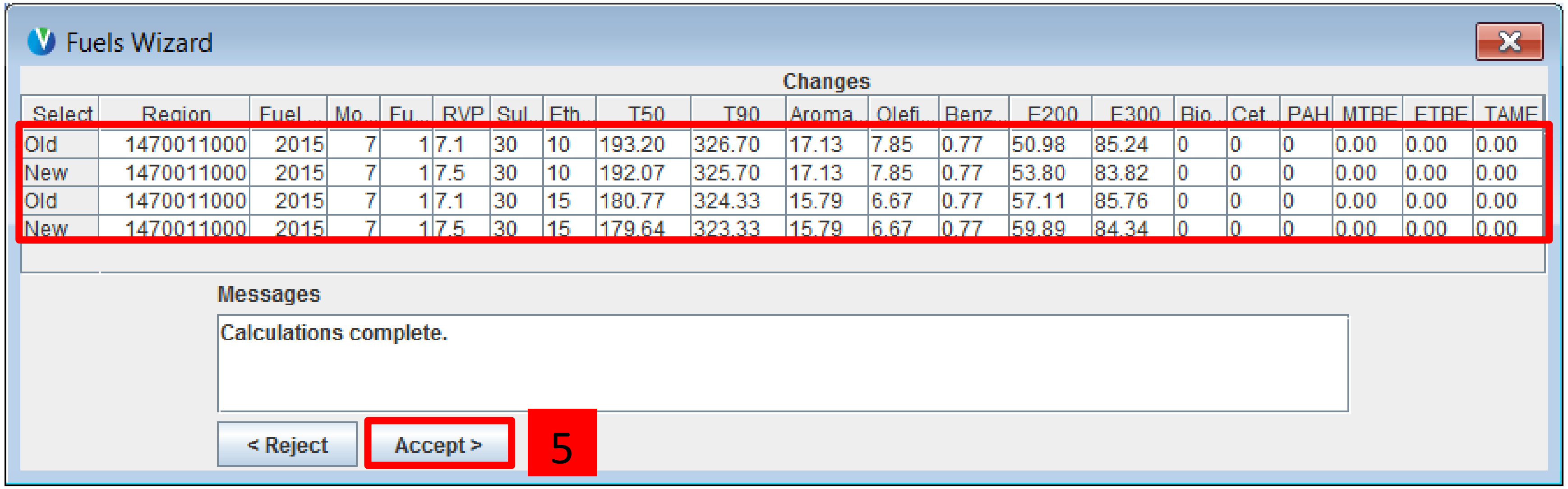
Both gasoline fuels (fuelTypeID 1) are selected



2

3

4



5

Fuel: Fuel Usage Fraction

- FuelUsageFraction specifies the fuel mix that E-85 capable vehicles actually use
  - Also known as FFVs, these vehicles are indicated with sourceBinFuelTypeID 5
  - The fuel actually used is indicated by fuelSupplyFuelTypeID
- The table below shows that 98.2% of fuel used by E-85 capable vehicles is gasoline and 1.8% is E-85
  - Value of 1 is required for other sourceBinFuelTypeIDs (gas, diesel, CNG, and electric vehicle types)

Vehicle's fuel type:

- Gasoline only
- Diesel only
- E-85 capable
- EV

	A	B	C	D	E	F
1	countyID	fuelYearID	modelYearGroupID	sourceBinFuelTypeID	fuelSupplyFuelTypeID	usageFraction
2	26161	2023	0	1	1	1
3	26161	2023	0	2	2	1
4	26161	2023	0	5	1	0.982134
5	26161	2023	0	5	5	0.017866
6	26161	2023	0	9	9	1
7						
8						

FuelUsageFraction | avft | County

Fuel actually used:

- Gasoline
- Diesel
- E-85
- Electricity

Fuel: Fuel Usage Fraction Guidance

- Section 4.8.2 of MOVES Technical Guidance
- MOVES contains the same default estimate of E-85 fuel usage for each county
  - This represents the national average, which is 1.8% in 2010 and later
- If local data are available and indicate different E-85 usage, specify the fraction of:
  - Gasoline used (fuelSupplyFuelTypeID 1) and
  - E-85 used (fuelSupplyFuelTypeID 5)

  in E-85 capable vehicles (sourceBinFuelTypeID 5)

Example scenario:	Usage fraction:
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

Fuel: AVFT (1)

- The Alternate Vehicle Fuel and Technology (AVFT) input defines the split between gasoline, diesel, CNG, E-85, and electric vehicles, for each source type and model year
  - All supported source type / fuel type combinations must be present in this table
  - Electric vehicles have fuelTypeID 9 and are further differentiated by the engTechID field:
    - Battery Electric Vehicles (BEV) are engTechID 30
    - Fuel Cell Electric Vehicles (FCEV) are engTech 40 – currently only supported for heavy-duty
    - Important: Hybrid Electric and Plug-in Hybrid Electric Vehicles (HEV and PHEV) are NOT included here. They are modeled as internal combustion vehicles (i.e., gasoline or diesel), consistent with EPA regulations for these vehicles
- MOVES requires these distributions for all model years in the run
  - All model years between the analysis year (calendar year) and 30 years prior
  - Additional model years can be included without issue

Fuel: AVFT (2)

- The fuel type distribution is provided in the fuelEngFraction column by fuelTypeID and engTechID for each sourceTypeID and modelYearID
- Therefore, the fuelEngFraction column must sum to 1 for each combination of sourceTypeID and modelYearID

	A	B	C	D	E
1	sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction
118	21	2019	1	1	0.942557
119	21	2019	2	1	0
120	21	2019	5	1	0.01274
121	21	2019	9	30	0.044703
122	21	2020	1	1	0.940982
123	21	2020	2	1	0
124	21	2020	5	1	0.002758
125	21	2020	9	30	0.05626

Sums to 1 for MY2019 passenger cars

AVFT | EngineTech | FuelType | Sou ...

Fuel: AVFT Guidance (1)

- Section 4.8.3 of MOVES Technical Guidance
- The use of local information is important for this table:
  - Fractions of fully electric vehicles are highly variable by county
  - Default AVFT information represents the nation as a whole and therefore will not reflect the fleet in any particular county
- Where available, use local data (e.g., vehicle registration data or large fleet owners)
- If local data are not available, you can use AVFT information that EPA has compiled as inputs for the National Emissions Inventory (NEI)
  - 2020 NEI inputs are available here: https://gaftp.epa.gov/air/nei/2020/doc/supporting_data/onroad/
  - To use, download and unzip the relevant state's file, locate the county of interest, and save the AVFT input file (this will be in the format of a MariaDB database file; see Module 4 for how to convert this to Excel format)

Fuel: AVFT Guidance (2)

- When developing this input, use registration data only for model years with complete data
  - Partial model years may not be representative of the entire model year cohort
- When projecting future fuel type distributions, the last (i.e., most recent) complete model year should be used as the baseline for future year projections
  - For example, registration data pulled on July 1, 2023, would include some MY2023 and MY2024 vehicles
  - Since MY2023 and MY2024 will continue to be sold after this date, these data only contain a partial view of these vehicles
  - However, MY2022 vehicle sales were finished by this date, so 2022 would be the **last complete model year** in this example.

Fuel Tools: AVFT Tool (1)

- This tool is useful for:
  - Projecting future fuel type distributions from local historic data (typically vehicle registration data) and projected national trends
  - Gap-filling local historic fuel type distribution data
  - Combining local data for some source types with default data for other source types
- Access via the Fuel tab in the CDB or the Tools dropdown menu in the main GUI
- Local historic data should be formatted like the AVFT table to use as input for the AVFT Tool
- The Technical Guidance Section 4.8.3.1 and the in-GUI help document are useful resources to have open when using the tool

Fuel Tools: AVFT Tool (2)

- Since MOVES models vehicles of various ages in each run, from brand new to 30+ years, the AVFT table needs to include information for all of these vehicle model years
  - The AVFT tool will gap-fill information for model years prior to the last complete model year, as necessary
- Gap-filling methods:
  - If there are gaps in the input data, the tool will fill them to avoid getting errors when using the results of the tool
  - Two methods available: “Fill with 0s” and “Use Defaults and Renormalize”
  - If there are no gaps in the input data, neither option will change the inputs
  - <u>Fill with 0s</u>: Provides all missing key combinations with a value of 0
    - Use this method when you have data for all model years and for all fuel types that exist in the county
    - For example, if rows for CNG do not exist because these vehicles don’t exist locally
    - If any model years are completely missing, this option will not help
      - Either manually enter a reasonable distribution for those model years or use the Use Defaults and Renormalize option

Fuel Tools: AVFT Tool (3)

- Gap-filling methods:
  - Use defaults and renormalize: Fills any missing key combinations with national default values and proportionally reduces user-provided values so that the distributions sum to 1 for each model year
    - Use this method for source types where local data are not available and/or not applicable, such as for long-haul trucks
    - Also use this method when the local data are known to be incomplete
      - E.g., if missing model years or if no rows for HD EV because the data were compiled using the MOVES3 source type / fuel type combinations, which couldn't model them
    - Before using this method, ensure all known 0s are present in your input data
      - E.g., if you know that no CNG is used locally, ensure the input data contain 0s for CNG
    - To ensure national defaults are used for long-haul trucks (sourceTypeIDs 53 and 62), do not include these source types in the input file, and select this method for them

Fuel Tools: AVFT Tool (4)

- Gap-filling summary:

AVFT Gap-Filling Method	Default Recommended Use	Considerations
Fill with 0s	All source types except long-haul vehicles	Use when data includes all model years and data covers all fuel types that exist locally
Use defaults and renormalize	Single-unit long haul trucks (53s) Combination long-haul trucks (62s)	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 modeled area

Fuel Tools: AVFT Tool (5)

- The analysis year (RunSpec year) may be farther in the future than the last complete model year. The AVFT table needs to include information for each of these future vehicle model years
  - The AVFT tool can be used to project AVFT for model years after the last complete model year
- Projection methods:
  - <u>Proportional</u>: Projects distributions based on proportional differences between the local and the national distributions
    - This method preserves differences between local conditions and the national average, while still accounting for expected changes in national trends
    - Use this method for source types where current EV fractions are known, but future fractions are not
  - <u>National Average</u>: Applies the national default fuel type distributions
    - Use this method for source types where local data are not available and/or not applicable, such as for long-haul source types

Fuel Tools: AVFT Tool (6)

- Projection methods (cont.):
  - Known Fractions: Incorporates user-specified fuel fractions for one or more fuel types, and projects the rest with the proportional method
    - Use this method for source types that have known future fractions
    - E.g., if the local area is subject to a ZEV program, you would provide the projected ZEV rates as the known EV fractions
  - Constant: Applies the last complete model year's distributions as-is for all projected model years
    - Use this method for source types that are not expect to have significant changes
      - For example, if a captive fleet has converted to all CNG vehicles and all future vehicles are expected to be CNG fueled as well

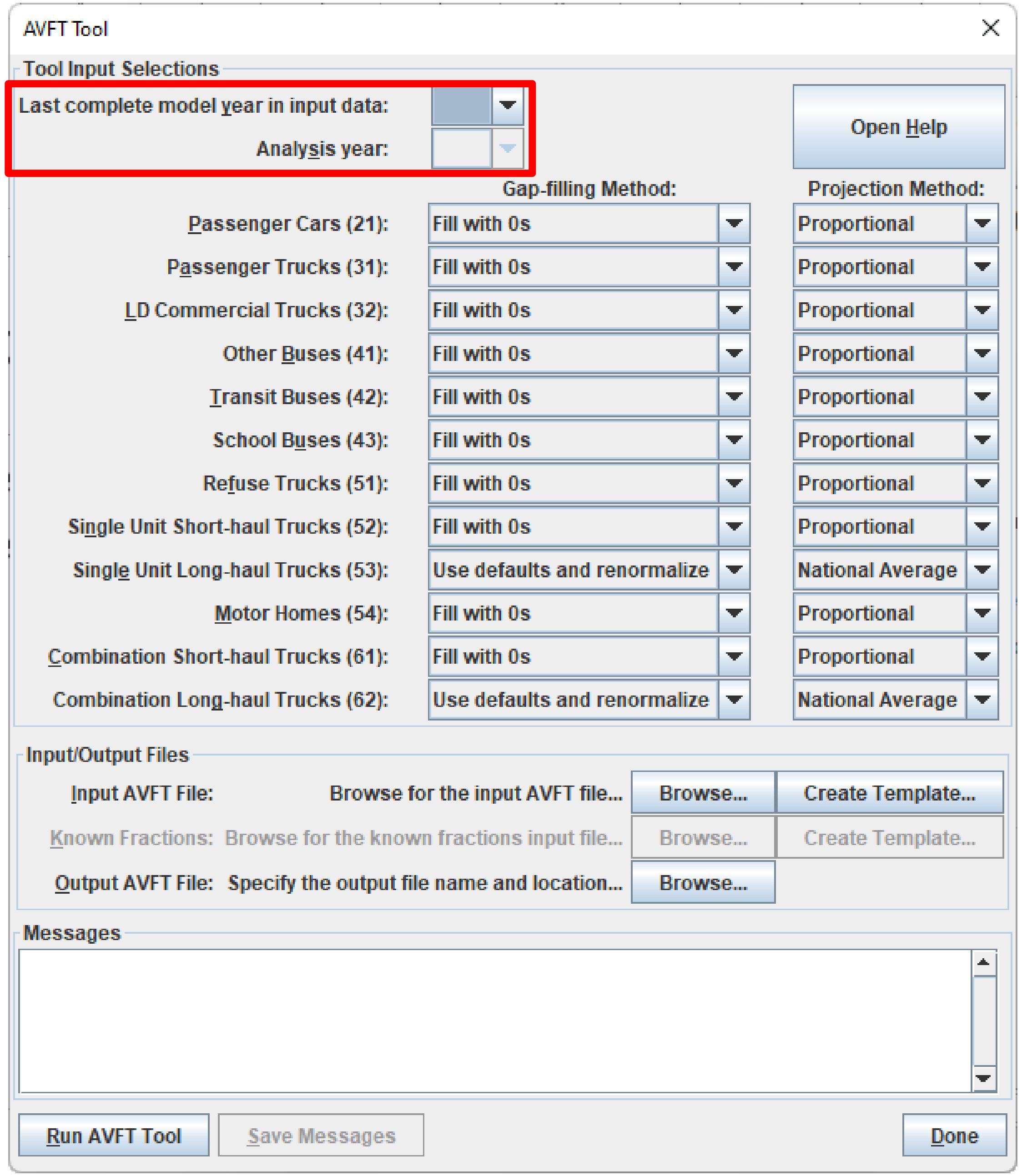
Fuel Tools: AVFT Tool (7)

- Projection methods summary:

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

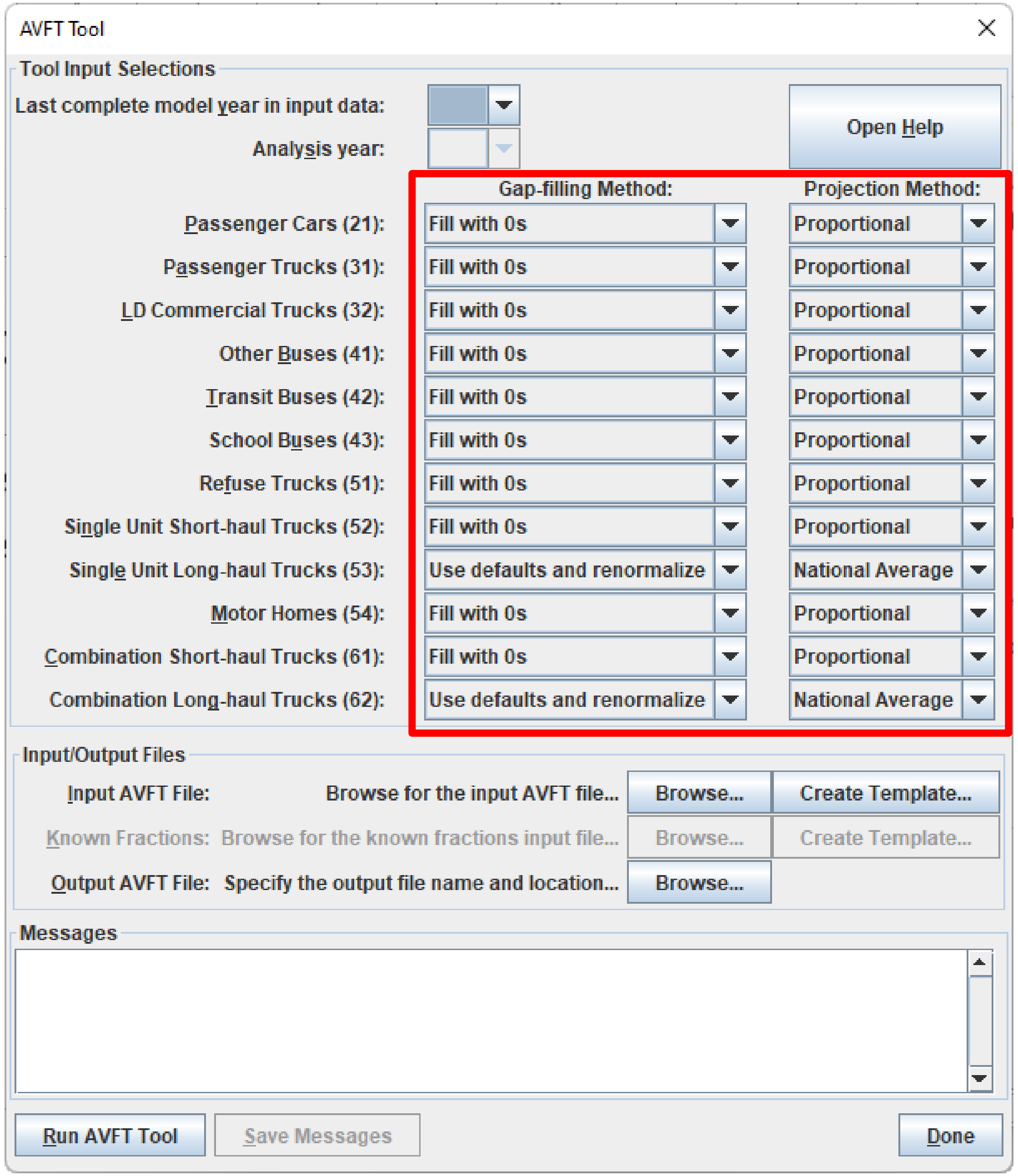
Using the AVFT Tool (1)

- The "Last complete model year in input data" is usually one year before the calendar year of the data pull (e.g., MY2022 for CY2023 data)
  - Unless data were pulled on the last day of the year, in which case, use that year
- The "Analysis year" is the year selected in the RunSpec



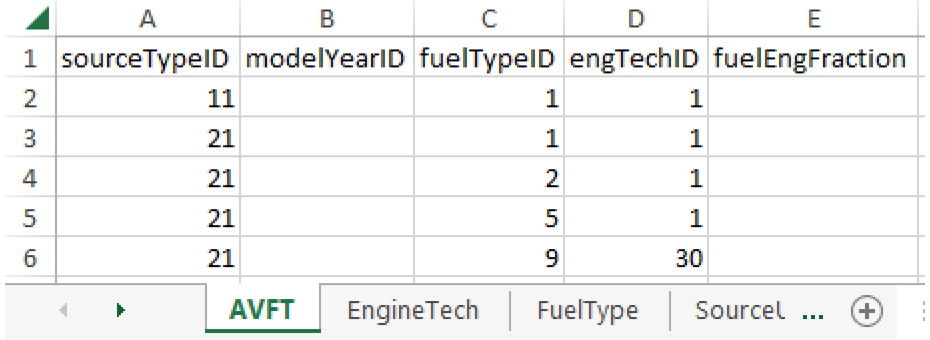
Using the AVFT Tool (2)

- For each source type, select the gap-filling method and projection method to use
  - For source types not included in your data, select "Use defaults and renormalize", or you will get error messages



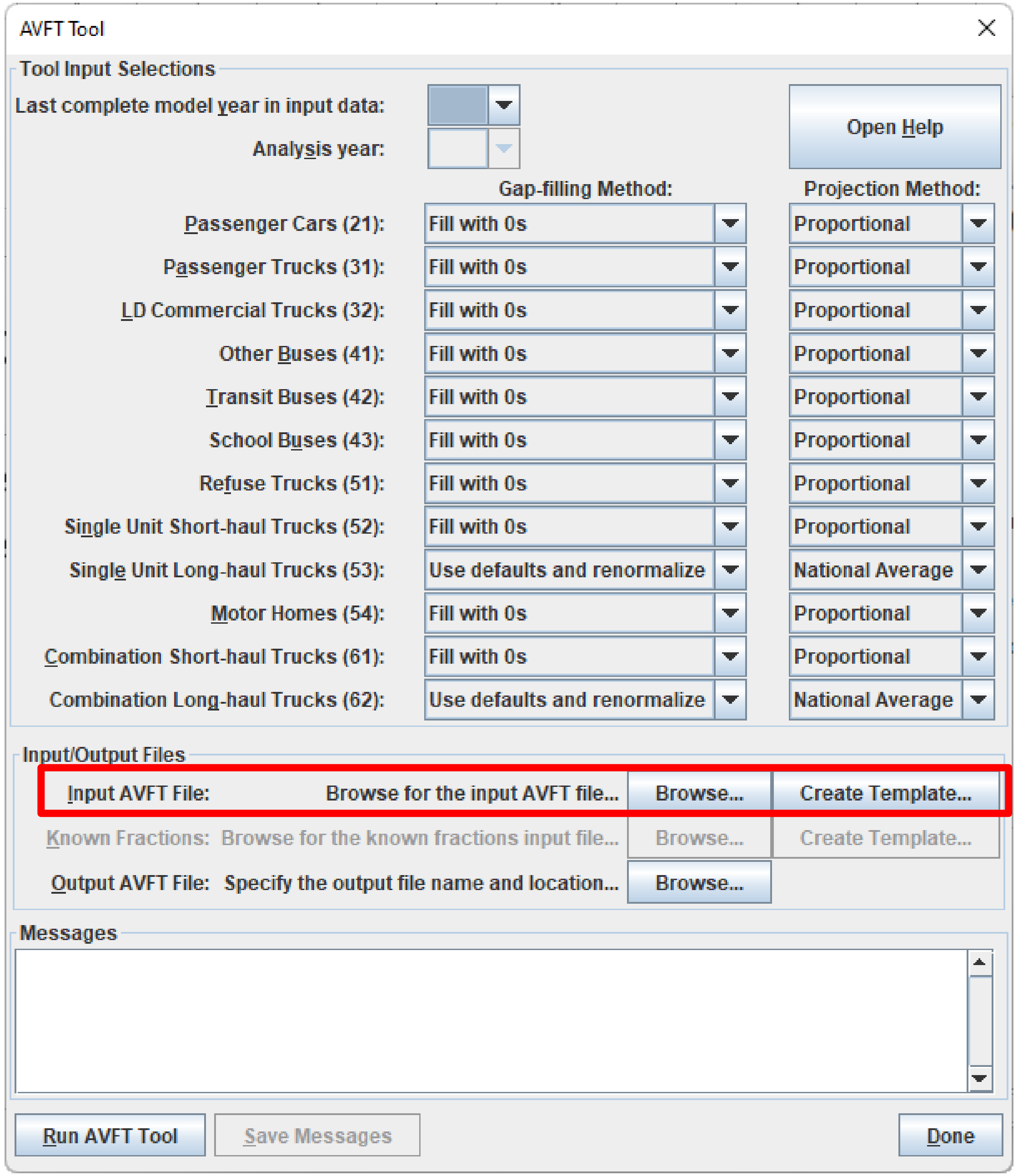
Using the AVFT Tool (4)

- Input AVFT File
  - The input data for this tool should look like a properly formatted AVFT input file
  - If you need to, you can create a template which will prepopulate all relevant source types, fuel types, and engine technology combinations. You will need to duplicate each set for each relevant model year (at least 30 years before the analysis year)



	A	B	C	D	E
1	sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction
2	11		1	1	
3	21		1	1	
4	21		2	1	
5	21		5	1	
6	21		9	30	

Use the decoding tabs if needed



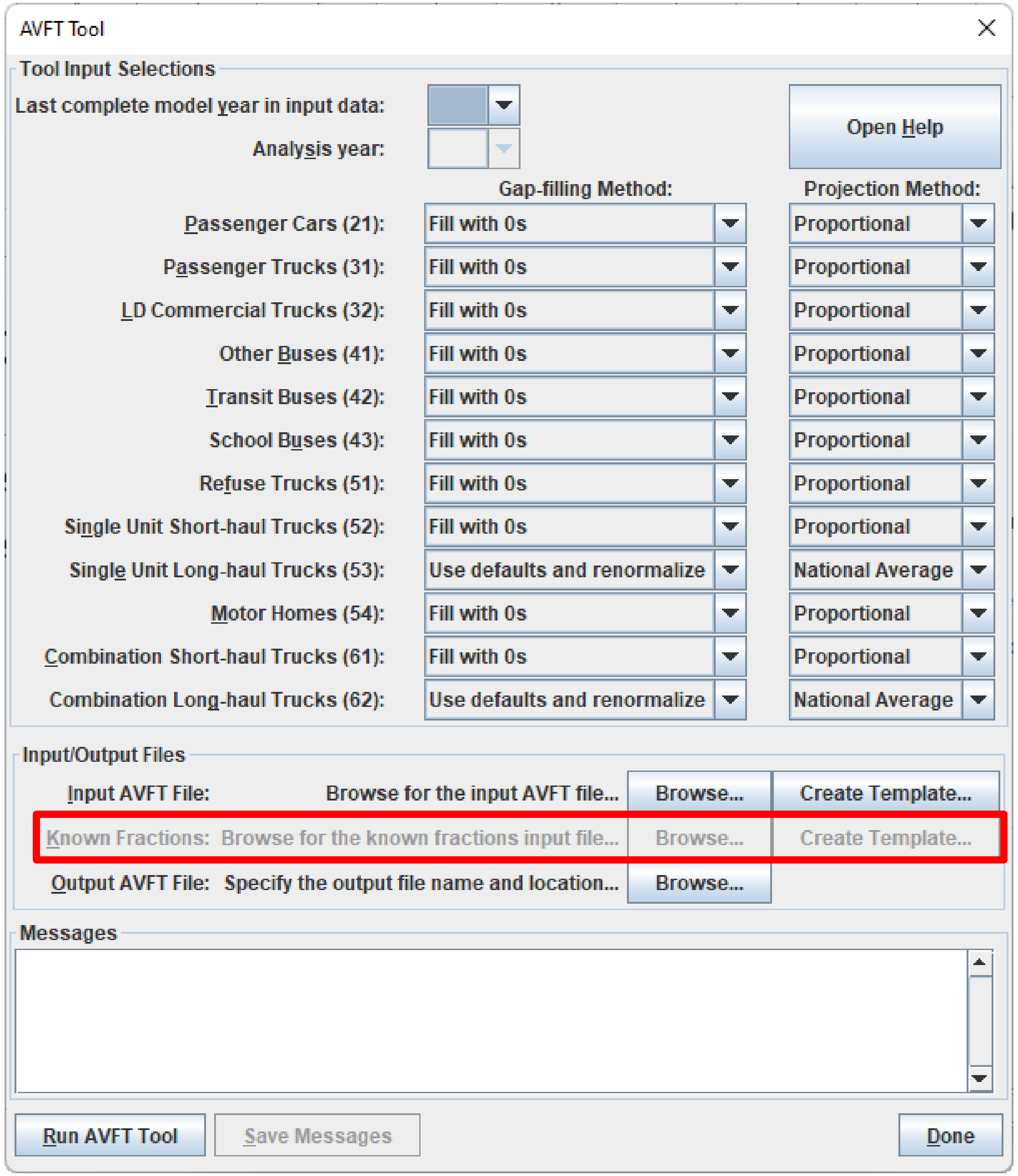
Using the AVFT Tool (5)

- Known Fractions
  - These controls are enabled if Known Fractions is a selected projection method
  - To use, create a template, then delete rows for all source types, fuel types, and engine technologies that you do not have known fractions for
  - Then, duplicate the remaining rows for all known model years, and enter the known factions in the fuelEngFraction column

	A	B	C	D	E
1	sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction
2	11		1	1	
3	21		1	1	
4	21		2	1	
5	21		5	1	
6	21		9	30	

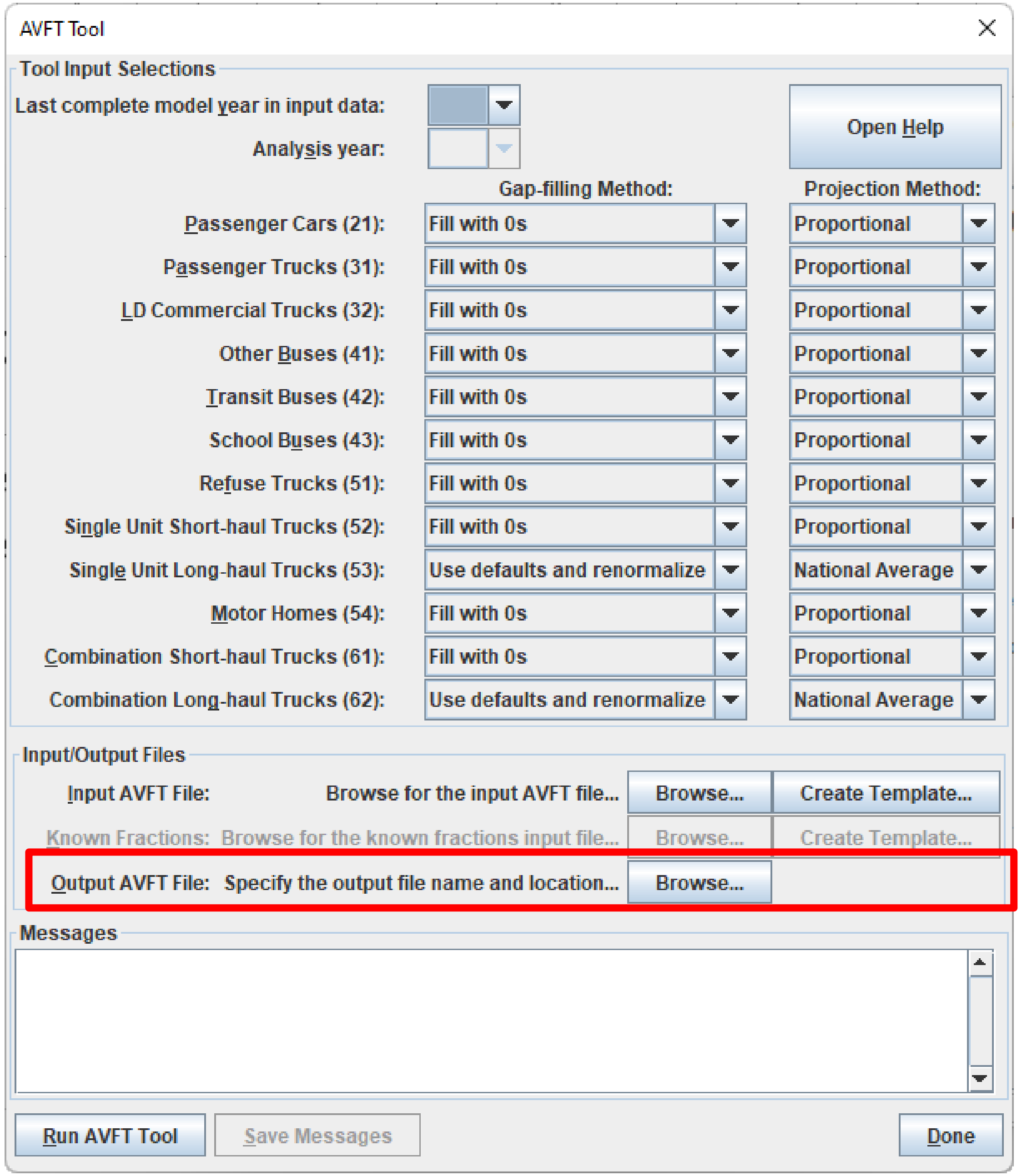
AVFT | EngineTech | FuelType | SourceT ...

Use the decoding tabs if needed



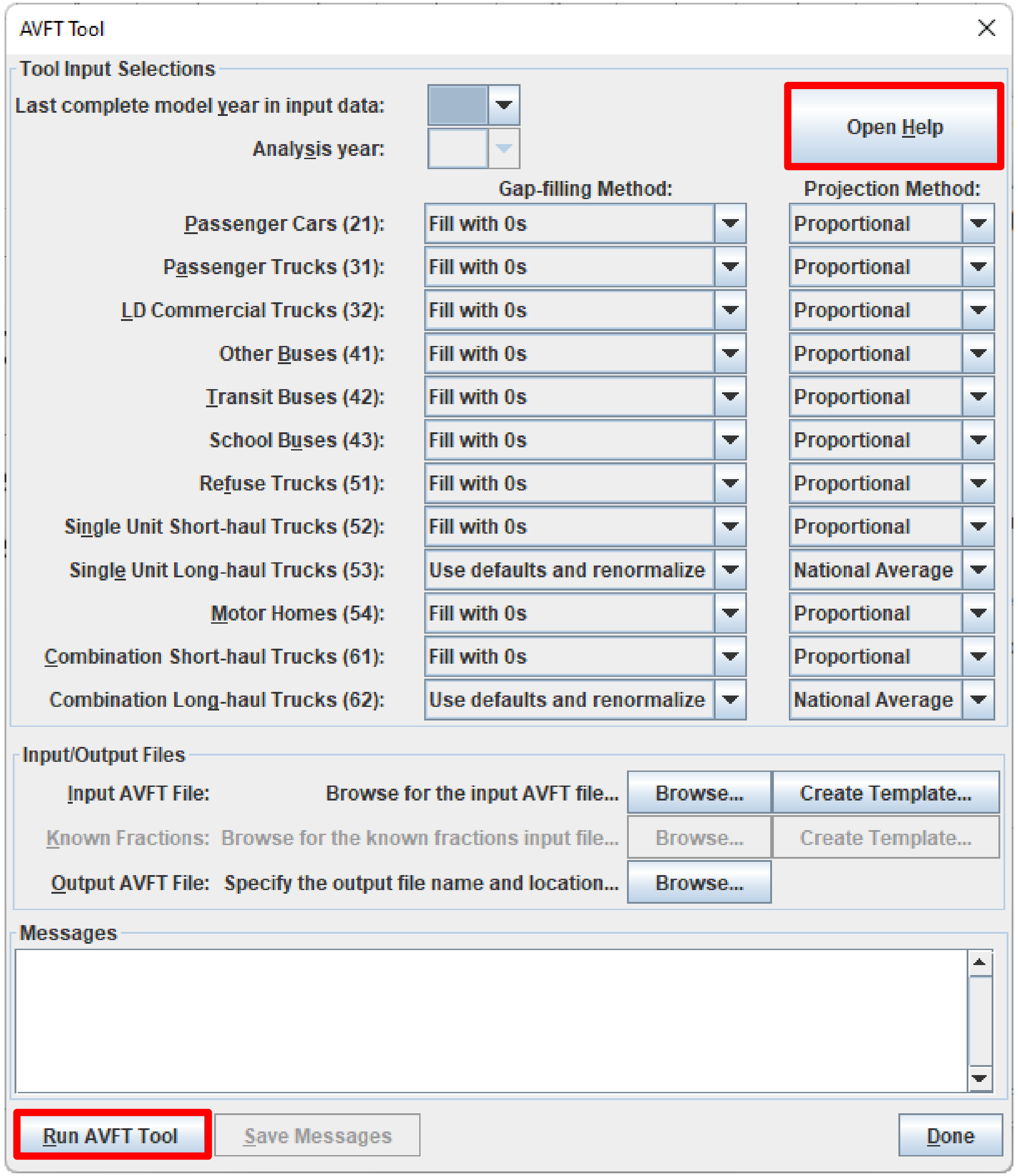
Using the AVFT Tool (6)

- The output of the AVFT Tool is an Excel file
  - Must specify .xlsx extension
- The resulting file has plots of the projected fuel type distributions
  - Requires Excel 2021 or Office 365 to view the plots
  - Review to ensure the results appear reasonable
- The file also has an AVFT tab so that you can directly import this file in the CDM



Using the AVFT Tool (7)

- Once all tool selections are made, the tool is run by clicking Run AVFT Tool
- Open Help will open a PDF help document, which describes in detail all the options in this tool



Fuel: Exercise Overview

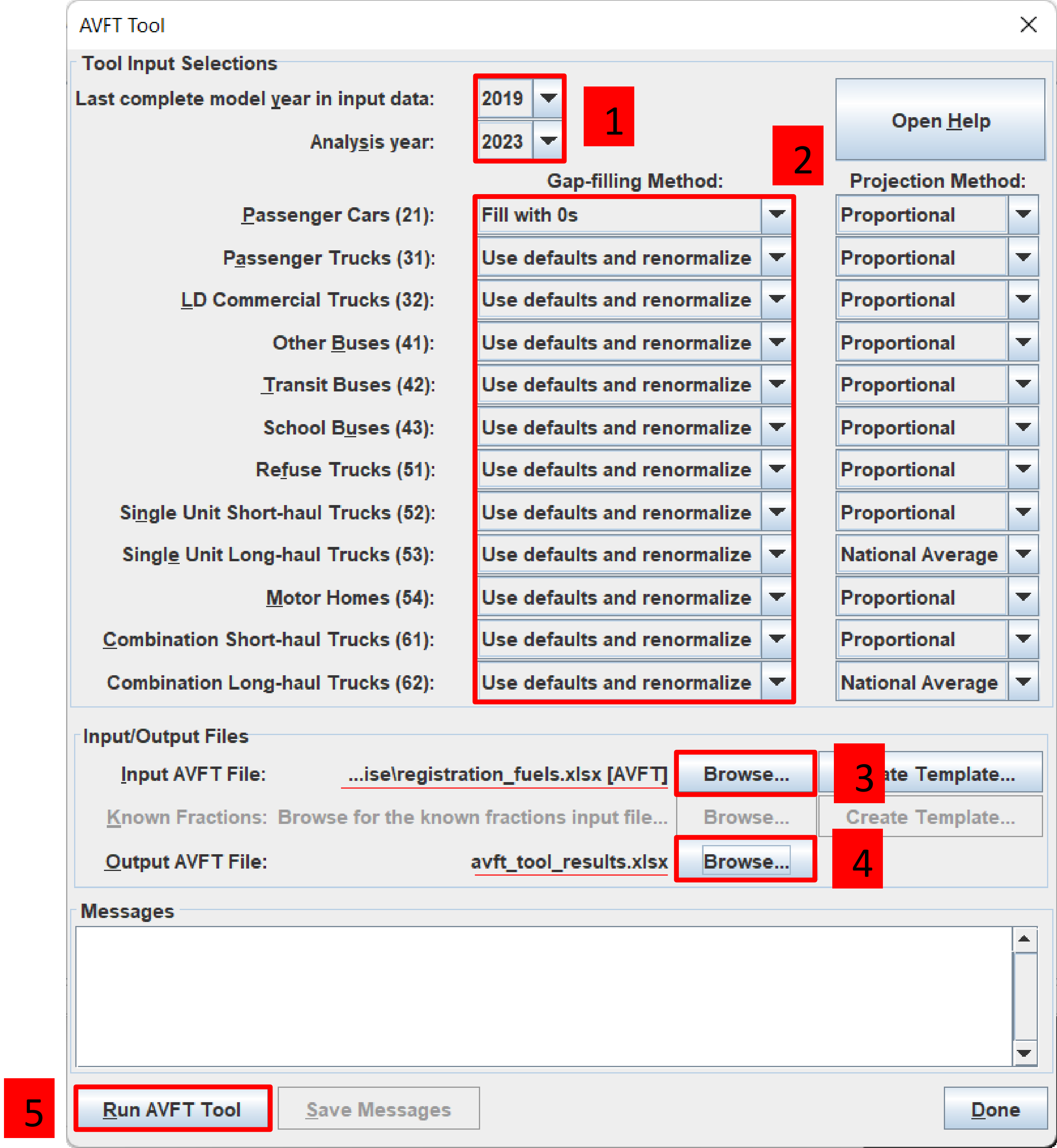
- Let's enter fuels data into the CDM for our county-level exercise
- In our scenario, we have obtained fuel type distribution data for passenger cars from local registration data for calendar year 2020
  - It is saved in the Module 3 - County Scale Exercise folder as *registration_fuels.xlsx*
- We need to project the fuel type distribution forward to 2023 for this analysis using the AVFT Tool
- We will use default fuel supply, fuel formulation, and fuel usage data

Fuel: Exercise – AVFT Tool

- Exercise instructions for the AVFT Tool:
  1. Click the AVFT Tool button on the Fuel tab of the CDM to open the tool
  2. Enter 2019 as the as the Last Complete Model Year and 2023 as the Analysis Year
  3. Keep passenger car selections at “Fill with 0s” and “Proportional”
  4. Set all other source types to “Use defaults and renormalize” because we don’t have data for them (tool will report an error otherwise)
  5. For the Input AVFT File, load the *registration_fuels.xlsx* file from the Module 3 - County Scale Exercise folder
  6. Name the Output AVFT file *avft_tool_results.xlsx*
  7. Click “Run AVFT Tool”, check for error messages, and click “Done” if none
  8. Open the output file and review the results for 21s

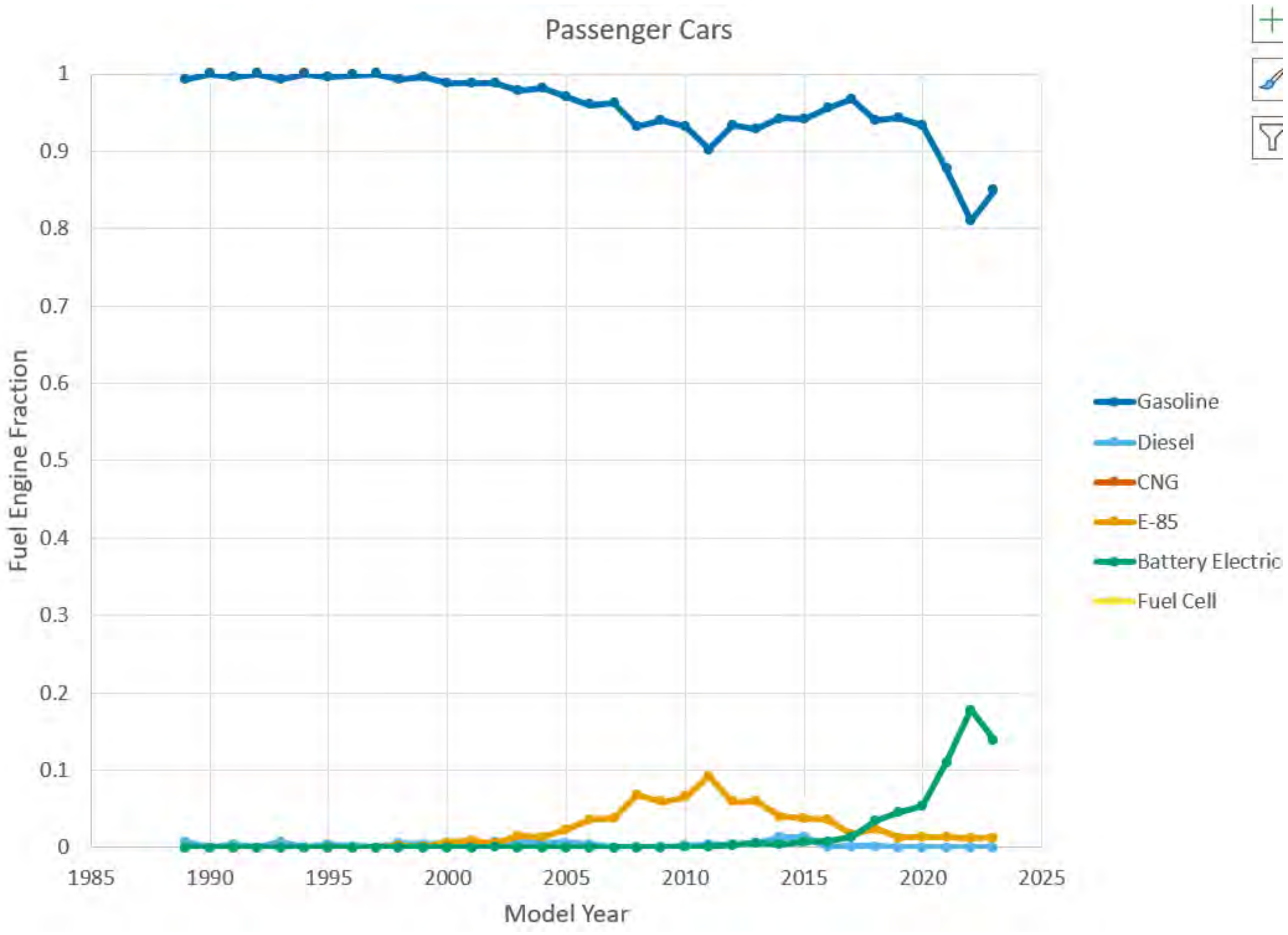
AVFT Tool Exercise (1)

- Make the selections as shown here
- After clicking "Browse" for the Input AVFT File, find the *registration_fuels.xlsx* file and then select the AVFT tab, which contains the input data
- Remember to include the .xlsx extension when naming the output file



AVFT Tool Exercise (2)

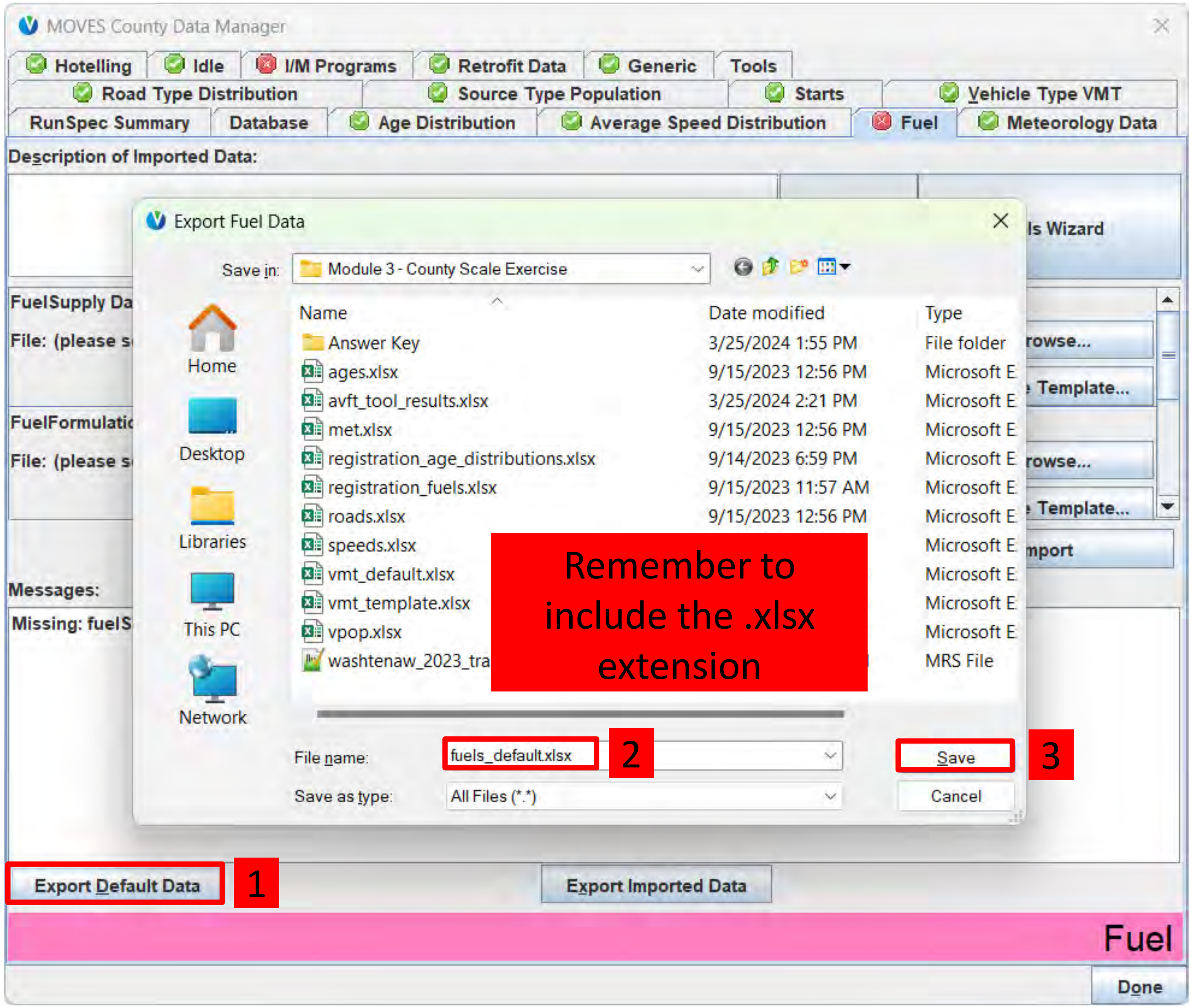
- Review the results



Fuel: Exercise – Export Defaults

- Exercise instructions for the Fuel tab in the CDM:
  1. Click “Export Default Data” and save the file as *fuels_default.xlsx*
  2. Open this file and review the default fuels data for Fuel Supply, Fuel Formulation, and Fuel Usage Fraction, then close it

Export Default Fuels Data



Review Default Fuels Data

- Best practice is to always review default data before using it
- In Windows Explorer, find the file you just created and open it
- Review the data on the Fuel Supply, Fuel Formulation, and Fuel Usage Fraction tabs. No changes are necessary
- Close when done

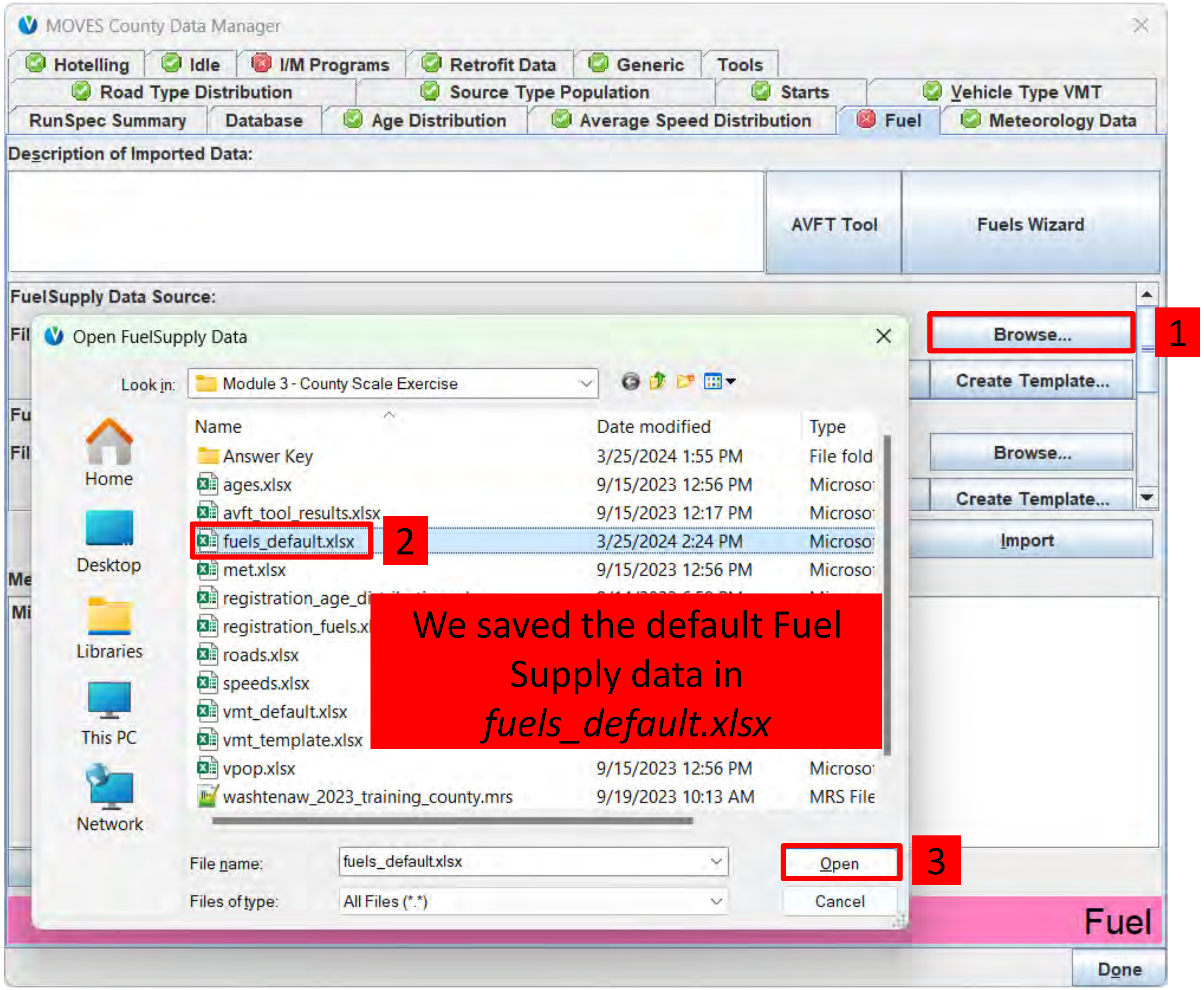
	A	B	C	D	E	F
1	fuelRegionID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
2	270000000	2023	7	90	1	0.5
3	270000000	2023	7	9114	1	0.5
4	270000000	2023	7	25003	1	0.5
5	270000000	2023	7	27002	1	0.5
6						

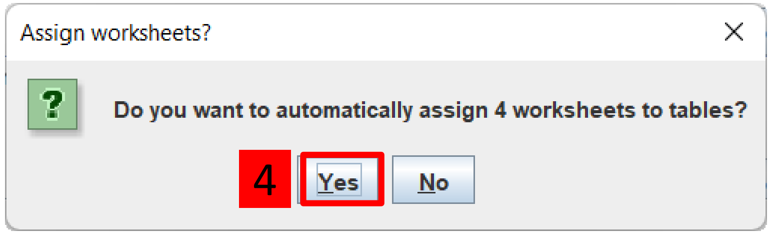
FuelSupply | FuelFormulation | ...

Fuel: Exercise – Import Data

- Exercise instructions for the Fuel tab in the CDM:
    1. In the CDM, click “Browse…” for the FuelSupply Data Source
    2. Find *fuels_default.xlsx*, and click “Open”
    3. Click “Yes” to automatically assign the worksheets to the tables
        - This saves time by automatically selecting the correct worksheet for Fuel Supply, Fuel Formulation, and Fuel Usage Fraction
        - It will also automatically assign the AVFT table from this file, which we don’t want—so we will need to manually load the AVFT table in the next step
    4. Scroll down to find the AVFT Data Source, and click its “Browse…”
    5. Find *avft_tool_results.xlsx*, click “Open”, then “Yes”
    6. Click “Import” and check for error messages

Importing the Default Fuels Data

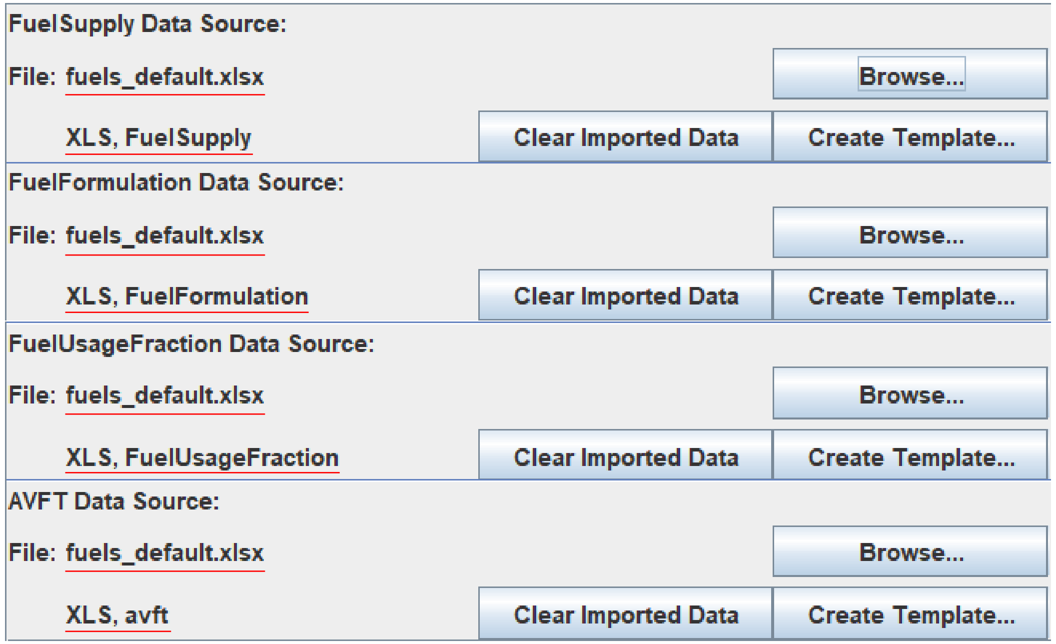




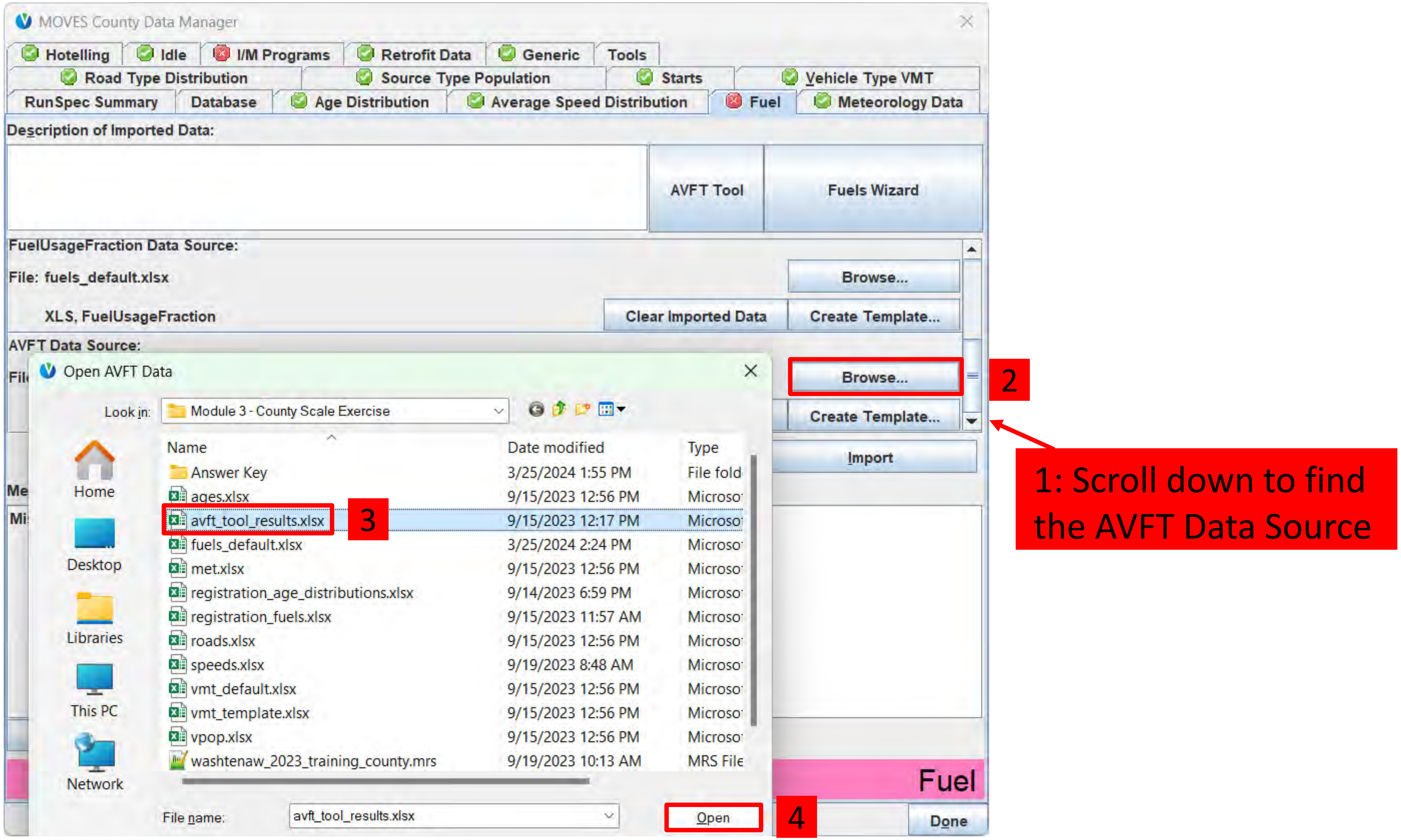
Choosing "Yes" will have MOVES automatically match tab names in the spreadsheet to "data sources" on this tab of the CDM. There are 4 data tabs in this spreadsheet. Even though we only want to load 3 of them – we are only using defaults for fuel supply, fuel formulations, and fuel usage fractions – it will save us time because we won't have to go through the "Browse/Select File/Select Tab" process for each of them.

Fuels: Automatically assigning worksheets to tables

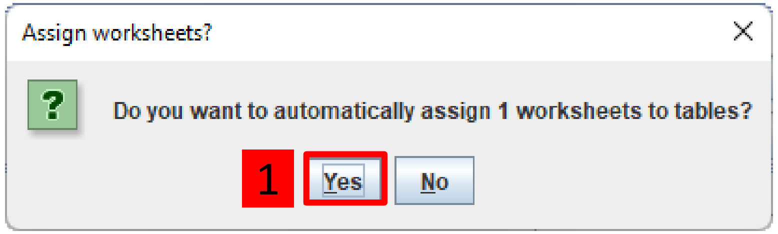
- By choosing “Yes”, MOVES automatically assigned each tab in the spreadsheet to the corresponding Data Source in the CDM fuels tab
- This is correct for the tables we wanted to load from the default data, but we do not want to use this file for the AVFT table



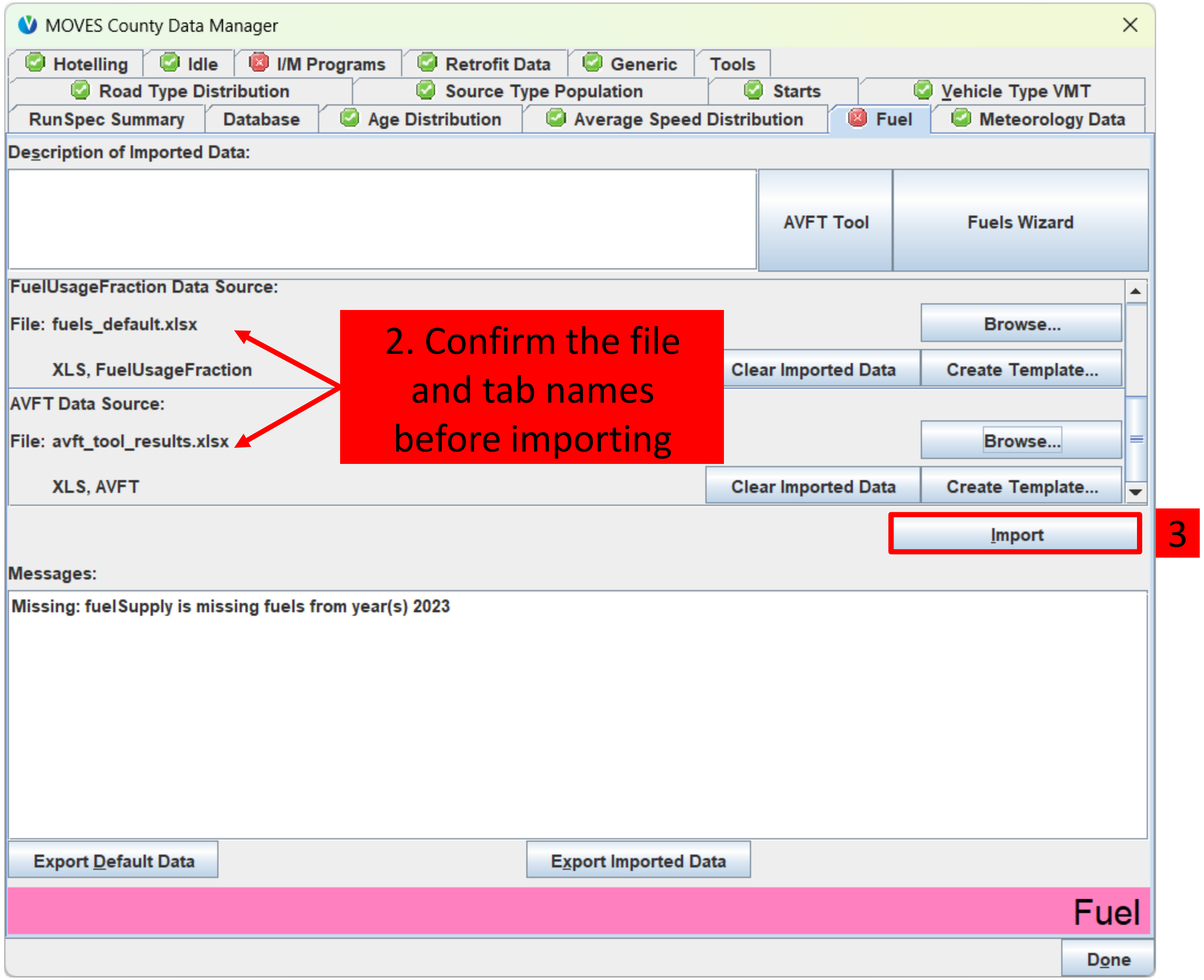
Importing the AVFT Tool Results (1)



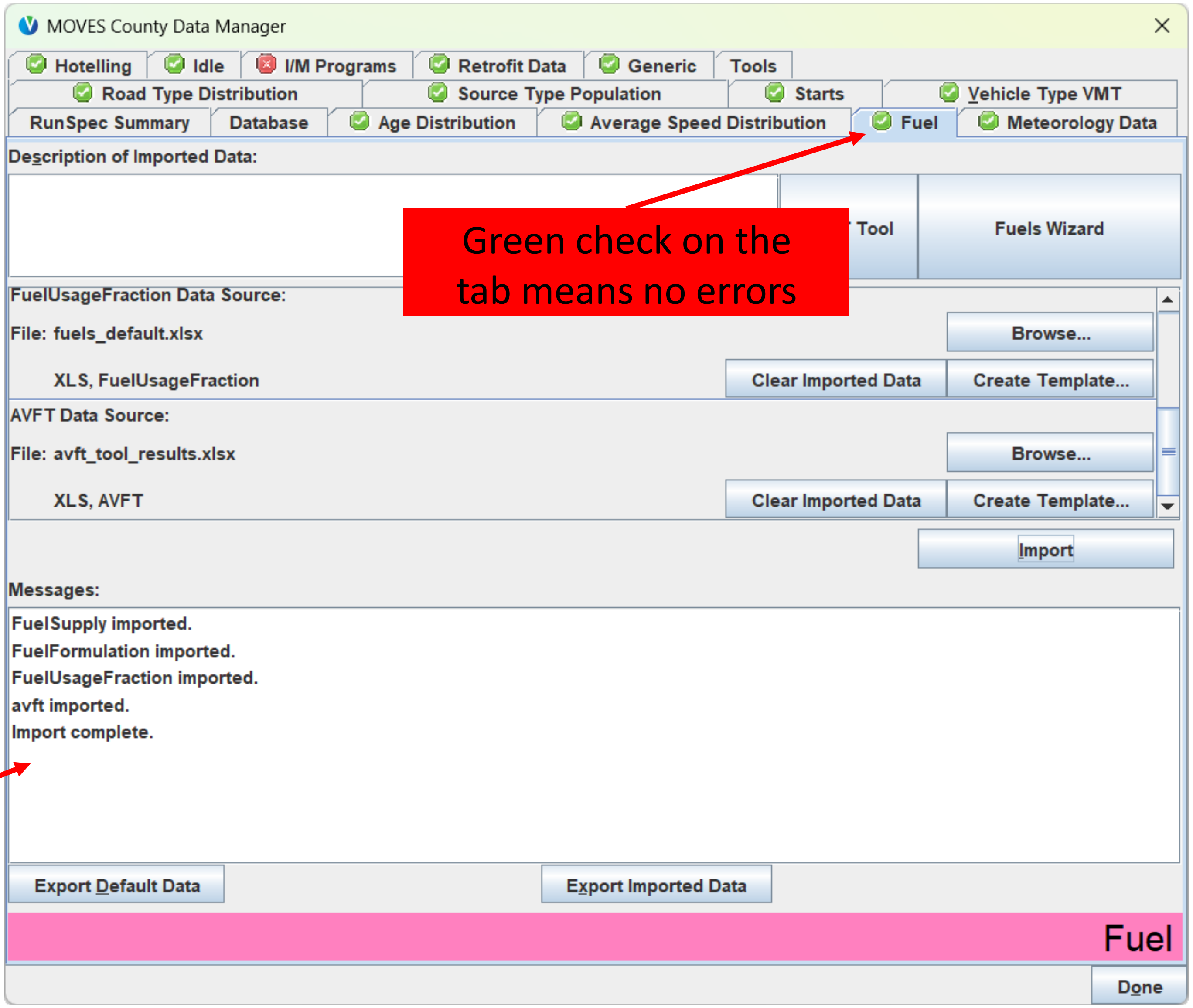
Importing the AVFT Tool Results (2)



Choosing "Yes" will have MOVES automatically match tab names in the spreadsheet to "data sources" on this tab of the CDM. There is only one data tab in this spreadsheet in this example, so it will not overwrite any other selections that we have already specified.



Check for Fuel Errors



Green check on the tab means no errors

Any errors will appear in the messages list

I/M Programs Tab

Inspection & Maintenance (I/M) Programs

- The IMCoverage table is used to specify the compliance factor by pollutant/process, source type, fuel type, and "IMProgramID"
  - IMProgramID is arbitrary number but must be unique for each inspection frequency, test standard, and model year range combination within a polProcessID, countyID, yearID, sourceTypeID, and fuelTypeID group

polProcessID	stateID	countyID	yearID	sourceTypeID	fuelTypeID	IMProgramID	begModelYearID	endModelYearID	inspectFreq	testStandardsID	useIMyn	complianceFactor
101	18	18089	2023	21	1	10	1996	2021	2	51	Y	93.12
101	18	18089	2023	21	1	6	1981	1995	2	33	Y	93.12
101	18	18089	2023	21	1	1	1976	1980	2	11	Y	93.12

IMCoverage | CountyState | FuelType | IMInspectFreq | IMPollutantProcess/ ...

- In this example, IMProgramID 10 is assigned to the component of the I/M program associated with 1996-2021 vehicles subject to the biennial (inspectFreq = 2) Exhaust OBD Check (testStandardsID = 51)

I/M Pollutants, Inspection Frequency and Test Standards

polProcessID	Process Name	Pollutant Name
101	Running Exhaust	Total Gaseous Hydrocarbons
102	Start Exhaust	Total Gaseous Hydrocarbons
112	Evap Fuel Vapor Venting	Total Gaseous Hydrocarbons
113	Evap Fuel Leaks	Total Gaseous Hydrocarbons
201	Running Exhaust	Carbon Monoxide (CO)
202	Start Exhaust	Carbon Monoxide (CO)
301	Running Exhaust	Oxides of Nitrogen (NOx)
302	Start Exhaust	Oxides of Nitrogen (NOx)

inspectFreq	Description
1	Annual
2	Biennial
3	Continuous

The test standards are described in more detail in the MOVES Technical Guidance, Section 4.9.7.

testStandardsID	Test Standards Description
11	Unloaded Idle Test
12	Two-mode, 2500 RPM/Idle Test
13	Loaded / Idle Test
21	ASM 2525 Phase-in Cutpoints
22	ASM 5015 Phase-in Cutpoints
23	ASM 2525/5015 Phase-in Cutpoints
24	ASM 2525 Final Cutpoints
25	ASM 5015 Final Cutpoints
26	ASM 2525/5015 Final Cutpoints
31	IM240 Phase-in Cutpoints
33	IM240 Final Cutpoints
41	Evaporative Gas Cap Check
42	Evaporative System Pressure Check
43	Evaporative System OBD Check
44	Evaporative Gas Cap and Pressure Check
45	Evaporative Gas Cap and OBD Check
46	Evaporative Pressure and OBD Check
47	Evaporative Gas Cap, Pressure and OBD Check
51	Exhaust OBD Check

No I/M Program

- The I/M Programs tab includes a checkbox labeled “No I/M Program”
- Check this box to get a green check for an area without an I/M program
- Can also use this feature to compare emissions with and without I/M
    - Note that checking the box removes the I/M coverage table from the county database
    - When unchecking box, you will need to re-import the I/M coverage table

I/M Programs: Guidance (1)

- Section 4.9 of MOVES Technical Guidance
- If the local area has an I/M program, begin by examining the default IMCoverage table using the "Export Default Data" button. Make any changes as necessary to match the local program before reimporting
  - In particular, review the grace periods and/or exemption periods as reflected in the model year ranges for accuracy
- If separate I/M programs apply to different weight classes within the same source type, the two programs cannot be accounted for in a single RunSpec
  - E.g., different exemption periods for regClassID 30 and regClassID 41 passenger trucks
  - If such a situation exists, assume the I/M program that covers a larger amount of the VMT within the source type applies to all weight classes for which there is an I/M program
- Note: I/M inputs do not affect direct PM or GHG emissions, but do affect some precursors

I/M Programs: Guidance (2)

- MOVES uses a single "compliance factor" to account for the program compliance rate, waiver rate, and an adjustment to account for I/M programs which may not cover an entire source type because the program only applies to certain weight classes
- The general equation for estimating the compliance factor is:

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

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

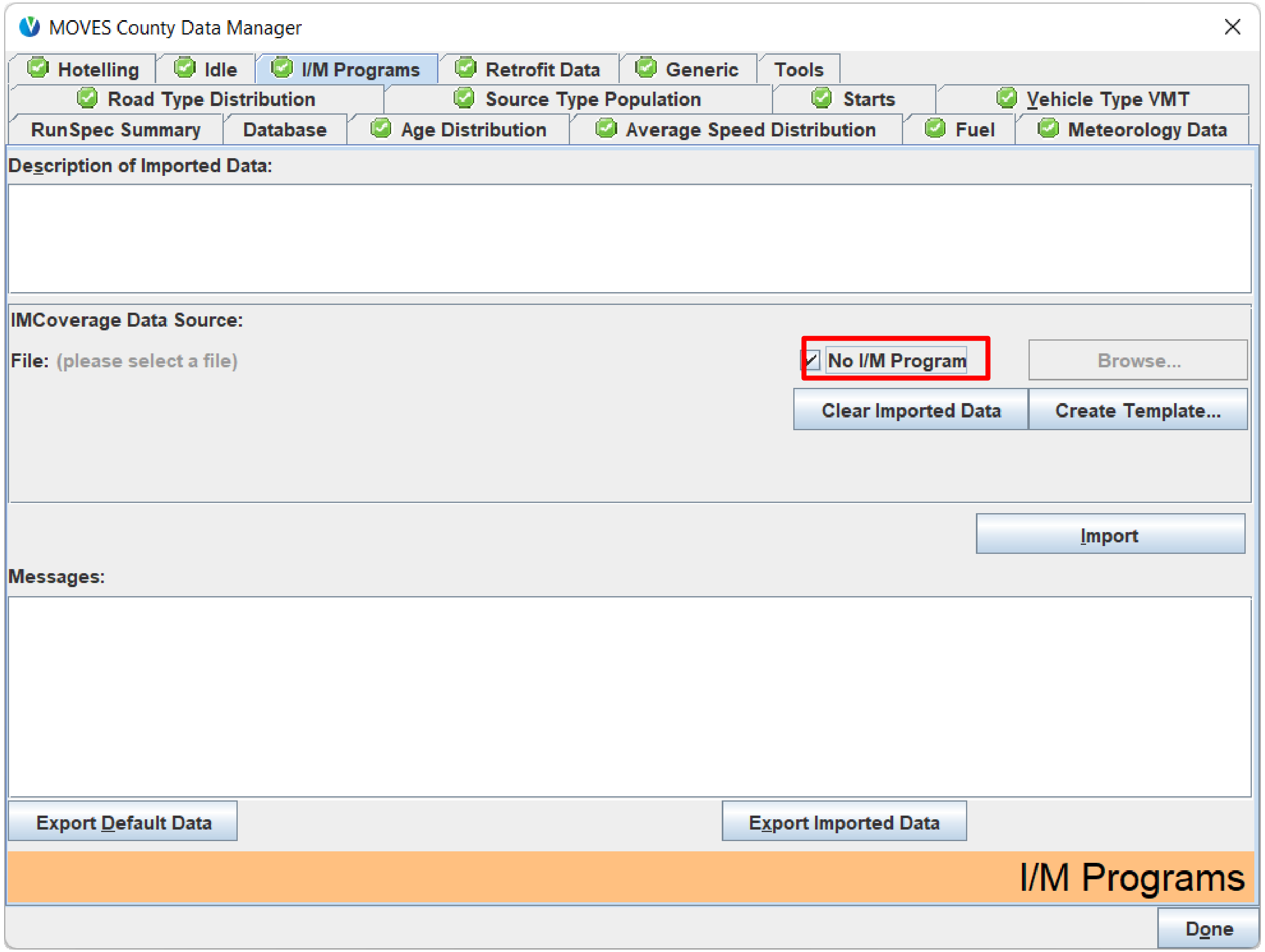
Each of these terms is explained in more detail in the MOVES Technical Guidance, Section 4.9.10

I/M Programs: Exercise

- Our County Scale exercise is for Washtenaw County, which does not have an I/M program
- Instructions for importing Vehicle Type VMT into the CDM:

1. Check the “No I/M Program” box on the I/M Programs tab

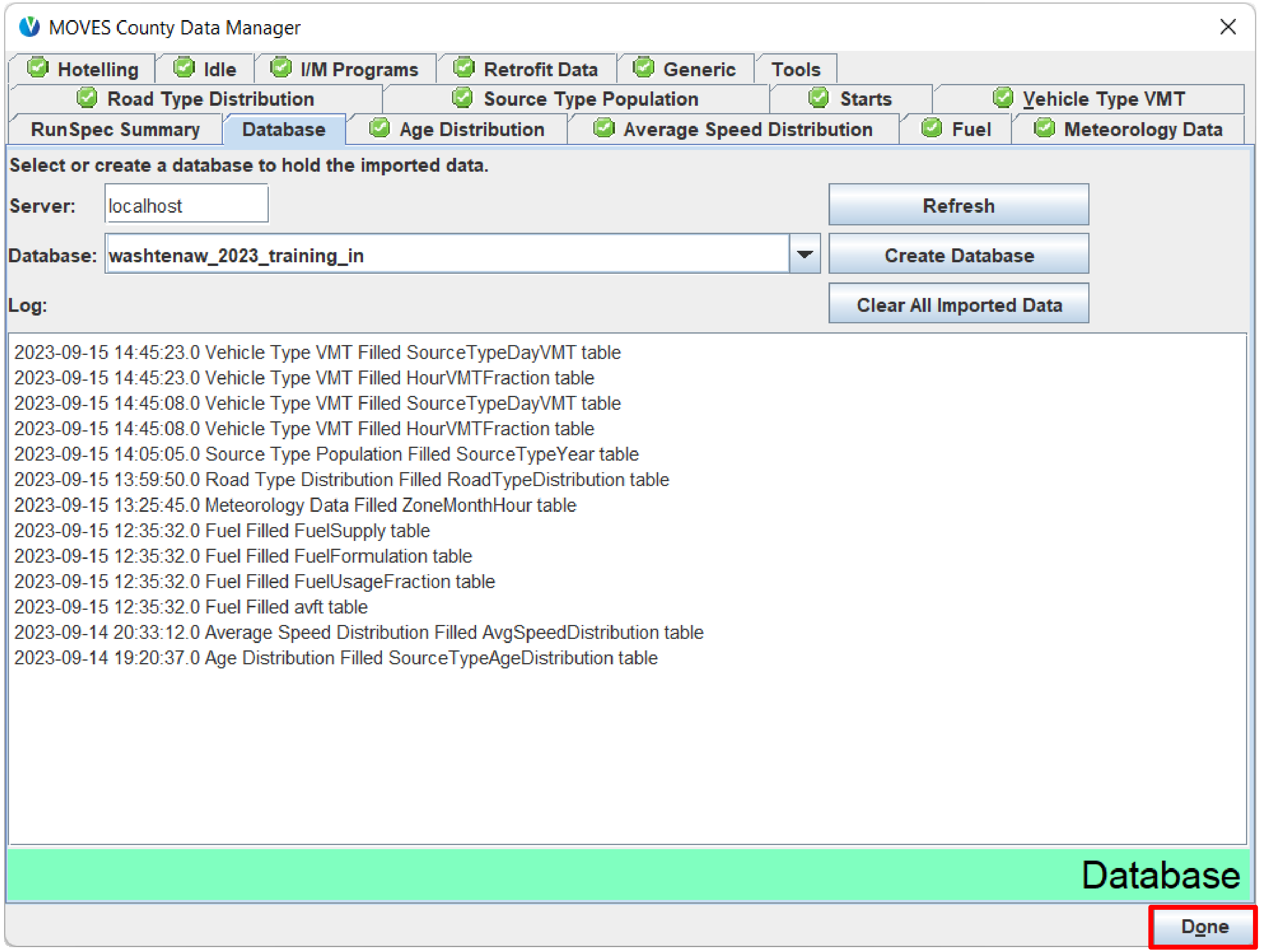
Exercise: Check No I/M Programs



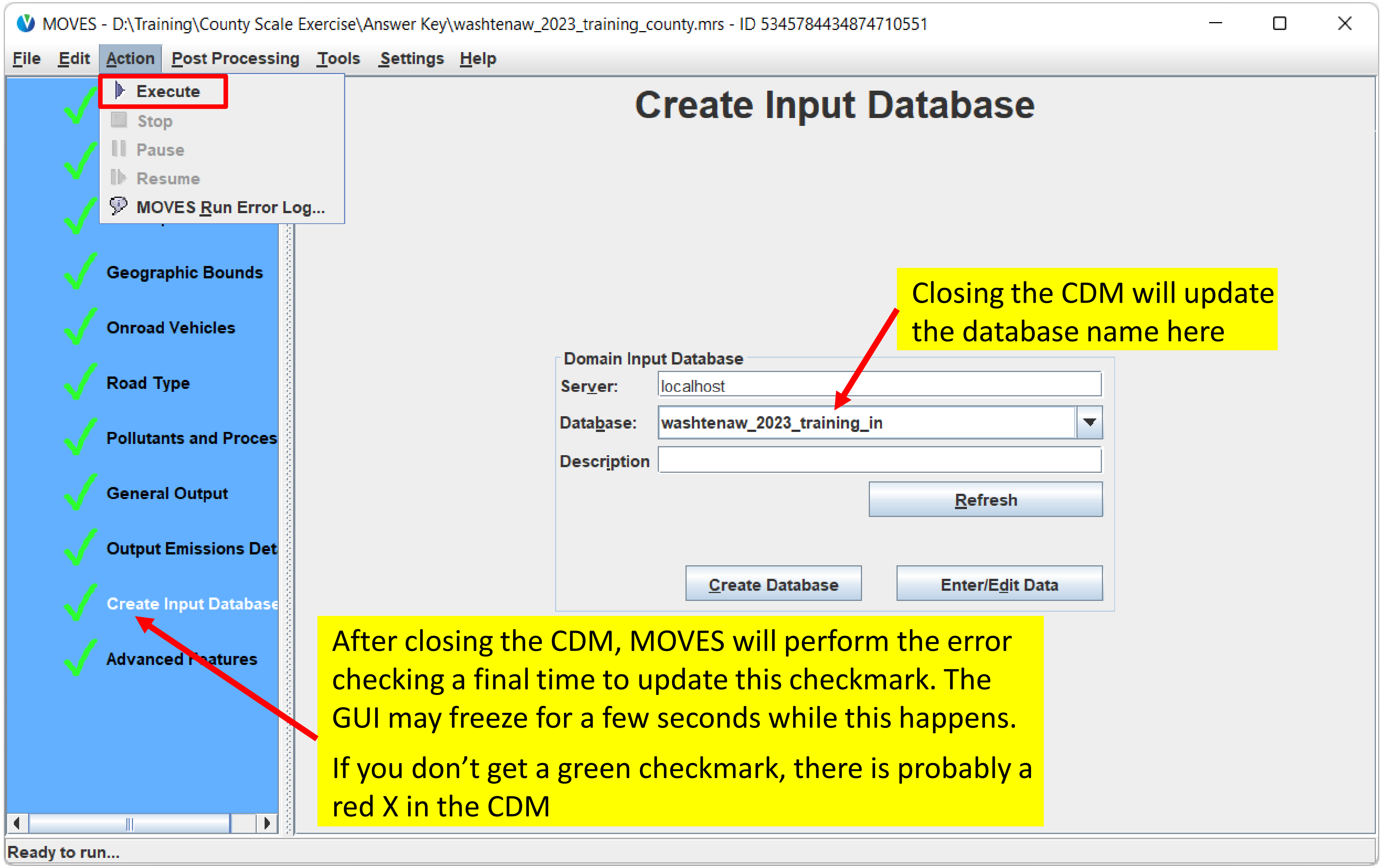
Run County Scale Exercise

- We will finish the CDM portion of the exercise by starting the MOVES run
  - While MOVES is running, we will review some of the optional inputs in the CDM
- First, ensure all tabs have a green check
- Then, close the CDM and start the MOVES run
- We will review the results of this exercise in Module 4

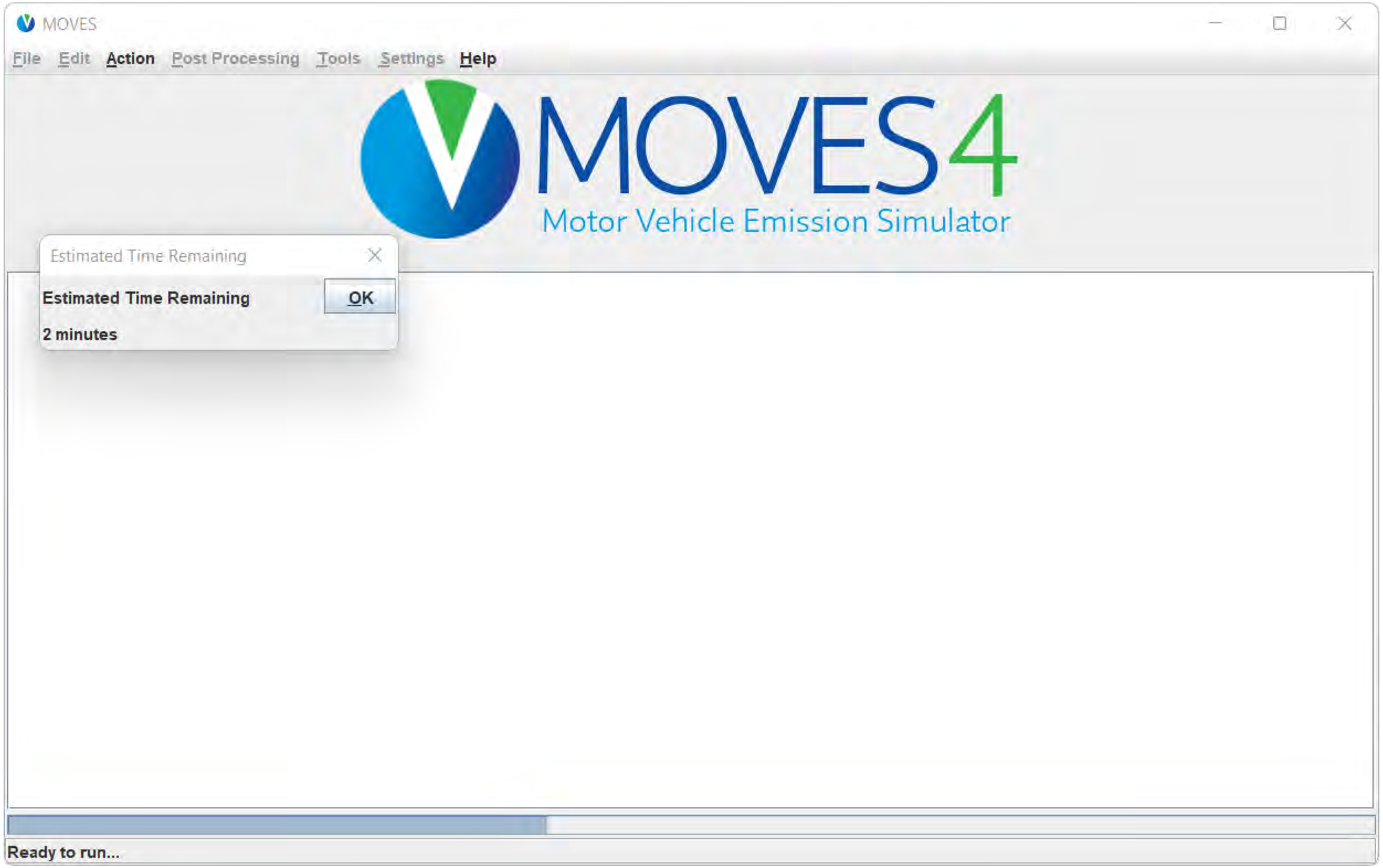
County Scale Exercise Is Ready to Run (CDM)



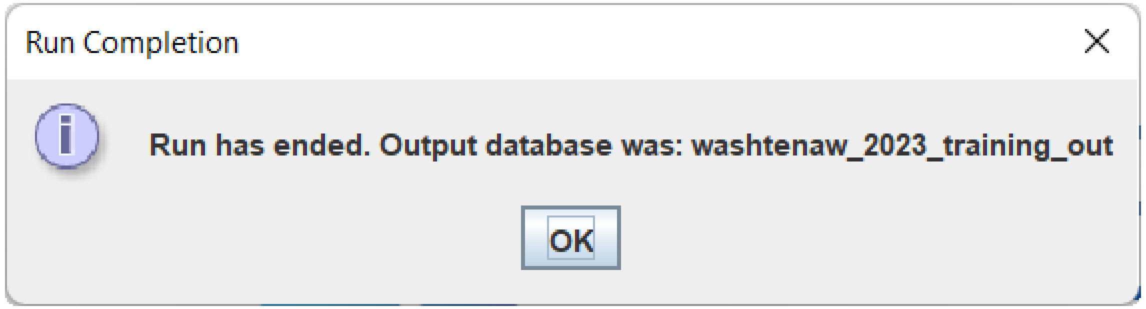
County Scale Exercise Is Ready to Run (Main GUI)



MOVES Running County Scale Exercise



County Scale Exercise Run Complete



Optional CDM Inputs and Other CDM Tables

Optional CDM Tabs: Starts (1)

- Section 4.10 of the MOVES Technical Guidance
- This input is optional: if no data are provided, MOVES calculates starts from the source type population input and default assumptions regarding starts per vehicle
- The primary table on this tab is the starts table
  - Use this if you have starts by source type, day, hour, age, and month
  - If this table is used, the only other table that could be provided on this tab is StartsOpModeDistribution
- If you do not have starts data at that level of detail, there are two other tables where you can provide the number of starts:
  - StartsPerDayPerVehicle – use when you know the number of starts per vehicle
  - StartsPerDay – use when you have the total number of vehicle starts per day
  - Do not use both StartsPerDay and StartsPerDayPerVehicle – use one or the other
- The StartsOpModeDistribution table can be used to adjust vehicle soak times

Optional CDM Tabs: Starts (2)

- The remaining tables on this tab are shaping tables. They allow you to provide one dimension of the starts table input, without needing to provide the other dimensions. You can provide any number of these tables together
  - StartsHourFraction – use when you know the distribution of starts throughout the day
  - StartsSourceTypeFraction – use when you want to allocate starts among the different source types
  - StartsMonthAdjust – use to adjust start activity by month
  - StartsAgeAdjustment – use to adjust start activity by vehicle age

Optional CDM Tabs: Hotelling (1)

- Section 4.11 of MOVES Technical Guidance
- The Hotelling input allows you to describe long-haul combination truck hotelling behavior. This input only applies to sourceTypeID 62
- The five tables are:
  - HotellingHoursPerDay – use to override MOVES' default assumptions for hotelling hours
  - HotellingHourFraction – use to supply the distribution of hotelling hours across a day
  - HotellingAgeFraction – use to allocate hotelling across different ages
  - HotellingMonthAdjust – use to adjust hotelling activity in different months
  - HotellingActivityDistribution – use to describe hotelling activity
- All are optional inputs
- Depending on what information is available, one or more may be used to define hotelling activity

Optional CDM Tabs: Hotelling (2)

- The HotellingActivityDistribution table (most common hotelling table to modify) is used to define the fraction of trucks in each of four modes of hotelling activity:
  - 200 – Extended Idling
  - 201 – Auxiliary Power Units (APUs)
  - 203 – Shore power (plug-in)
  - 204 – Battery/Engine Off
- Export defaults provides national fractions
- ZoneID = the countyID + “0”
- OpModeFraction must sum to 1 for each fuel type and model year range

zoneID	fuelTypeID	beginModelYearID	endModelYearID	opModeID	opModeFraction
261610	2	1960	2009	200	0.8
261610	2	1960	2009	201	0
261610	2	1960	2009	203	0
261610	2	1960	2009	204	0.2
261610	2	2010	2020	200	0.73
261610	2	2010	2020	201	0.07
261610	2	2010	2020	203	0
261610	2	2010	2020	204	0.2
261610	2	2021	2023	200	0.48
261610	2	2021	2023	201	0.24
261610	2	2021	2023	203	0
261610	2	2021	2023	204	0.28
261610	2	2024	2026	200	0.4
261610	2	2024	2026	201	0.32
261610	2	2024	2026	203	0
261610	2	2024	2026	204	0.28
261610	2	2027	2060	200	0.36
261610	2	2027	2060	201	0.32
261610	2	2027	2060	203	0
261610	2	2027	2060	204	0.32

hotellingActivityDistribution

Optional CDM Tabs: Idle (1)

- Section 4.12 of the MOVES Technical Guidance
- The optional input is used with local information on total idle activity
- Total idle activity = the total amount of idle time between key-on and key-off, but not including long-haul hotelling
- This input is used to calculate “off-network idle”, which is activity is associated with idling not occurring during a drive cycle
  - E.g., picking up kids from school or while loading a truck

Optional CDM Tabs: Idle (2)

- Multiple tables are available to provide local idle information that will overwrite the MOVES default assumptions. These tables include:
  - TotalIdleFraction – use to provide total idle fractions by source type, month, day, and model year
  - IdleModelYearGrouping – use to provide total idle fractions by source type and model year. If you provide this input, you must also provide the following tables:
    - IdleMonthAdjust – use to adjust idle activity by month
    - IdleDayAdjust – use to adjust idle activity by day
- Generally, the default information should not be replaced unless a comprehensive local idling survey was completed
- Note that emissions output for off-network idle activity is under roadTypeID 1 (off-network) and processID 1 (running emissions)

Optional CDM Tabs: Retrofit

- Section 4.13 of the MOVES Technical Guidance
- The retrofit importer is used to model diesel retrofit programs
- This is an optional input
- This example table shows a sample retrofit program:

pollutantID	processID	fuelTypeID	sourceTypeID	retrofitYearID	beginModelYea	endModelYearID	cumFractionRetrofit	retrofitEffectiveFraction
3	1	2	62	2024	2020	2024	0.5	0.3

  - Applying to diesel combination long-haul trucks (sourceTypeID 62)
  - Affecting running emissions (process ID 1) of NOx (pollutantID 3)
  - For model years 2020 through 2024 (beginModelYearID/endModelYearID)
  - Where 50% of all vehicles are retrofitted (cumFractionRetrofit 0.5)
  - And the retrofit technology reduces emissions 30% (retrofiteffectivefraction 0.3)
  - The retrofitYearID should always be the analysis year

Optional CDM Tabs: Generic

- The Generic tab allows advanced users to enter data into many tables used by MOVES to complete its calculations
- The most common use for this input is to provide corrected information regarding Stage II Refueling programs
  - See Section 4.14 of the MOVES Technical Guidance regarding Stage II
- However, most users will not have a reason to enter data through this tab
  - See Section 4.15 of the MOVES Technical Guidance regarding the Generic tab

Other CDM Tables: AuditLog

- The AuditLog is an important table in County Scale and Project Scale input databases
  - Input databases must have this table to appear in the input database dropdown lists
- It stores the optional descriptions for each input table, as well as a timestamp for when the tables were imported
  - This information is displayed on the Database tab in the CDM
- If the “No I/M Program” checkbox is checked, this table will contain an entry for the “I/M Programs Flag” with a value of “No data needed”
  - Sometimes this entry is unintentionally dropped when clearing data on other tabs. If this happens, you may unexpectedly see a red X on the I/M Programs tab. Simply select the I/M Programs tab and recheck “No I/M Program” to resolve

Module 3 Questions?

MOVES
Motor Vehicle Emission Simulator

Module 4:
Processing MOVES Output

Module 4 Overview

- Description of MOVES output tables
- Using the Post Processing Menu
- Overview of Structured Query Language (SQL) commands and HeidiSQL
- Filtering and aggregation in SQL
- Comparing the results of the MOVES Default Scale and County Scale exercises using HeidiSQL
- Calculating a monthly inventory

MOVES Output: General

- MOVES run results are stored in MariaDB database tables
- These results can be accessed by:
  - Using MOVES Summary Reporter
  - Using SQL query commands via HeidiSQL
    - See the SQL Tip Sheet as a reference
  - Using other analysis tools (e.g., R, Python, or Excel) via either:
    - A SQL connector, such as Open Database Connectivity (ODBC)
    - Exporting data from HeidiSQL to .csv

Output Database: Inventory and Run Tables

- The MOVES output database includes tables that detail MOVES results and lots of other information about the run
- *MOVESOutput* table
  - Inventory results by source type, pollutant/process, etc., based on output detail selections made in the RunSpec
- *MOVESActivityOutput* table
  - Activity measurements used by MOVES when calculating the inventory results (e.g. VMT, population, etc., based on output detail selections made in the RunSpec)
- *MOVESRun* table
  - Information about the run (e.g., date/time of run, domain and scale, units selected)

Output Database: Rates Tables

- Some tables are only populated when doing an Emission Rates run (not relevant to Inventory run, and discussed further in Module 6):
  - *RatePerDistance*
  - *RatePerVehicle*
  - *RatePerProfile*
  - *RatePerStart*
  - *RatePerHour*
  - *StartsPerVehicle*

Output Database: Diagnostic Tables

- Some tables are useful for user diagnostic purposes:
  - *MOVESError* (this is good to check after every run)
  - *MOVESTablesUsed*
- Some tables are reserved for advanced debugging purposes and generally are not useful for most users:
  - *BaseRateOutput*
  - *BaseRateUnits*
  - *BundleTracking*
  - *MOVESEventLog*
  - *MOVESWorkersUsed*

Output Database: Decoding Tables

- Some tables are useful for decoding MOVES' numeric ID codes:
  - *Translate_ActivityType*
  - *Translate_AvgSpeedBin*
  - *Translate_County*
  - *Translate_Day*
  - *Translate_EngTech*
  - *Translate_FuelSubType*
  - *Translate_FuelType*
  - *Translate_HP*
  - *Translate_NRSCC*
  - *Translate_Pollutant*
  - *Translate_Process*
  - *Translate_RegClass*
  - *Translate_RoadType*
  - *Translate_Sector*
  - *Translate_SourceType*
  - *Translate_State*

Output Database: Other Tables

- Some tables are not present by default, but are added when you run certain post-processing scripts
  - *DecodedMOVESOutput*
  - *DecodedMOVESActivityOutput*
  - *SummaryReportBody*
  - *SummaryReportDecode*
  - *SummaryReportHeader*
  - Etc.

MOVES Post Processing Menu

- The post-processing scripts use the output database identified in the loaded RunSpec
  - If you are interested in doing any post-processing from the Post Processing Menu, it's often easiest if you do so immediately upon conclusion of the run
  - Alternately, you can use File > Open to open the desired RunSpec and database
- Options in this menu for processing output include:
  - Execute the SQL scripts embedded in MOVES
  - Summarize results into text files using Summary Reporter

Post-Processing Scripts Overview

- There are several SQL scripts stored in the /database/OutputProcessingScripts folder of the MOVES installation directory
- You can write your own scripts and add them to this folder or add scripts obtained from other users
- When planning to use a script, read the script documentation before running MOVES
  - Project Scale scripts may require that you set up the RunSpec in a particular way
    - For example, scripts may require running with a specific calculation type or certain units in the output
  - Script documentation is shown when you select a script to run

General Post-Processing Scripts

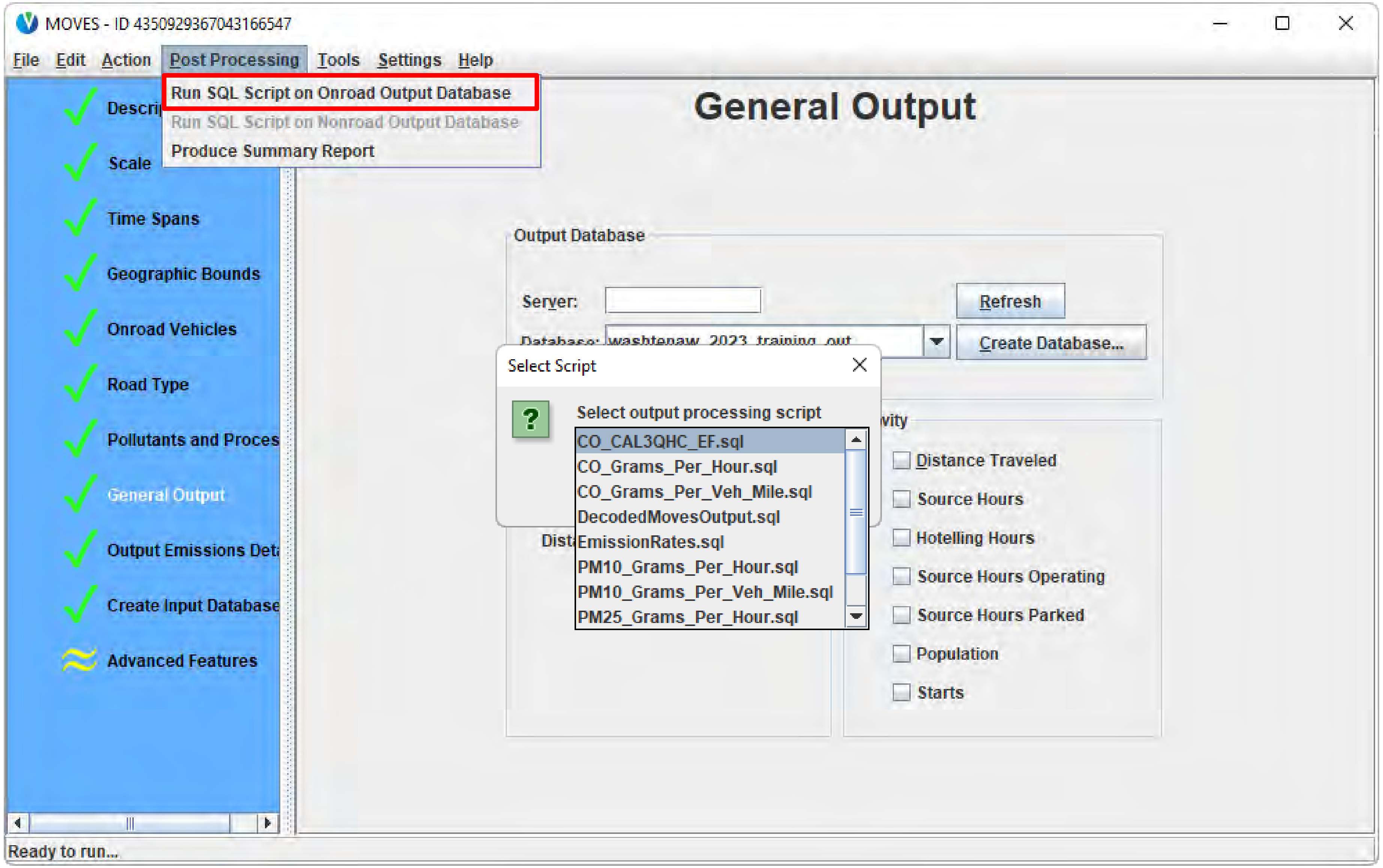
Script Title	Description
DecodedMOVESOutput.sql	Decodes most key fields of *MOVESOutput* and *MOVESActivityOutput* tables. This script creates new tables *DecodedMOVESOutput* and *DecodedMOVESActivityOutput* in your output database.
EmissionRates.sql	Produces an output table which reports inventory emission results in units of mass per distance. These are "back-of-envelope" emission rates and are not appropriate for SIPs or conformity analyses.
TabbedOutput.sql	Produces tab-delimited output suitable for reading into Excel or another analysis tool without needing to use HeidiSQL. These are saved to the MariaDB output database folder.

- In addition to DecodedMOVESOutput, you may find the MOVES Cheat Sheets to be useful for decoding MOVES output. They are available in the Help menu of MOVES.

Project Scale Post-Processing Scripts

Script Title	Description
CO_CAL3QHC_EF.sql	Produces CO emission rates for use in the CAL3QHC air quality model
CO_Grams_Per_Hour.sql	Produces CO emission rates as grams per hour for each link
CO_Grams_Per_Veh_Mile.sql	Produces CO emission rates as grams per vehicle-mile for each link
PM10_Grams_Per_Hour.sql	Produces PM10 emission rates as grams per hour for each link
PM10_Grams_Per_Veh_Mile.sql	Produces PM10 emission rates as grams per vehicle-mile for each link
PM25_Grams_Per_Hour.sql	Produces PM2.5 emission rates as grams per hour for each link
PM25_Grams_Per_Veh_Mile.sql	Produces PM2.5 emission rates as grams per vehicle-mile for each link

Selecting a Post-Processing Script



Post Processing Menu: Summary Report

- Uses the output tables in the database referenced in the current RunSpec
- Reports output emissions and activity in varying levels of detail, based on selections you make in the tool
- Covered in detail in Module 2

Post Processing Menu: Tabbed Output

- The TabbedOutput post-processing script exports MOVES output to *.txt* files
  - This creates individual files for the MOVESOutput, MOVESActivityOutput, and MOVESRun tables
  - Files are saved to your output database folder in the MariaDB data directory
- Data have header rows, values are tab-separated, and null values are represented by \N
- These files can be read by any analysis tool that you are comfortable with (e.g., R, Python, Excel, etc.)
  - Note: Very large MOVES output files may exceed the limits of Excel

SQL Post-Processing

- A recommended option for post-processing MOVES output is to use SQL queries and scripts
  - Well-written commands can analyze or summarize large MOVES output tables, even on computers with limited resources
  - HeidiSQL provides a useful interface for building and running these scripts
- A common analysis workflow is to filter, aggregate, or summarize using SQL commands, then export to another tool (R, Python, Excel, etc.) for further analysis or for generating tables and figures

MariaDB/HeidiSQL

- Installed as part of MOVES setup package
- HeidiSQL replaces MySQL Workbench (the tool used with older MOVES versions)
  - It is a tool for viewing MariaDB databases and executing queries
- Results can be exported as .csv (and easily imported with Excel or other tools)
- Queries are written as scripts
  - You can rerun queries without retyping
  - Scripts can be saved and included as documentation along with MOVES results

Hands-on Exercise Exploring MOVES Output with HeidiSQL

MOVES

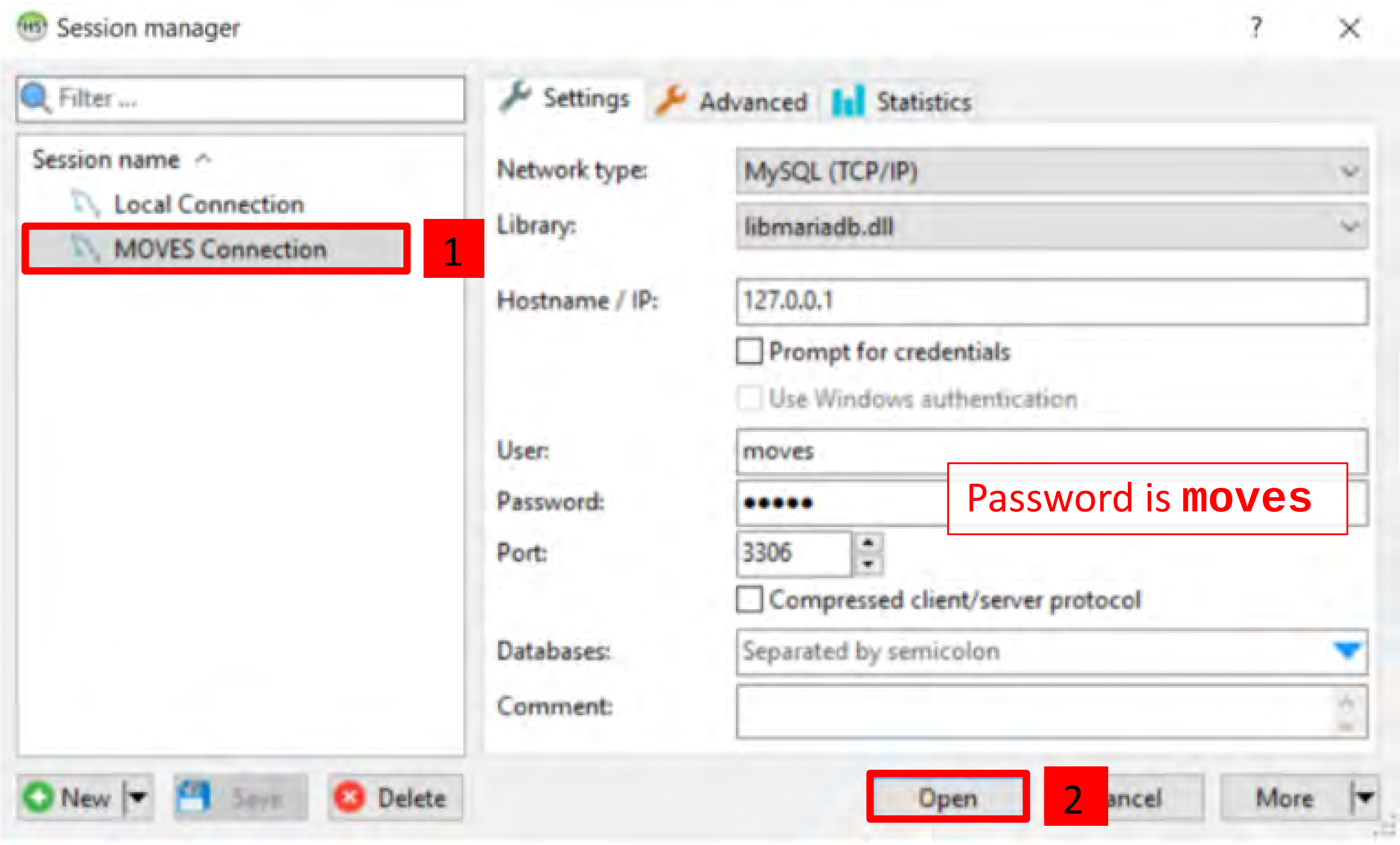
Motor Vehicle Emission Simulator

Exploring MOVES Databases with HeidiSQL

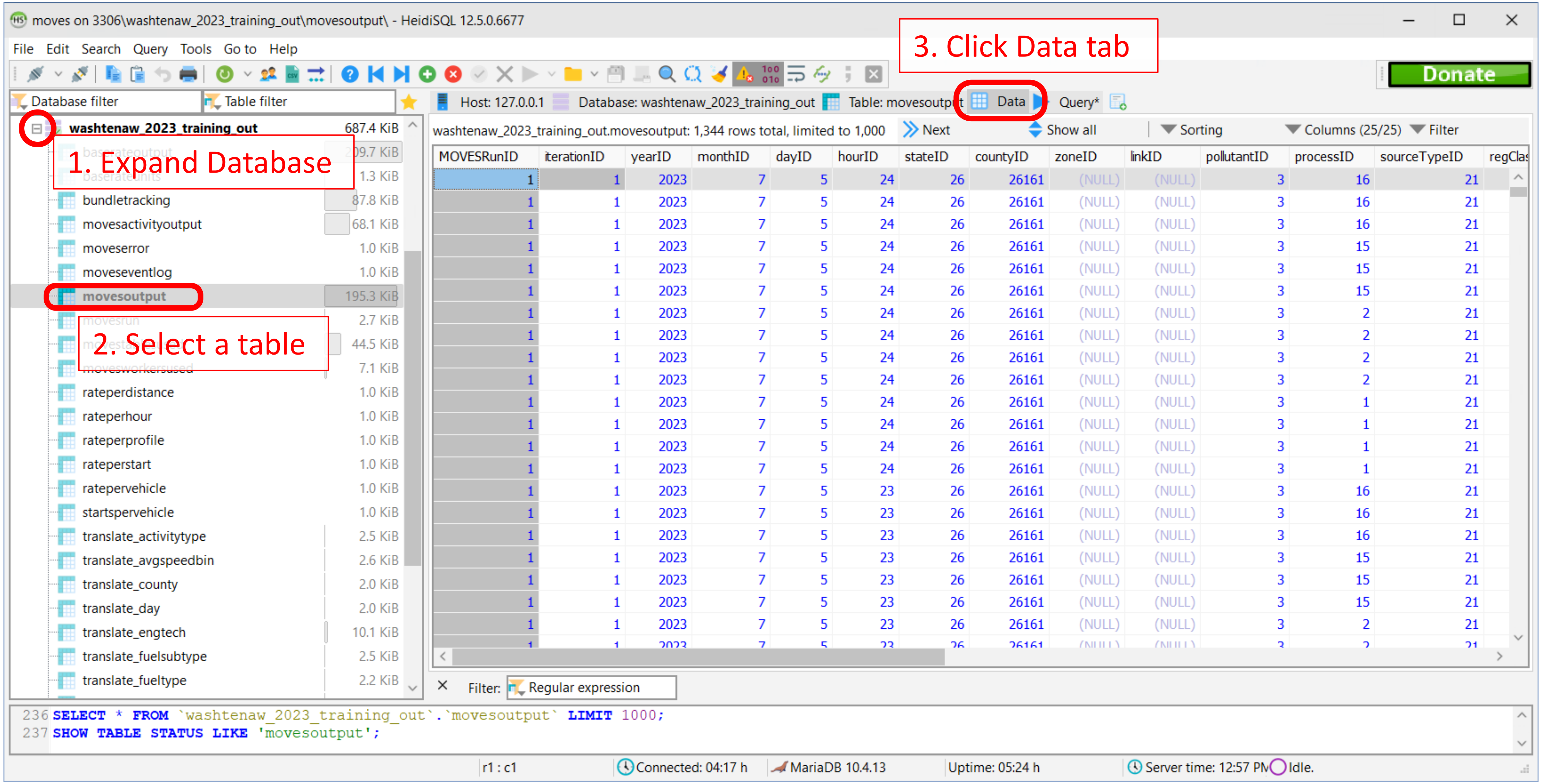
- This hands-on exercise will use our Module 2 Default Scale and Module 3 County Scale output database *washtenaw_2023_training_out*
  - MOVESRunID=1 is output using Default Scale
  - MOVESRunID=2 is output using County Scale
  - If you do not have these results, you can load them from the Module 3 “Answer Key” folder
- Instructions for Exploring MOVES Databases Exercise:
  - Open HeidiSQL
  - You will see a screen called Session Manager. Under Session name, select “MOVES Connection”
    - If this connection is missing, create a new connection with user “moves” and password “moves”. Port is likely 3306, although it could be 3307 etc. if you have multiple versions of MariaDB installed on your computer
  - Click “Open”

HeidiSQL

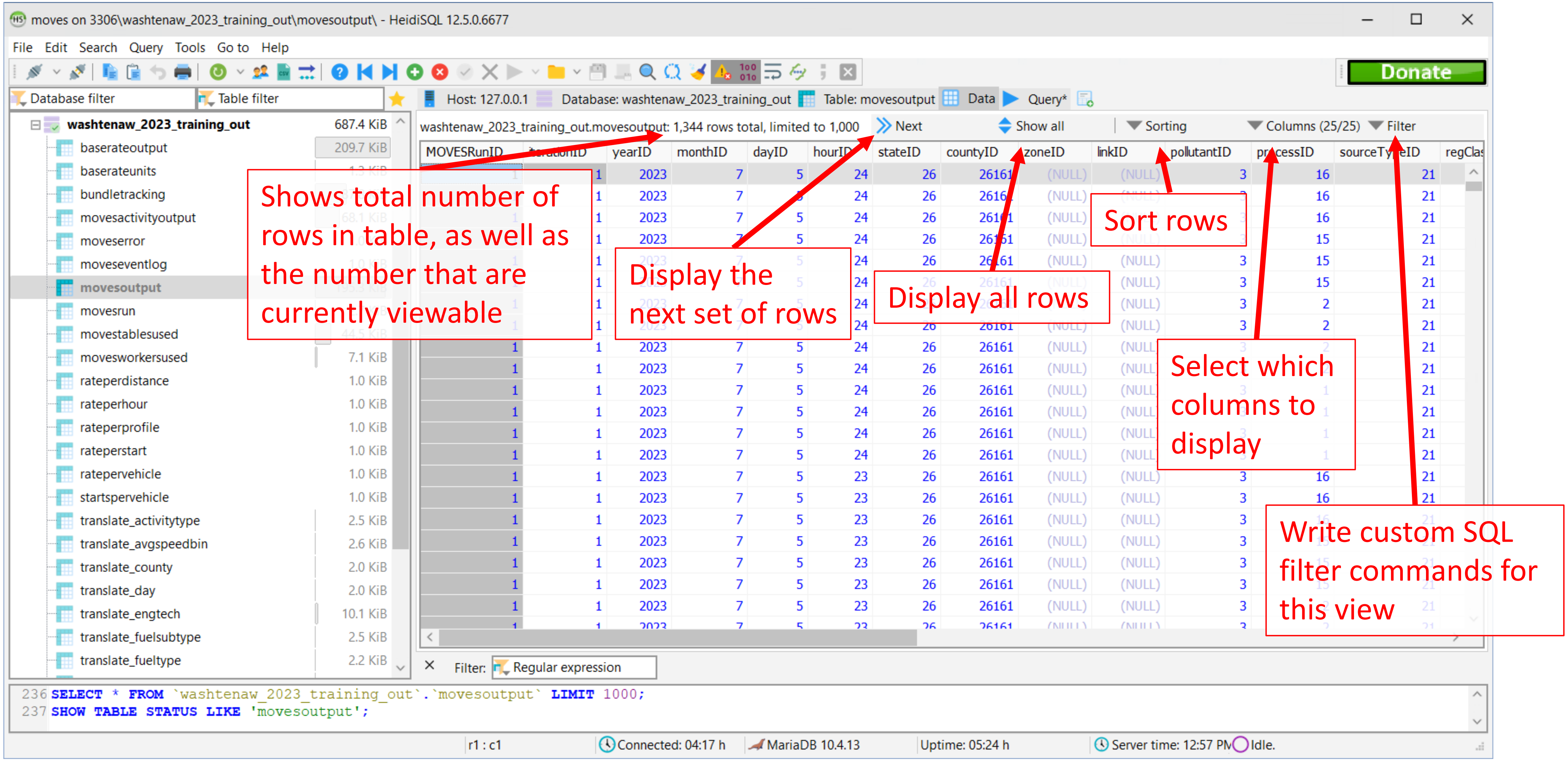
HeidiSQL: Getting Started



HeidiSQL: Layout



HeidiSQL: Data Tab



Introduction to Writing SQL Queries

- SQL is a computer programming language designed to access data in relational databases
  - "Relational databases" contain multiple tables with related data, using "ID" (or "key") columns to define the relationships
- The SQL commands we will be focusing on in this module are called "queries"
- Queries can be simple (e.g. select all the data in a table)
- Or complex (e.g., join multiple tables together, filter out unwanted data, and aggregate the results)
- Multiple queries can be saved as a script, which can be included in documentation for an analysis

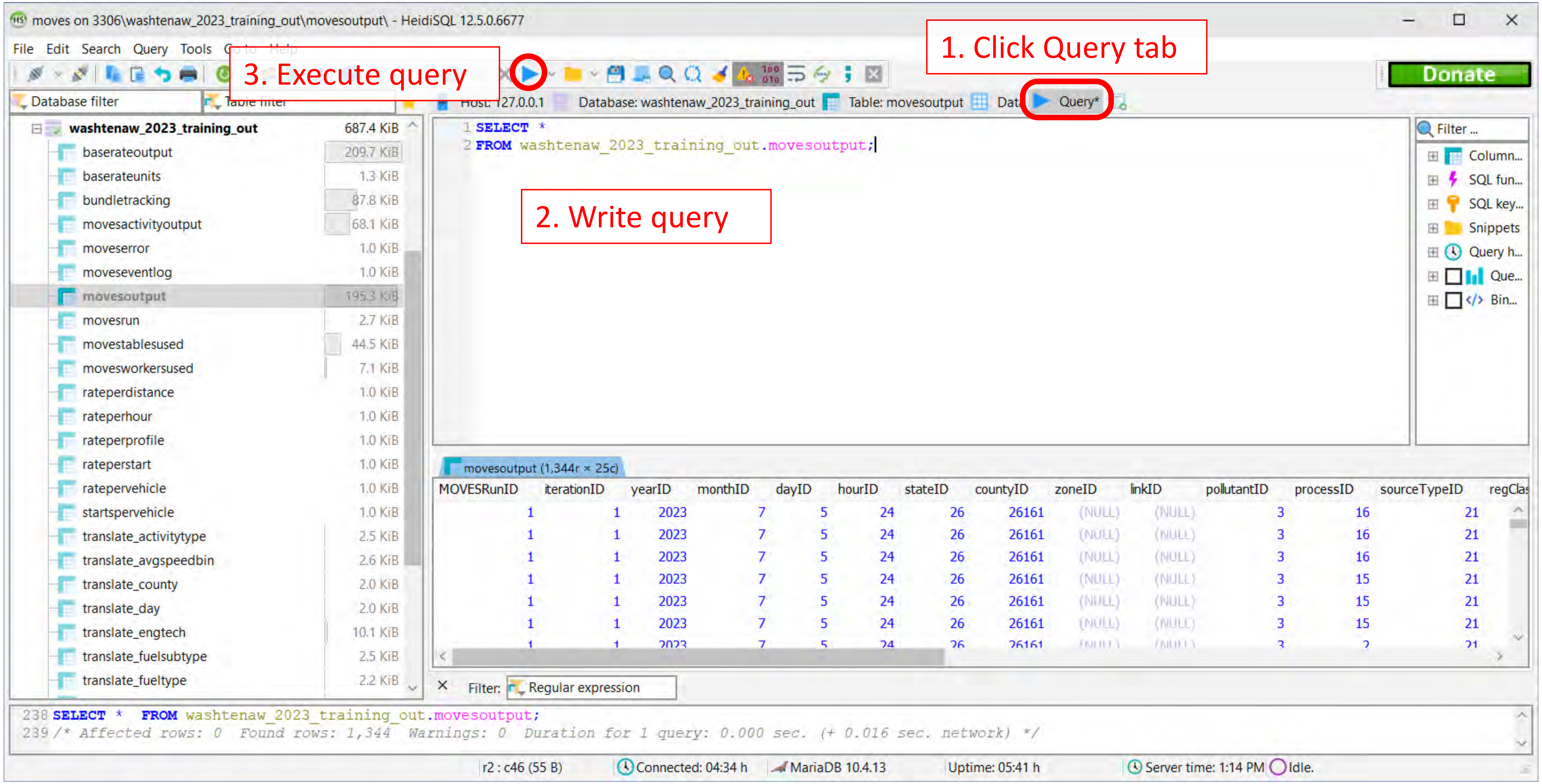
SQL Queries: Syntax

- The order and arrangement of query commands are important:
  - Syntax must be used in the correct order
  - Not all keywords are needed to complete every query
  - Commas are used to separate multiple fields following a command
- Every query ends with a semicolon “;”
- Click the ▶ button in HeidiSQL to execute queries
- The next slide is a handy SQL syntax reference sheet
- The rest of this module is dedicated to building SQL queries, starting simple and adding complexity as we go
  - All the queries in this module can be run from Module 4 - Post-Processing\postprocessing.sql
  - Having the Onroad Cheat Sheet open will help you decode MOVES IDs

SQL Queries: Command Words

Syntax	Function	Example
SELECT	Selects one or more data fields, separated by commas. A "*" following the SELECT command indicates "all fields"	SELECT MOVESRunID, pollutantID
SUM	Adds up the data in the field indicated in parentheses (note no space between SUM and the parenthesis)	SUM(emissionQuant)
AS	Used to name results (optional, but can be useful with commands such as SUM)	AS inventory
FROM	Indicates the database and table that the SELECT command is pulling from. Database and table must be separated by period (no spaces before or after period)	FROM demo_out.movesoutput
JOIN … USING (…)	Allows you to pull data from multiple tables. Specify the columns that are in common between the tables via the USING clause	JOIN demo_out.translate_pollutant USING (pollutantID)
WHERE	Used to filter the result set	WHERE dayID = 5
AND / OR	Used to specify more than one field when using the WHERE command	WHERE dayID = 5 AND sourceTypeID = 21
GROUP BY	Aggregates data together by the field(s) indicated **(when using aggregation, all non-aggregated columns must be listed here)**	GROUP BY MOVESRunID, pollutantID
ORDER BY … ASC / DESC	Sets the order of the result set. Optionally specify if ordering should be ascending (ASC) or descending (DESC)	ORDER BY pollutantID ASC, MOVESRunID DESC

HeidiSQL: Running queries



Building SQL Queries: Select All

- Start with a simple select all command:

```
SELECT *
FROM washtenaw_2023_training_out.movesoutput;
```

- In natural language, this query means:
  - Select all columns from the `movesoutput` table of the `washtenaw_2023_training_out` database

- Here are the results:

MOVESRunID	iterationID	yearID	monthID	dayID	hourID	stateID	countyID	zoneID	linkID	pollutantID	processID	sourceTypeID	regClassID	fuelTypeID	fuelSub
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	16	21	(NULL)	5	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	16	21	(NULL)	2	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	16	21	(NULL)	1	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	15	21	(NULL)	5	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	15	21	(NULL)	2	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	15	21	(NULL)	1	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	2	21	(NULL)	9	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	2	21	(NULL)	5	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	2	21	(NULL)	2	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	2	21	(NULL)	1	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	1	21	(NULL)	9	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	1	21	(NULL)	5	
1	1	2023	7	5	24	26	26161	(NULL)	(NULL)	3	1	21	(NULL)	2	

Building SQL Queries: Select Columns

- Select only the columns of interest:

```sql
SELECT MOVESRunID, dayID, hourID, pollutantID, processID,
       sourceTypeID, fuelTypeID, emissionQuant
FROM washtenaw_2023_training_out.movesoutput;
```

- In natural language, this query means:
  - Select the run, day, hour, pollutant, process, source type, fuel type, and `emissionQuant` columns from the `movesoutput` table of the `washtenaw_2023_training_out` database

- Here are the results:

MOVESRunID	dayID	hourID	pollutantID	processID	sourceTypeID	fuelTypeID	emissionQuant
1	5	24	3	16	21	5	0.0000418464
1	5	24	3	16	21	2	0.000501568
1	5	24	3	16	21	1	0.079437
1	5	24	3	15	21	5	0.0000663463
1	5	24	3	15	21	2	0.00745267
1	5	24	3	15	21	1	0.366925
1	5	24	3	2	21	9	0
1	5	24	3	2	21	5	1.04616
1	5	24	3	2	21	2	9.16128
1	5	24	3	2	21	1	1985.92
1	5	24	3	1	21	9	0
1	5	24	3	1	21	5	1.65866
1	5	24	3	1	21	2	35.2251
1	5	24	3	1	21	1	[illegible]

Building SQL Queries: Filtering (1)

- Filter the data to only look at running emissions:

```
SELECT MOVESRunID, dayID, hourID, pollutantID, processID,
       sourceTypeID, fuelTypeID, emissionQuant
FROM washtenaw_2023_training_out.movesoutput
WHERE processID = 1;
```

- In natural language, this query means:
  - Select the run, day, hour, pollutant, process, source type, fuel type, and `emissionQuant` columns from the `movesoutput` table of the `washtenaw_2023_training_out` database
  - Filter to include only the results where `processID` is 1 (i.e., only rows that contain running emissions)

Building SQL Queries: Filtering (2)

- Here are the results from the previous query:

MOVESRunID	dayID	hourID	pollutantID	processID	sourceTypeID	fuelTypeID	emissionQuant
1	5	24	3	1	21	9	0
1	5	24	3	1	21	5	1.65866
1	5	24	3	1	21	2	35.2251
1	5	24	3	1	21	1	9173.12
1	5	23	3	1	21	9	0
1	5	23	3	1	21	5	2.30924
1	5	23	3	1	21	2	49.2897
1	5	23	3	1	21	1	12781.5
1	5	22	3	1	21	9	0
1	5	22	3	1	21	5	3.02284
1	5	22	3	1	21	2	64.8302
1	5	22	3	1	21	1	16731.8
1	5	21	3	1	21	9	0

Building SQL Queries: Aggregation (1)

- Aggregate over all fuel types:

```
SELECT MOVESRunID, dayID, hourID, pollutantID,
       processID, sourceTypeID, SUM(emissionQuant)
FROM washtenaw_2023_training_out.movesoutput
WHERE processID = 1
GROUP BY MOVESRunID, dayID, hourID, pollutantID,
         processID, sourceTypeID;
```

- In natural language, this query means:
  - Select the run, day, hour, pollutant, process, source type values, and the sum of values in the `emissionQuant` column from the `movesoutput` table
  - Filter for the results where `processID` is 1 (i.e., only rows that contain running emissions)
  - Group the results by run, day, hour, pollutant, process, and source type (i.e. report the summed `emissionQuant` by these columns)

Building SQL Queries: Aggregation (2)

- Aggregate over all fuel types:

```
SELECT MOVESRunID, dayID, hourID, pollutantID,
       processID, sourceTypeID, SUM(emissionQuant)
FROM washtenaw_2023_training_out.movesoutput
WHERE processID = 1
GROUP BY MOVESRunID, dayID, hourID, pollutantID,
         processID, sourceTypeID;
```

fuelTypeID is missing from this list of columns because we are aggregating over it

GROUP BY contains all columns in the SELECT that are not summed

- In natural language, this query means:
  - Select the run, day, hour, pollutant, process, source type values, and the sum of values in the `emissionQuant` column from the `movesoutput` table
  - Filter for the results where `processID` is 1 (i.e., only rows that contain running emissions)
  - Group the results by run, day, hour, pollutant, process, and source type (i.e. report the summed `emissionQuant` by these columns)

Note: When more than one pollutant is selected in the RunSpec, **always** **SELECT** and **GROUP BY** pollutantID so that you do not **SUM** different pollutants

Building SQL Queries: Aggregation (3)

- Here are the results from the previous query:

MOVESRunID	dayID	hourID	pollutantID	processID	sourceTypeID	SUM(emissionQuant)
1	2	1	3	1	21	8649.556964993477
1	2	2	3	1	21	5896.522958755493
1	2	3	3	1	21	4518.160921394825
1	2	4	3	1	21	3200.3037363290787
1	2	5	3	1	21	3049.1031482219696
1	2	6	3	1	21	4634.096011936665
1	2	7	3	1	21	8080.665146350861
1	2	8	3	1	21	11517.512737989426
1	2	9	3	1	21	15986.09694981575
1	2	10	3	1	21	21769.99003148079
1	2	11	3	1	21	26942.32826423645
1	2	12	3	1	21	31401.171865463257
1	2	13	3	1	21	34422.592643260956
1	2	14	3	1	21	[illegible]

Building SQL Queries: Daily Emissions (1)

- Calculate total daily emissions (aggregate over hour, process, and fuel type and don't include the filter):

```
SELECT MOVESRunID, dayID, pollutantID, sourceTypeID, SUM(emissionQuant)
FROM washtenaw_2023_training_out.movesoutput
GROUP BY MOVESRunID, dayID, pollutantID, sourceTypeID;
```

- In natural language, this query means:
  - Select the run, day, pollutant, source type values, and the sum of values in the `emissionQuant` column from the `movesoutput` table
  - Group the results by run, day, pollutant, and source type (i.e. report the summed `emissionQuant` by these columns)
- This will result in daily emissions because our output includes all hours that we are adding together

Building SQL Queries: Daily Emissions (2)

- Here are the results from the previous query:

MOVESRunID	dayID	pollutantID	sourceTypeID	SUM(emissionQuant)
1	2	3	21	574159.9009712844
1	5	3	21	696796.6607208232
2	2	3	21	686575.3150325738
2	5	3	21	846914.7876600586

Building SQL Queries: Examining Activity (1)

- That's quite a difference between the runs! Let's do a similar query, but for activity:

```
SELECT MOVESRunID, dayID, activityTypeID, sourceTypeID, SUM(activity)
FROM washtenaw_2023_training_out.movesactivityoutput
GROUP BY MOVESRunID, dayID, activityTypeID, sourceTypeID;
```

- Differences between `movesoutput` and `movesactivityoutput`:
  - Results are stored in the `activity` column instead of `emissionQuant`
  - Has the `activityTypeID` column instead of `pollutantID` or `processID`
- In natural language, this query means:
  - Select the run, day, activity type, source type values, and sum of the activity values from the `movesactivityoutput` table
  - Group the results by run, day, activity type, and source type (i.e. report the summed activity by these columns)

Note: When more than one activityTypeID is present in the output, always **SELECT** and **GROUP BY** activityTypeID so that you do not **SUM** different activity types.

Building SQL Queries: Examining Activity (2)

- Here are the results from the previous query:

MOVESRunID	dayID	activityTypeID	sourceTypeID	SUM(activity)
1	0	6	21	112785.41695404053
1	2	1	21	3111492.518713951
1	5	1	21	3809339.331048012
2	0	6	21	200000.11682891846
2	2	1	21	4000000.1617469788
2	5	1	21	5000000.368991852

dayID 0 is used when the associated value explicitly does not vary by day type

Building SQL Queries: Joins (1)

- Join with the translate_activity table to decode the activityTypeIDs:

```
SELECT MOVESRunID, dayID, activityTypeDesc, sourceTypeID, SUM(activity)
FROM washtenaw_2023_training_out.movesactivityoutput
JOIN washtenaw_2023_training_out.translate_activitytype
     USING (activityTypeID)
GROUP BY MOVESRunID, dayID, activityTypeDesc, sourceTypeID;
```

- In natural language, this query means:
  - Select the run, day, activity type description, source type values, and sum of the activity values
  - The source tables are the `movesactivityoutput` and the `translate_activitytype` tables, and the common column activityTypeID will be used to join the two tables
  - Group the results by run, day, activity type description, and source type (i.e. report the summed activity by these columns)

Building SQL Queries: Joins (2)

- Here are the results from the previous query:

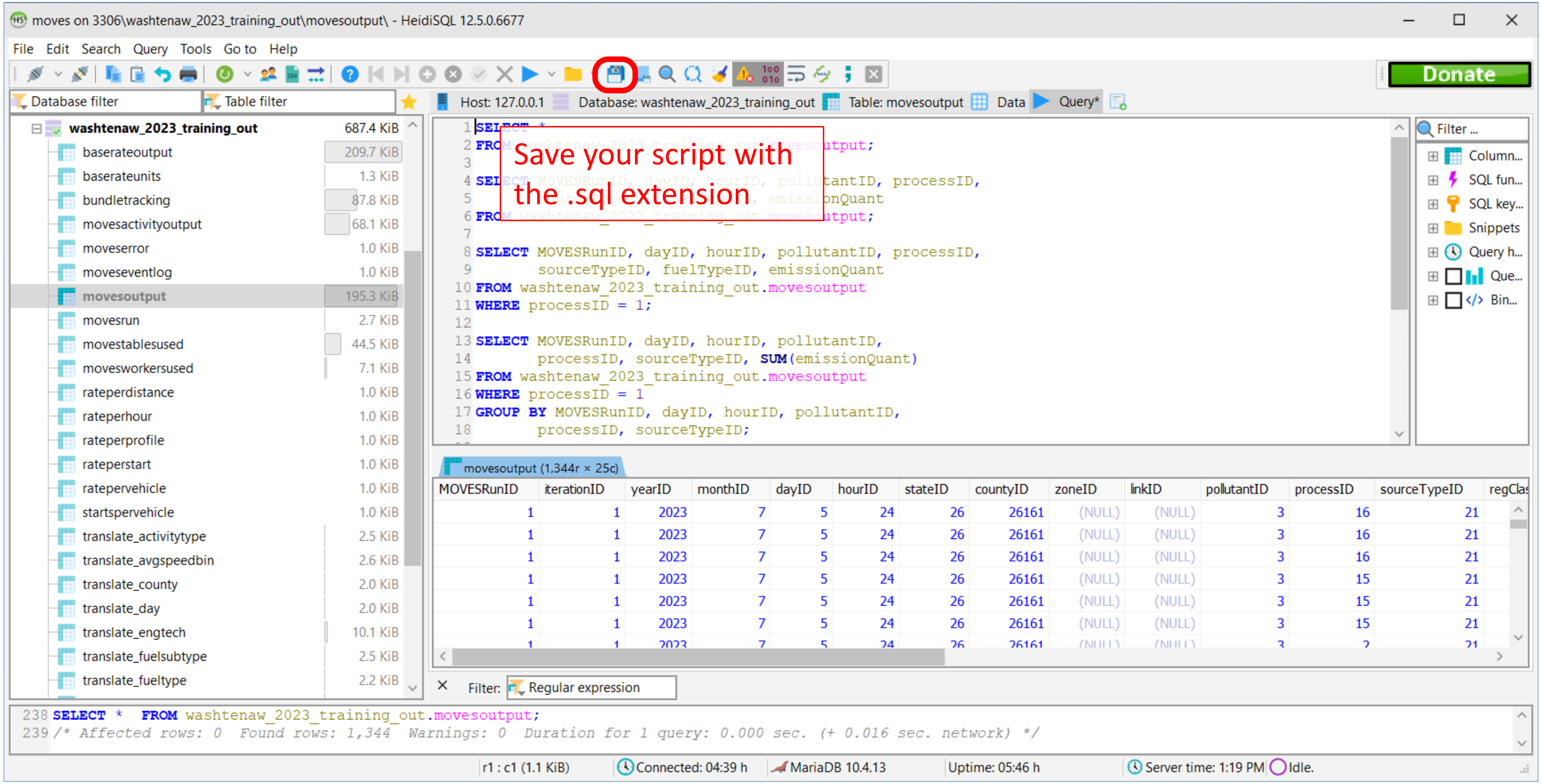
MOVESRunID	dayID	activityTypeDesc	sourceTypeID	SUM(activity)
1	0	Population	21	112785.41695404053
1	2	Distance traveled	21	3111492.518713951
1	5	Distance traveled	21	3809339.331048012
2	0	Population	21	200000.1168289184
2	2	Distance traveled	21	4000000.161746978
2	5	Distance traveled	21	5000000.368991852

Vehicle population does not vary by day type

Other HeidiSQL Actions

- Saving scripts
- Sharing databases with others for review
- Exporting result sets

Saving Scripts



Sharing SQL Databases

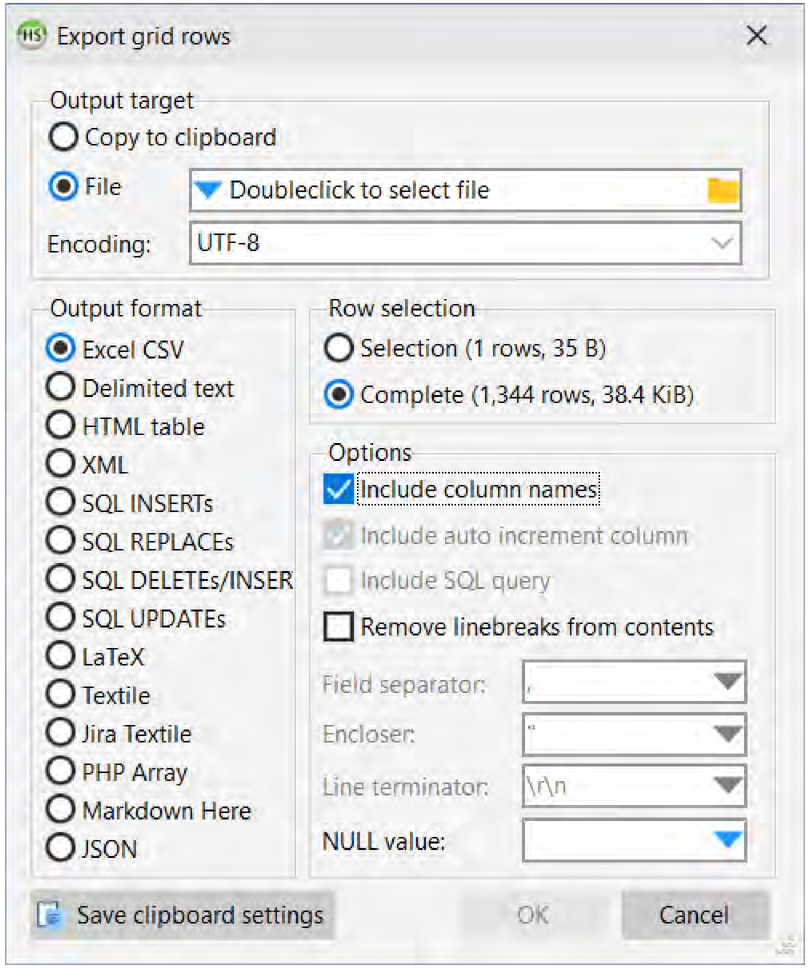
- Input and output databases are stored in the MariaDB data directory
  - There should be a shortcut on your desktop
  - If not, it usually can be found in C:\ProgramData
    - For example: C:\ProgramData\MariaDB\MariaDB 10.11\data
    - C:\ProgramData is hidden, but if you type it into Windows Explorer, you can see it
    - Also, you may have a different MariaDB version number, and that's OK

MariaDB 10.11 Data

- Databases appear as folders in the data directory, which may be copied and zipped for sharing and review
  - Before copying or zipping database folders, run the following command in HeidiSQL to ensure MariaDB doesn't have any database files locked:

```
FLUSH TABLES;
```

Exporting Result Sets



- Any result set in HeidiSQL (i.e., when using the Data or Query tab) can be exported to CSV for easy access in another analysis tool
- Available in Tools > Export Grid Rows or by right-clicking on the result set and selecting Export Grid Rows
- Ensure the row count matches what you expect. It may be limited to 1000 if you did not select the option to Show All
- This may not work with very large data sets. In that case, you may need to use the [**`SELECT INTO OUTFILE`**]() command

Final Exercise: Calculate a Monthly Inventory

- Since our runs included all hours and both day types, we can calculate a July inventory of NOx from passenger cars in Washtenaw County
- Remember from Module 2 that we cannot simply sum the daily inventories together to make a monthly inventory
- Two methods available to weight the daily inventories:
  1. Multiply each day type's inventory by the number of those day types in the month
     - This is the most precise option, but can be complicated if aggregating several months or repeating the calculation for different years
  2. Multiply each day type's inventory by the number of those day types in a week, then multiply by the number of weeks in the month
     - Number of weeks is the number of days in the month divided by 7

Calculating a Monthly Inventory in SQL

- Either option can be applied if you first export the daily inventory to Excel
- Or the second option is easy to implement in SQL:

```
SELECT MOVESRunID, monthID, pollutantID, sourceTypeID,
       SUM(emissionQuant * dayID) * noOfDays / 7 AS monthInventory
FROM washtenaw_2023_training_out.movesoutput
JOIN movesdb20230615.monthofanyyear USING (monthID)
GROUP BY MOVESRunID, monthID, pollutantID, sourceTypeID;
```

- Notes:
  - `movesdb20230615` is MOVES4.0.0 default database
  - `monthofanyyear` is a table that contains the number of days in each month (`noOfDays`)
  - Multiplying `emissionQuant` by `dayID` gets the portion of week inventory, summing that gets a weekly inventory
  - Multiplying a weekly inventory by the number of weeks in a month (`noOfDays / 7`) gets the monthly inventory

Monthly Inventory Result

- Here are the results from the previous query:

MOVESRunID	monthID	pollutantID	sourceTypeID	noOfDays	monthInventory
1	7	3	21	31	20514485.181706756
2	7	3	21	31	24834208.8027612

Module 4 Questions?

MOVES
Motor Vehicle Emission Simulator

Module 5:
Review and Best Practices

MOVES
Motor Vehicle Emission Simulator

EPA

Module 5 Overview

- Review of Modules 1-4
- Best practices and tips
- Common mistakes
- Reviewing your work, or someone else's
  - Checking a RunSpec
  - Checking an input database
  - Checking the output database

Review of Modules 1-4

- What is MOVES and how does it work?
- Using MOVES at the Default Scale
  - Developing a simple RunSpec
  - Using the Summary Reporter
- Using MOVES at the County Scale
  - Required for SIPs and regional conformity analyses
  - Guidance on RunSpec parameters
  - Introduction to the County Data Manager, or CDM
  - Guidance on CDM inputs
- Processing MOVES output in SQL
  - Using HeidiSQL to view and process MOVES output

Important References for MOVES

- Know the basic regulatory requirements
- Read the MOVES Technical Guidance
  - Contains important information on what local inputs are needed and when national defaults can be used
  - Consistency with guidance is a key thing reviewers will look at
- Refer to the MOVES Cheat Sheets to decode MOVES IDs
  - Onroad Cheat Sheet
  - Nonroad Cheat Sheet
- Check out other references on the MOVES website, such as:
  - FAQs: include answers to many common user questions
  - EPA Releases MOVES4 Q and A: highlights differences between MOVES4 and earlier versions
  - MOVES Overview Report: for a high-level overview
- Send questions to mobile@epa.gov

Best Practices: Documentation (1)

- Documentation is necessary to meet requirements for interagency and public review
  - But also important as a reference for you and your own agency
- See MOVES Technical Guidance, Section 2.6, for details about best practices, summarized here:
  - For each county and calendar year modeled, include:
    - RunSpec file
    - Input database
    - Output database
    - AVFT Tool input table and results
  - Describe data and analysis used to populate the input database
  - Describe any other methods and assumptions, including methods and files used to post-process output

Best Practices: Documentation (2)

- In addition, use the built-in MOVES documentation features:
  - Use the Description panel in the RunSpec to describe run
  - Use the Description of Imported Data box in each CDM tab to describe input data used
  - These descriptions become part of the output and/or input databases

Best Practices: Naming Conventions

- Use consistent naming conventions
  - Name Runspec files with a consistent file extension (e.g., ".mrs")
  - Identify input and output databases in a consistent manner (e.g., _in and _out)
  - Identify related RunSpecs and databases with consistent names (e.g. Lake2025BaseCase.mrs, Lake2025BaseCase_in, Lake2025BaseCase_out)
- Save the tools you use for pre-processing your inputs and post-processing your output
- Consider organization and names of input files, e.g.,
  - Create a "MOVES inputs" folder
  - Create sub-folders for each run's supporting files, named similarly to the RunSpec

Important Tips for RunSpec Creation

- RunSpec selections and input database data should reflect the purpose of the analysis
- Finish the RunSpec before creating the input database
  - Creating the input database too early can result in conflicts with the RunSpec
- For SIP and conformity analyses:
  - Include the relevant pollutants and precursors
    - MOVES now includes a check that all prerequisite pollutants are included
  - Always include all *processes* for a particular pollutant
    - If it's a PM run, be sure to include brake wear and tire wear
  - Include all source types, fuels, and road types that are present in the modeling area

Reviewing Your Work or Someone Else's

- All elements needed to run a MOVES scenario are usually required to complete a review (should be able to recreate the results, if needed)
  - RunSpec
  - Input database
  - Output database
  - Refer to earlier slide about best practices for documentation
- Compare Inputs and RunSpec with EPA guidance to ensure they are complete and correct
  - Use interagency consultation process to do this <u>before</u> you begin runs
  - E.g., all required pollutants and processes selected, correct age and speed distribution(s) used…
- Outputs should appear logical and complete

Checking a RunSpec (1)

- Scale
  - County Scale for SIPs or regional conformity analysis
  - Project Scale for a hot-spot analysis
  - Default Scale is not appropriate for SIP or conformity purposes; useful for other analyses, such as GHG
  - Note the calculation type used
- Time Spans
  - Are the year, month, day, and hours appropriate for the analysis?

Checking a RunSpec (2)

- Geographic Bounds
  - Correct county?
  - Does the input database name match the input database file supplied?
- Onroad Vehicles
  - Are the appropriate source types selected?
  - For a county-level inventory, all source types should be selected
- Pollutants and Processes
  - Have the appropriate pollutants been selected?
  - For SIP/conformity analyses, all processes associated with a given pollutant must be selected

Checking a RunSpec (3)

- General Output
  - Does the output database name match the output file supplied?
  - Are the units appropriate?
    - Hourly emissions should use grams, larger units may result in rounding down to zero
- Output Emission Detail
  - Is level of detail appropriate for how the results are to be post-processed?
    - E.g., if analysis is related to emissions saved from EVs, was emissions by “fuel type” selected?
    - E.g., if analysis goal is a daily inventory and output is by hour, are the results properly summed during post-processing to determine daily emissions?

Checking an Input Database

- An input database is more complicated than a RunSpec and more difficult to review
- Documentation is key
  - Which data are defaults and which are local?
  - What is the source of the local data?
  - How recent are the local data?
  - What assumptions have been made?
- Refer to EPA's MOVES Technical Guidance when reviewing
  - Guidance on choice of default vs. local data
  - Guidance on sources of local data
  - See Table 4-1 for a quick summary of guidance for each input
- In general, input database should contain the most recent and best local data available for fleet and activity inputs

Looking at Specific Inputs (1)

- Meteorology (ZoneMonthHour)
  - Temperature and humidity inputs
  - Local data needed
    - Default data based on historical 10-year averages that may not be appropriate for all types of analysis
- Source type population (SourceTypeYear)
  - Number ("population") of local vehicles operating in the area
  - Important for start and evaporative emissions
  - Local data needed
    - Default data likely to be inaccurate
  - Technical guidance provides suggestions for sources

Looking at Specific Inputs (2)

- Age distribution (SourceTypeAgeDistribution)
  - Age fractions of fleet by age and source type
  - Local data needed
    - Default distribution is a national average
    - Default data may be used for categories not locally registered, e.g., single unit and combination long-haul trucks
  - Vehicle registration data are usually best source
- Vehicle Type VMT (HPMSVTypeYear and others)
  - Total annual or daily VMT by HPMS vehicle type or source type
  - Also month, day, and hour VMT fractions
  - Local data needed
    - Default data likely to be inaccurate
  - Transportation demand models and HPMS are sources

Looking at Specific Inputs (3)

- Average Speed Distribution (AvgSpeedDistribution)
  - Speed distribution by road type, hour and source (vehicle) type
  - Local data needed
    - Default is a national average, not appropriate for local conditions
  - Recommended source is post-processed output from a travel demand model

- Road Type Distribution (RoadTypeDistribution)
  - Fraction of source type VMT on different road types
  - Local data needed
    - Default is a national average, not appropriate for local conditions

Looking at Specific Inputs (4)

- Fuels (FuelSupply, FuelFormulation, FuelUsage, AVFT)
  - Market share and composition of fuel blends
  - FuelSupply, FuelFormulation: Defaults available by county and recommended
    - If it was necessary to change RVP to reflect local requirements, the Fuel Wizard should have been used
    - Other changes only if appropriate local volumetric fuel property data are available
  - FuelUsageFraction: Default recommended, use local data if available for E-85 fuel usage
  - AVFT: use local data – registration records, or NEI data
    - If AVFT Tool was used, review inputs and outputs

- I/M Programs (IMCoverage)
  - Data on I/M programs at the county level
  - Check to make sure values are consistent with program

Reviewing Inventory Output (1)

- Output database contains multiple tables to review
  - *MOVESRun*
  - *MOVESOutput*
  - *MOVESActivityOutput*
  - *MOVESError*
- *MOVESRun*
  - MOVESRunID
  - Distance and mass units
  - RunSpec file name and description
  - Default database and MOVES version
  - Domain database name (input database used)
  - Bundles expected should match bundles processed

Reviewing Inventory Output (2)

- *MOVESOutput*: EmissionQuant
  - Broken down by whatever detail was specified in the RunSpec
  - Units are specified in the RunSpec and echoed in the MovesRun table
- *MOVESActivityOutput*: Activity (VMT and/or vehicle population)
- *MOVESError*: Make sure there are no errors reported for each run
- You will also need to review the user's documentation to understand how results were post-processed
  - Make sure post-processing "makes sense" – e.g., it does not make sense to sum emissions of different pollutants

Note: Reviewing Emission Rates output will be covered in the next module

Module 5 Questions?

Module 6:
Emission Rates
for County Scale Analyses

MOVES
Motor Vehicle Emission Simulator

EPA

Module 6 Overview

- Introduction to Rates Mode
  - How rates vary
  - How to calculate an emissions inventory using rates
- Guidance for creating a rates mode RunSpec and input database
- Exercise: Calculate an inventory from a simple rates run

Module 6 Key References

County Scale:

- The *MOVES Technical Guidance* provides guidance on County Scale RunSpec selections and input data when running MOVES in Emission Rates mode
  - Some input guidance is presented in this course, but refer to Technical Guidance for more detail

Project Scale:

- *PM Hot-Spot Guidance: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas*
  - See EPA's Project-Level Conformity and Hot-Spot Analyses webpage for latest version
- *Using MOVES in Project-Level Carbon Monoxide Analyses*
  - See EPA's Project-Level Conformity and Hot-Spot Analyses webpage for latest version

Introduction to Emission Rates

- You can use Rates mode at the Default, County, and Project Scales
  - This module focuses on County
- Output from an Emission Rates run is a set of emission rates: e.g., rate per mile, per vehicle, per hour, per start
  - There are different types of rates for different emission processes
- You will have to post-process results by multiplying rates for each process by the appropriate activity (e.g., miles, vehicles) to get total emissions
  - MOVES does for you when using Inventory mode
  - Because there is more post-processing in Rates mode, there is greater potential for error

Why use rates?

- When you need flexibility to estimate emissions over a wide range of conditions, e.g., multiple counties
  - For creating SIP or other inventories
  - For modeling specific episodes in a SIP for photochemical modeling
- When you want to create a look-up table of rates to use for a link-based inventory (e.g., in a travel model post-processor) by applying the specific rates needed on each link

Other Considerations for Emission Rates vs. Inventory

- Either approach is acceptable for SIP and regional conformity analyses
- Trade-offs in both approaches; choice depends on the area and purpose
  - In many cases, Inventory is the more appropriate calculation type
    - Shorter run times and less post-processing
  - But, in certain cases, Emission Rates may require fewer runs
- Think carefully about which approach makes the most sense for your situation
  - Consider doing some test runs to get a sense of differences in input requirements, run time, post-processing, and output file size for each approach

When Using Either Mode

- Be consistent. While you can get the same answer regardless of the approach, it is much easier to avoid problems if you:
  - Use the same approach for base and projection years
  - Use the same approach for SIP and conformity analyses
- Use interagency consultation to make sure everyone agrees on best approach from the start (e.g., before modeling)
  - Interagency consultation is required on developing SIPs (see 40 CFR 93.105(b)(1))
  - Interagency consultation on modeling and associated methods and assumptions to be used is required for transportation conformity analyses (see 40 CFR 93.105(c)(1)(i))

Is there an easier method to generate emission rates?

- The emissions rates script in the MOVES Post Processing menu takes MOVES Inventory output and divides by VMT to estimate emission rates in units of mass per distance (e.g., grams/mile)
  - All emissions are in these units, including emissions from non-running processes
- This can be useful for "back of the envelope" analyses of fleet average emissions over time, differences in average emissions by source type, etc.
- Not appropriate for SIPs and conformity because these rates are not as granular as the rates produced in Emission Rates mode

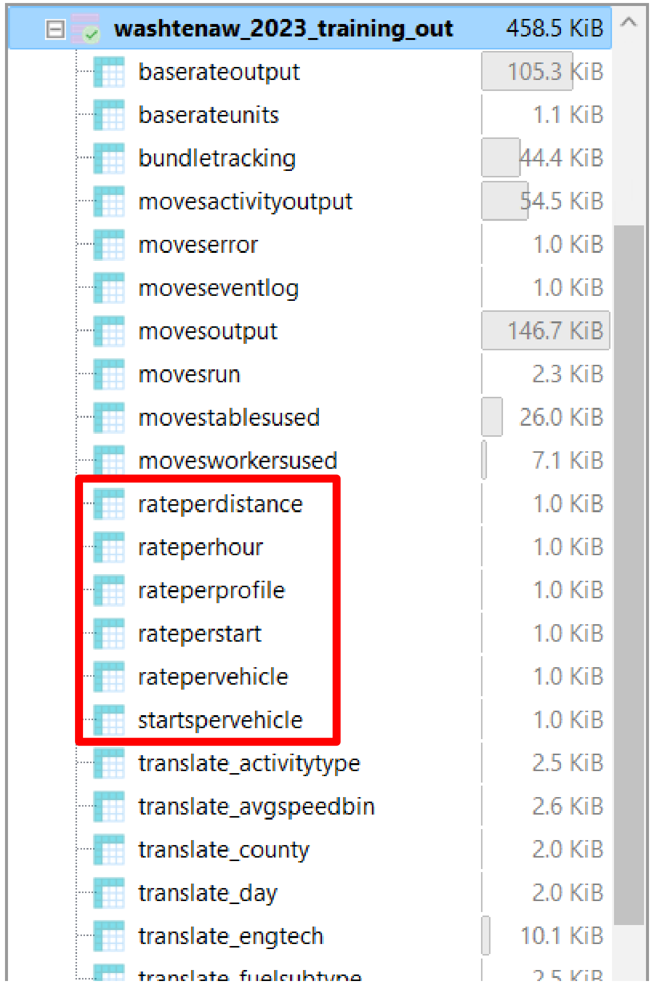
Calculating an Inventory from Rates Mode Overview

1. Run MOVES for your modeling scenario
   - As with Inventory mode, this involves making a RunSpec and an input database
2. MOVES will output emission rates for each selected pollutant and process
3. Multiply each emission rate by the appropriate activity measure for that rate

Emission Processes in MOVES

ProcessID	Emission Process	Process Applies When Vehicles Are…
1	Running Exhaust	Running
2	Start Exhaust	Starting
9	Brakewear	Running
10	Tirewear	Running
11	Evap Permeation	Running and Parked
12	Evap Fuel Vapor Venting	Running and Parked
13	Evap Fuel Leaks	Running and Parked
15	Crankcase Running Exhaust	Running
16	Crankcase Start Exhaust	Starting
17	Crankcase Extended Idle Exhaust	Hotelling
18	Refueling Displacement Vapor Loss	Running and Starting
19	Refueling Spillage Loss	Running, Starting, and Hotelling
90	Extended Idle Exhaust	Hotelling
91	Auxiliary Power Unit Exhaust	Hotelling
93	Shore Power	Hotelling

Output Database Tables for Rates Mode



- In Emission Rates mode, MOVES output database includes rate tables that cover all the emissions processes:
  - RatePerDistance: Running processes and off-network idle
  - RatePerVehicle: Start, Hotelling, Evap, Refueling processes
    - RatePerStart: Start processes
    - RatePerHour: Hotelling processes
  - RatePerProfile: Evap fuel vapor venting

- To calculate an inventory that captures all vehicle activity, you will need to use rates from several rate tables

Processes Included in Each Rate Table

MOVES Output Table	Process ID and Process:	
RatePerDistance	1: Running exhaust (including ONI)	
	9: Brakewear	
	10: Tirewear	
(when running)	11: Evap permeation	
(when running)	12: Evap fuel vapor venting	
(when running)	13: Evap fuel leaks	
	15: Crankcase running exhaust	
	18: Refueling displacement vapor loss	
	19: Refueling spillage loss	
RatePerVehicle	2: Start	*alternative:* use rate from **RatePerStart**
(when not running)	11: Evap permeation	
(when not running)	13: Evap fuel leaks	
	16: Crankcase start	*alternative:* use rate from **RatePerStart**
	17: Crankcase extended idle	*alternative:* use rate from **RatePerHour**
	18: Refueling displacement	
	19: Refueling spillage	
	90: Extended idle	*alternative:* use rate from **RatePerHour**
	91: Aux power exhaust	*alternative:* use rate from **RatePerHour**
RatePerProfile (when not running)	12: Evap fuel vapor venting	

When would I use alternative rates?

- Depends on the activity information you have

If you have:	Then use rates from:	To get emissions for:	Notes:
Number of vehicle starts	RatePerStart	Start (2, 16)	Use these rates ***instead*** of rates from RatePerVehicle
Number of hours that trucks are hoteling	RatePerHour	APU (90) Extended idle (17, 91)	Use these rates ***instead*** of rates from RatePerVehicle
Only number of vehicles, and no other info	RatePerVehicle	Start (2, 16) APU (90) Extended idle (17, 91)	Use these rates if you ***don't*** have number of starts Use these rates if you ***don't*** have hours hotelling

How Emission Rates Vary

MOVES
Motor Vehicle Emission Simulator

Level of Detail in Emission Rates Mode

- By checking boxes on the Output Emissions Detail Panel in the RunSpec, you can obtain rates that vary by:
  - Source use type (vehicle type)
  - Fuel type
  - Model year
  - Regulatory class
- If you don’t check a box, MOVES produces composite emissions rates over that category

Selecting Level of Detail

- When would you check each box?
  - ❒ Source use type (×13 source types)
    - Check this box if you have activity (VMT, population) by source type
    - This is generally ***always*** the case. Otherwise, MOVES will calculate a composite emission factor covering all vehicle types, including both light-duty and heavy-duty
    - Remainder of module assumes this box is checked
  - ❒ Fuel type (×5 fuel types)
    - Check this box *ONLY IF* you have activity by fuel type, you are doing an analysis comparing fuel types, or you have different fuel distributions by county and you need to estimate emissions for each county individually
  - ❒ Model year (×31 ages)
    - Check this box *ONLY IF* you have different age distributions by county and you need to estimate emissions for each county individually
  - ❒ Regulatory class (×9 reg classes)
    - Check this box if you have activity by regulatory class. This is rarely necessary

How Rates Vary: Temperature

- High temperatures and humidity affect air conditioning use, which increases emissions of some pollutants:
  - HC, CO & NOx and energy consumption from all LD vehicles
  - Energy consumption from electric HD vehicles
- Ambient temperature also affects:
  - Start emissions of THC, CO, NOx, PM and energy consumption
  - Running emissions
    - For diesel vehicles: NOx from heavy-duty MY 2027-and later (also extended idle emissions)
    - For electric vehicles: energy consumption
  - Evaporative hydrocarbon emissions

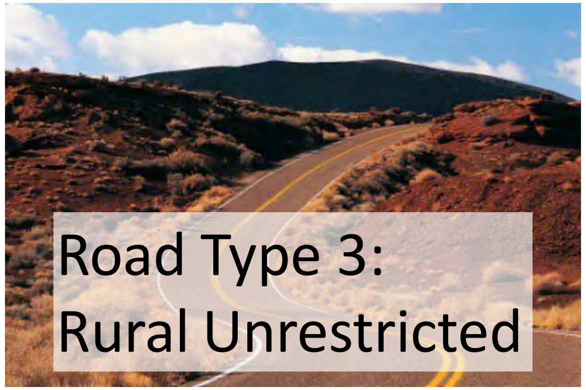
How Rates Vary: Running Emissions

- Running rates vary with:
  - Temperature
  - Road type: rates for each of five different road types
  - Speed bin: rates for each speed bin
    - roadTypeID 1 only includes off-network idle (avgSpeedBinID 0) rates
    - roadTypeIDs 2-5 only include rates for avgSpeedBinIDs 1-16
- How many rates does the rateperdistance table produce?
  - [up to 9 processes] × [13 source types] × [4 road types] × [16 speed bins] × [# of temps]
  - = Up to 7488 rates per temperature, for each pollutant (plus rates for off-network idle for each source type and temperature)
  - ×5, if you request output by fuel type

avgSpeedBinID	Description
0	Off-network idling
1	Speed < 2.5mph
2	2.5mph <= speed < 7.5mph
3	7.5mph <= speed < 12.5mph
4	12.5mph <= speed < 17.5mph
5	17.5mph <= speed < 22.5mph
6	22.5mph <= speed < 27.5mph
7	27.5mph <= speed < 32.5mph
8	32.5mph <= speed < 37.5mph
9	37.5mph <= speed < 42.5mph
10	42.5mph <= speed < 47.5mph
11	47.5mph <= speed < 52.5mph
12	52.5mph <= speed < 57.5mph
13	57.5mph <= speed < 62.5mph
14	62.5mph <= speed < 67.5mph
15	67.5mph <= speed < 72.5mph
16	72.5 <= speed

Why Do Running Emissions Vary by Average Speed and Road Type?

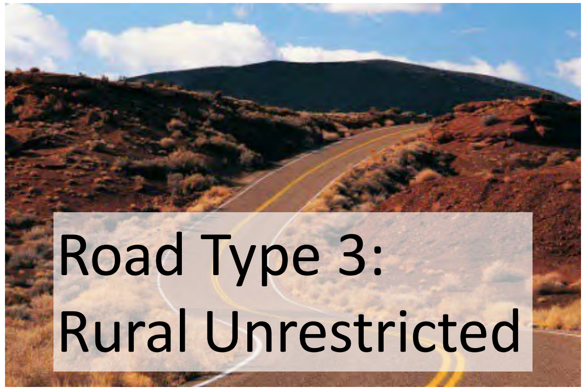
- Suppose the average speed of each of these road types is 35 mph:



- Why wouldn't the emissions rate at 35 mph be the same in each case?

Why Do Running Emissions Vary by Average Speed and Road Type? Answer

- Suppose the average speed of each of these road types is 35 mph:



- Why wouldn't the emissions rate at 35 mph be the same in each case?
  - Vehicle activity that results in an average speed of 35 will be different on each of these road types due to different driving conditions
    - Road type 3: Average speed of 35 may be mostly "cruise"
    - Road type 4: Average speed of 35 on a freeway is likely congested
    - Road type 5: Average speed of 35 includes stop time at traffic lights, acceleration, cruise, deceleration
  - Amount of time vehicles spend in each operating mode differs by road type

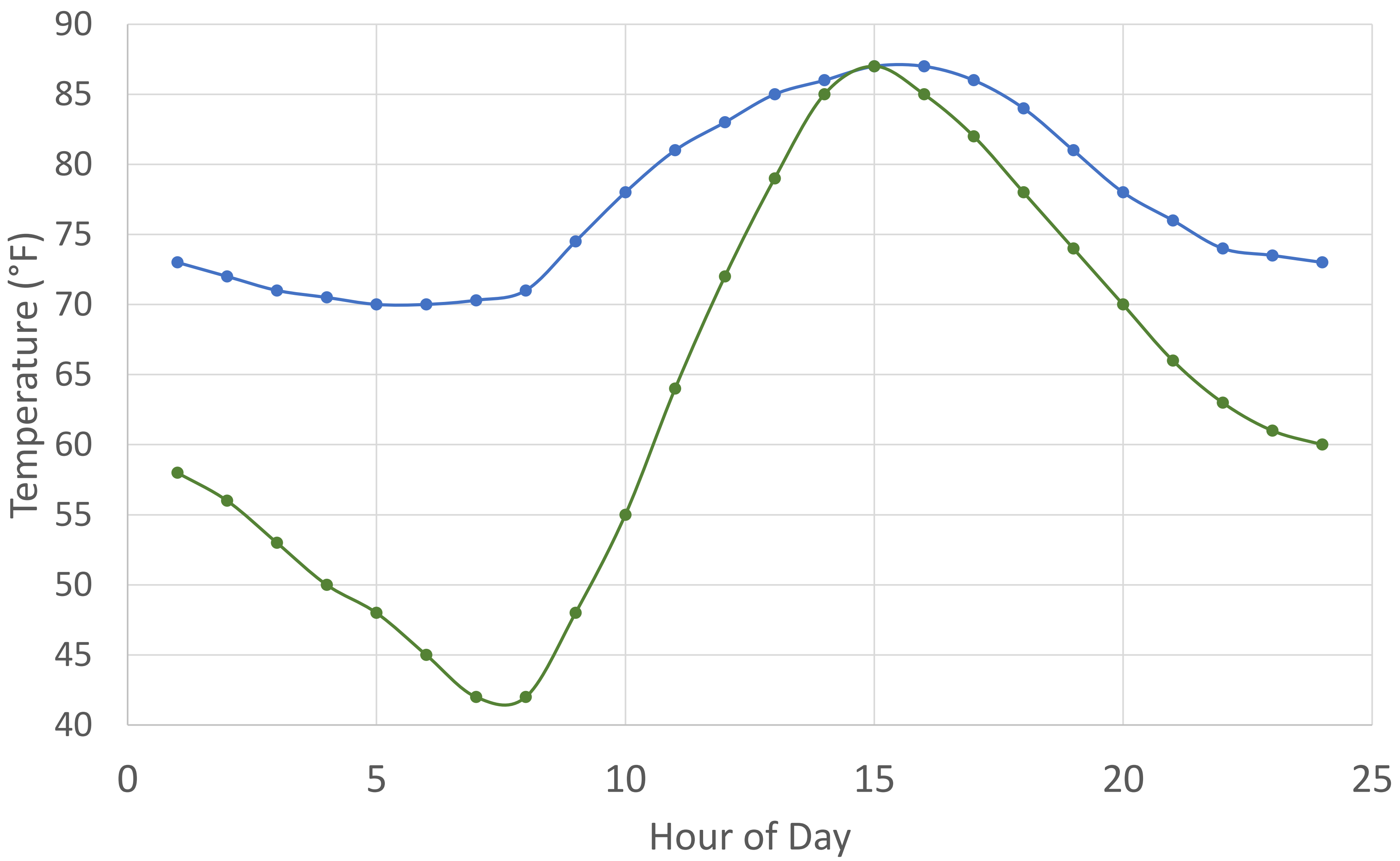
How Rates Vary: Start, Hotelling, Evap, Refueling

- RatePerVehicle rates (9 processes), RatePerStart rates (2 processes), and RatePerHour rates (3 processes) vary with:
    - Temperature (based on what you enter for a daily "temperature profile" – the temperature over the course of a day)
    - Type of day (weekday vs. weekend day)
    - Hour of day
- How many rates does the RatePerVehicle table produce?
    - [up to 9 processes] x [13 source types] x [2 day types] x [24 hours] x [# of temperature profiles]
    - = up to 5616 rates for each temperature profile, for each pollutant
        - Similarly, up to 1248 rates per temperature in the RatePerStart table
        - And up to 1872 rates per temperature in the RatePerHour table

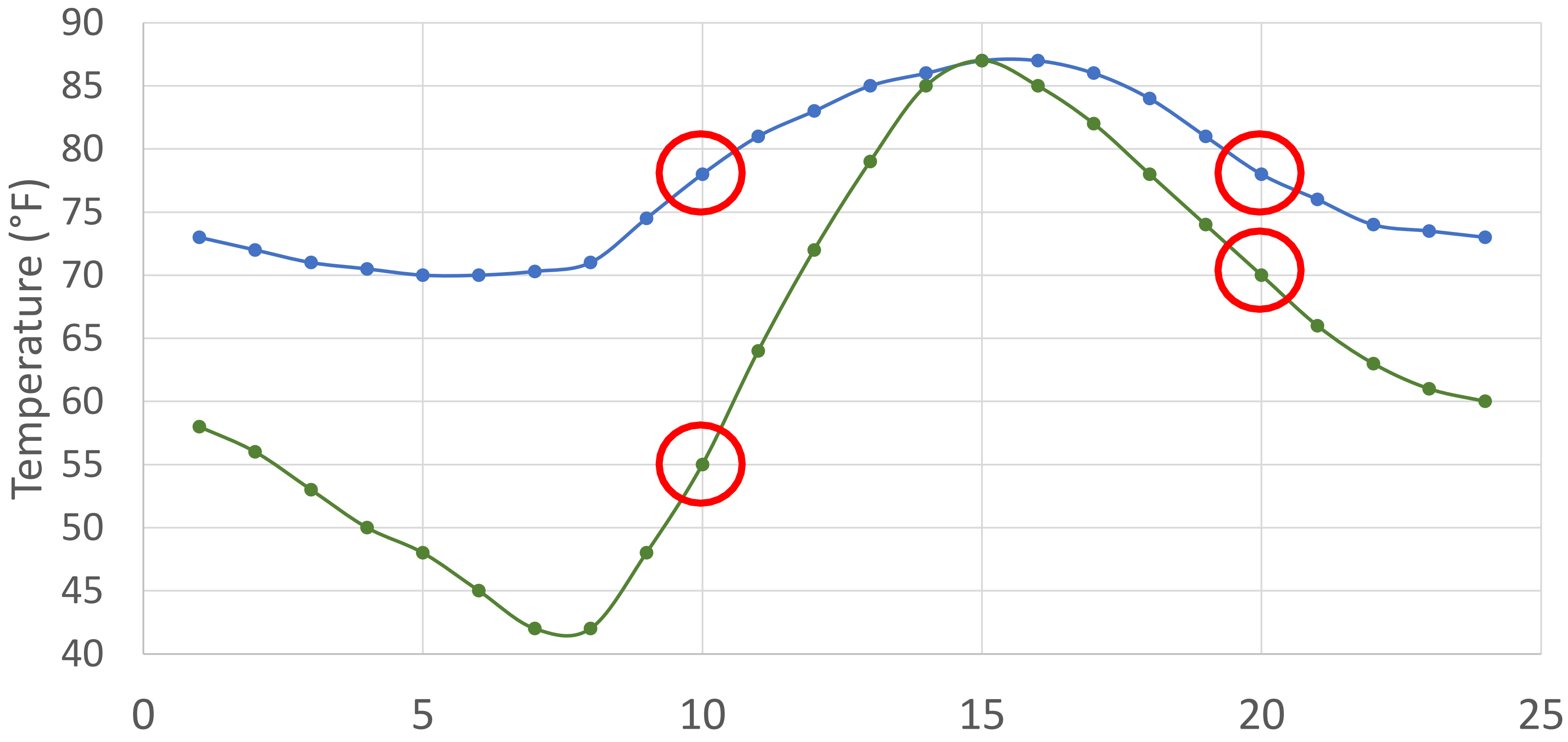
How Rates Vary: Evaporative Fuel Vapor Venting

- RatePerProfile rate (1 process) varies with
  - Temperature (based on what you enter for a daily temperature profile),
  - Temperature in the previous hours
  - Type of day (weekday vs. weekend day)
  - Hour of day
- How many rates does the RatePerProfile table produce?
  - [1 process] x [13 source types] x [2 day types] x [24 hours] x [# of temperature profiles]
  - = 624 rates for each temperature profile, for each pollutant

How do temperature profiles affect rates?



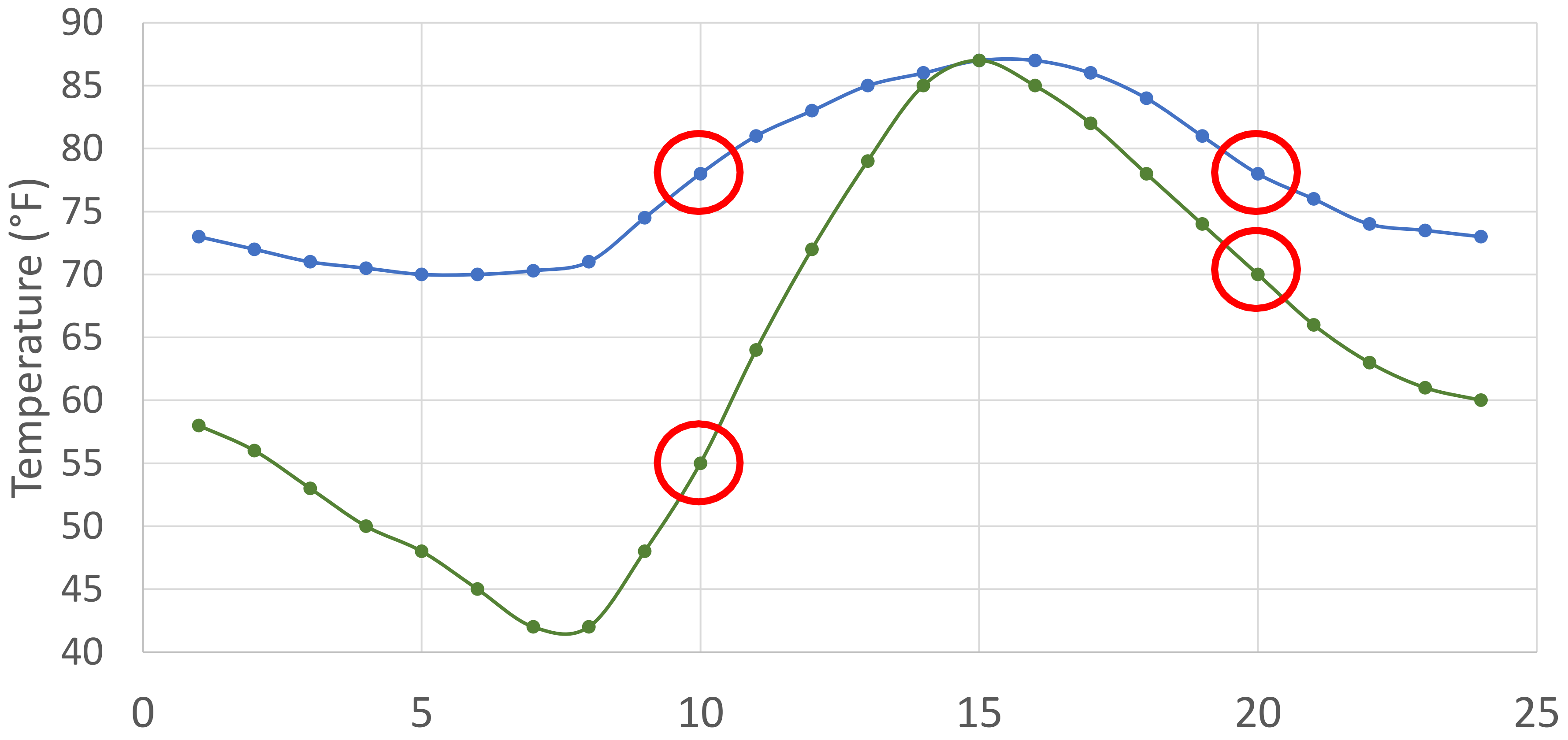
Temperature Profile: Running Emissions



Are the RatePerDistance running rates for hour 10 and hour 20 the same or different, in the

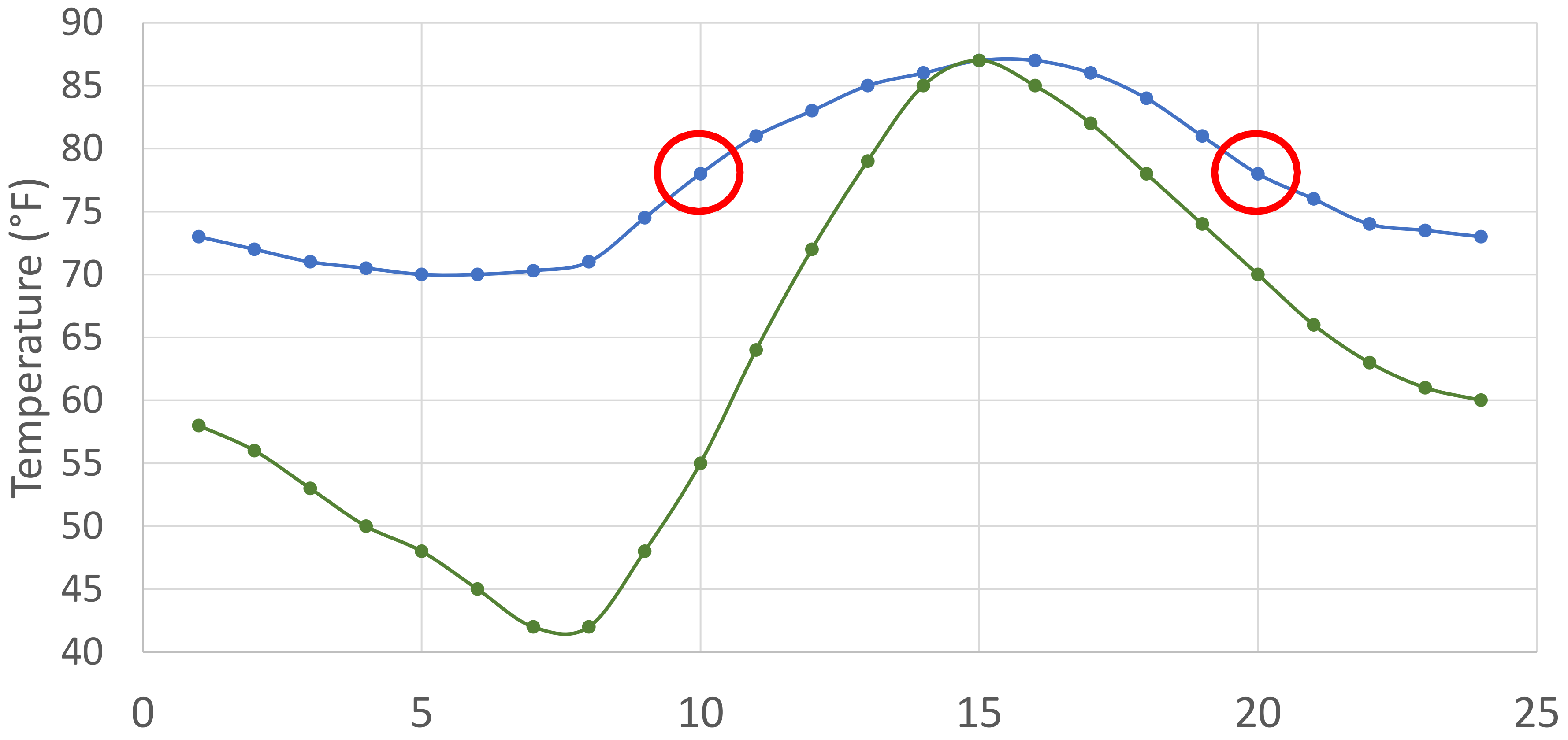
- Blue (upper) temperature profile?
- Green (lower) temperature profile?

Temperature Profile: Running Knowledge Check



For the blue (upper) profile, the rates for hour 10 and hour 20 are identical since the temperatures are the same.
For the green (lower) profile, they are different because the temperatures are different

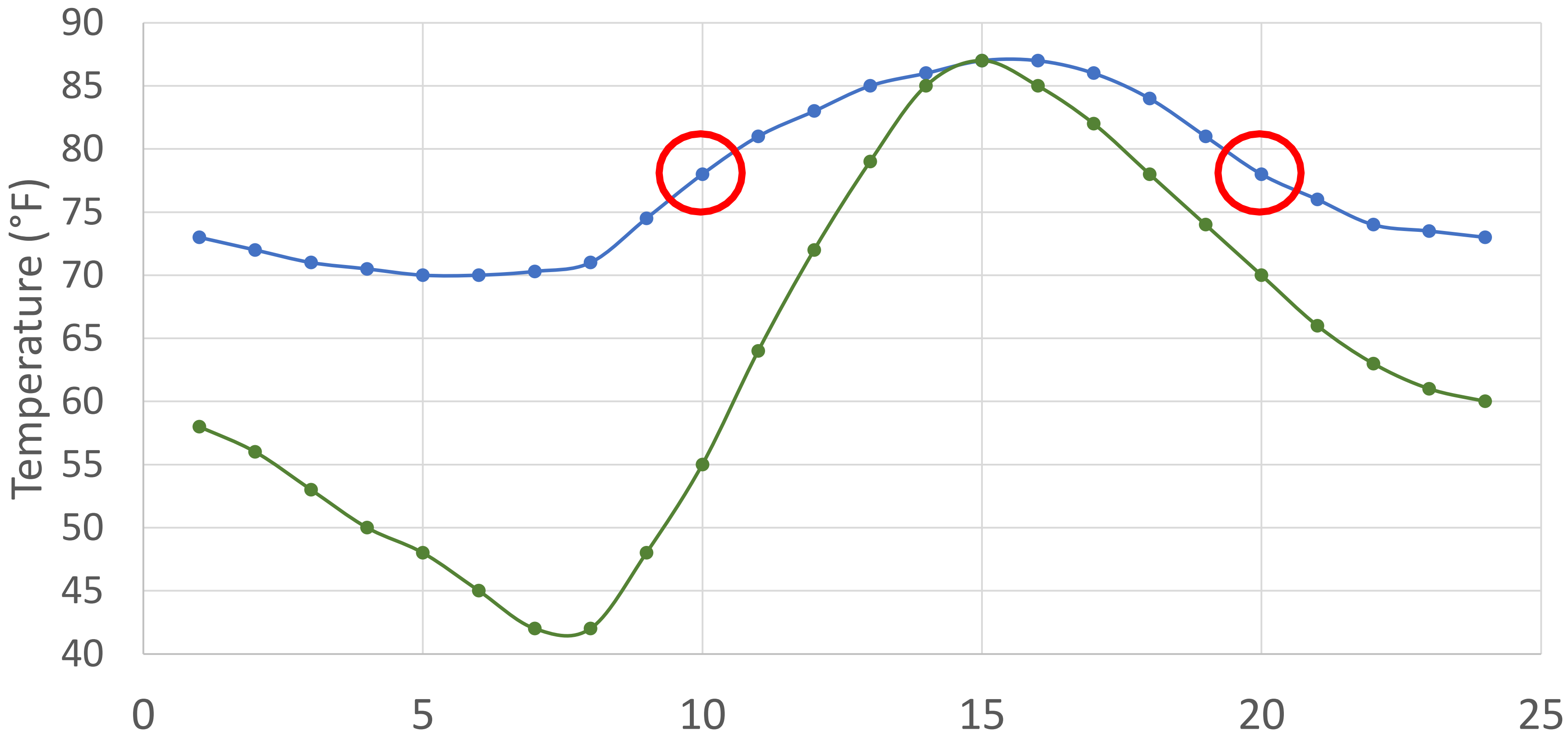
Temperature Profile: Starts



For the blue (upper) temperature profile, will the RatePerVehicle start rates for hour 10 and hour 20 be the same or different?

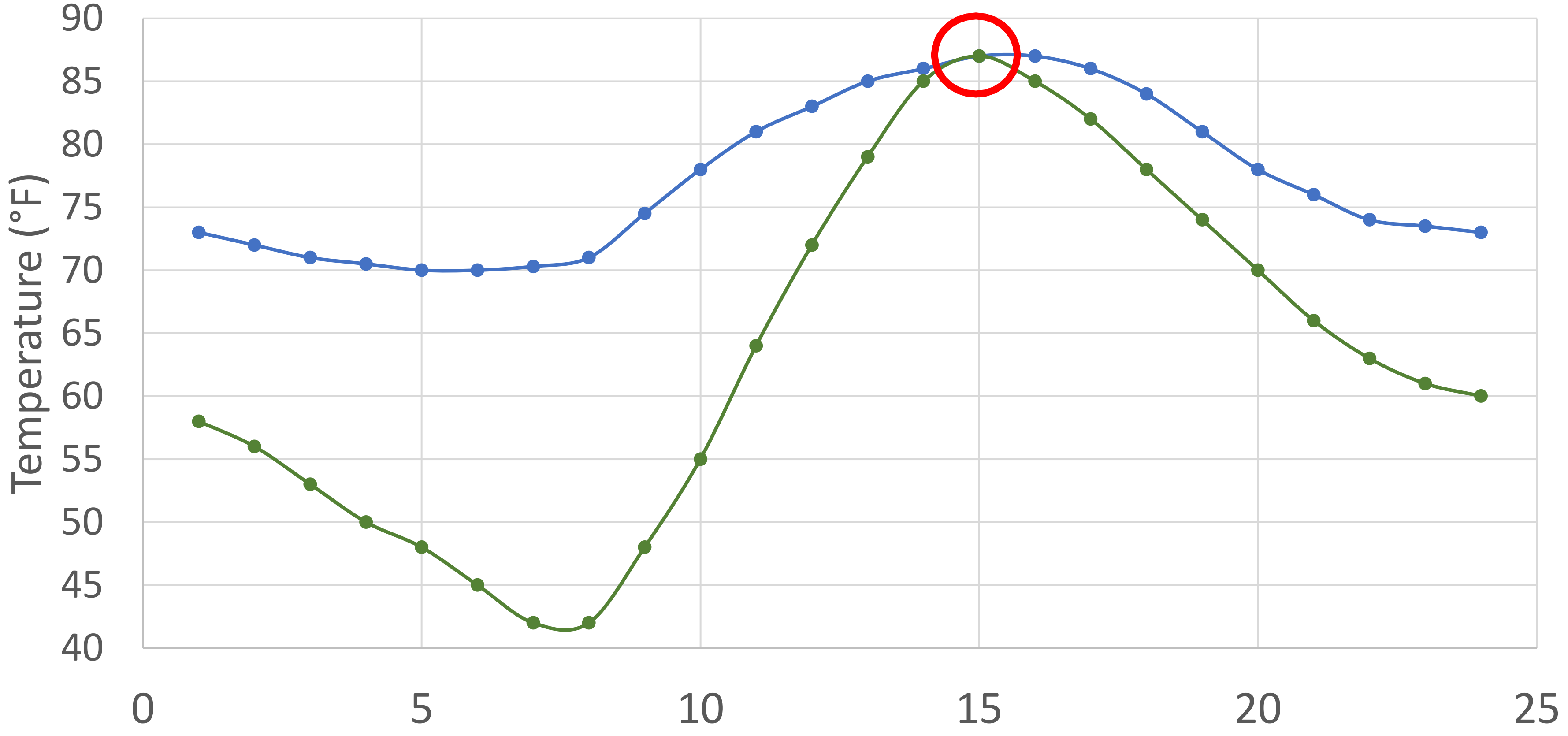
Hint: with RatePerVehicle, the rate will be multiplied by number of vehicles. What else do start rates depend on?

Temperature Profile: Starts Knowledge Check



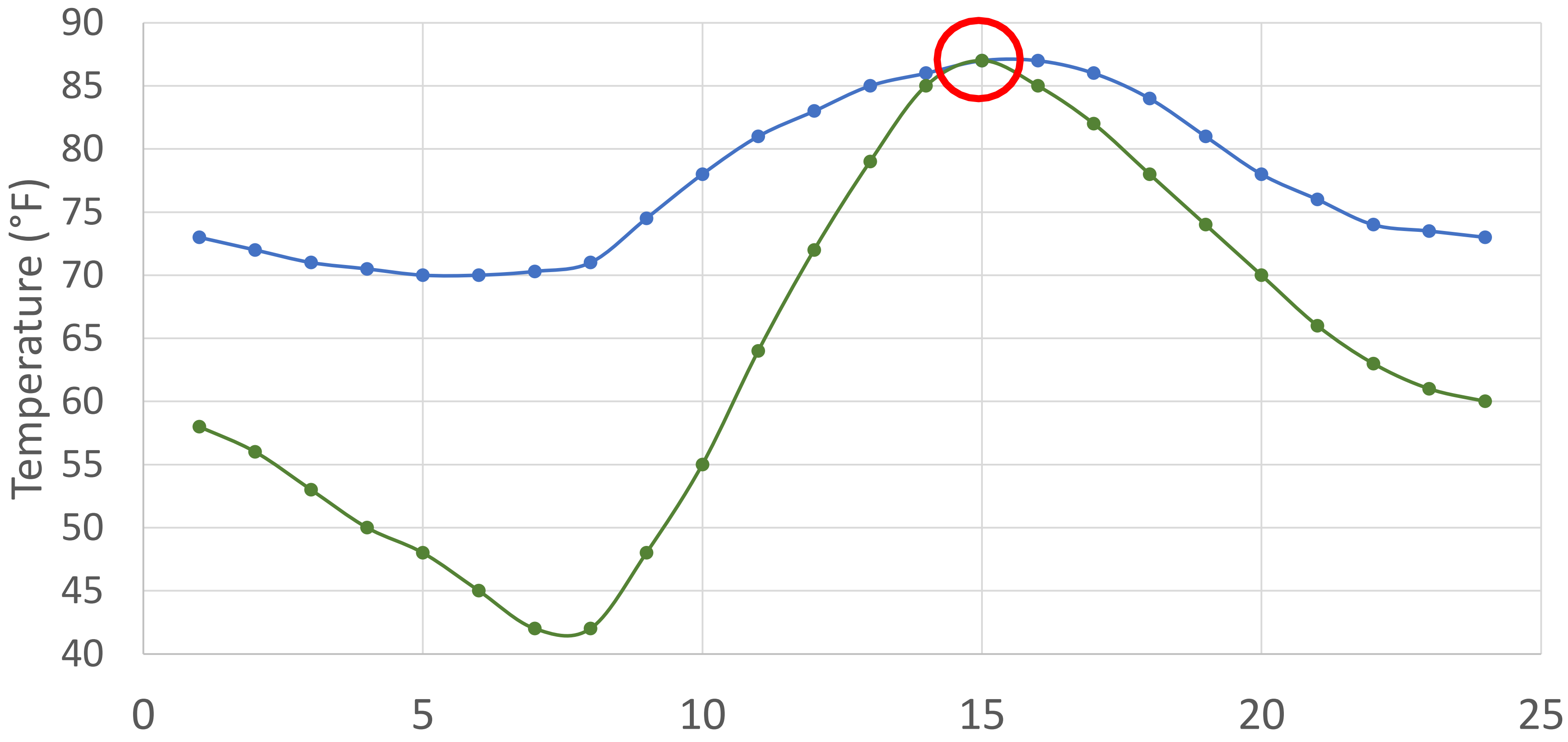
For the blue (upper) profile, the rates for hour 10 and hour 20 will be different since the number of starts and soak-time distributions differ by hour

Temperature Profile: Evap



Will the evaporative emissions at hour 15 in RatePerVehicle and RatePerProfile be the same or different with the blue (upper) and green (lower) temperature profiles?

Temperature Profile: Evap Knowledge Check



The evaporative emissions rates at hour 15 will be different with each profile because the ambient temperature in the previous hour is different

Check Your Understanding of Rates Mode: Questions

- Why would RatePerVehicle, RatePerStart, and RatePerHour rates vary by temperature, hour of day, and day type?

- Why would RatePerProfile vary by temperature, hour of day, and day type?

Check Your Understanding of Rates Mode: Answers

- Why would RatePerVehicle, RatePerStart, and RatePerHour rates vary by temperature, hour of day, and day type?
  - As seen in the charts, different temperatures produce different emission rates
  - Hour of day is important because the underlying distribution of activity that determines the rate changes. For example, when vehicles are starting, how long they are soaking, etc.
  - Day type is important because when vehicles are starting, and how long they are soaking for, both change by day type. For example, weekdays have a different pattern of starts than weekend days
- Why would RatePerProfile vary by temperature, hour of day, and day type?
  - Vapor venting depends on history effects. The temperature in the previous hour affects how filled the canister is. The length of soak time matters as well, which varies by day type

How Rates Vary: Summary

Rates vary with:	RatePerDistance	RatePervehicle RatePerstart RatePerhour	RatePerProfile
Vehicle type (x 13)	Only if selected	Only if selected	Only if selected
Temperature (x ?)	Yes	Yes – rates vary with temperature profile	Yes – rates vary with temperature profile
Road type (x 5)	Yes	--	--
Speed bin (x 16)	Yes	--	--
Type of day (x 2) (Weekday/Wkend)	No	Yes	Yes
Hour of Day (x 24)	No	Yes	Yes
Model year (x 31)	Only if selected	Only if selected	Only if selected
Fuel type (x 5)	Only if selected	Only if selected	Only if selected

Calculating an Emissions Inventory Using Rates Mode

MOVES
Motor Vehicle Emission Simulator

Running Emissions (RatePerDistance Table)

- Total on-network running emissions =

  (Running emissions rate) × (VMT)

- Rates given in *mass per distance* (e.g., grams per vehicle-mile)
- To get a total running inventory, repeat calculation for each process, vehicle type, on-network road type, and speed bin at the relevant temperature, then sum results

- Off-network idle rates are reported in the RatePerDistance table for roadTypeID 1. However, these rates are in terms of *mass per hour* (e.g., gram/hour)
- Total off-network idle emissions =

  (Off-network emissions rate) × (hours of activity)

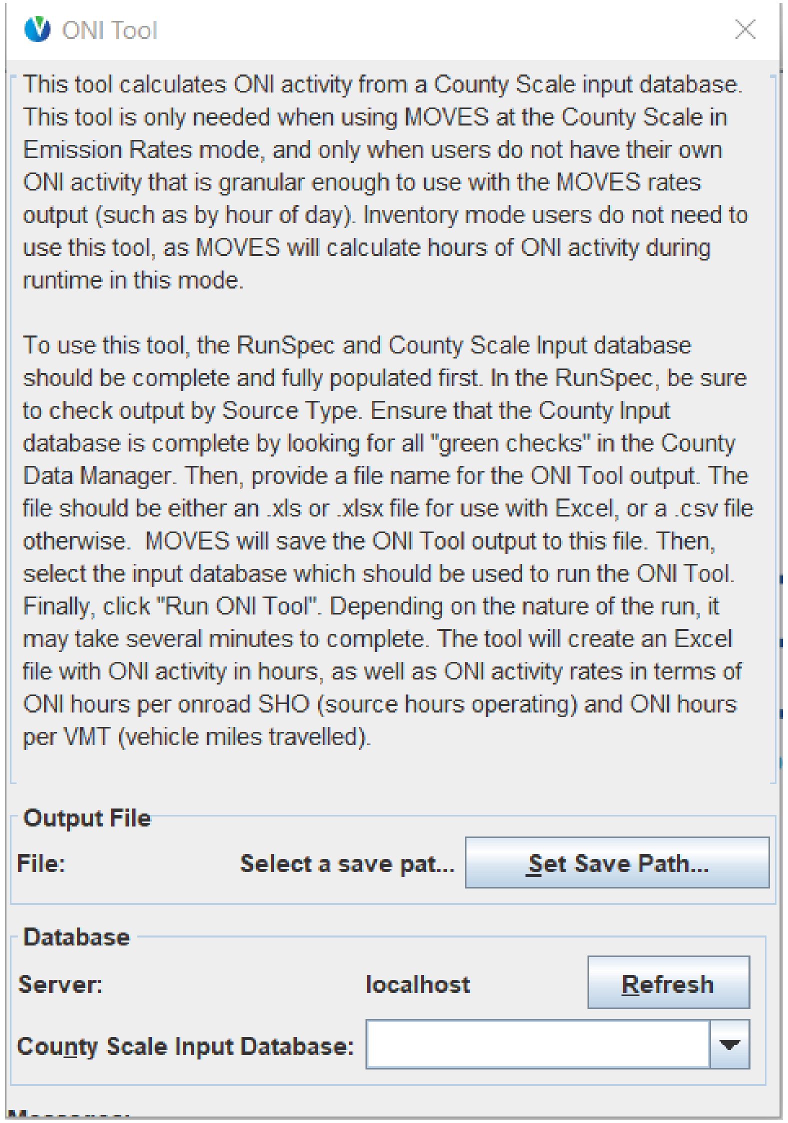
VMT by Average Speed Bin

- Need VMT by average speed bin for on-network running emissions
- If you are using the average speed bin distribution to calculate this, remember that AvgSpeedDistribution is by time, not distance (i.e., source hours operating [SHO], not vehicle miles traveled [VMT])
  - In this case, start with SHO by road type
  - Multiply this by the avgSpeedFraction to get SHO by road type and speed bin
  - Multiply this by the average bin speed to get VMT by road type and speed bin

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

Off-Network Idle Tool

- Off-network idle (ONI) is defined as time where a vehicle is idling, but not as part of regular driving (as at a traffic signal)
  - E.g, vehicle is idling because the driver is waiting
  - Could be occurring in a parking lot or driveway, or even on the shoulder or side of the road
  - This activity does not include hotelling idle
- These emissions are given the off-network road type (roadTypeID 1)
- The rate per hour must be combined with hours of ONI activity for each source type
- If hours of ONI activity are not known, the ONI Tool (available in the Tools menu) can be used to estimate default ONI activity. After populating an input database (and either before or after running MOVES), the tool can be used to generate an Excel file with default idle hours



Off-Network Idle Tool Output

	A	B	C	D	E	F	G	H	I	J	K	L
1	yearID	monthID	dayID	hourID	sourceTypeID	minModelYearID	maxModelYearID	onroadSHO (hr)	VMT (mi)	ONI (hr)	ONI per VMT (hr idle/mi)	ONI per SHO (hr idle/hr operating)
2	2023	7	5	1	21	1960	2060	2755.911143	105954.7692	476.0890702	0.004493324	0.172751967
3	2023	7	5	2	21	1960	2060	1876.68541	71303.8014	325.3068478	0.004562265	0.173341172
4	2023	7	5	3	21	1960	2060	1428.321865	54162.46828	231.2492982	0.004269549	0.161902792
5	2023	7	5	4	21	1960	2060	978.2303103	37276.20599	159.3182863	0.004273994	0.16286378

ONI Tool Output

- The ONI Tool provides output for each month, day, hour, and source type in your input database:
  - Hours of ONI
  - Hours of ONI per VMT (hours of idle per mile traveled)
  - Hours of ONI per SHO (hours of idle per hours operated)
- If your input database contains the actual activity inputs that you would use for an inventory run (i.e., not simply “representative” values), you can use the hours of ONI values directly
- Otherwise, use either the ONI per VMT or ONI per SHO values
  - E.g., multiply your VMT by month, day, hour, and source type by ONI per VMT to get hours of ONI
- To calculate the ONI emissions inventory, multiply hours of ONI by the Off-network Emissions Rate

Start Emission Rates

- Start rates are produced in both:
  - *Mass per vehicle* from the RatePerVehicle table, for each hour of day, for each daily temperature profile
    - E.g.: gram/vehicle
    - Calculate inventory by multiplying by vehicle population
  - *Mass per start* from the RatePerStart table, for each hour of day, for each daily temperature profile
    - E.g.: gram/start
    - Calculate inventory by multiplying by number of starts
- WARNING: Use one or the other – not both

Calculating Start Emissions

- Calculate total start emissions by multiplying:

$$\begin{pmatrix}\text{Start emissions rate} \\ \text{from RatePerVehicle}\end{pmatrix} \times (\text{vehicle population})$$

OR

$$\begin{pmatrix}\text{Start emissions rate} \\ \text{from RatePerStart}\end{pmatrix} \times (\text{number of starts})$$

- To get total daily start emissions, repeat calculation for each:
  - Vehicle type
  - Start process (2, 16)
  - Hour of the day at the relevant temperature
- Then sum results

Hotelling Emission Rates: APU, Extended Idle

- Hotelling rates given in both:
  - *Mass per vehicle* from the RatePerVehicle table, for each temperature and hour of day
    - E.g.: g/vehicle
    - Calculate inventory by multiplying by vehicle population (i.e, number of source type 62s)
  - *Mass per hour* from the RatePerHour table, for each temperature and hour of day
    - E.g.: g/hr
    - Calculate inventory by multiplying by number of hotelling hours
- WARNING: Use one or the other – not both
- Be sure to check "Source Use Type" on Output Emissions Detail panel – if not selected, MOVES will give you a composite rate that applies to all vehicles

Calculating Hotelling Emissions: APU, Extended Idle

- Calculate total extended idle emissions, and total APU emissions by multiplying:

  (rate from RatePerVehicle) × (number of source type 62s)

  OR

  (rate from RatePerHour) × (number of hotelling hours)

- To get total daily hotelling emissions, repeat calculation for each hotelling process (17, 90, 91) and hour of the day at the relevant temperature; sum results

Evaporative Fuel Vapor Venting Emission Rates

- Rate given in *mass per vehicle* for each temperature and hour of day
  - E.g.: g/vehicle
- Recall, these rates are affected by the temperature, hour of day, and temperature of the previous hours
- Inventory is calculated by multiplying the rate by the vehicle population (not the number of parked hours)

Calculating Evaporative Fuel Vapor Venting Emissions

- Calculate total evaporative emissions by multiplying:

(Evaporative Fuel Vapor Venting rate) × (number of vehicles)

- For total daily evaporative fuel vapor venting emissions, repeat calculation for each vehicle type and hour, for the relevant temperature profile; sum results

Guidance for Creating a Rates Mode RunSpec

MOVES

Motor Vehicle Emission Simulator

Rates RunSpec Guidance: Scale Panel

- Select County in the Domain/Scale
  - Remember, one of the reasons for using rates is to cover a broad area with minimal run(s)
  - You are still using County scale, and you will still need to choose a single county, but keep this point in mind
- Select Emission Rates
- MOVESScenarioID is required (but will not affect results)
  - Used for SMOKE-MOVES
  - If not using SMOKE-MOVES, enter something descriptive

Rates RunSpec Guidance: Time Spans

- Select all hours
- Select one or both day types
  - Start/evap rates will vary by day type
  - An annual inventory should use rates for weekend and weekdays
  - Daily inventory may just use weekday
- Select all relevant months
  - Fuels and temperature profiles vary by month
- Can only select one year for County Scale analyses

Rates RunSpec Guidance: Geographic Bounds

- Select a single county
- Emission rates produced by MOVES can be used for multiple counties if all counties share the same age distribution, fuels, and I/M program

Rates RunSpec Guidance: Vehicle/Equipment

- Select all vehicle/fuel types present in modeling domain
- If you want MOVES to produce emissions rates for each
  - ☑ source type
  - ☑ fuel type
- How would you tell MOVES to do that?

Rates RunSpec Guidance: Vehicle/Equipment Knowledge Check

- Select all vehicle/fuel types present in modeling domain
- If you want MOVES to produce emissions rates for each
  - ☑ source type
  - ☑ fuel type
- How would you tell MOVES to do that?
- By checking these boxes on the Output Emissions Detail Panel – coming up

Rates RunSpec Guidance: Road Type

- In general, select all road types
- A running emissions rate will be produced for each of the 5 road types
  - “off-network idle” is considered a running process and is therefore included in the running emissions rates – for roadTypeID 1 (off-network road type)
  - Therefore, if you are modeling running emissions, you must select all road types (even if not all are present in the modeling domain)
- Start and hotelling rates are for activity occurring on the “off network” road type only
- Evaporative rates occur on all road types

Rates RunSpec Guidance: Pollutants and Processes

- Select all pollutants of interest
- For a complete inventory, it is necessary to select all processes
- A rate will be produced for each pollutant and process
  - Either expressed as RatePerDistance, RatePerVehicle, or RatePerProfile

Rates RunSpec Guidance: General Output

- Create an output database
- Recommend grams, joules, and miles
  - Note that selecting other units here will change the units of your output
  - For example, running rates can be expressed in g/km
- Activity output is not selectable for rates runs

Rates RunSpec Guidance: Output Emissions Detail

- Road type and emission process are auto-selected
  - Rates will be produced for each road type and emissions process
- Additional selections depend on what activity data you have for VMT and vehicle population
  - Do you have VMT by source type?
    - Usually available: If so, check "Source Use Type"
  - Do you have VMT by fuel type?
    - If so, and you're interested in emissions by fuel type, then check it
  - Do you have VMT by model year?
    - Unlikely. Since checking this box increases rows of output ×31, this is not recommended

Guidance for Creating a Rates Mode Input Database

Rates Inputs Guidance: Meteorology

- Guidance about the meteorology input is the same as for Inventory mode
- Local temperature and humidity data are required inputs for SIP and regional conformity analysis with MOVES
- Default data are based on historic 10-year averages, which may not be appropriate for all types of analysis
- Temperatures for conformity analysis must be consistent with temperatures used to develop SIP emissions budgets

Rates Inputs Guidance: SourceTypePopulation

- Even though you will multiply RatePerVehicle and RatePerProfile rates by vehicle population, vehicle population is still necessary as an input
- A population should be entered that is reasonable and consistent with VMT
  - One option is to enter the total vehicle population of the modeling domain
  - Alternatively, a representative county's vehicle population can be used
- Most important, the ratio of vehicle population to VMT must reflect actual conditions
  - MOVES uses VMT and VPOP to estimate proportion of time a vehicle is parked, which affects evaporative emission rates
  - If source type is not selected as an output detail, the ratio of vehicle populations between the source types must reflect actual conditions, so that differences between source types are appropriately weighted

Rates Inputs Guidance: Age Distribution

- Users should enter the Age Distribution of the modeling domain
- This must be uniform across all counties if you intend to use the output rates for the entire area
- If age distribution is not uniform across all counties you need to model, what would you need to do?

Rates Inputs Guidance: Age Distribution Knowledge Check

- Users should enter the Age Distribution of the modeling domain
- This must be uniform across all counties if you intend to use the output rates for the entire area
- If age distribution is not uniform across all counties you need to model, what would you need to do?
- Either:
  - Do multiple runs, or
  - Select ☑ Model Year on the output emissions detail to produce rates for each model year. Then use these rates in post-processing to account for varying age distributions in the different counties within the modeling domain
    - Note that this will increase the size of your output by ×31

Rates Inputs Guidance: VMT (HPMSVTypeYear, etc.)

- Even though you will need to multiply RatePerDistance rates by VMT after the run, VMT is still necessary as an input
- VMT should be entered that is reasonable, and consistent with vehicle population
  - One option is to enter the total VMT of the modeling domain
  - Alternatively, a representative county's VMT can be used
- Most importantly, the ratio of vehicle population to VMT must reflect actual conditions
  - MOVES uses VMT and VPOP to estimate proportion of time a vehicle is parked, which affects evaporative emission rates
  - If source type is not selected as an output detail, the ratio of VMT between the source types (or HPMS classes) must reflect actual conditions, so that differences between source types are appropriately weighted

Rates Inputs Guidance: VMT (month, day, hour fractions)

- MonthVMTfraction, DayVMTfraction, and HourVMTfraction are also required by MOVES
- These fractions impact emission rate calculations
- Reasonable values should be entered
    - Either local fractions or MOVES defaults

Rates Inputs Guidance: Speed Distribution

- Running emission rates for RatePerDistance will be produced on each road type, for each source type (if selected on the Output Emissions Detail Panel), in each of 16 speed bins
- MOVES still requires an average speed distribution input
  - MOVES uses speed information when calculating evaporative emission rates
  - Therefore, this should be a reasonable distribution – either a local distribution or MOVES defaults
- Replace any zeros in the AvgSpeedDistribution with low non-zero values. Otherwise, MOVES will not produce emission rates for those speed bins

Rates Inputs Guidance: Road Type Distribution

- Running emission rates for RatePerDistance will be produced for each road type
- MOVES still requires a road type distribution input
- This should be a reasonable distribution
    - Either local distribution or MOVES defaults

Rates Inputs Guidance: Fuel

- Guidance about fuel inputs is the same as for Inventory (see Module 3)
  - Users should input the fuel information used in the modeling domain
  - Rates cannot be applied to areas that use different fuels
- Fuel Supply and Fuel Formulation tables: MOVES default data is appropriate
- Fuel Usage Fraction and AVFT: Local data should be used
  - However, if you are getting rates by fuel type, you can use the defaults for both Fuel Usage Fraction and AVFT. ***Why?***

Rates Inputs Guidance: Fuel Knowledge Check

- Guidance about fuel inputs is the same as for Inventory
  - Users should input the fuel information used in the modeling domain
  - Rates cannot be applied to areas that use different fuels
- Fuel Supply and Fuel Formulation tables: MOVES default data is appropriate
- Fuel Usage Fraction and AVFT: Local data should be used
  - However, if you are getting rates by fuel type, you can use the defaults for both Fuel Usage Fraction and AVFT. ***Why?***
  - Because if you get rates by fuel type, you will be multiplying those rates by the corresponding activity values for each type of fuel

Rates Inputs Guidance: I/M Programs

- Users should input the Inspection and Maintenance program used in the modeling domain
  - Rates cannot be applied to areas that have a different I/M program or different I/M compliance rates

Hands-on Exercise: Calculating an Inventory with Rates Mode

MOVES
Motor Vehicle Emission Simulator

Rates Mode Exercise Overview (1)

- We will use MOVES to develop a NOx inventory for passenger cars in Washtenaw County, MI from **12am-1am** on a summer day in 2023
  - Similar analysis to the Module 3 County Scale inventory run
  - We will only calculate the inventory for a single hour to simplify the post-processing
- All processes will be modeled to produce RatePerDistance and RatePerVehicle tables
  - RatePerProfile tables will not be generated since they only cover pollutants with evaporative processes (NOx is not an evaporative pollutant)
- The output tables will be queried for relevant information and applied to known vehicle activity

Rates Mode Exercise Overview (2)

- To save time setting up the run, we will use a preconfigured RunSpec, which will use our database from Module 3
- We will use the ONI Tool to estimate off-network idle activity
- After running MOVES, we'll set up an Excel spreadsheet to calculate the emissions inventory using the MOVES output emission rates

Rates Mode Exercise: Step 1

Load the RunSpec:

- Load *washtenaw_2023_training_rates.mrs* from the Module 6 - Rates Exercise folder
- This RunSpec is identical to the Module 3 exercise RunSpec, except:
  - Emission Rates are selected on the Scale Panel
  - Only 12am-1am and only weekdays are selected on the Time Spans Panel
  - A different output database is used: washtenaw_rates_out
  - Fuel type is not included in the output detail

Rates Mode Exercise: Step 2

Run the ONI Tool:

- You should have all green checks in the RunSpec
  - If you do not have the washtenaw_2023_training_in database, you can find it in the Module 3 - County Scale Exercise\Answer Key folder. Copy and paste it into your MariaDB data folder
- Open the ONI Tool from the Tools menu in MOVES
  - Specify an output file with the .xlsx extension
  - Select washtenaw_2023_training_in as the County Scale Input Database
  - Click “Run ONI Tool”

Rates Mode Exercise: Step 3

Run MOVES:

- Execute MOVES using the Action menu
  - This run should take approximately 5-10 minutes

What rates do we need?

- A reminder of our scenario:
  - Develop a NOx inventory for passenger cars in Washtenaw County, MI from **12am-1am** on a summer day in 2023
- Need running rates (processIDs 1 and 15) in RatePerDistance
  - For road types 2-5
- Need start rates (processIDs 2 and 16) in RatePerVehicle
  - Could also use RatePerStart, but we don't have number of starts, only number of vehicles
- Need off-network idle rates (processID 1) in RatePerDistance
  - For the off-network road type (roadTypeID 1)

Rates Mode Exercise: Step 4

Populate fields in Module 6 - Rates Exercise\Inventory Calculations Template.xlsx to calculate the inventory

- The VMT tab has VMT activity by road type and speed bin
  - Query your MOVES output in HeidiSQL and output to Excel to populate the Running Tailpipe and Running Crankcase rates columns
  - Enter the correct formula to calculate the running tailpipe and running crankcase inventories
- The Population tab has population activity
  - Query your MOVES output to populate g/vehicle values and then enter the correct formula to calculate the inventories
- The ONI tab has a template for ONI activity
  - Paste the relevant rows from the ONI tool on this tab
  - Query your MOVES output to populate ONI rate values and then enter the correct formulate to calculate the inventories

Querying the output: Running Rates

On-network Running Rates Queries:

```
SELECT roadTypeID, avgSpeedBinID, ratePerDistance AS runningTailpipe
FROM washtenaw_2023_rates_out.rateperdistance
WHERE roadTypeID IN (2, 3, 4, 5) AND processID = 1
ORDER BY roadTypeID, avgSpeedBinID;

SELECT roadTypeID, avgSpeedBinID, ratePerDistance AS runningCrankcase
FROM washtenaw_2023_rates_out.rateperdistance
WHERE roadTypeID IN (2, 3, 4, 5) AND processID = 15
ORDER BY roadTypeID, avgSpeedBinID;
```

Export the result set to Excel and copy values to the VMT tab

Querying the output: Start Rates

RatePerVehicle query:

```
SELECT processID, ratePerVehicle
FROM washtenaw_2023_rates_out.ratepervehicle
ORDER BY processID;
```

Export the result set to Excel and copy values to the Population tab

Querying the output: ONI Rates

ONI query:

```
SELECT processID, rateperdistance AS ONIRate
FROM washtenaw_2023_rates_out.rateperdistance
WHERE roadTypeID = 1
ORDER BY processID;
```

Export the result set to Excel and copy values to the ONI tab

ONI Tool Output

- Find the relevant row in the ONI Tool output file and copy/paste it to the ONI tab
  - DayID = 5
  - HourID = 1
- Since our input database contains the actual VMT, population, etc. activity values, we can directly use the ONI (hr) value from this row

Rates Mode Exercise Results

- After entering the correct formulas on the VMT, Population, and ONI tabs, the Total Inventory tab should automatically update to calculate the total sum
- The result should equal **13,647.9** grams
- Note that this total is only for a very small part of the overall NOx inventory:
  - Passenger cars at **12-1am** on a summer weekday
- To get a complete daily inventory using Emission Rates mode, this process would be repeated for all source types and all hours
- An annual inventory or an inventory including evaporative emission rates would involve even more post-processing

Module 6 Summary

- An Emission Rates run allows you to generate rates for a variety of applications, especially useful for wide geographic areas
- Generates potentially thousands of rates, found in several tables
  - Multiply the rates by the appropriate activity after the run
  - Be careful in post-processing to avoid introducing errors
  - This is best done using scripts that you and others can check for quality and comment on. Include these scripts with your other documentation
- Either Emission Rates or Inventory is acceptable for SIP and conformity purposes and will produce the same results if done correctly
  - MOVES does the multiplying for you in Inventory mode
  - Consider whether Inventory would be simpler, e.g., for modeling a small number of counties

Module 6 Questions?

Module 7:
Project Scale Analyses

MOVES
Motor Vehicle Emission Simulator

EPA

Module 7 Overview

- Introduction to Project Scale Analyses
    - What is the Project Scale, and why would you use it?
- Project Scale RunSpecs
- All about links, and how to enter link information with the Project Data Manager
    - Running links
    - Off-network links
- Hands-on exercise: modeling a simple truck terminal project
    - Part 1: Defining links, entering data, and running MOVES
    - Part 2: Same project, using drive cycle data for some links
    - Looking at emissions output with HeidiSQL

Introduction to Project Scale

- The National Academy of Sciences suggested that EPA add a 'microscale' modeling domain to its emission modeling 'toolkit'
  - EPA's model has included the ability to model a project since the first MOVES version was released, in 2010
- Project Scale allows MOVES modeling at the 'Link' level
  - Roadway links
  - Off-network link
- Project Scale models the 'average' conditions on one or more links
  - However, it is not a traffic simulation model

Summary: The Three Scales of MOVES (Project)

	Default	County	Project

Geographic area covered	• Entire nation
	• One or more states
	• One or more counties
		• One county
		• A multi-county area
		  • modeled with a representative single county, or
		  • each modeled separately and summed
		• A partial county
			An individual transportation project (e.g., a highway, intersection, or transit project)

Purpose	Non-regulatory only	Required for SIP and regional conformity analyses	Required for project-level conformity analyses
Input database	User does not need to create; use of Data Importer is optional	User creates with local data, through the County Data Manager	User creates with local data, through the Project Data Manager
Default data	Used unless overridden	Access to default data is limited	Access to default data is limited

MOVES Project Scale

- Project scale is appropriate for:
  - CO and PM “hot-spot” analyses for project-level conformity
  - National Environmental Policy Act (NEPA) Environmental Impact Statements (EISs)
  - Roadway/Intersection level energy and greenhouse gas analyses
- Link-specific and project-specific data must be entered
  - NOTE: No default data options for VMT, population, speeds, etc.
- Use the Project Data Manager (PDM) to prepare input databases for Project Scale runs

Project Scale vs. Default and County Scales

- Uses the same MOVES emission rates and correction factors as County and Default Scale
- Calculates emissions at the link level, compared to the county-level (or higher) at County and Default Scale
- Allows the user to model only one hour per run
  - Therefore, you cannot use Project Scale to evaluate evaporative processes
  - You can make just one selection for each of the following:
    - County
    - Year
    - Month
    - Day type
    - Hour

e.g.,
Washtenaw County, Michigan
2030, January, weekday, at 8:00am

Module 7 Key References

- *PM Hot-Spot Guidance: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas*
  - See EPA's Project-Level Conformity and Hot-Spot Analyses webpage for latest version
- *Using MOVES in Project-Level Carbon Monoxide Analyses*
  - See EPA's Project-Level Conformity and Hot-Spot Analyses webpage for latest version
- Both guidance documents reflect MOVES3 and still largely apply to MOVES4
  - However, the AVFT tool is new in MOVES4: follow Fuel input guidance from MOVES4 Technical Guidance
- This module does not cover all of EPA's guidance for hot-spot analyses
  - It provides an overview and illustrative example of MOVES capabilities at the Project Scale

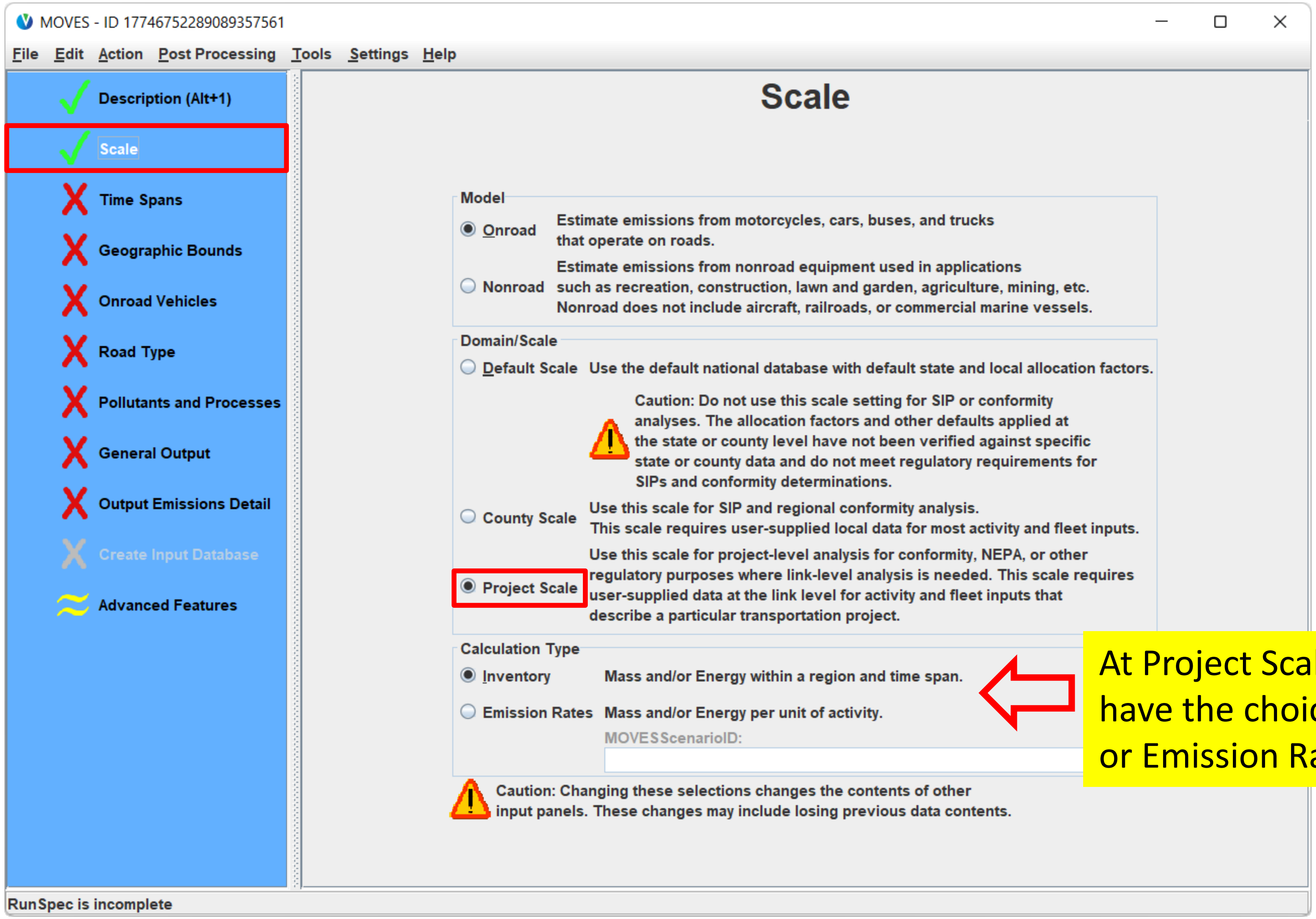
PM Hot-spot Training Course

- EPA and US DOT have developed a 3-day training course specific to the PM hot-spot requirement in the conformity rule
  - The training covers how to use MOVES in accordance with EPA guidance
  - Also covers air quality modeling, background concentrations, design values, and other topics
- See the training materials at EPA's Project Level Training website
  - These were last updated in 2018, but are still largely applicable
  - Note that MOVES, AERMOD, and the PM Hot-Spot Guidance have all since been updated
  - See EPA's Project-Level Conformity and Hot-Spot Analysis website for more information, including a guidance change bulletin that describes the latest updates

Project Scale for Regulatory Purposes

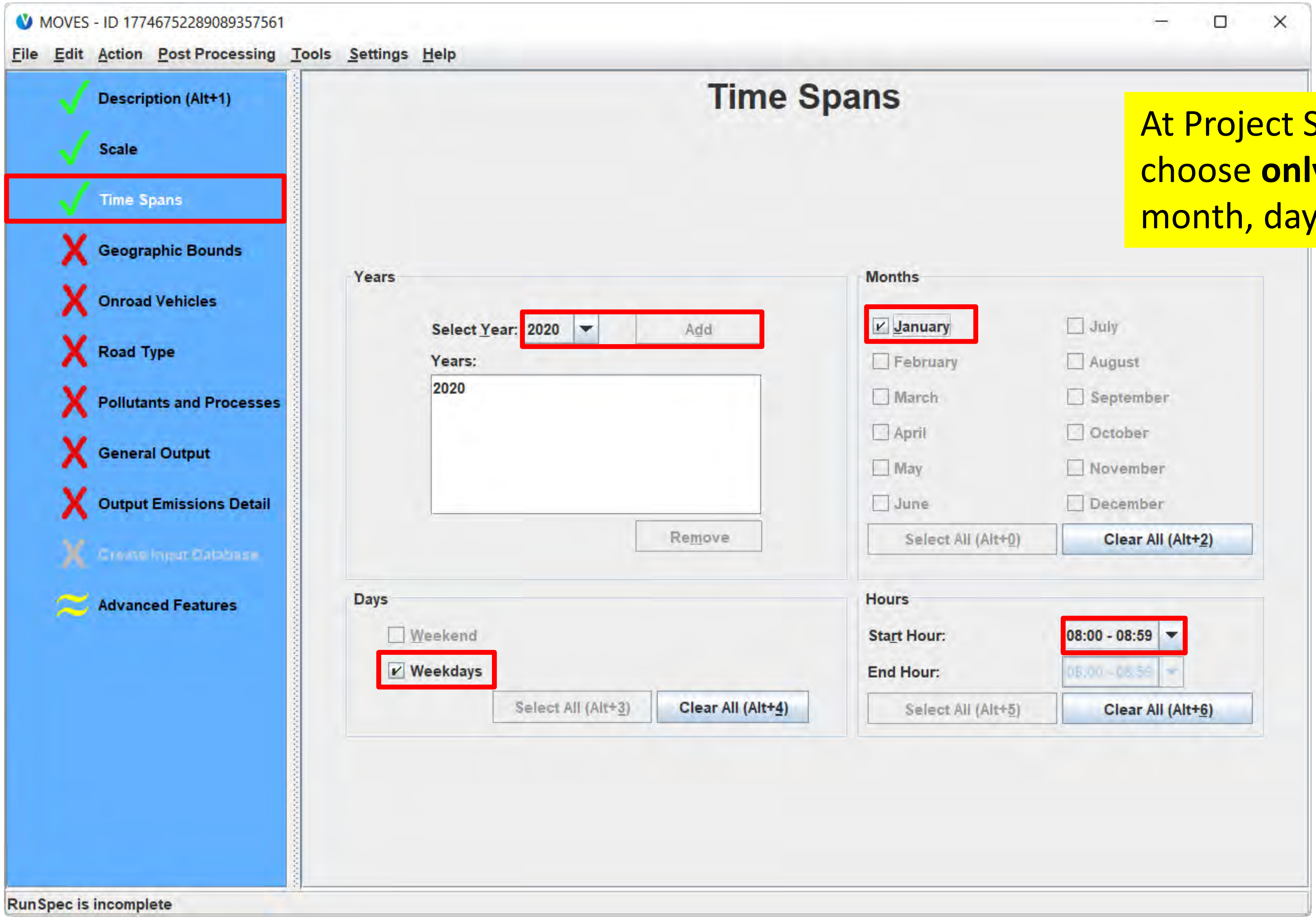
- At Project Scale, you need a unique RunSpec and input database for each hour you want to model
- For a PM hot-spot analyses, more than one run is needed to capture variability over time
  - Activity and temperature vary over the course of a day and over the course of a year
  - Fuels also vary over the course of a year
- For a CO hot-spot analysis:
  - One run (the worst-case conditions) is needed for a screening analysis
  - More than one run needed for a refined analysis
- See EPA guidance mentioned above for more information

Project Scale: Scale Panel



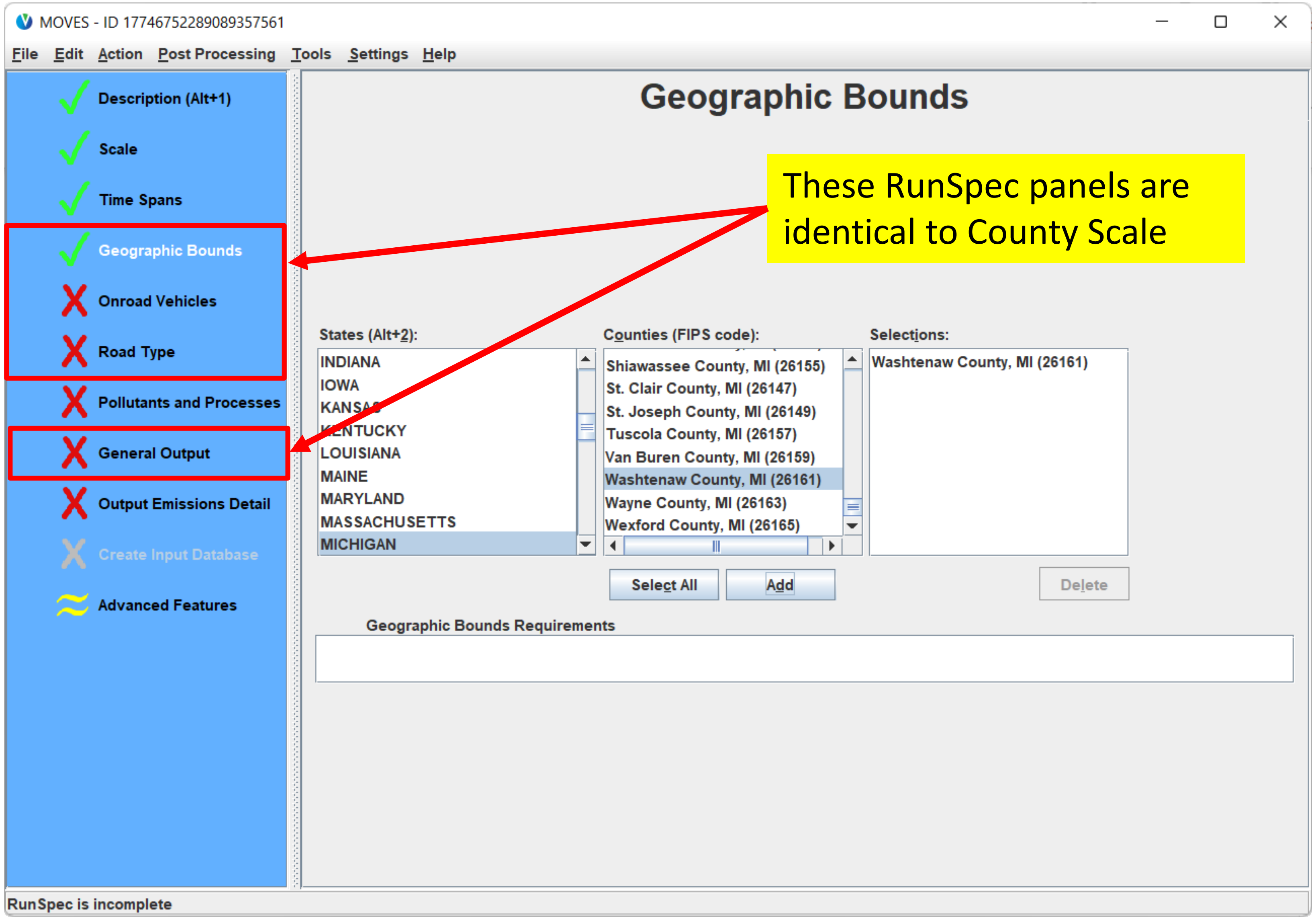
At Project Scale, you still have the choice of Inventory or Emission Rates

Project Scale: Time Spans Panel

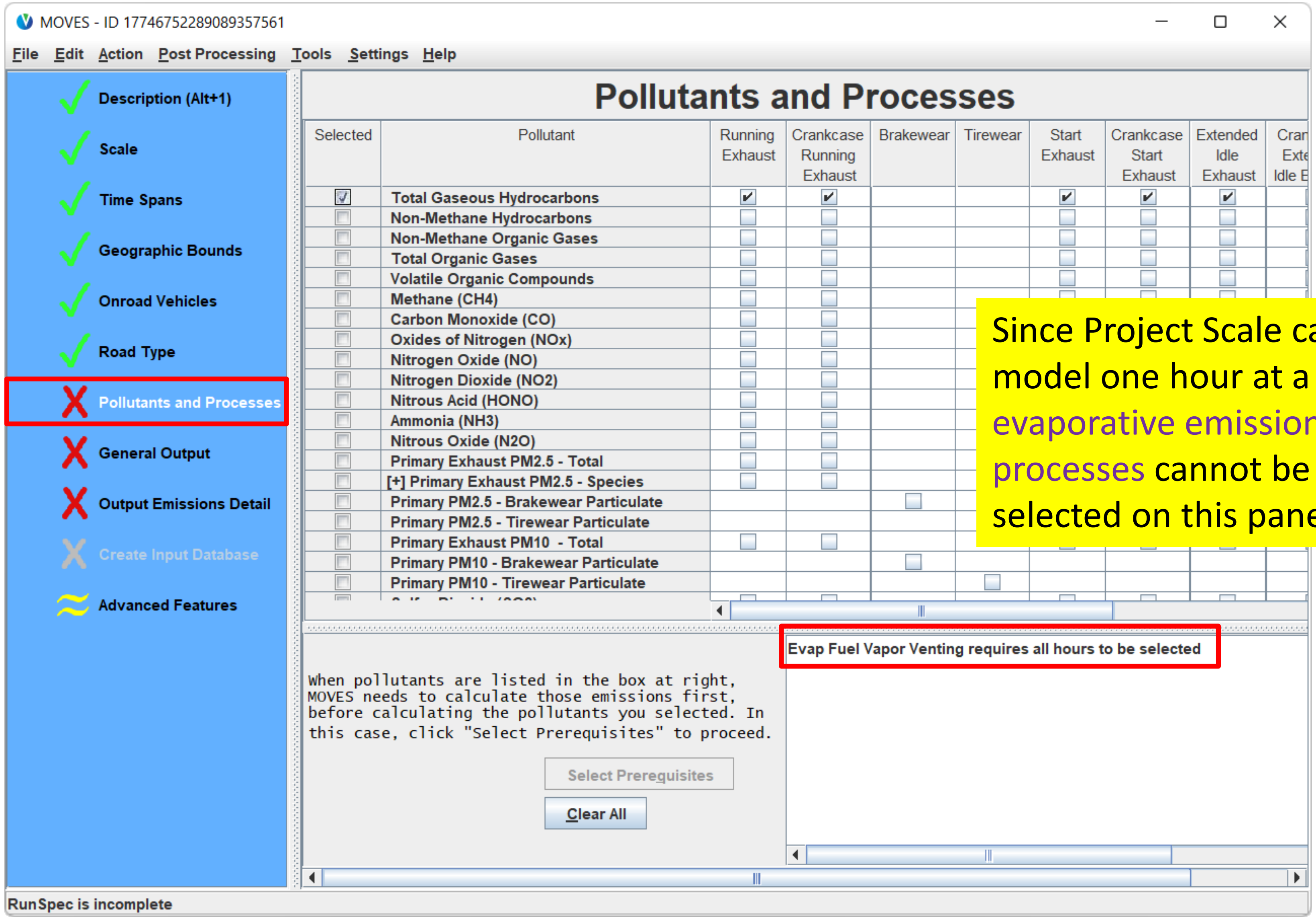


At Project Scale, you can choose **only one** year, month, day type, and hour

Project Scale: Other RunSpec Panels

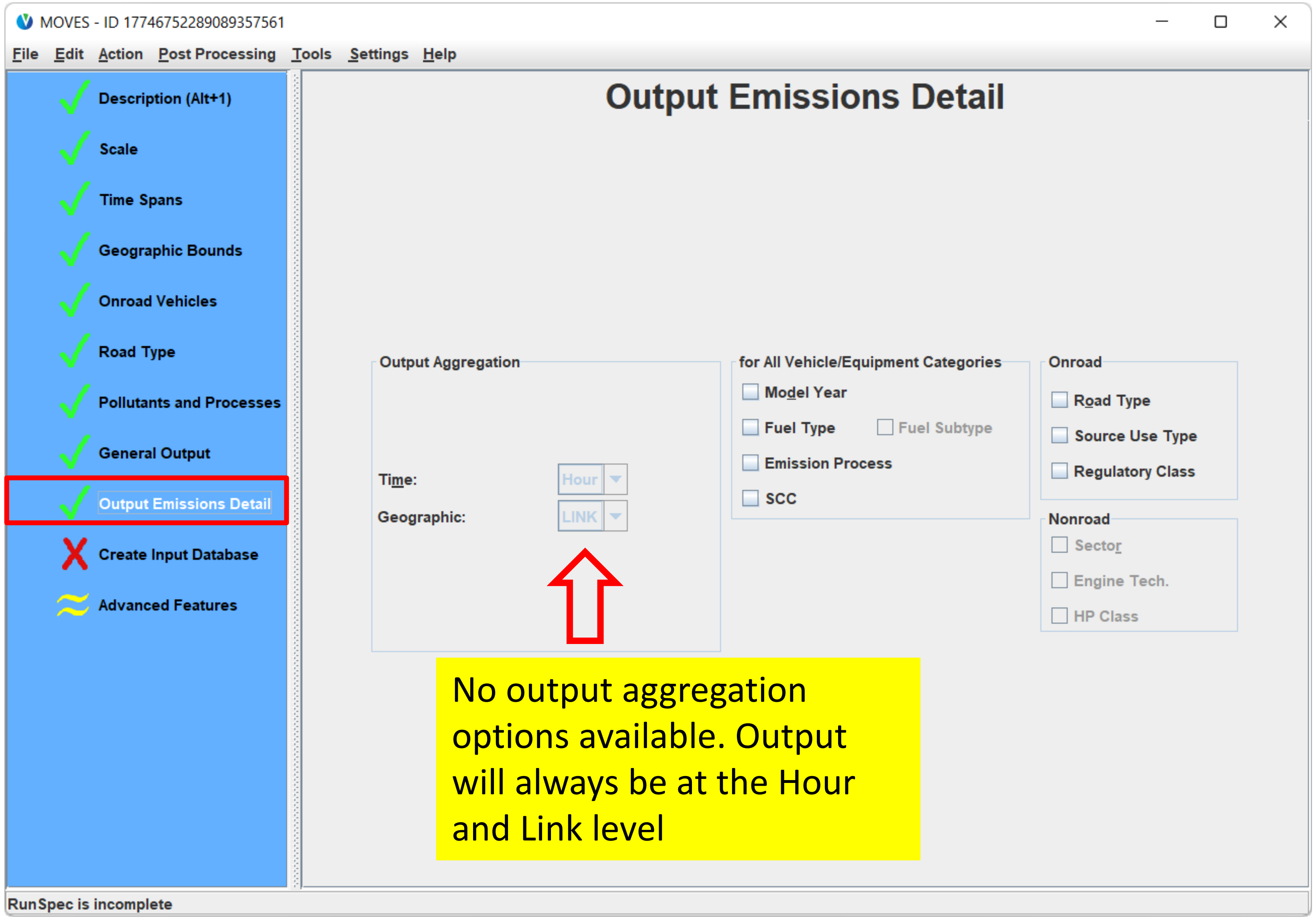


Project Scale: Pollutants and Processes Panel

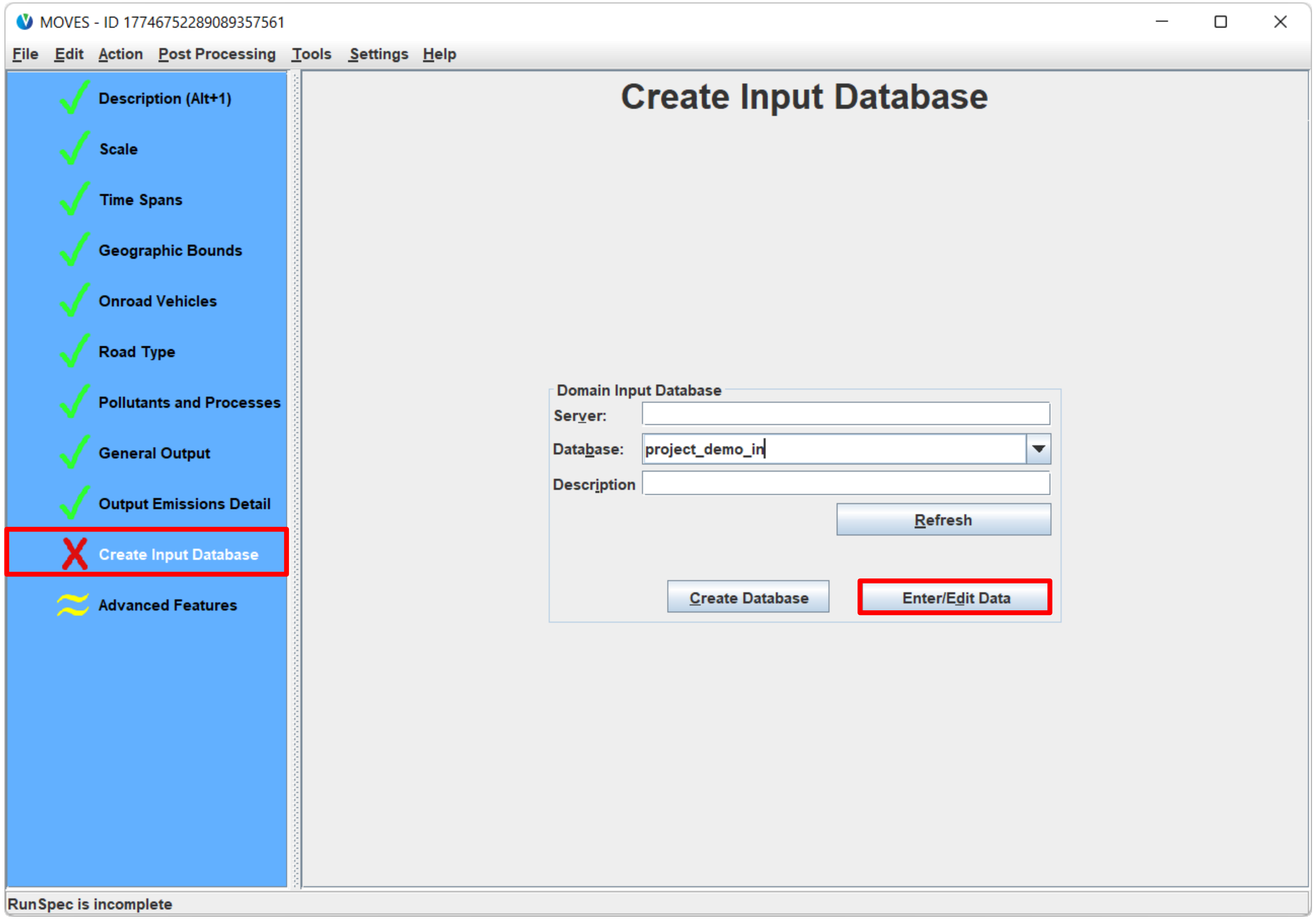


Since Project Scale can only model one hour at a time, evaporative emission processes cannot be selected on this panel

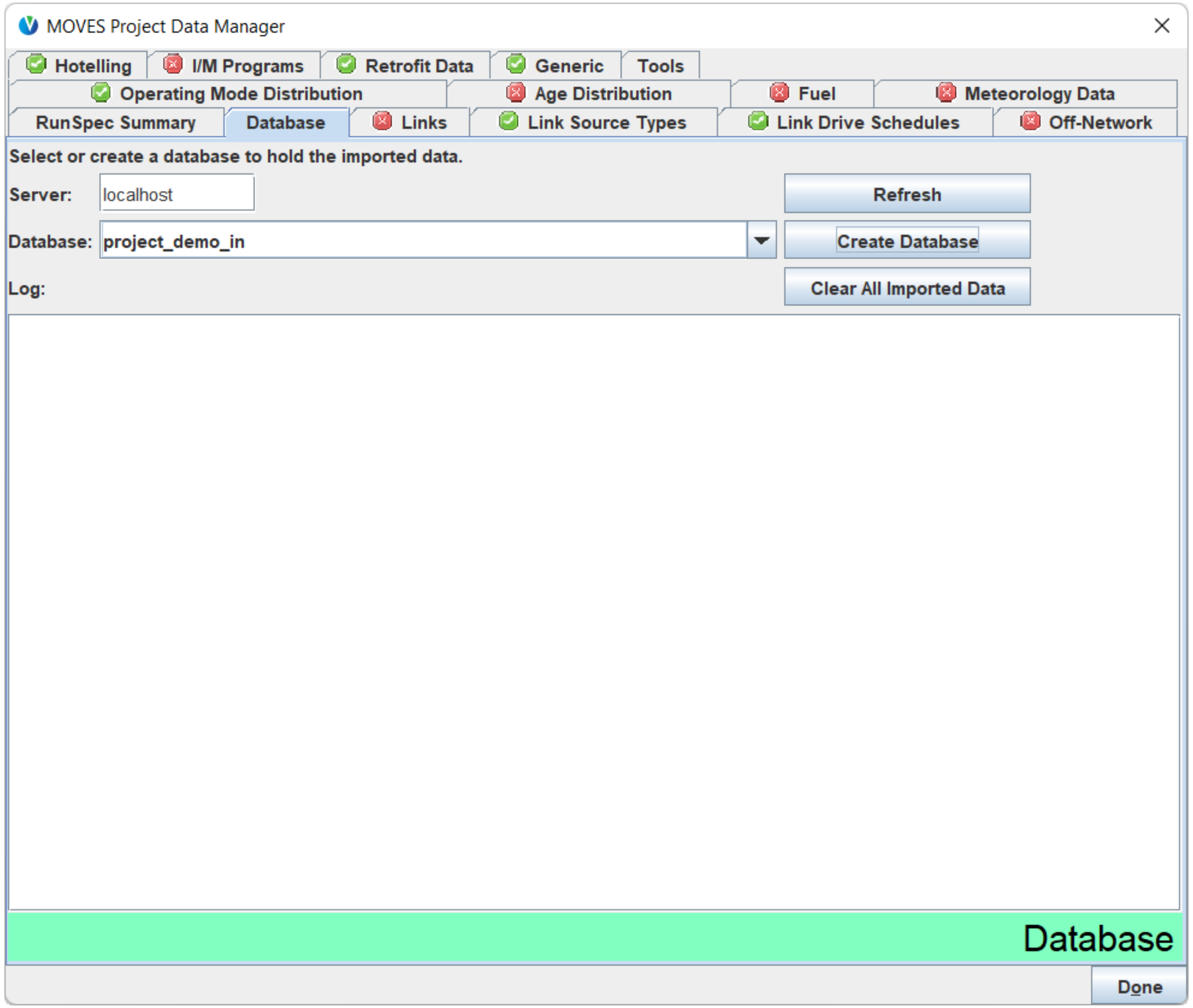
Project Scale: Output Emissions Detail Panel



Accessing the Project Data Manager (PDM)



A Newly-Opened PDM



Project Data Manager Inputs

- Links
- Link Source Types
- Link Drive Schedules
- Off-Network
- Operating Mode Distribution

These inputs are unique to the Project Scale

- Age Distribution
- Fuel
- Meteorology Data
- Hotelling
- I/M Programs
- Retrofit Data

These inputs are common to analyses at County and Project Scales

What is a MOVES link?

- A link is a segment of road or an "off-network" location where vehicle activity occurs
- There are two primary types of links. They are used for different types of vehicle activity and for different emission processes:
  - Running links
    - Used to describe driving activity: e.g., free-flow highways, ramps, arterials, intersections (cruise, deceleration, idle, and acceleration activity)
    - Emissions: Running exhaust, crankcase running exhaust, brake/tire wear emissions
    - No limit on the number of running links in a Project Scale run
  - Off-Network links
    - Used to describe start and hotelling activity: e.g., parking areas, truck or transit terminals
      - Note: Hotelling applies only to combination long-haul trucks (SourceTypeID 62)
    - Emissions: start, hotelling, (including crankcase)
    - Only needed if a project contains vehicles starting or hotelling
    - You can define only one off-network link per run

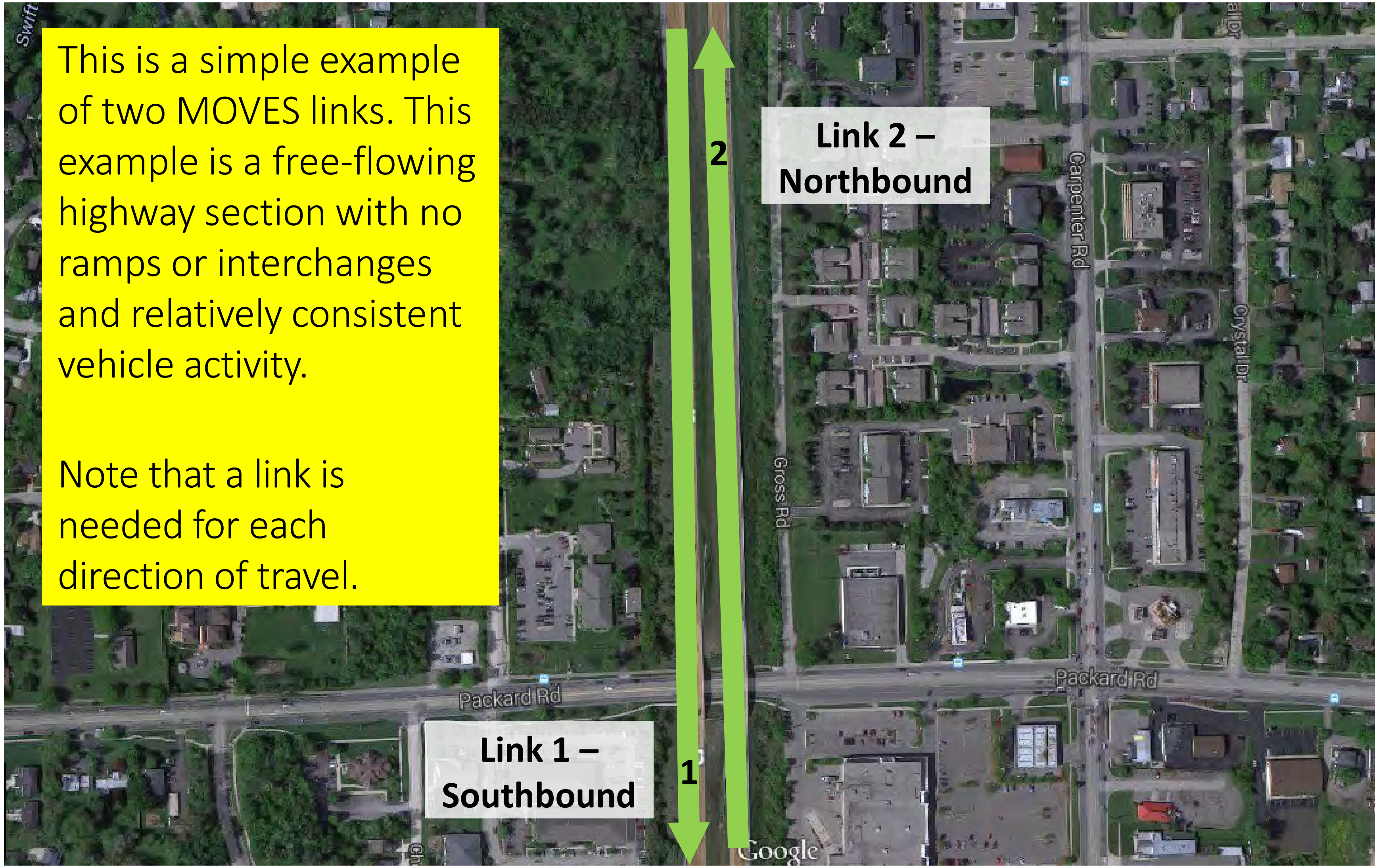
MOVES Running Links (1)

- A link must have consistent vehicle activity. When vehicle activity changes, a new link needs to be defined
- When is a new unique running link needed?
  - When vehicle volumes change?
    - Yes. For example, links begin and end at intersections because volumes will be different before and after the intersection
  - When the vehicle activity changes?
    - Yes. Use a new link when the main type of activity changes: accelerating, cruising, decelerating, idling. For example, freeway on- and off-ramps will need unique links, because vehicle activity differs from the highway main line
  - When a road curves and changes direction?
    - No, as long as the expected activity is the same
  - When a road has a significant change in grade?
    - Yes. Use a new link and define the grade as non-zero. Grade will affect activity (in terms of vehicle specific power and perhaps speed or drive cycle)

MOVES Running Links (2)

- At Project Scale, idle activity (other than hotelling) is also modelled with a running link
  - This activity is considered "Off-Network Idle" (ONI) at Default & County Scale
  - At County Scale, these emissions are associated with the off-network road type (roadTypeID 1)
  - At Project Scale, include these emissions on a link that you define as Urban or Rural Unrestricted (roadTypeID 5 or 3, whatever is more appropriate)
- A parking area may need to be modeled as two links:
  - one to capture off-network activity (start and hotelling), and
  - one to capture idling

Running Link Example 1

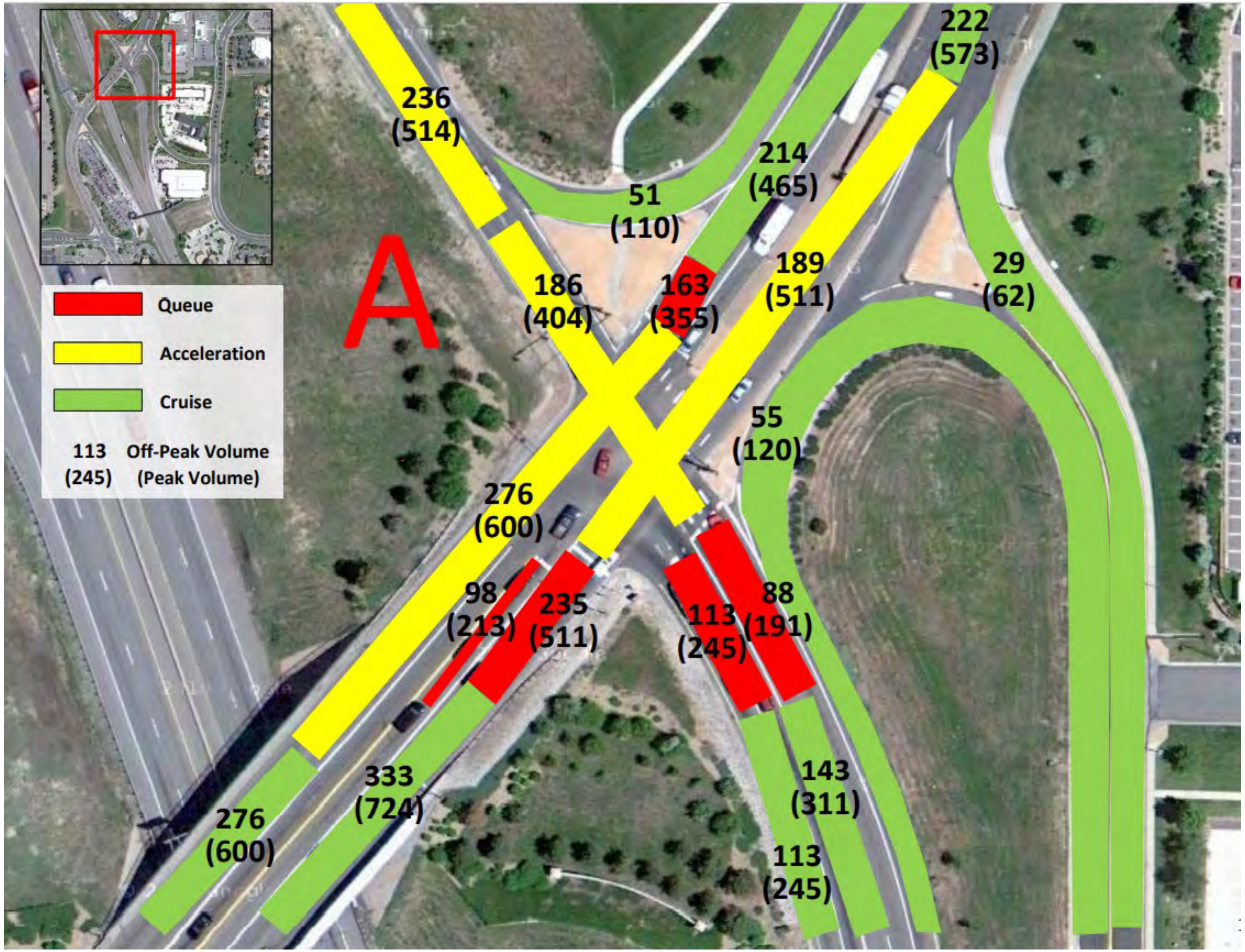


Running Link Example 2

This example illustrates a set of links that is far more complex in terms of vehicle activity.

Running Link Example 2 (Inset)

A detailed look at a specific intersection included on the previous slide



Defining Vehicle Activity on Running Links

You have three options for defining vehicle activity, for each link:

1. Define a link average speed, through the Links input
    - MOVES includes default operating mode distributions based on typical driving cycles
2. Enter a link specific drive cycle, through Link Drive Schedules input
    - User defines a second-by-second drive cycle for each link
    - If you include this optional input for a link, it will override the link average speed on the Links input
3. Directly enter a link specific OpMode distribution, through the Operating Mode Distribution input
    - Precisely describes distribution of activity on a link (fraction of time spent in each operating mode)
    - Not a typical output from current traffic models
    - If you include this optional input for a link, it will override the link average speed on the Links input

- The hands-on exercise for this module compares options 1 and 2

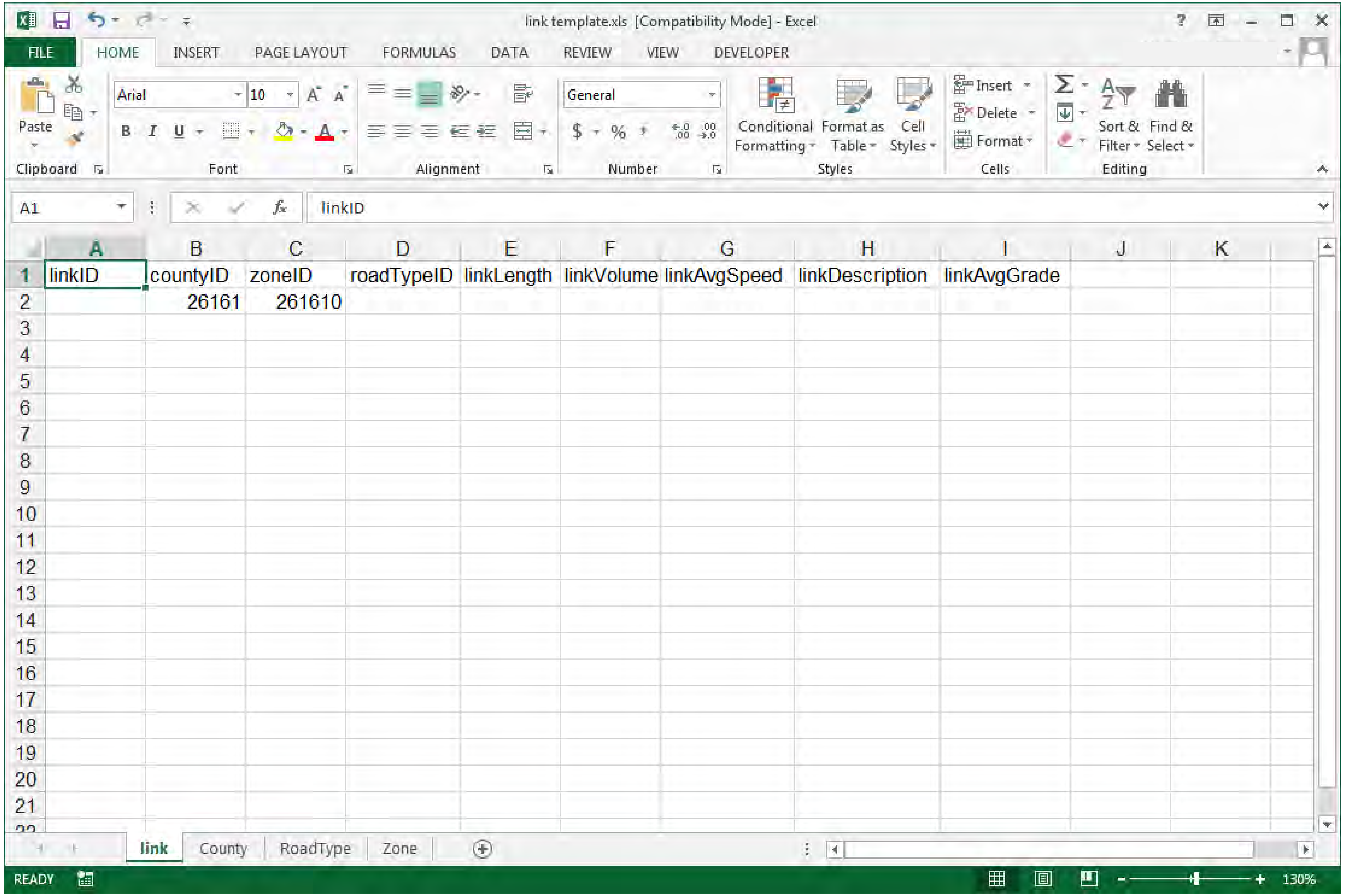
Inputs Unique to Project Scale: Running Links

- For running links, you need to complete:
  - Links: Used to describe the link (road type, length, vehicle activity, etc.)
  - Link Source Types: Used to define vehicle mix on each link
- Optional inputs for running links:
  - Link Drive Schedules: Used for activity option 2 on previous slide
  - Operating Mode Distribution: Used for activity option 3 on previous slide
- There is no limit on the number of running links that can be defined in one run

Links Input, for Running Links

- For each running link, you will need to include:
  - LinkID: give each link in the project a unique numeric ID
  - CountyID: automatically filled out for you by the template
  - ZoneID: automatically filled out for you by the template (the county ID + “0”)
  - RoadTypeID: identify the road type (1-5) of each link
  - Link Length: in miles (or whatever units you chose in the RunSpec)
  - Link Volume: total traffic volume in the hour selected in the RunSpec
  - Link Average Speed: in MPH (assuming you chose miles in the RunSpec)
    - You can use optional inputs instead of average speed to more precisely define activity
  - Link Description: text field for you describe the link (optional, but recommended)
  - Link Grade: in percent grade (100% = 45 degree slope)
- The Links input is also needed for an off-network link; coming up in a future slide

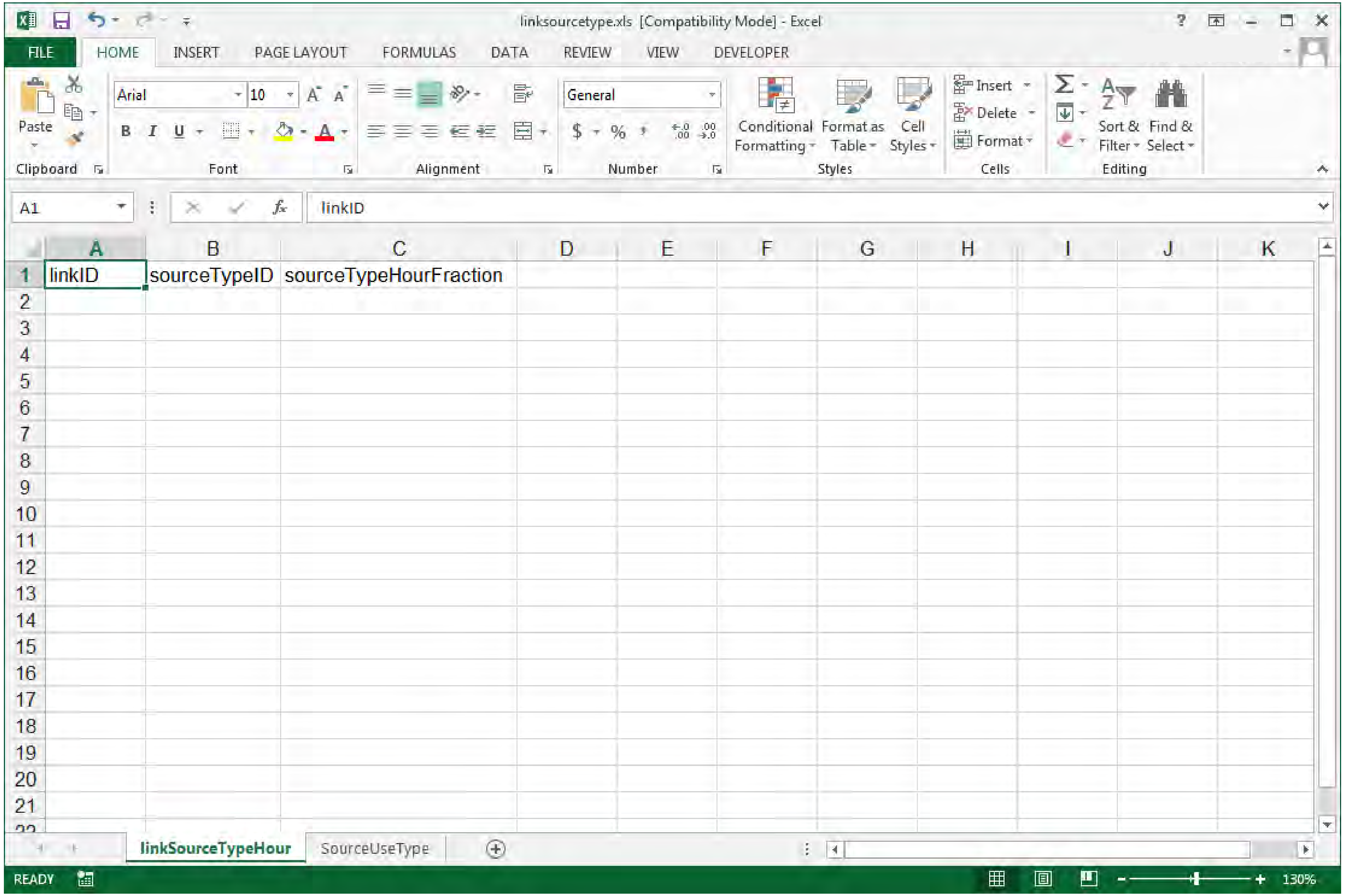
Links Input Template



Link Source Types Input, Running Links Only

- The Link Source Types tab is used to input the *LinkSourceTypeHour* table
- Three items need to be completed in this table for each link:
  - LinkID
    - Must include all roadway LinkIDs defined in Links Input
  - SourceTypeID
    - Must include all source types selected in the RunSpec
  - SourceTypeHourFraction
    - Specify vehicle mix (fraction of vehicle hours travelled, or VHT) on each link
    - Fractions must sum to 1.0000 for each linkID
- This input is not used for the off-network link

Link Source Types Input Template



Off-Network Link Examples (1)

Bus terminal off-network link: start activity only

Truck terminal off-network link: start and hotelling activity

- An off-network link represents start and/or hotelling emissions only
  - Hotelling applies to long-haul combination trucks only
- Also use one or more running links for any driving activity and idling activity that takes place in the same area
  - Long-haul combination trucks could be hotelling **and/or** idling in a Project Scale run
  - All other vehicles that are idling are not hotelling. Use a running link to represent that activity (e.g., buses at the bus terminal)

Off-Network Link Examples (2)

Park and Ride lot off-network link: start activity only

- Start activity only; no long-haul combination trucks and, therefore, no hotelling
- Use running link(s) for driving/idling activity in this lot

Inputs Unique to Project Scale: Off-Network Link

- For the off-network link, you will need to complete:
  - Links input: Same input table as running links. The off-network link would be defined as a row in this table with roadTypeID 1
    - Note: If your Links input includes an off-network link, you will not get a green check for this tab until the Off-Network input is complete!
  - Off-Network input: Used to describe vehicle activity on the off-network link
  - Operating Mode Distribution input: Used to describe fraction of time in each operating mode bin (this input is optional for running links, but required for the off-network link)
- Optional for the off-network link:
  - Hotelling Activity Distribution input: Used to define type of hotelling activity (only applies when modeling combination long-haul truck hotelling)
- MOVES can model <u>only one</u> off-network link per run

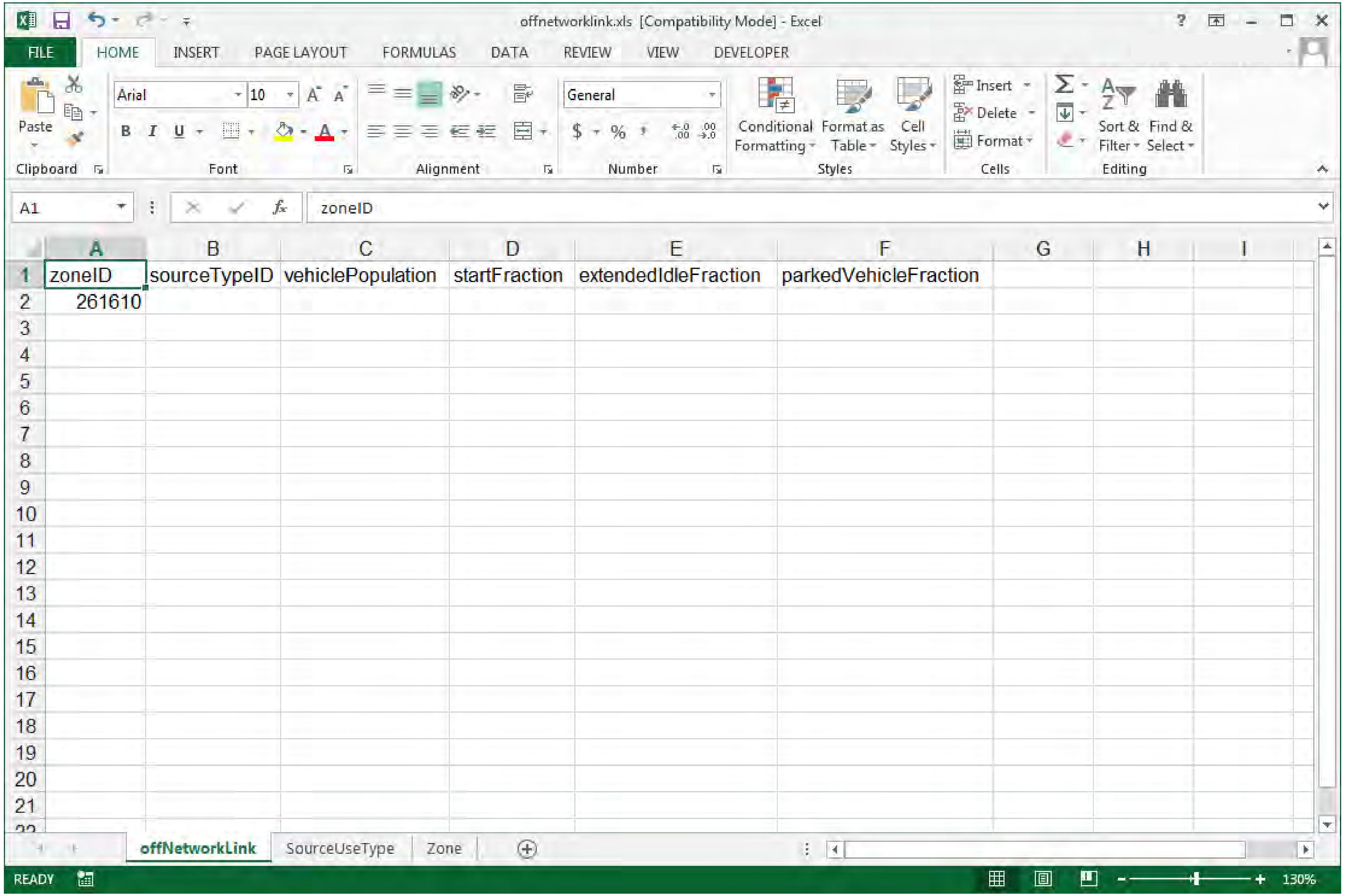
Links Input for the Off-Network Link

- This is the same input table used for running links. The off-network link needs to also be included in this input with the following information:
  - LinkID: give the off-network link a unique numeric ID
  - CountyID: automatically filled out for you by the template
  - ZoneID: automatically filled out for you by the template (the county ID + "0")
  - RoadTypeID: use 1 for the off-network roadTypeID
  - Link Length: for the off-network link, enter "0"
  - Link Volume: total number of vehicles present in the hour selected in the RunSpec
  - Link Average Speed: for the off-network link, enter "0"
  - Link Description: text field for you describe the link (optional, but recommended)
  - Link Grade: for the off-network link, enter "0"

Off-Network Input

- You will need to include the following information for this input:
  - ZoneID: automatically filled out for you by the template (the county ID + "0")
  - SourceTypeID: include all source types selected in the RunSpec. If these source types are not present on the off-network link, give them a Vehicle Population of 0
  - Vehicle Population: Average number of each vehicle type on the off-network link
  - Start Fraction: Average fraction of the population that started during the hour
    - May be greater than 1.0 if the average vehicle is started more than once per hour
  - Extended Idle Fraction: Fraction of source hours where hotelling is occurring
    - Applies only to long-haul combination trucks (SourceTypeID 62)
    - Enter a decimal number between 0 and 1
    - E.g., if number of long-haul combination trucks is 20 and 10 of them are hotelling for the entire hour, enter fraction of 0.5
  - No input needed for Parked Vehicle Fraction: currently inactive (would be used only for evaporative emissions)

Off-Network Input Template



Operating Mode Distribution Input

You need to complete this input for the off-network link, but it is optional for running links

- sourceTypeID: Include all source types selected in the RunSpec
- hourDayID: Automatically filled out for you by the template (concatenated hour and day type, e.g. 8-9 am on weekday = "95")
- linkID: Enter the linkID for the off-network link as defined in Links input and optionally any running linkIDs
- polProcessID: Automatically filled out for you by the template (concatenated pollutant and emission process IDs)
- opModeID: All operating modes are included in the template
- opModeFraction:
  - Necessary for the off-network link
    - The relevant operating modes are for start processes
    - Enter the fraction of starts associated with each soak bin
  - Optional for running links
    - If using, include the fraction of time spent in each running operating mode
    - If not, delete all the running operating modes (see Cheat Sheet)

See the template helper tabs or Onroad Cheat Sheet to decode these IDs

Operating Mode Distribution Input Template

	A	B	C	D	E	F	G	H	I
1	sourceTypeID	hourDayID	linkID	polProcessID	opModeID	opModeFraction			
2	21	95		201	0				
3	21	95		201	1				
4	21	95		201	11				
5	21	95		201	12				
6	21	95		201	13				
7	21	95		201	14				
8	21	95		201	15				
9	21	95		201	16				
10	21	95		201	21				
11	21	95		201	22				
12	21	95		201	23				

opModeDistribution | HourDay | OperatingMode | PollutantProcessAs ...

The hourDayID, polProcessID, and opModeID fields are decoded in the helper tabs in this file. Or refer to the Onroad Cheat Sheet, available from the MOVES Help menu.

Hotelling Input (Optional, Off-Network Link)

This input pertains to long-haul combination trucks only, and includes six columns:

- zoneID: Automatically filled out for you by the template (the county ID + "0")
- fuelTypeID: Automatically filled out for you by the template
- beginModelYearID and endModelYearID: Hotelling activity can vary by model year. These columns are used to specify the model year range associated with this operating mode distribution
- opModeID: Automatically filled out for you by the template
- opModeFraction: Enter the fraction of the hotelling activity associated with each operating mode (must sum to 1 for each fuel type and model year range)

Hotelling Input Template

zoneID	fuelTypeID	beginModelYearID	endModelYearID	opModeID	opModeFraction
261610	2			200	
261610	2			201	
261610	2			203	
261610	2			204	
261610	3			200	
261610	3			201	
261610	3			203	
261610	3			204	
261610	9			200	
261610	9				
261610	9				
261610	9				

hotellingActivityDistrib

opModeID	opModeName
200	Extended Idling
201	Hotelling Diesel Auxiliary Power Unit (APU)
203	Hotelling Shore Power (plug-in)
204	Hotelling Battery or All Engines/Accessories Off

OperatingModeAux | Zone

Project Scale Hands-on Exercise

MOVES
Motor Vehicle Emission Simulator

Project Scale Exercise Files

- The zip file of course materials contains a folder called Module 7 - Project Exercise
  - This folder contains input data that we will use throughout the exercise
- If you have not done so, unzip the course materials to a convenient location, such as your desktop
- If you get lost or have technical difficulties, the course files for this module contain an *Answer Key* folder, where you can find the completed RunSpec and resulting output database

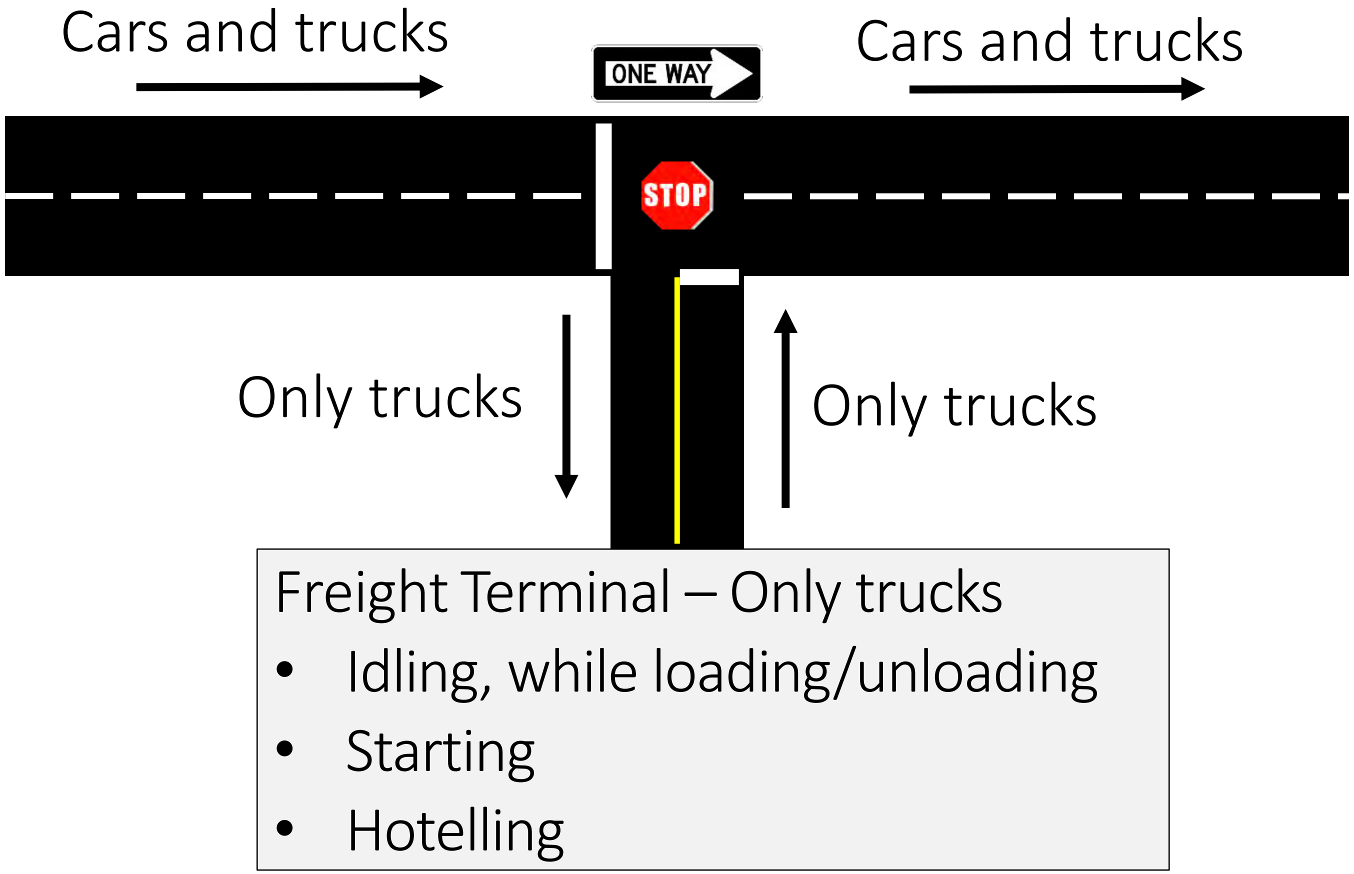
Project Scale Exercise Overview

- Use MOVES at the Project Scale to model carbon monoxide (CO) emissions from a freight terminal and associated roads
  - Results will be in grams for the hour, for each link
  - These link-specific grams/hour emission factors could then be used in air quality dispersion modeling
- Compare emissions using two of the three activity input options
  - Run #1: Use average speeds (Links Input)
  - Run #2: Include drive cycles (Link Drive Schedules Input)
- Goal is to demonstrate some of MOVES capabilities at the Project Scale
  - Not intended to reflect all of EPA's technical or policy guidance
  - Like other examples in this training, we have made simplifying assumptions

Project Scale Exercise Simplifying Assumptions

- The main road is one-way only, to reduce the number of links needed
- The only vehicles on the roads are gasoline passenger cars and diesel combination long-haul trucks (source types 21 and 62)
  - For a real-world project, include all vehicle and fuel types present
- The only vehicles at the freight terminal are diesel combination long-haul trucks
  - For a real-world project, include all vehicle and fuel types present. Additional fuel types for long-haul trucks include gasoline, CNG, and electricity
- Only looking at one hour, the peak hour
  - This is sufficient for a CO hot-spot analysis
  - For a PM hot-spot analysis, additional runs would be needed to capture variability over the day and year

Project Diagram



- Main road: one-way
  - Cars and trucks
- Freight terminal access road: two-way
  - Only trucks
- Freight terminal
  - Only trucks

Setting up the Project Scale Exercise RunSpec

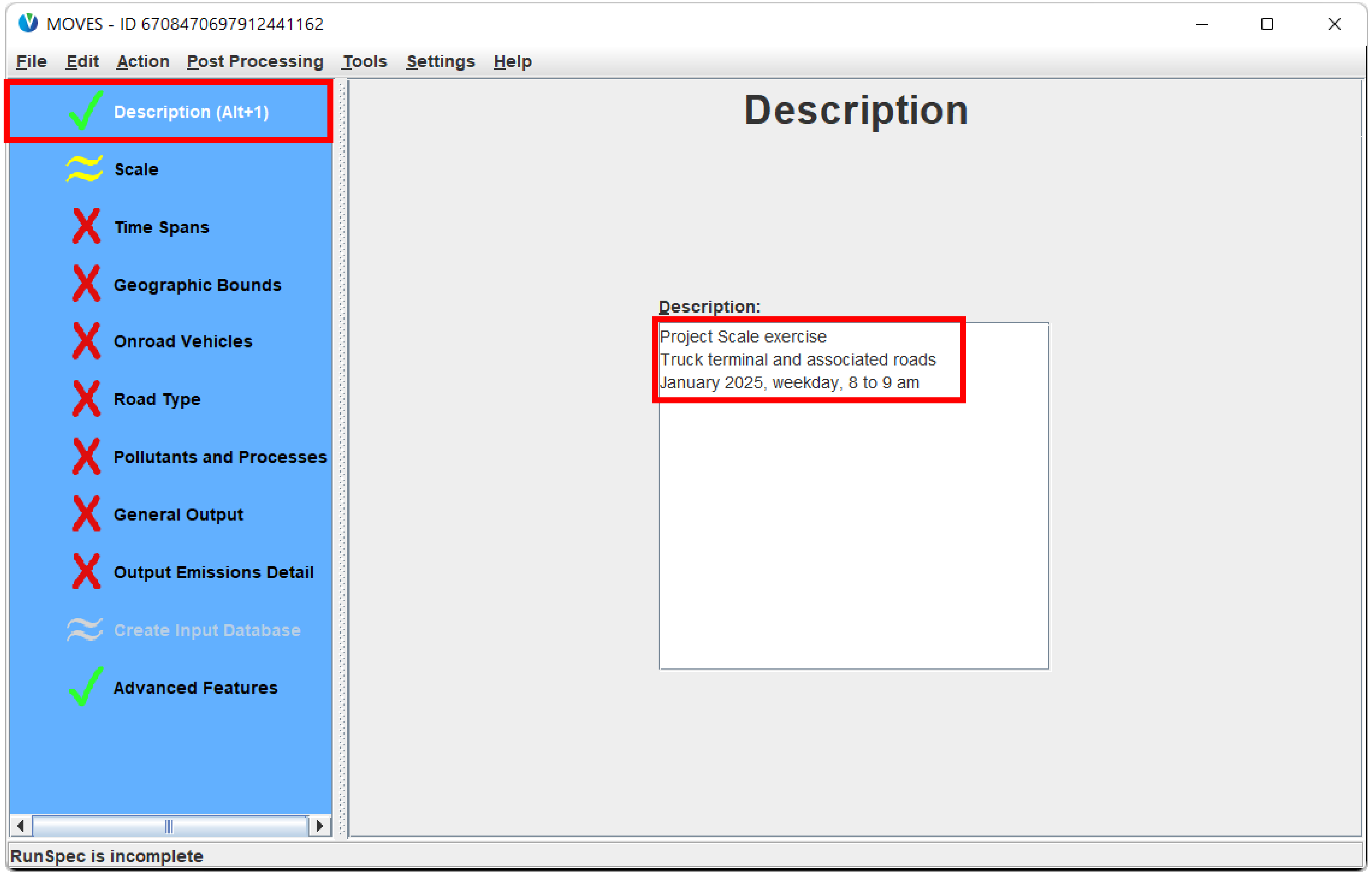
MOVES
Motor Vehicle Emission Simulator

Project Details Needed for the RunSpec

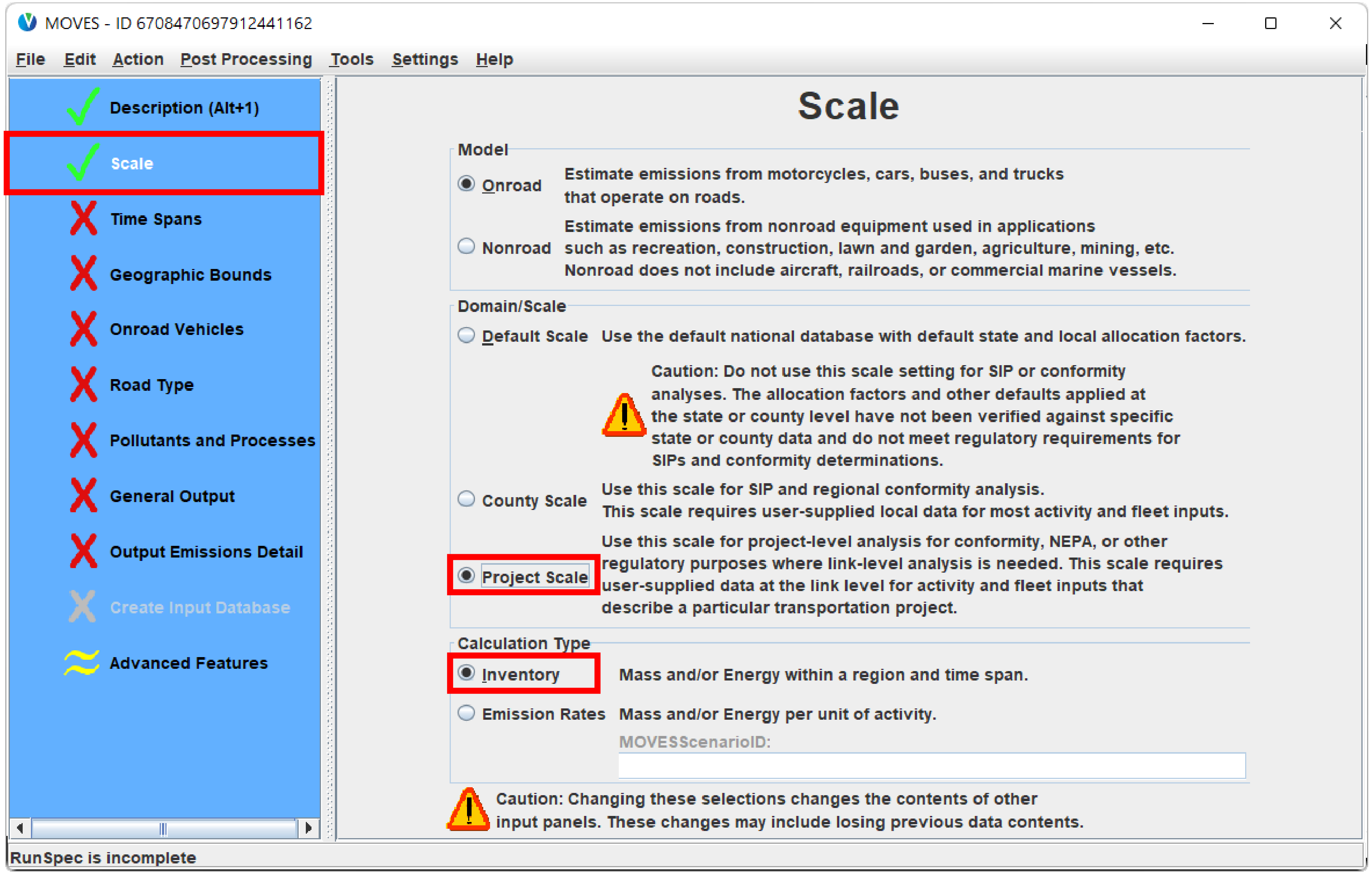
Use the following information to create a RunSpec for this exercise:

RunSpec Item	Project Detail
Project location:	Washtenaw County, MI
Calendar year:	2025
Month:	January
Weekday/Weekend:	Weekday
Hour:	8:00 AM to 8:59 AM (hour 9)
Vehicles present:	Passenger cars, combination long-haul trucks
Road types present:	Urban Unrestricted and Off-Network
Pollutant needed:	CO, in total grams for the hour
Processes to include:	Running, start, hotelling
Output emissions by:	Emissions process, and Vehicle type

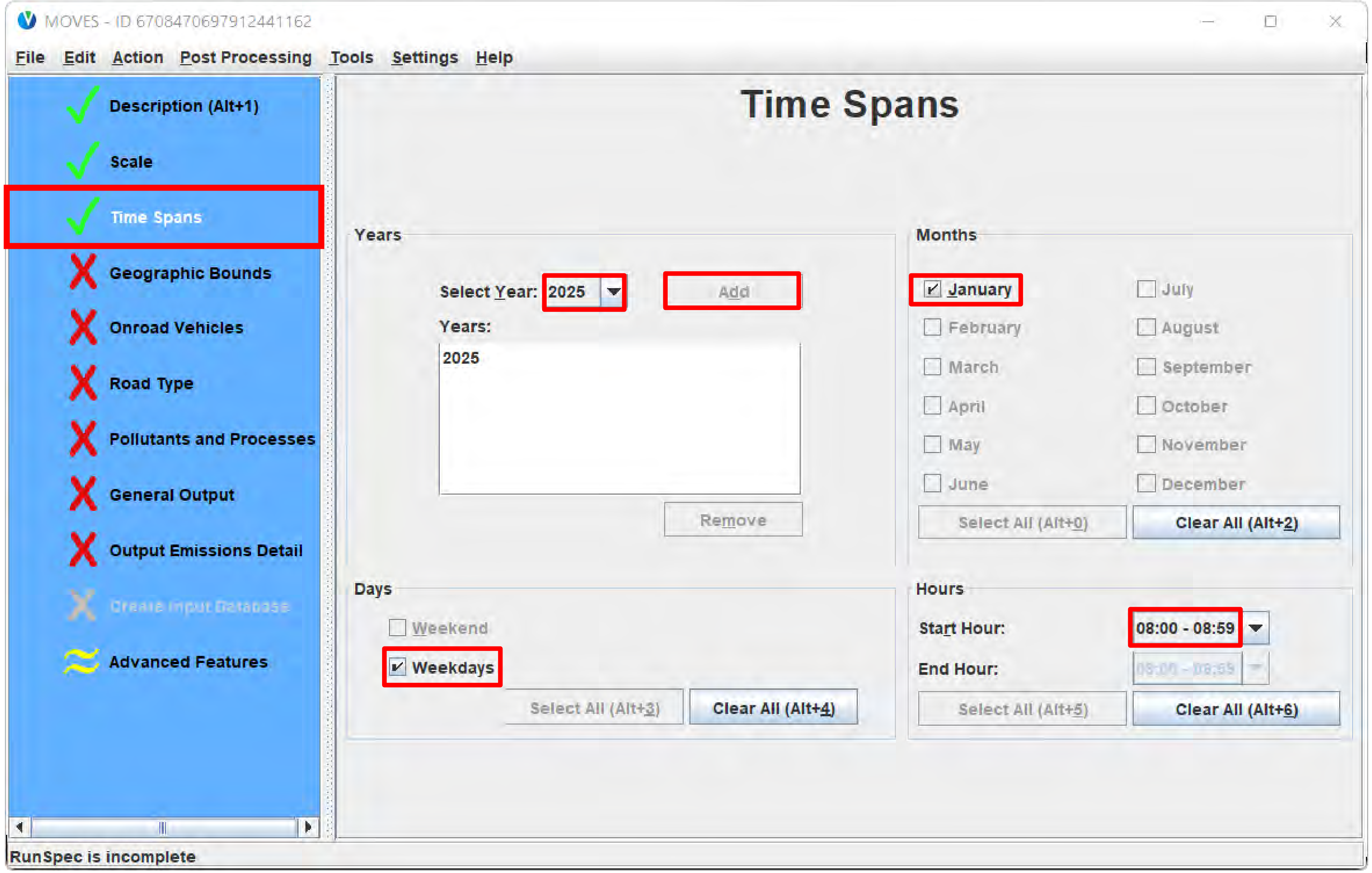
Project RunSpec: Description



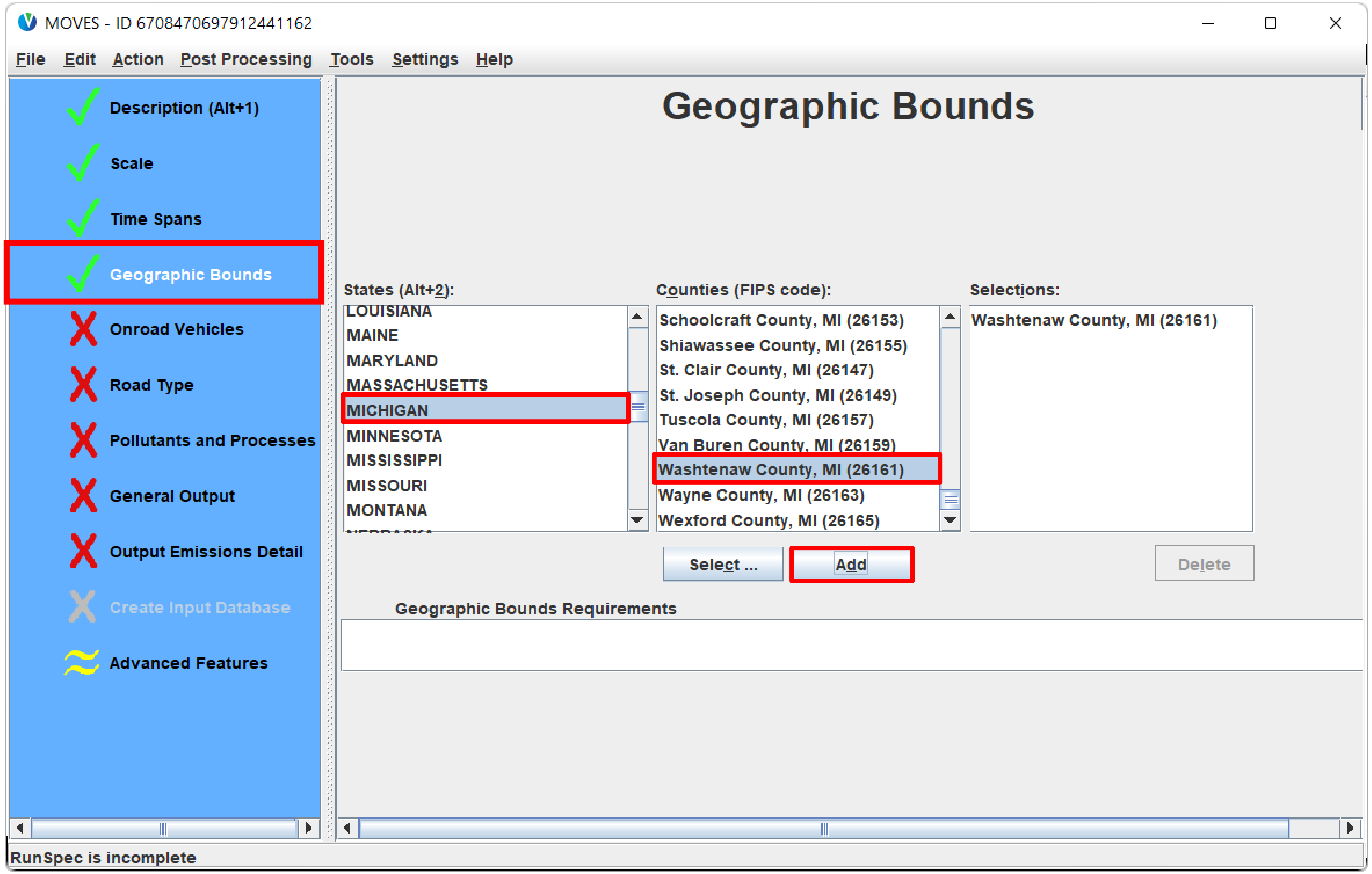
Project RunSpec: Scale



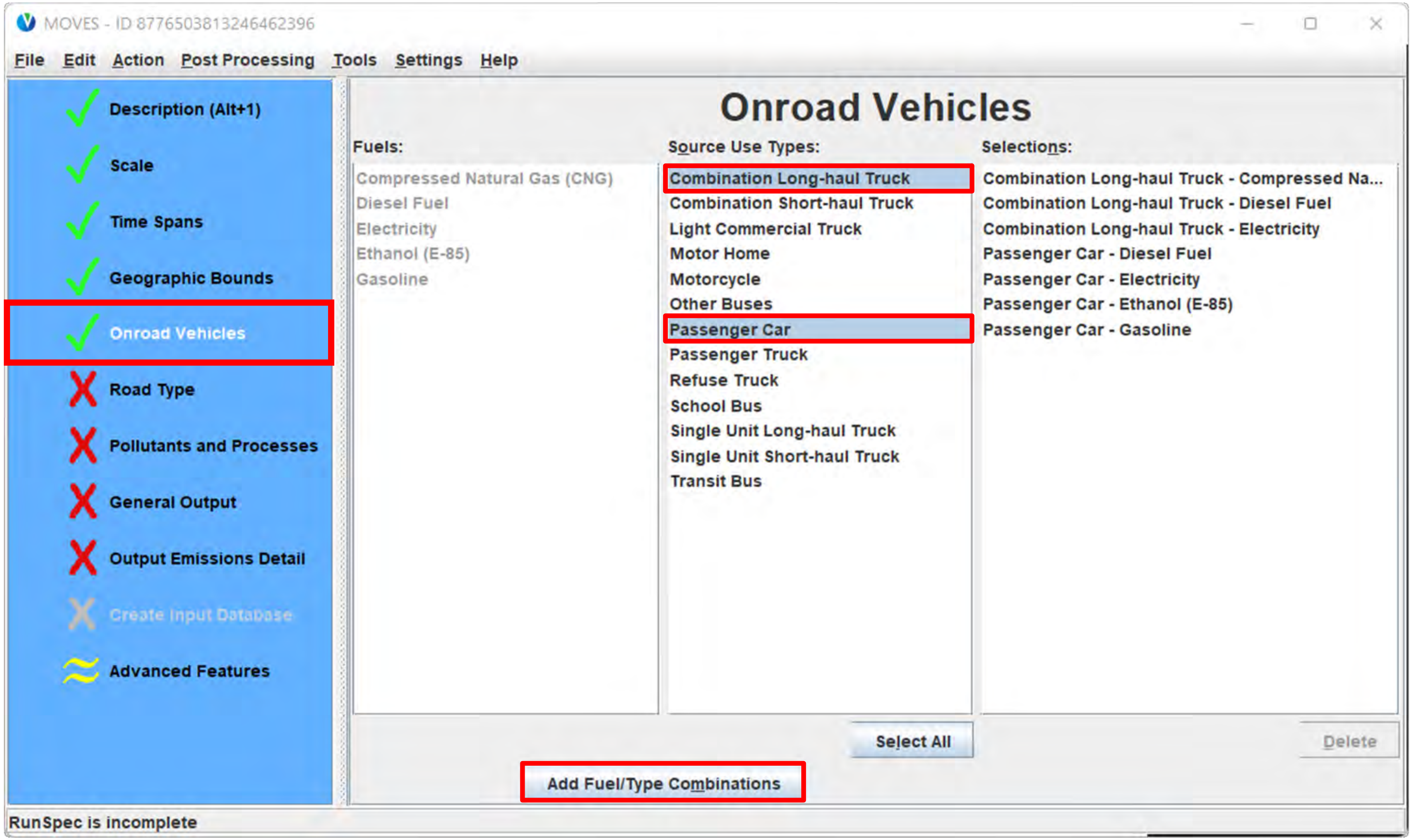
Project RunSpec: Time Spans



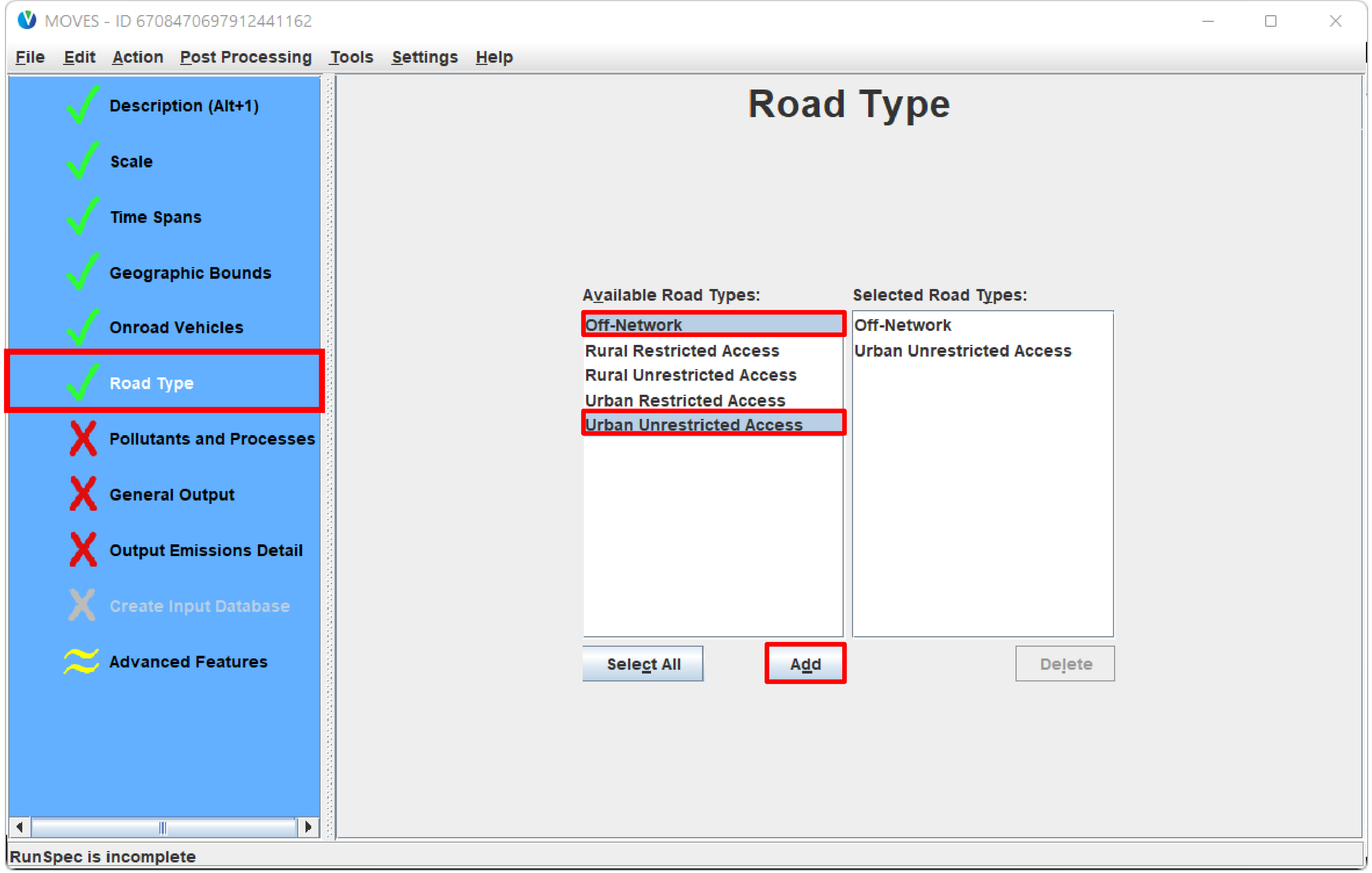
Project RunSpec: Geographic Bounds



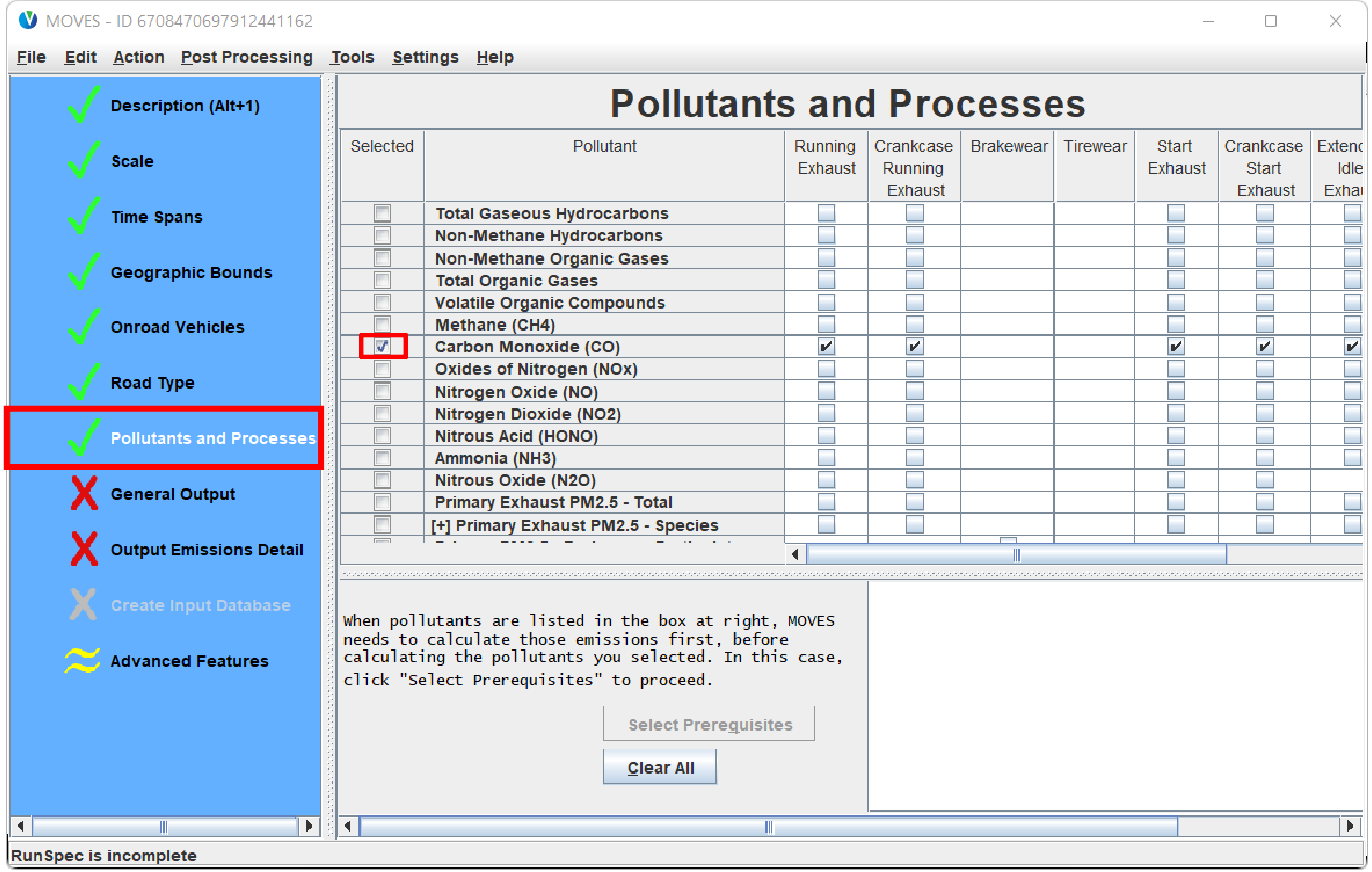
Project RunSpec: Onroad Vehicles



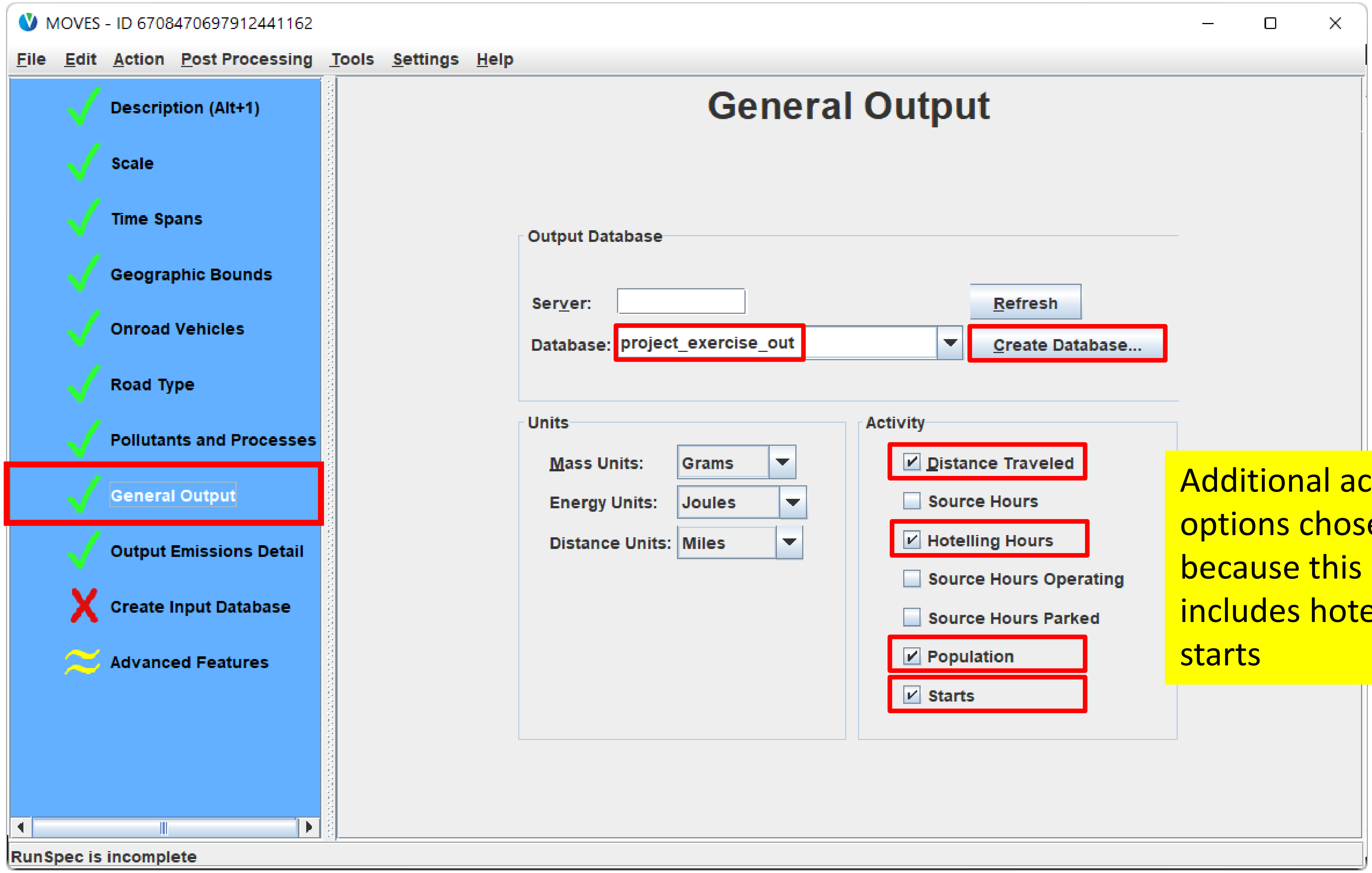
Project RunSpec: Road Type



Project RunSpec: Pollutants and Processes

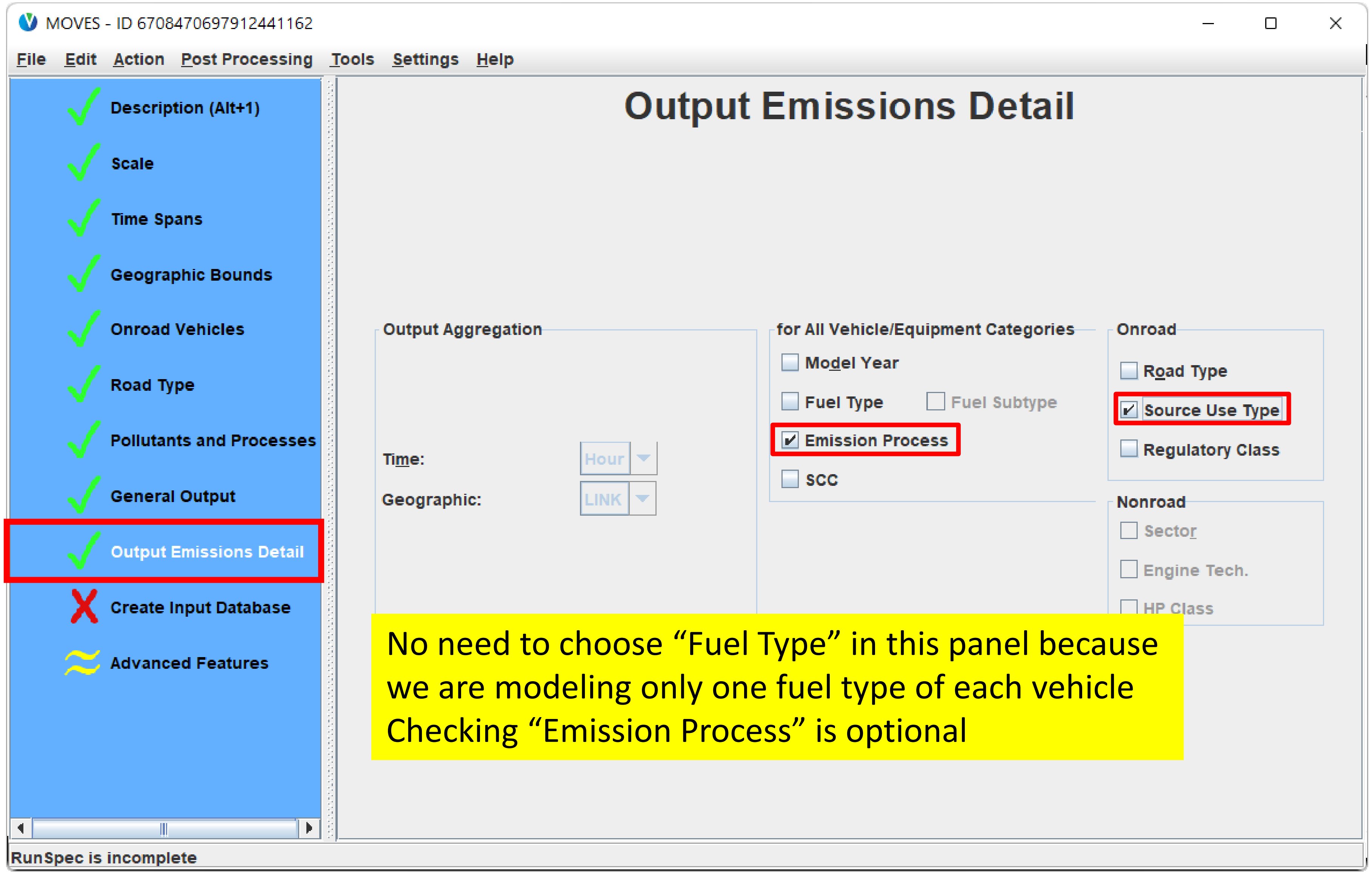


Project RunSpec: General Output



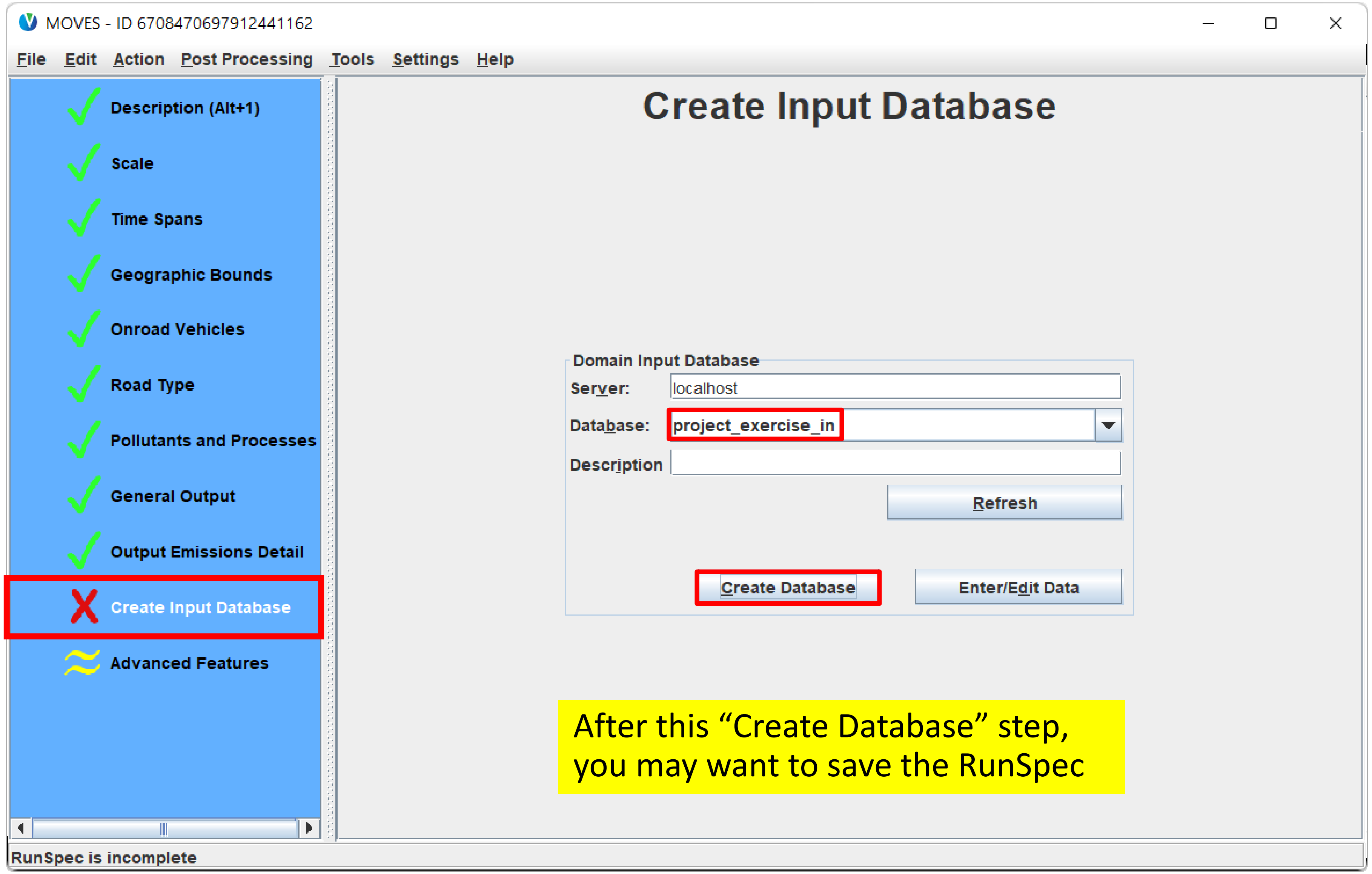
Additional activity options chosen because this project includes hotelling and starts

Project RunSpec: Output Emissions Detail



No need to choose “Fuel Type” in this panel because we are modeling only one fuel type of each vehicle
Checking “Emission Process” is optional

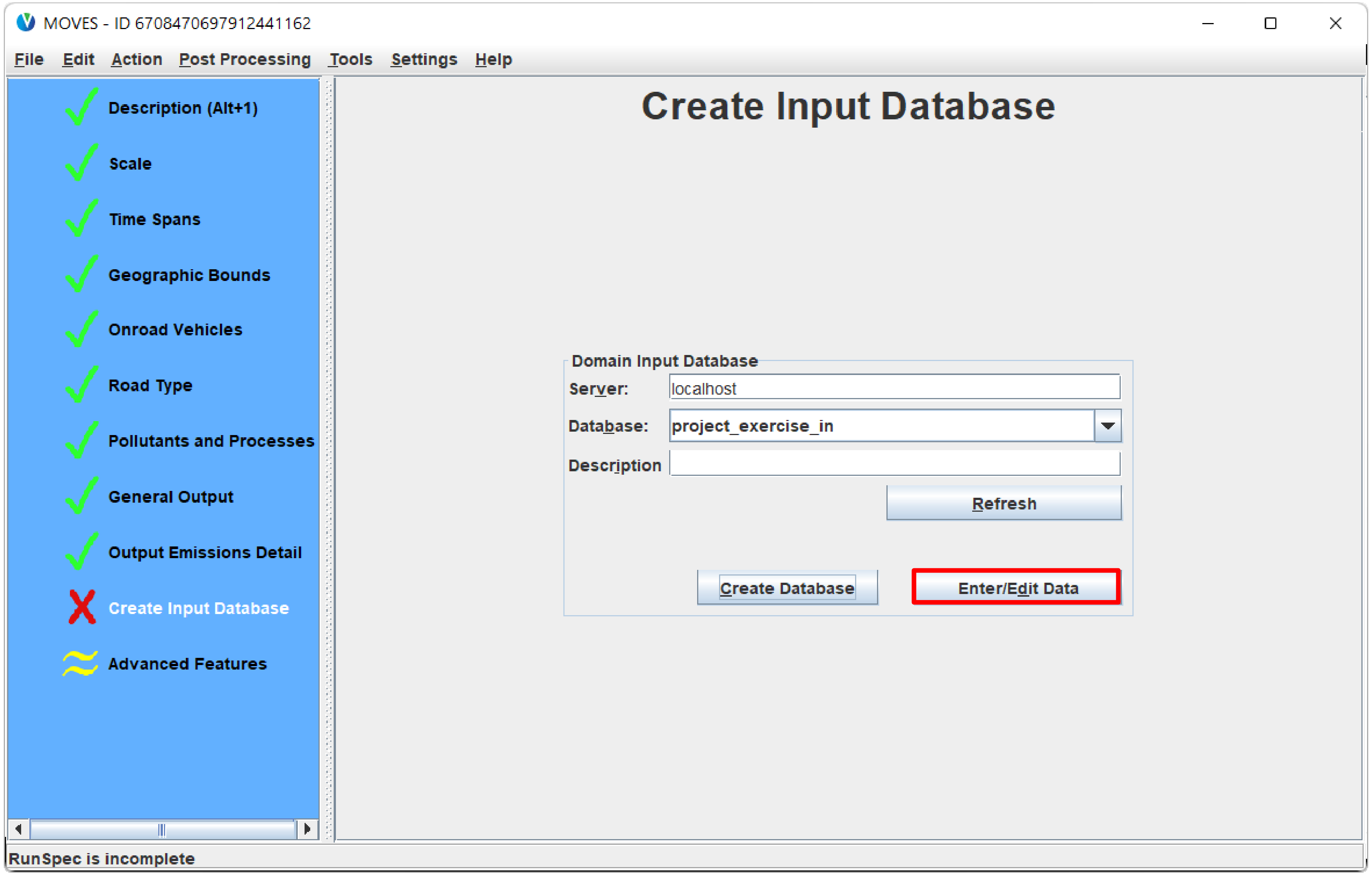
Project RunSpec: Create Input Database



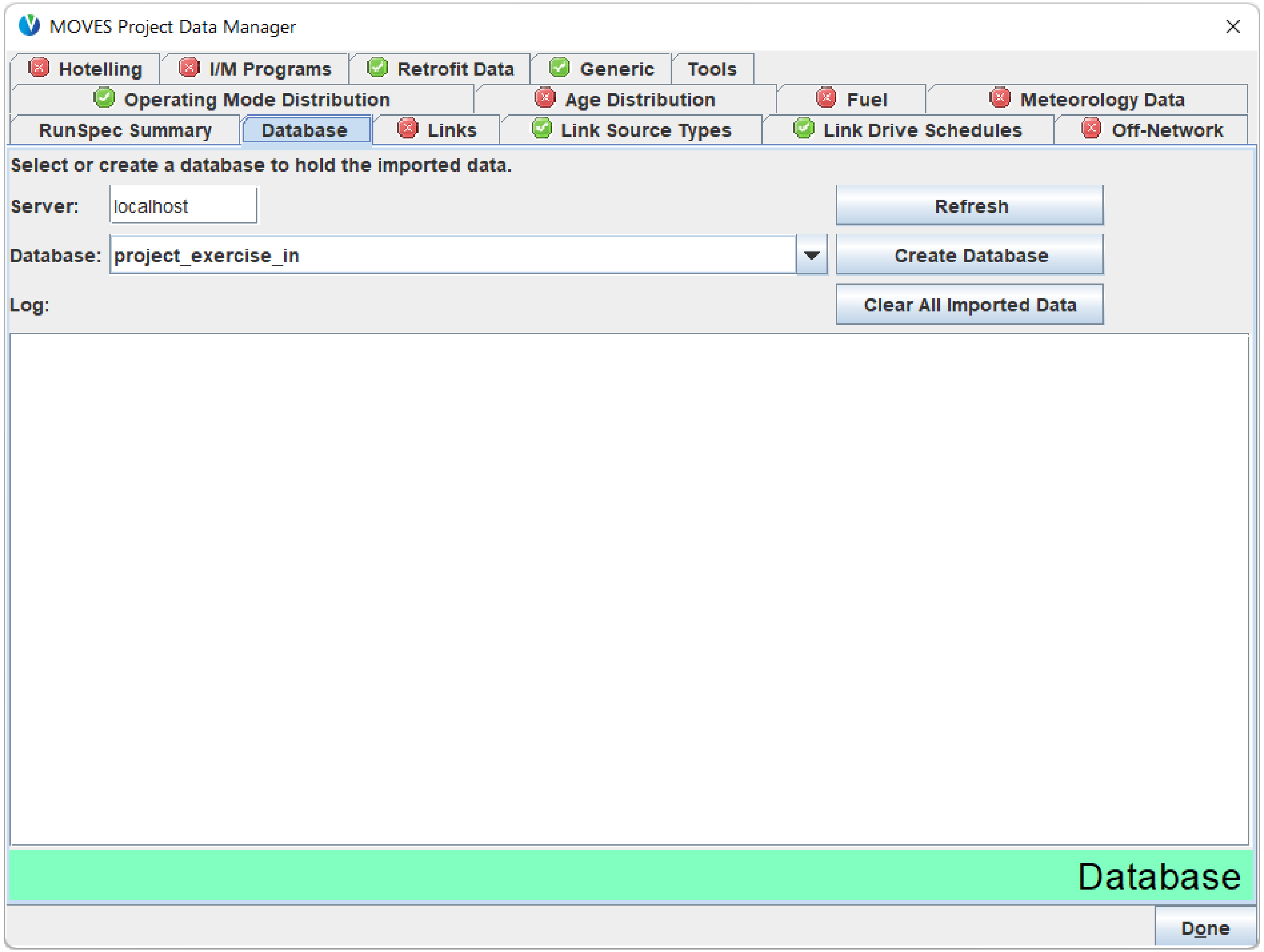
Creating an Input Database for the Project Scale Exercise

MOVES
Motor Vehicle Emission Simulator

Opening the Project Data Manager



Project Data Manager



If you clicked "Create Database" in the main GUI, there is nothing to do on this tab.

Otherwise, you will need to enter the database name and click "Create Database" in the CDM before doing anything else.

Project Data Manager Inputs: Reminder

- Links
- Link Source Types
- Link Drive Schedules
- Off-Network
- Operating Mode Distribution

These inputs are unique to the Project Scale

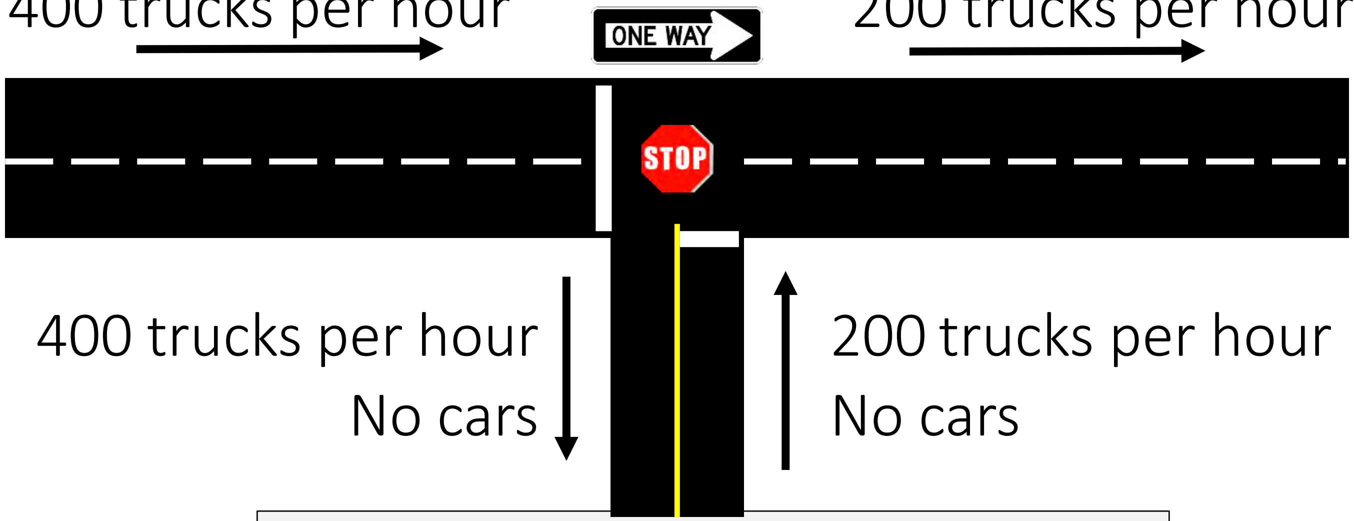
- Age Distribution
- Fuel
- Meteorology Data
- Hotelling
- I/M Programs
- Retrofit Data

These inputs are common to analyses at County and Project Scales

Project Diagram Scenario

600 cars per hour
400 trucks per hour

600 cars per hour
200 trucks per hour



400 trucks per hour
No cars

200 trucks per hour
No cars

Freight Terminal peak hour activity:

- 800 trucks present, each idles 30 min
- 200 trucks start in this hour:
  - 100 after soak of 30 minutes
  - 100 after soak of 8 hours
- 400 trucks hotelling
  - 100 are plugging in
  - 300 are extended idling

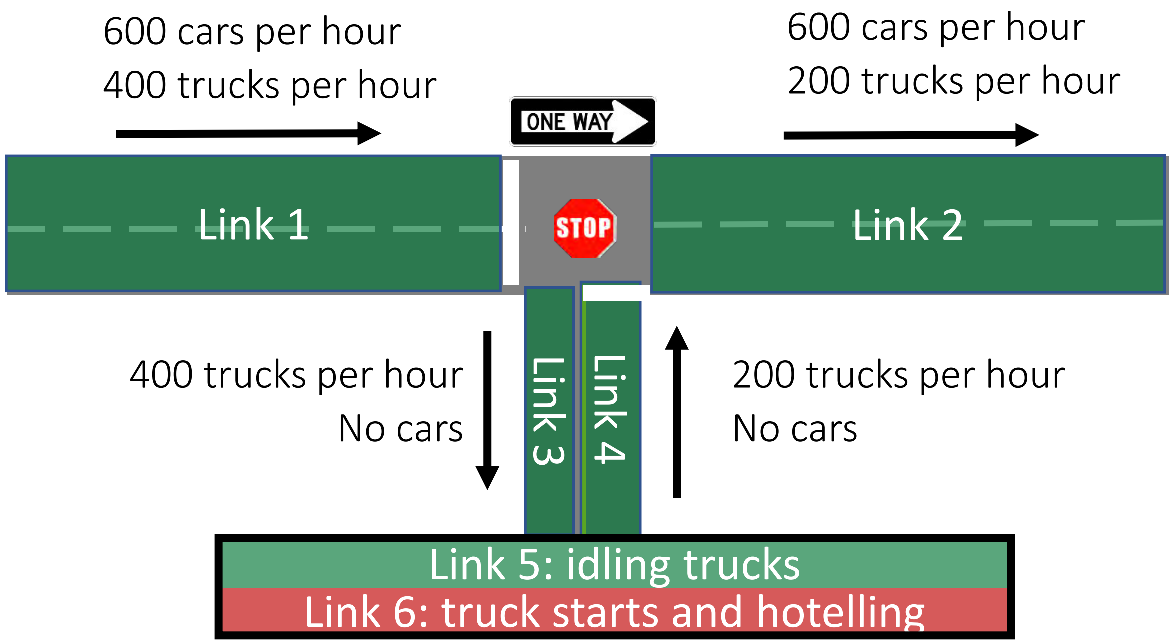
For Discussion:

1. How many links are needed to represent this project?
2. What kind of links are needed?
3. Is the Operating Mode Distribution input needed?
4. Why could trucks have both non-hotelling idling and hotelling idling?
5. How much non-hotelling idling is happening in the hour?

Project Diagram Scenario Answers

1. How many links are needed to represent this project?
    - 6 links are needed
2. What kind of links are needed?
    - 5 running links
        - 4 links for the roadways (a new link is needed for each road segment with different traffic volumes)
        - 1 running link for the non-hotelling idling at the terminal
    - 1 off-network link, to capture the start and hotelling emissions
3. Is the Operating Mode Distribution input needed?
    - Yes, because we have start emissions, so we will need it to define soak times
4. Why could trucks have both non-hotelling idling and hotelling idling?
    - Trucks at the terminal can be idling while they are loading and unloading
    - Trucks at the terminal can be hotelling while the driver has a rest period
5. How much non-hotelling idling is happening in the hour?
    - 800 trucks idle for 30 minutes (half of the hour being modeled)
    - 800 × (1/2) hour = 400 trucks per hour

Project Link Details



Link ID	Road Type	Link Length	Link Volume	Truck Fraction	Car Fraction	Average Speed (accounting for intersection delay)
1	Urban Unrestricted	0.5 mi	1000	0.4	0.6	25 mph
2	Urban Unrestricted	0.5 mi	800	0.25	0.75	35mph
3	Urban Unrestricted	0.25 mi	400	1	0	15 mph
4	Urban Unrestricted	0.25 mi	200	1	0	15 mph
5	Urban Unrestricted	0	400	1	0	0
6	Off-Network	0	800	1	0	0

PDM Instructions for this Exercise

Input	Instructions
Age Distribution	Import into PDM from the Module 7 - Project Exercise folder
Meteorology Data	Import into PDM from the Module 7 - Project Exercise folder
Fuel	Import into PDM from the Module 7 - Project Exercise folder
Links	Create a template and create a row for each link
Link Source Types	Create a template and fill in. You will need two rows for each **running** link with cars and trucks (Links 1 and 2), and one row for each **running** link with just trucks (Links 3, 4, and 5). (Link 6, the **off-network** link, does not belong in this table.)
Link Drive Schedule	Not needed for Run #1
Off-Network	Create a template and fill in. Include information for the off-network link only.
Operating Mode Distribution	Create a template and fill in. Only needed for the **off-network** link, so delete all "running modes" from template and just use for **starts**.
Hotelling	Create a template and fill in. Used only for 62s.
I/M Programs	Check "No I/M Program"
Retrofit Data	Not needed for this example

Let’s start with familiar inputs

- Since these three inputs were covered in previous modules, we will not focus on them here. Import these inputs directly from the Module 7 - Project Exercise folder:
  - Age Distribution: “age_distribution.xlsx”
  - Meteorology: “met.xlsx”
  - Fuel: “fuels.xlsx”
- For the I/M Programs input, check the box for “No I/M Program”

PDM: Age Distribution Input

- The file in the folder was created by exporting the default age distribution
- It includes only source types 21 and 62 – partial table shown here
  - For a real project, you would use the local data you have and use the Age Distribution tool to project it to the year 2025

	A	B	C	D
1	sourceTyp	yearID	ageID	ageFraction
2	21	2025	0	0.043882
3	21	2025	1	0.044654
4	21	2025	2	0.043707
5	21	2025	3	0.04379
6	21	2025	4	0.034317
7	21	2025	5	0.034532
8	21	2025	6	0.044054
9	21	2025	7	0.048133
10	21	2025	8	0.05507
11	21	2025	9	0.056082
12	21	2025	10	0.060459
13	21	2025	11	0.056719
14	21	2025	12	0.058573
15	21	2025	13	0.049616
16	21	2025	14	0.034792
17	21	2025	15	0.032073
18	21	2025	16	0.025725
19	21	2025	17	0.02876

SourceTypeAgeDi: ...

PDM: Meteorology Input

- The file in the folder was created from a template and filled in with appropriate temperature and humidity

	A	B	C	D	E	F	G
1	monthID	zoneID	hourID	temperatu	relHumidity		
2	1	261610	9	20.3	70		
3							
4							
5							

ZoneMonthHour | HourOfAnyDay | ...

PDM: Fuels Input

- The Fuels input file was created by exporting the default, and changing the AVFT Table so that:
  - All passenger cars (21s) are gasoline
  - All combination long-haul trucks (62) are diesel
  - Note the fuelEngFraction column numbers repeat for all model years

The AVFT tab of the fuels input, showing passenger cars

	A	B	C	D	E	F
1	sourceTyp	modelYear	fuelTypeID	engTechID	fuelEngFraction	
2	21	1960	1	1	1	
3	21	1960	2	1	0	
4	21	1960	5	1	0	
	21	1960	9	30	0	
	21	1961	1	1	1	
	21	1961	2	1	0	
	21	1961	5	1	0	
	21	1961	9	30	0	
	21	1962	1	1	1	
11	21	1962	2	1	0	
12	21	1962	5	1	0	
13	21	1962	9	30	0	
14	21	1963	1	1	1	

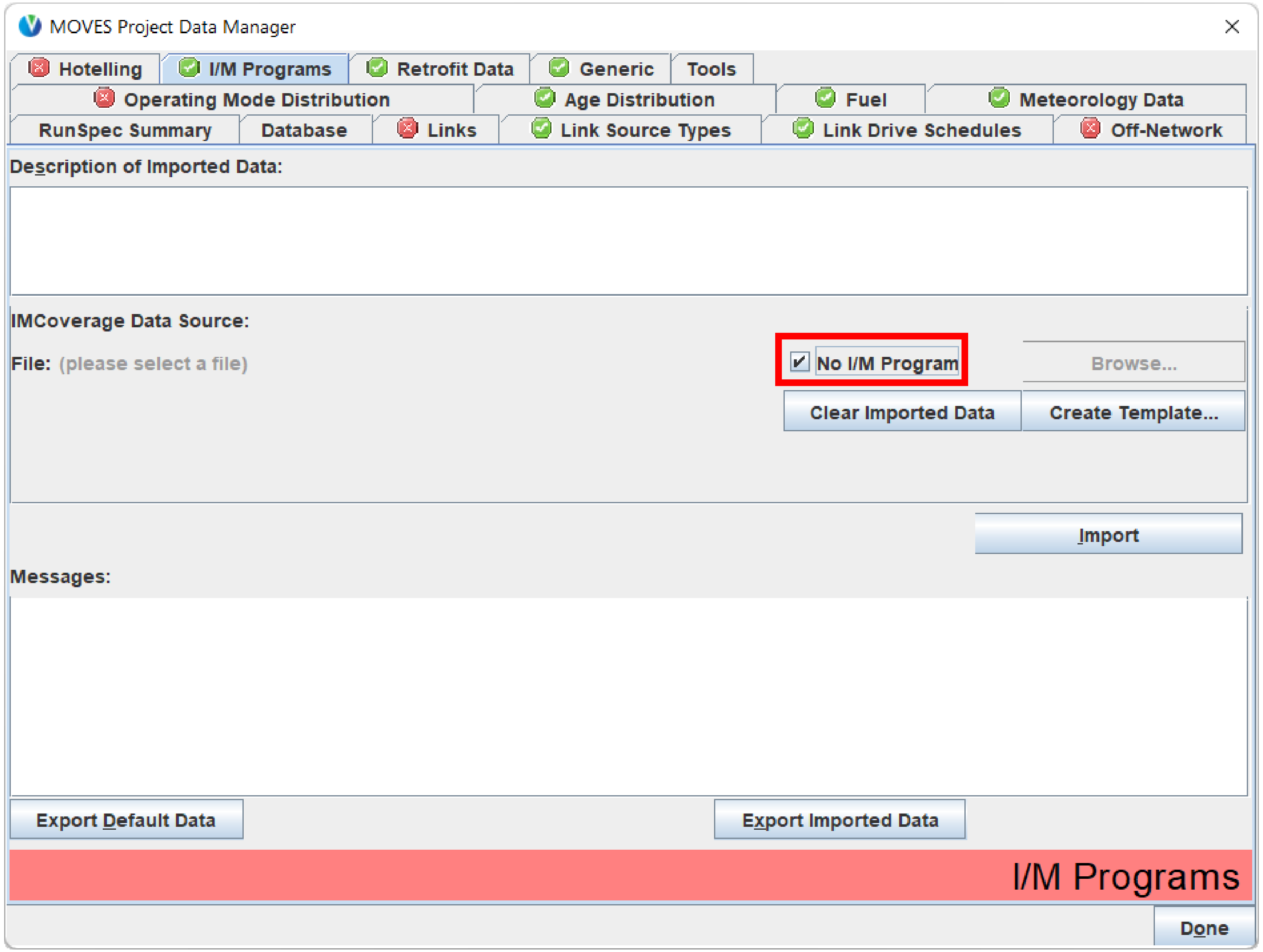
avft | County | E ...

	A	B	C	D	E	F
1	sourceTyp	modelYear	fuelTypeID	engTechID	fuelEngFraction	
266	62	1960	2	1	1	
267	62	1960	3	1	0	
268	62	1960	9	30	0	
269	62	1960	9	40	0	
270	62	1961	2	1	1	
271	62	1961	3	1	0	
272	62	1961	9	30	0	
273	62	1961	9	40	0	
274	62	1962	2	1	1	
275	62	1962	3	1	0	
276	62	1962	9	30	0	
277	62	1962	9	40	0	
278	62	1963	2	1	1	

avft | County | E ...

The AVFT tab of the fuels input, showing long-haul combination trucks

PDM: I/M Programs Input



Unique Project Scale Inputs

- You will need to create templates, fill them in, and import them for the following inputs:
  - Links
  - Link Source Type
  - Off-Network
  - Operating Mode Distribution
  - Hotelling
- Next slides show these inputs

PDM: Links Input

	A	B	C	D	E	F	G	H	I
1	linkID	countyID	zoneID	roadTypeID	linkLength	linkVolume	linkAvgSpeed	linkDescription	linkAvgGrade
2	1	26161	261610	5	0.5	1000	25	Arterial - West link	0
3	2	26161	261610	5	0.5	800	35	Arterial - East link	0
4	3	26161	261610	5	0.25	400	15	Terminal Drive SB	0
5	4	26161	261610	5	0.25	200	15	Terminal Drive NB	0
6	5	26161	261610	5	0	400	0	Running link for ON	0
7	6	26161	261610	1	0	800	0	Off-network link	0
8									

link | County | RoadType | Zone

This input is now populated with project-specific data (from previous slides)

Links input includes all road types, including the Terminal as both a running link (linkID 5) and an off-network link, linkID 6 (roadtypeID 1)

Since the Links Input includes an off-network link, you will get **an error message** and **continue to get a red "X"** for this input until the Off-Network Input is imported!

PDM: Link Source Type Input

linkID	sourceTypeID	sourceTypeHourFraction
1	21	0.6
1	62	0.4
2	21	0.75
2	62	0.25
3	62	1
4	62	1
5	62	1

Sums to 1

Sums to 1

linkSourceTypeHour

This input is used to define the fleet mix on each running link
Note also that for each link, the sourceTypeHourFractions sum to 1
Links 5 **included**: Link 5 is a running link for the non-hotelling idling at the terminal
Link 6 **not included**: start and hotelling activity is included in other inputs

PDM: Off-Network Input

	A	B	C	D	E	F
1	zoneID	sourceTypeID	vehiclePopulation	startFraction	extendedIdleFraction	parkedVehicleFraction
2	261610	21	0	0	0	0
3	261610	62	800	0.25	0.5	0
4						
5						
6						
7						
8						

offNetworkLink | SourceUseType | Zor ...

This input is for the off-network link only

- It is somewhat equivalent to Link Source Type inputs for running links

Once it's imported, you will get a green check for both this input and the Links Input

PDM: Operating Mode Distribution Input

	A	B	C	D	E	F	G
1	sourceTyp	hourDayID	linkID	polProcessID	opModeID	opModeFraction	
2	21	95	6	202	101	1	
3	21	95	6	202	102	0	
4	21	95	6	202	103	0	
5	21	95	6	202	104	0	
6	21	95	6	202	105	0	
7	21	95	6	202	106	0	
8	21	95	6	202	107	0	
9	21	95	6	202	108	0	
10	62	95	6	202	101	0	
11	62	95	6	202	102	0	
12	62	95	6	202	103	0.5	
13	62	95	6	202	104	0	
14	62	95	6	202	105	0	
15	62	95	6	202	106	0	
16	62	95	6	202	107	0.5	
17	62	95	6	202	108	0	

opModeDistribution | Ho ...

Sums to 1

Sums to 1

Only Link 6, the off-network link, needs to be included on this template.

- All rows with running opModeIDs have been deleted
- Only rows for the start opModeID are needed

OpModesFractions must sum to 1 for each vehicle type and polProcessID

No cars (21s) are at the terminal, but still need car starting opModes to sum to 1

For the trucks (62s), recall:

½ of the starts occur after 30 minutes of soak time, and ½ after 8 hours of soak time

PDM: Hotelling Input

	A	B	C	D	E	F	G
1	zoneID	fuelTypeID	beginModelYear	endModelYear	opModeID	opModeFraction	
2	261610	2	1960	2060	200	0.75	
3	261610	2	1960	2060	201	0	
4	261610	2	1960	2060	203	0.25	
5	261610	2	1960	2060	204	0	
6	261610	3	1960	2060	200	0.75	
7	261610	3	1960	2060	201	0	
8	261610	3	1960	2060	203	0.25	
9	261610	3	1960	2060	204	0	
10	261610	9	1960	2060	200	0	
11	261610	9	1960	2060	201	0	
12	261610	9	1960	2060	203	1	
13	261610	9	1960	2060	204	0	

hotellingActivityDistribution

Of the 400 (diesel) trucks hotelling:

- 300 are extended idling
- 100 are plugging in

Fuel Types:

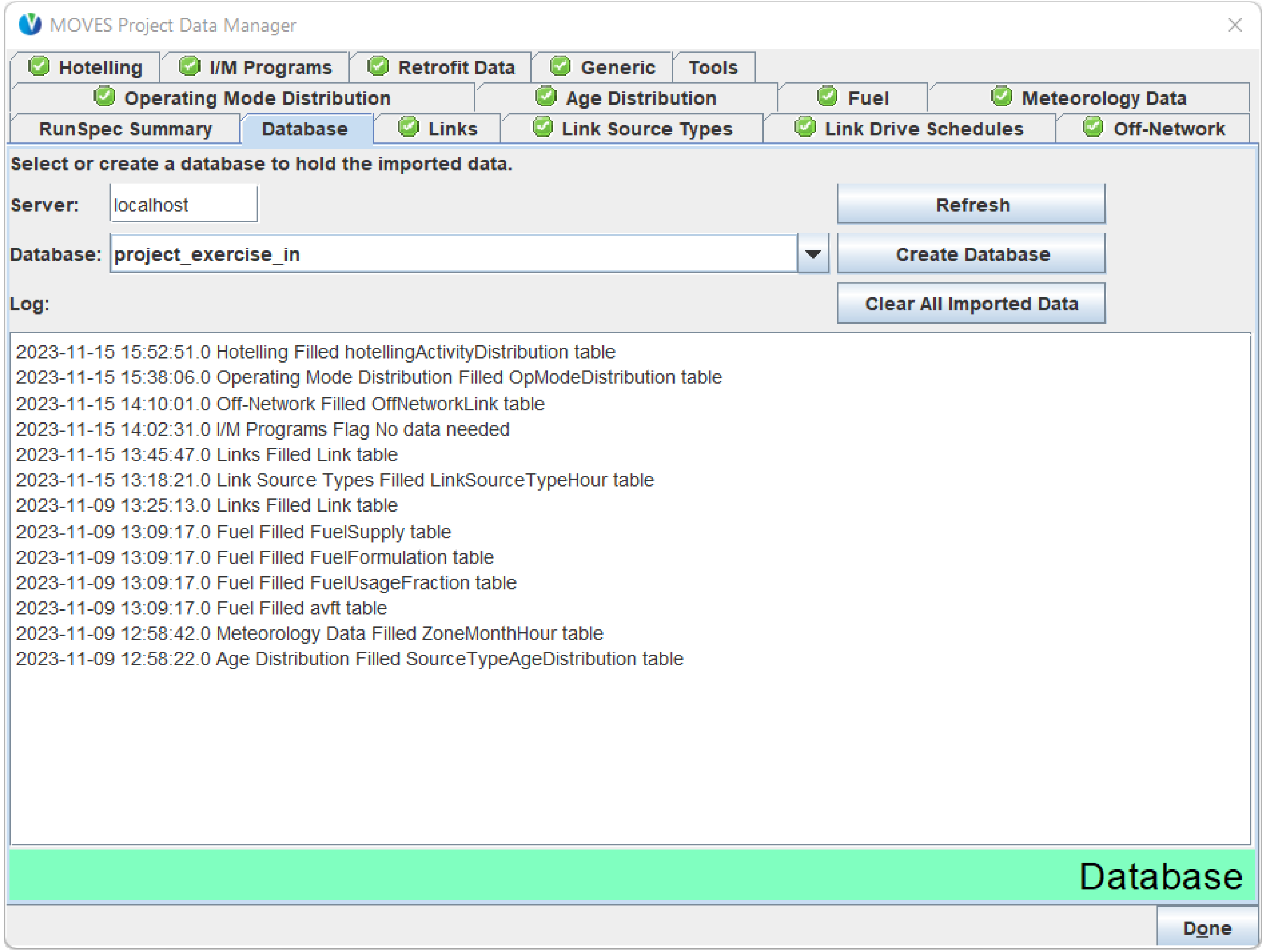
In the example project, we have only diesel trucks. However, you have to include inputs for all fuel types to get a green check

- We gave CNG trucks (fuelTypeID 3) the same distributions as diesel trucks
- EV trucks (fuelTypeID 9) cannot “Extended idle”, so we made them 100% plug-in

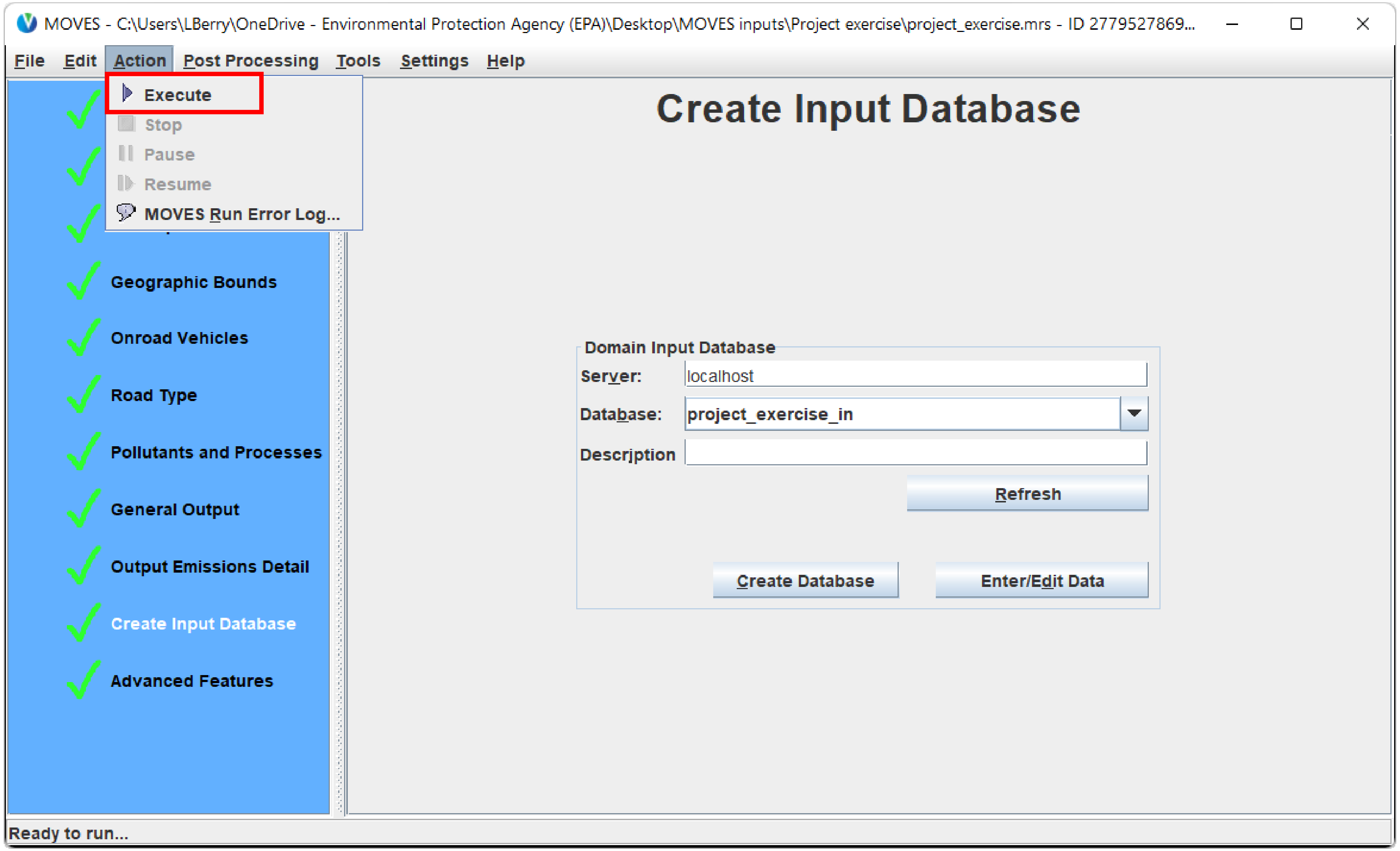
Begin and End Model Years:

- Additional years can be included without issue, which allows you to use the same table for multiple runs if you are doing multiple analysis years. By using the 1960-2060 range, we are modeling the same hotelling activity for all model years
- In this case, the analysis year is 2025, so MOVES will not use model years after that

Completed Project Scale Input Database



Execute the Project Scale Exercise



Project Exercise Output in HeidiSQL

MOVESRunID	yearID	monthID	dayID	hourID	stateID	countyID	linkID	pollutantID	processID	sourceTypeID	emissionQuant
1	2025	1	5	9	26	26161	1	2	1	21	1260.23
1	2025	1	5	9	26	26161	1	2	1	62	764.173
1	2025	1	5	9	26	26161	1	2	15	21	0.65532
1	2025	1	5	9	26	26161	1	2	15	62	11.8673
1	2025	1	5	9	26	26161	2	2	1	21	1062.75
1	2025	1	5	9	26	26161	2	2	1	62	282.724
1	2025	1	5	9	26	26161	2	2	15	21	0.552629
1	2025	1	5	9	26	26161	2	2	15	62	4.72047
1	2025	1	5	9	26	26161	3	2	1	62	548.021
1	2025	1	5	9	26	26161	3	2	15	62	7.95428
1	2025	1	5	9	26	26161	4	2	1	62	274.011
1	2025	1	5	9	26	26161	4	2	15	62	3.97714
1	2025	1	5	9	26	26161	5	2	1	62	8007.11
1	2025	1	5	9	26	26161	5	2	15	62	161.502
1	2025	1	5	9	26	26161	6	2	2	21	0
1	2025	1	5	9	26	26161	6	2	2	62	848
1	2025	1	5	9	26	26161	6	2	16	21	0
1	2025	1	5	9	26	26161	6	2	16	62	27.6879
1	2025	1	5	9	26	26161	6	2	17	62	218.158
1	2025	1	5	9	26	26161	6	2	90	62	12744.7
1	2025	1	5	9	26	26161	6	2	91	62	0

Calculating Link Emissions (grams/hour)

```
SELECT MOVESRunID, linkID, SUM(emissionQuant)
FROM project_exercise_out.movesoutput
GROUP BY MOVESRunID, linkID;
```

MOVESRunID	linkID	SUM(emissionQuant)
1	1	2036.9255741238594
1	2	1350.7470979690552
1	3	555.9752759933472
1	4	277.9881262779236
1	5	8168.611862182617
1	6	13838.546100616455

Options for Defining Running Activity

Running Activity Options

- There are three user options available for defining running activity:
  1. Average speed, on the Links input
  2. Link Drive Schedule input
  3. Operating Mode Distribution input
- If average speed or link drive schedule is used, MOVES will perform additional steps to calculate a representative operating mode distribution
  - The operating mode distribution is then used by MOVES to weight together base emission rates for different kinds of vehicle activity

Running Activity Options: Average Speed

- Average Speed is the default activity measure, as it must be defined for every entry in the Links input
  - This is how we defined activity on the running links in the exercise
- If the other activity options are not provided, MOVES will:
  1. Look up two drive schedules (second-by-second speed traces) for the relevant road type in the default database:
     1. One with an average speed above the input average speed
     2. One with an average speed below the input average speed
  2. Calculate an operating mode distribution for each source type on each drive schedule using the link average grade
  3. Calculate an average operating mode distribution for each source type to approximate the input average speed
- Note: Whether or not the other activity options are provided, the correct average speed must be provided in the Links input regardless, as it is used to calculate source hours operating on each link

Running Activity Options: Link Drive Schedule

- A link drive schedule defines second-by-second speed and grade
  - Speed is always MPH, regardless of the units selected in the RunSpec
  - Grade is vertical distance / lateral distance. E.g., 100% grade = 45° slope
- Drive schedules can be based on chase (or floating) cars or expected vehicle activity based on an analysis of link geometry
  - These represent average vehicle activity on the link
- If a drive schedule is provided for a link, MOVES will directly calculate the operating mode distribution for each source type on the link
  - This is more precise than using average speed
  - Note that all source types present on a link will use the same drive schedule
  - If source types are not using the same driving schedule, use multiple links to define this physical space, each with its own driving schedule and source type fractions

Running Activity Options: Operating Mode Distribution

- Operating mode distributions can be directly imported. For each link using this activity option:
  - An operating mode distribution must be provided for each source type and pollutant/process combination
  - This will be used for calculating **running** emissions instead of creating an operating mode distribution from the average speed in the Links input or from the Link Drive Schedule input

- This option is an advanced technique and not covered further in this course

Demonstration of using the Link Driving Schedule input

Review of the Links input

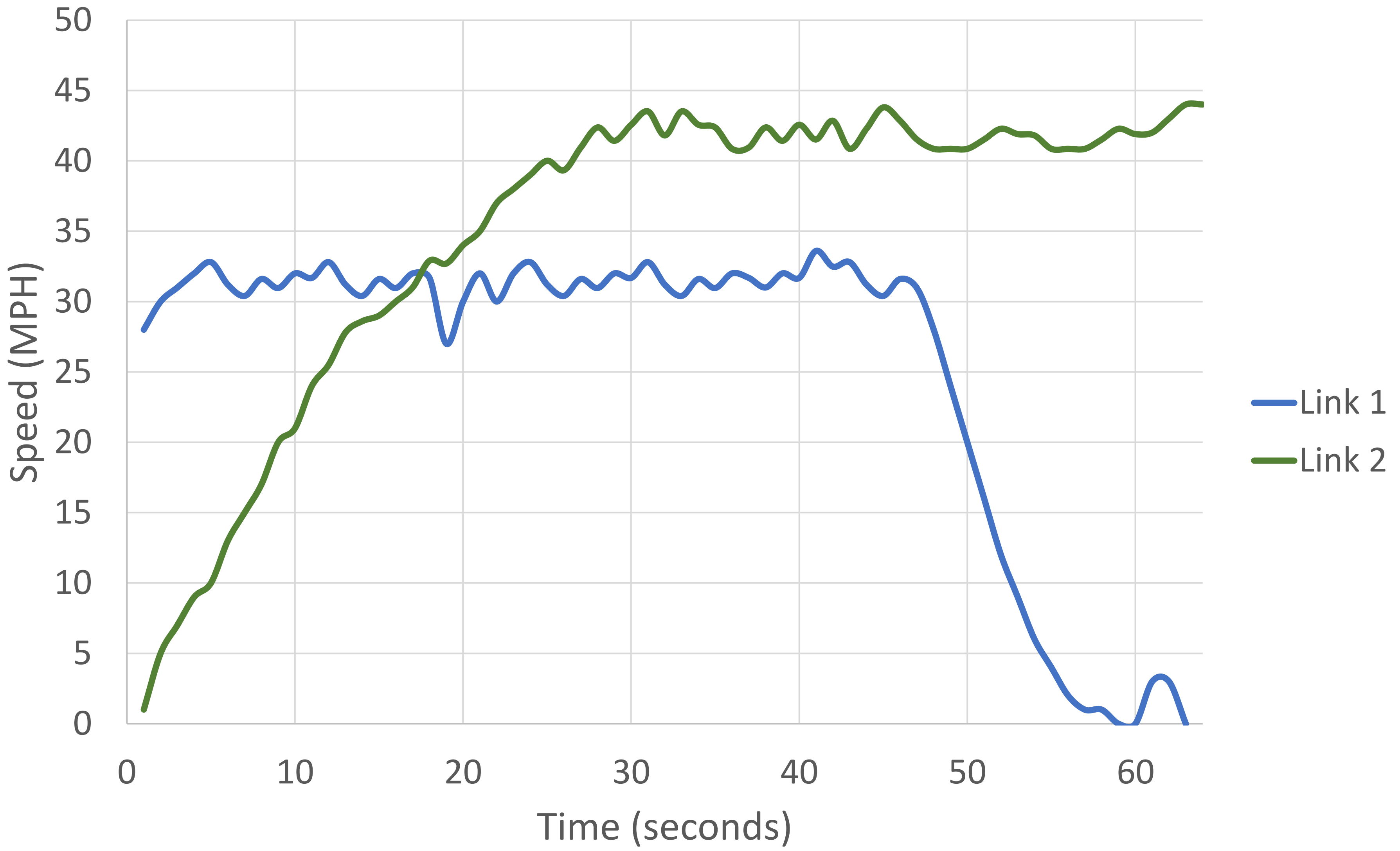
- The run we just did relied on average speed included in the Links input:

	A	B	C	D	E	F	G	H	I
1	linkID	countyID	zoneID	roadTypeID	linkLength	linkVolume	linkAvgSpeed	linkDescription	linkAvgGrade
2	1	26161	261610	5	0.5	1000	25	Arterial - West link	0
3	2	26161	261610	5	0.5	800	35	Arterial - East link	0
4	3	26161	261610	5	0.25	400	15	Terminal Drive SB	0
5	4	26161	261610	5	0.25	200	15	Terminal Drive NB	0
6	5	26161	261610	5	0	400	0	Running link for ON	0
7	6	26161	261610	1	0	800	0	Off-network link	0
8									

link | County | RoadType | Zone

- But what if we had measured or modelled speed traces for these links?

Sample Link Drive Schedules for Links 1 & 2



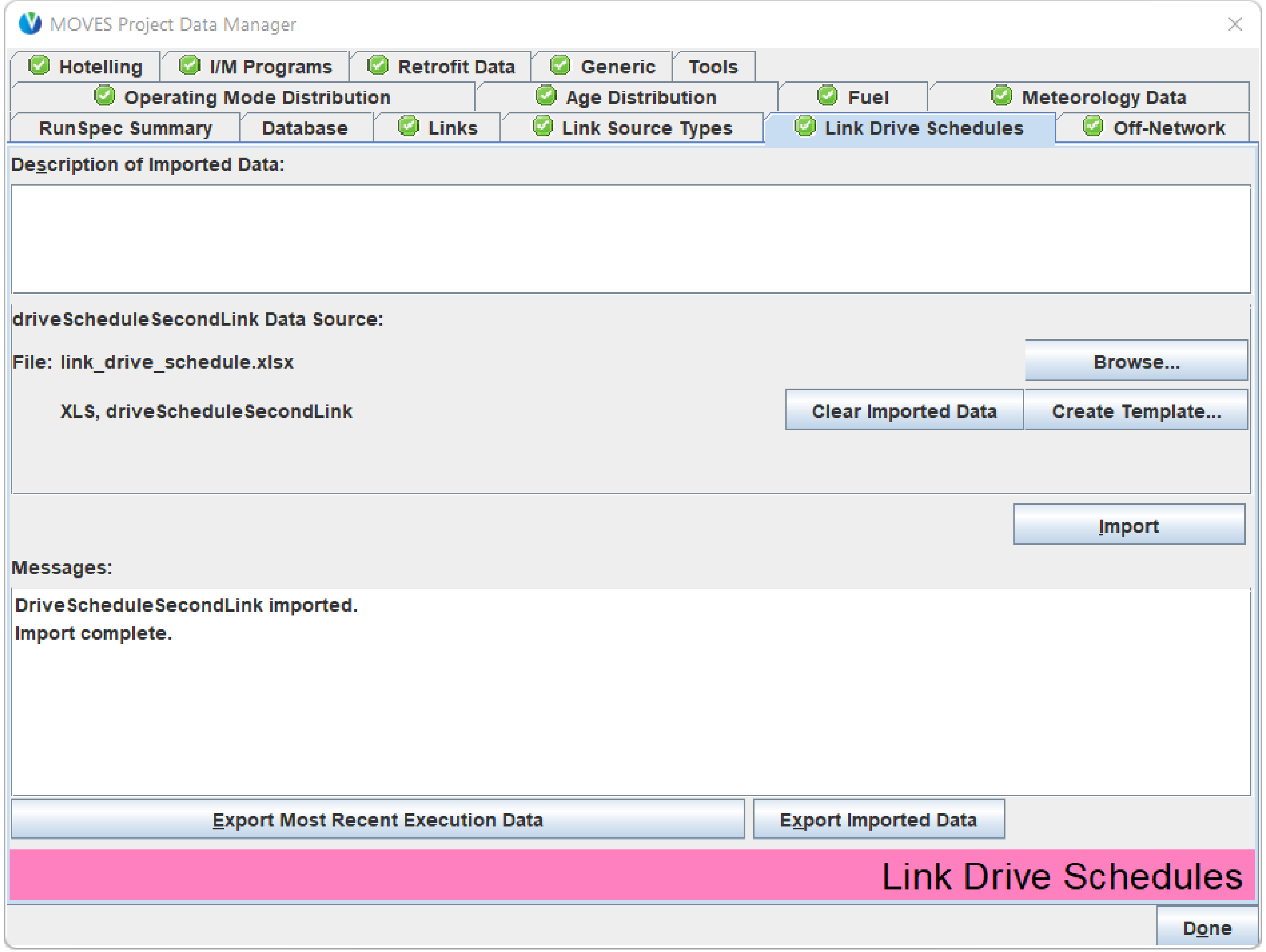
Link Drive Schedules Input

	A	B	C	D	E	F	G	H
1	linkID	secondID	speed	grade				
2	1	1	28.0	0				
3	1	2	30.0	0				
4	1	3	31.0	0				
5	1	4	32.0	0				
6	1	5	32.8	0				
7	1	6	31.2	0				
8	1	7	30.4	0				
9	1	8	31.6	0				
10	1	9	31.0	0				
11	1	10	32.0	0				
12	1	11	31.7	0				
13	1	12	32.8	0				
14	1	13	31.2	0				
15	1	14	30.4	0				
16	1	15	31.6	0				
17	1	16	31.0	0				
18	1	17	32.0	0				
19	1	18	31.7	0				
20	1	19	27.0	0				
21	1	20	30.0	0				
22	1	21	32.0	0				
23	1	22	30.0	0				
24	1	23	32.0	0				
25	1	24	32.8	0				

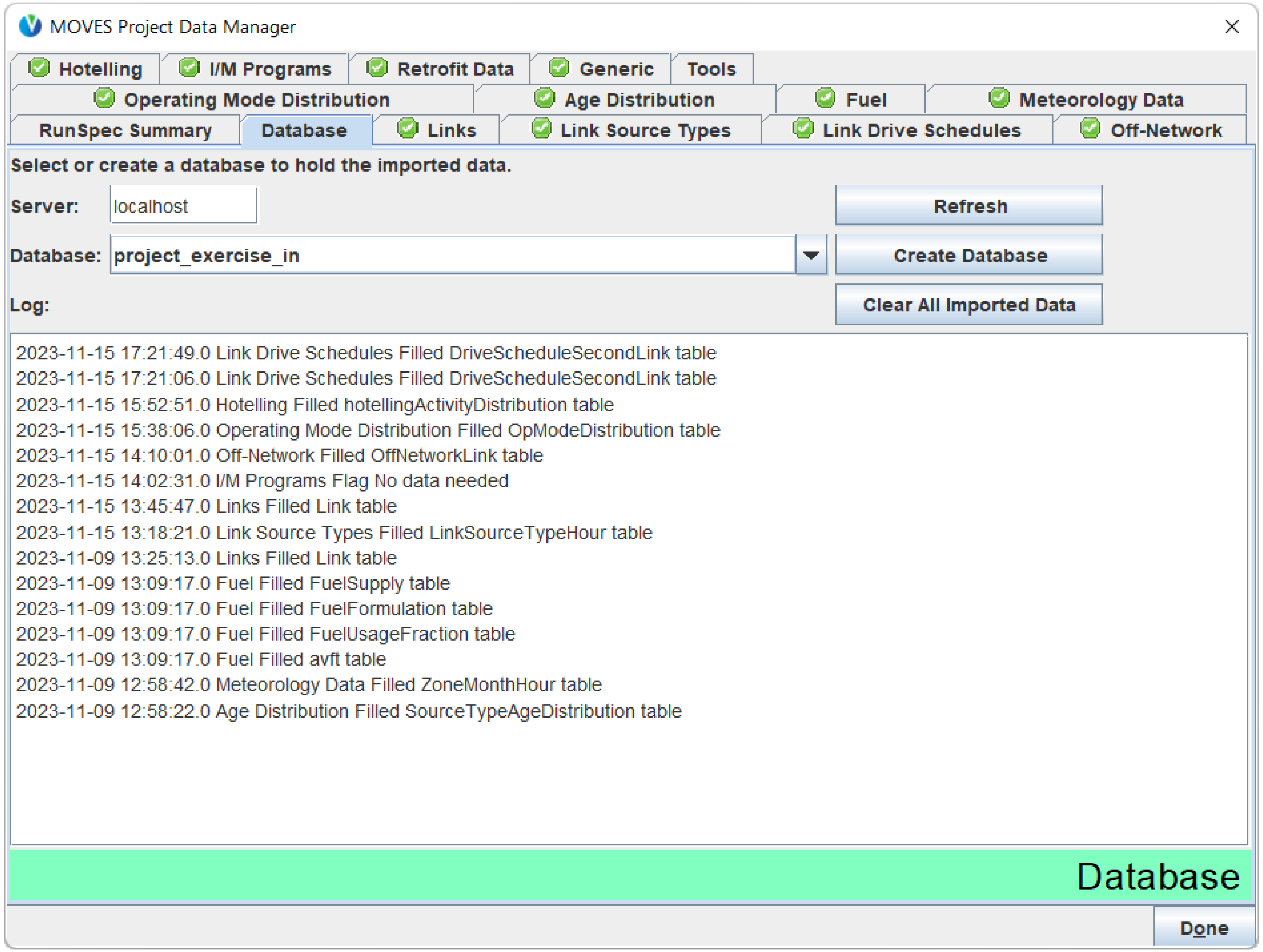
driveScheduleSecondLink

The spreadsheet *link_drive_schedule.xlsx* in the **Module 7 - Project Exercise\Answer Key** folder has second-by-second speed and grade for Links 1 and 2

Import Link Drive Schedule



Completed Input Database After Importing Link Drive Schedules



Comparing the Project Scale Exercise Results

```
SELECT MOVESRunID, linkID, SUM(emissionQuant)
FROM project_exercise_out.movesoutput
GROUP BY MOVESRunID, linkID
ORDER BY linkID, MOVESRunID;
```

MOVESRunID	linkID	SUM(emissionQuant)
1	1	2036.9255741238594
2	1	1942.5723404288292
1	2	1350.7470979690552
2	2	1775.703817307949
1	3	555.9752759933472
2	3	555.9752759933472
1	4	277.9881262779236
2	4	277.9881262779236
1	5	8168.611862182617
2	5	8168.611862182617
1	6	13838.546100616455
2	6	13838.546100616455

The link drive schedule input included only Links 1 and 2

- Results for Links 1 and 2 differ between the two runs
- Results for Links 3–6 are identical in the two runs

Module 7 Questions?

MOVES
Motor Vehicle Emission Simulator

Module 8: Capstone Exercise

MOVES
Motor Vehicle Emission Simulator

EPA

Module 8 Overview

- This capstone exercise is designed to check your understanding of MOVES modeling
- Before you start:
  - Read the project description
  - Skim the provided files
  - Think about how you will structure your work
- If needed, read the hints in the next few slides before going through the module exercise
- The expected answer is provided after the hint slides
- For a review of best practices, or if you have problems or get stuck, the remainder of the module provides a step-by-step demonstration of how to complete the exercise

Capstone Exercise Goals

- Develop a CO inventory for a typical January 2028 weekday in Washtenaw County, Michigan
- In this hypothetical scenario, the county has the following plans:
  - All refuse trucks purchased in 2021 and later will be CNG
  - All transit buses and school buses purchased in 2023 and later will be BEV
- **Read handout in Module 8 - Capstone Exercise before starting, which contains more details than covered here**
- Work with data provided, which are not always in MOVES format
- Post-process results to obtain total inventory

Capstone Exercise Instructions

- Create a MOVES RunSpec
- Create a blank input database
- Populate the input database with appropriate tables
  - All necessary files are located in Module 8 - Capstone Exercise folder
  - Some files require using a tool
  - Others will need to be copied into a template for correct formatting
  - Some data files will be generated using “Export Defaults”
- Run MOVES
- Post-process output to generate a total inventory

Hints: MOVES Inputs Provided by MPO

- The MPO has supplied some data files already formatted for MOVES
  - Average Speed Distribution (*speeddistribution.xlsx*)
  - Road Type Distribution (*roadtypedistribution.xlsx*)
  - Age Distributions (*agedistribution-2020.xlsx*)
  - AVFT (*avft-2020.xlsx*)
- These files are located in the Module 8 - Capstone Exercise\MPO MOVES Files folder
- Average speed and road type distributions can be directly imported into MOVES
- Use the Age Distribution Projection Tool and the AVFT Tool to model the scenario

Hints: Other Information Provided

- Other necessary files are provided in the Module 8 - Capstone Exercise\Additional Data Files folder:
  - Temperature and humidity
  - Daily VMT for 2028
  - Vehicle Population for 2028
- This information must be properly formated for use in MOVES
  - For the Meteorology and Source Type Population tabs, create a template and copy/paste data from the Additional Data Files
  - For the VMT tab, export the default data to get the default hourly VMT fractions; you can copy/paste the data from the Additional Data Files into this file

Hints: Inputs that Need Modification (1)

- Age Distribution
  - Use the Age Distribution Projection Tool to project the MPO's base age distribution data for Washtenaw County in 2020 to 2028
  - Export the default age distributions, then copy/paste the default data for combination long-haul trucks (source type 62) into the Age Distribution Projection Tool output
- Hotelling
  - The hypothetical scenario has an anti-idling requirement for diesel MY2009 and earlier combination long-haul trucks
  - For these specific trucks, change their hotelling activity distribution to 100% shore power
  - All other trucks can use the default hotelling activity distribution assumptions

Hints: Inputs that Need Modification (2)

- AVFT
  - Use the AVFT Tool to project the MPO's base fuel type distribution data for Washtenaw County to 2028
  - These data were pulled on July 1, 2020, so the Last Complete Model Year is 2019
  - In this hypothetical scenario, we have known fractions for:
    - Refuse trucks: 100% CNG (fuelTypeID 3, engTechID 1) starting in MY2021
    - Transit buses: 100% BEV (fuelTypeID 9, engTechID 30) starting in MY2023
    - School buses: 100% BEV (fuelTypeID 9, engTechID 30) starting in MY2023
    - Create a Known Fractions template to provide this data to the tool
  - All other non-long-haul vehicles can be projected with the Proportional method

Hints: Default Inputs

- Fuels:
  - Export and review the default fuel supply, fuel formulation, and fuel usage fraction data
- I/M
  - Washtenaw County does not have an I/M program

Capstone Exercise Post-Processing

- Results must be appropriately summed to generate the total CO inventory

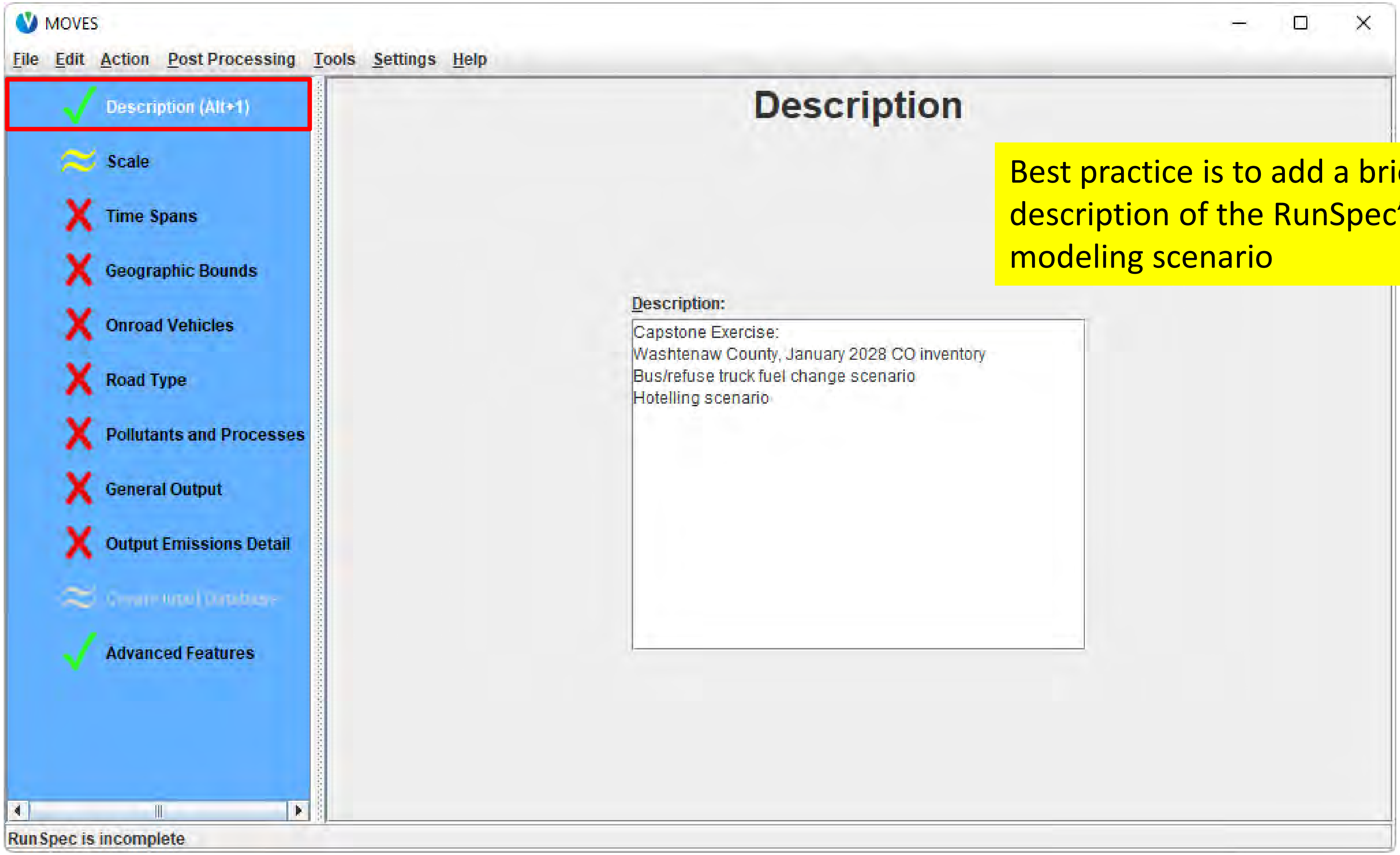
Capstone Exercise Answer

- If you selected Hourly output and post-processed the output: **30,604,863 grams**
- If you selected 24-Hour output: **30,604,870 grams**
- The 7 gram difference (0.00002%) is due to intermediate rounding by MOVES

Demonstration of the Capstone Exercise

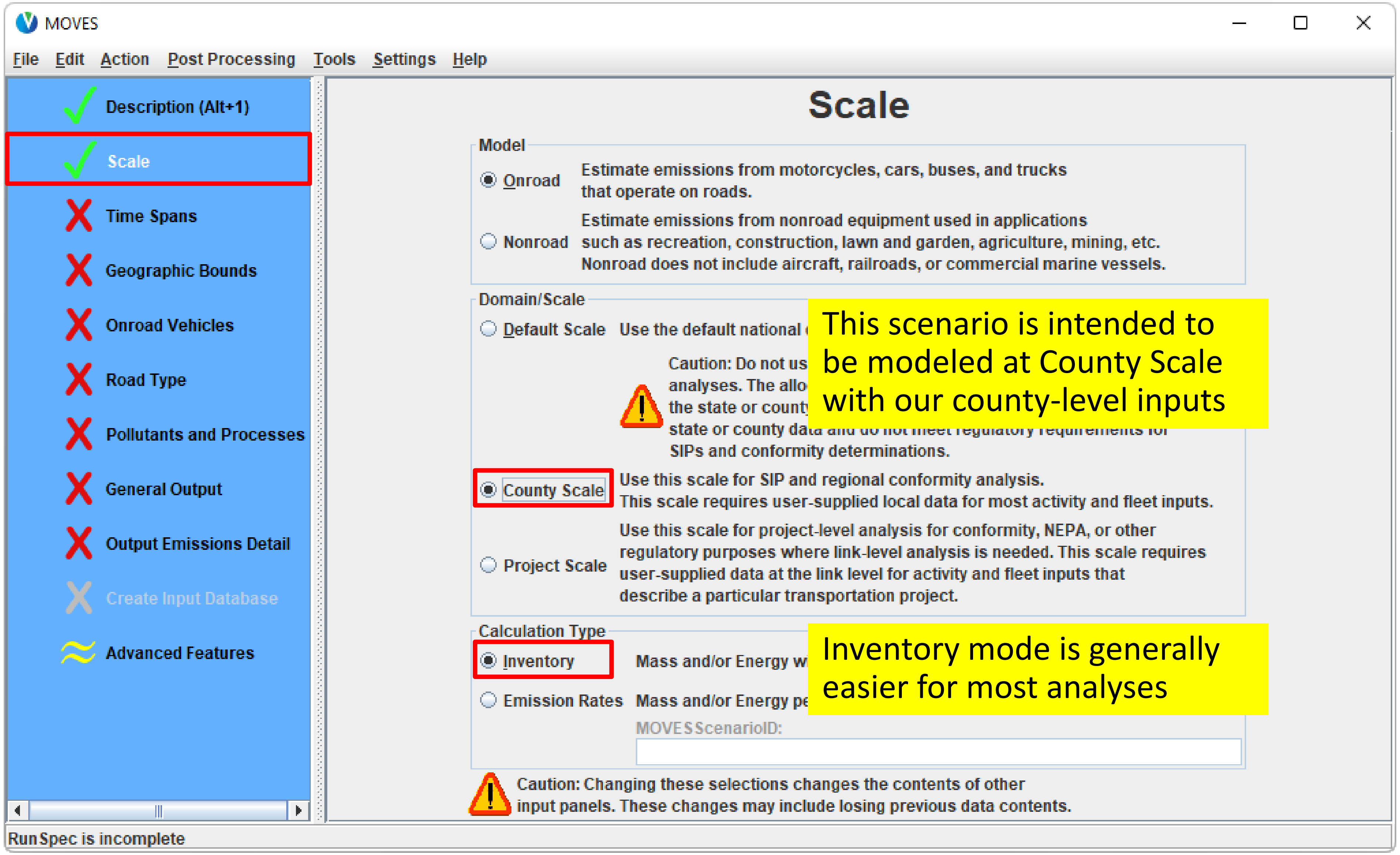
MOVES
Motor Vehicle Emission Simulator

Capstone RunSpec: Description

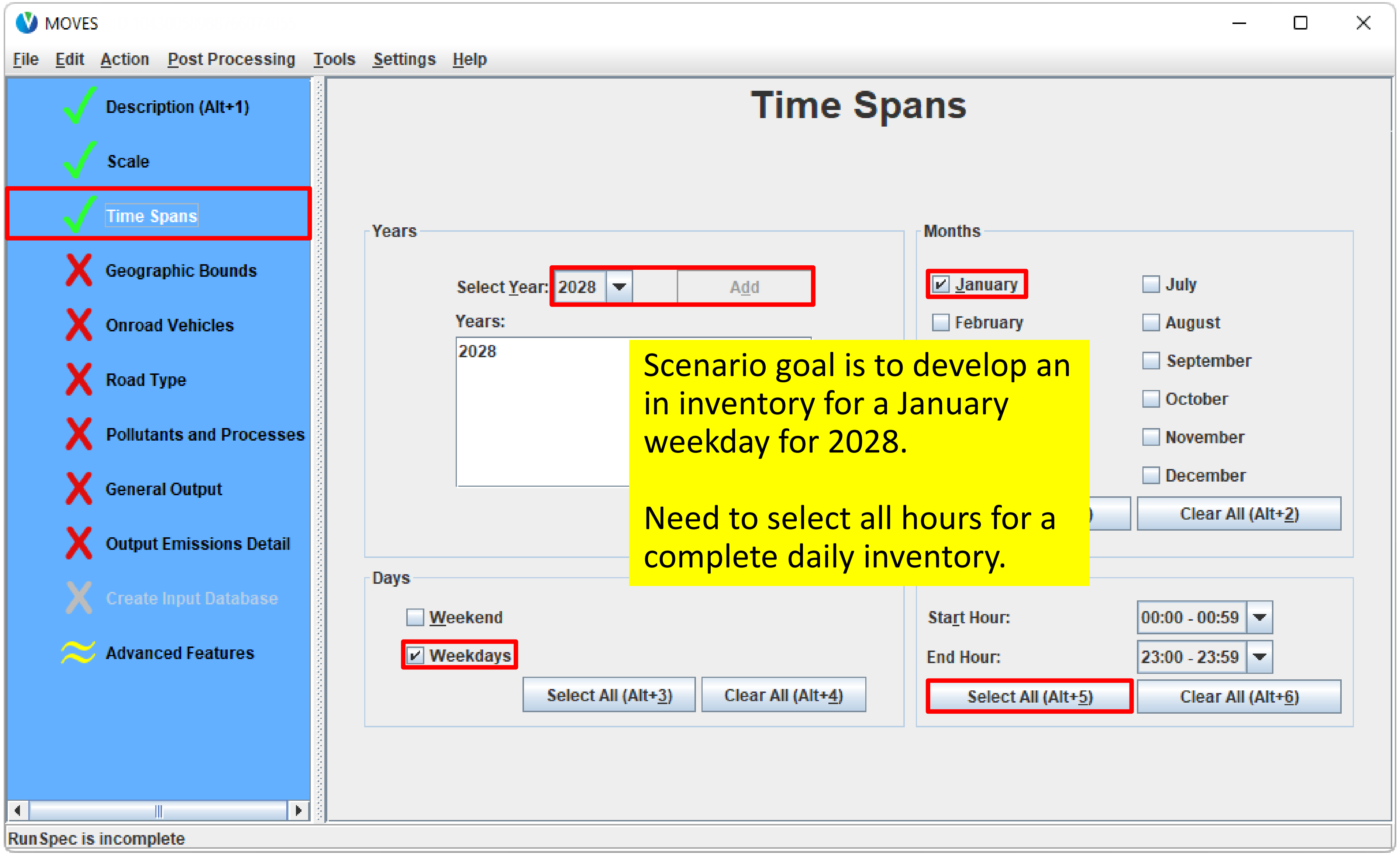


Best practice is to add a brief description of the RunSpec's modeling scenario

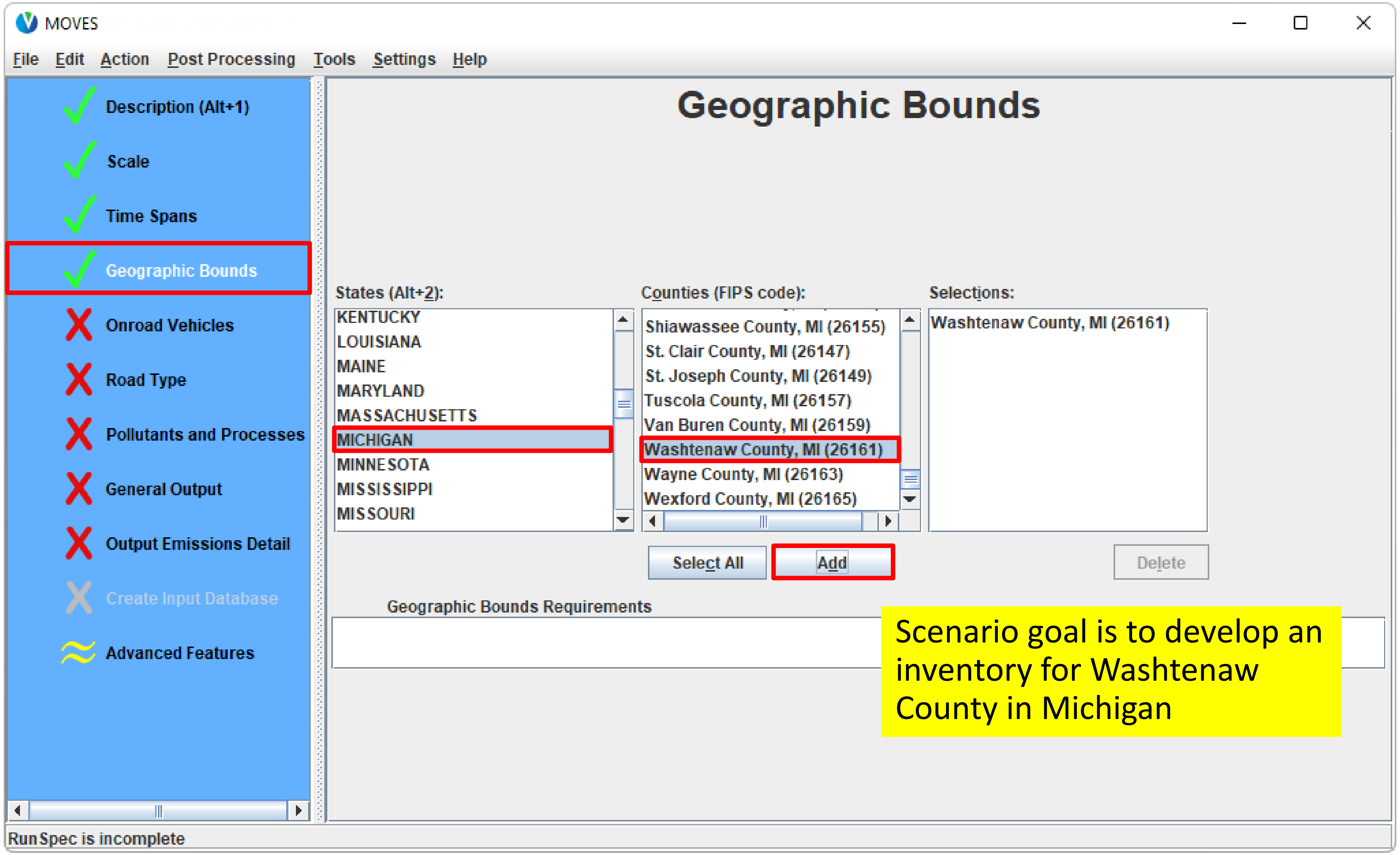
Capstone RunSpec: Scale



Capstone RunSpec: Time Spans

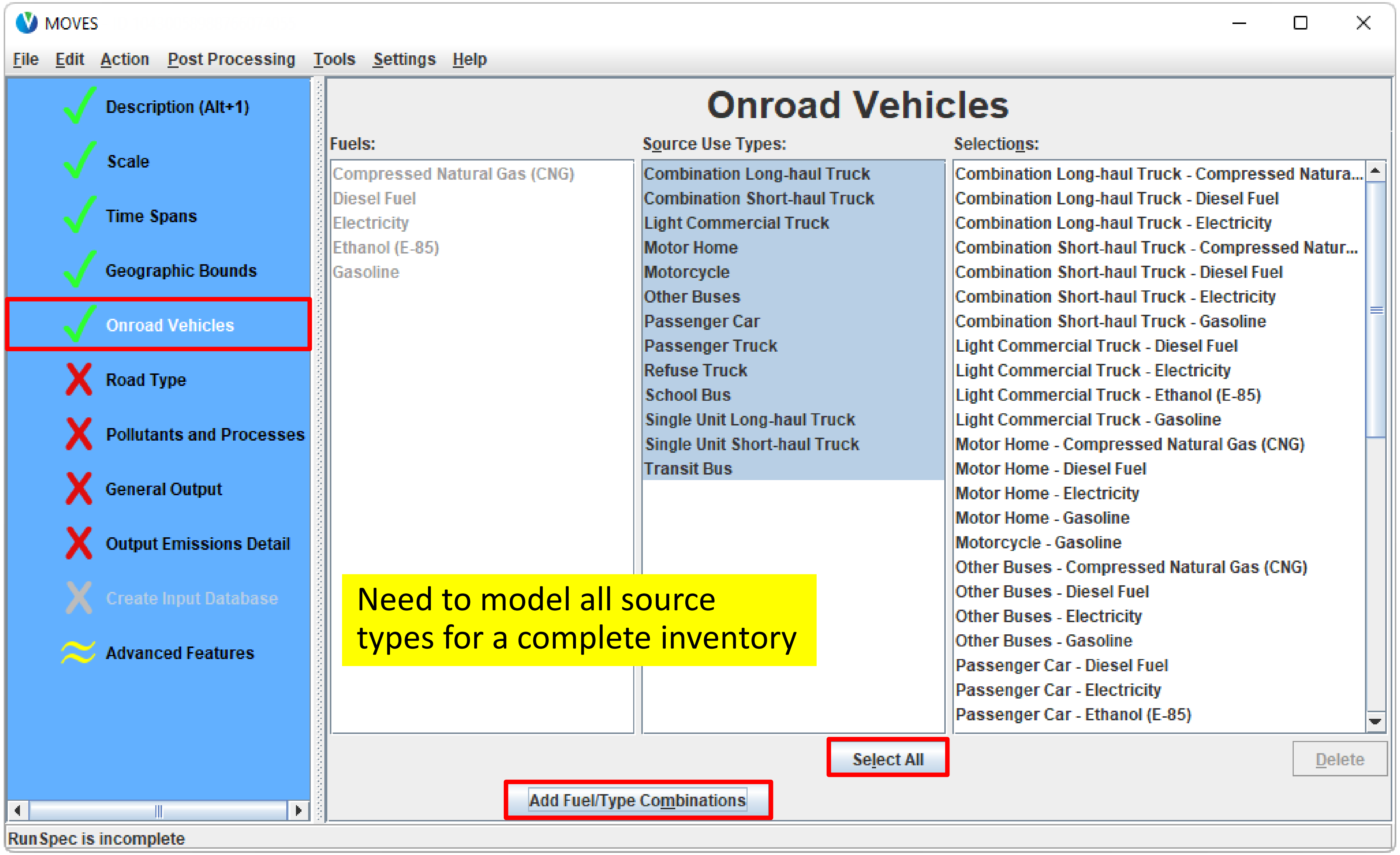


Capstone RunSpec: Geographic Bounds

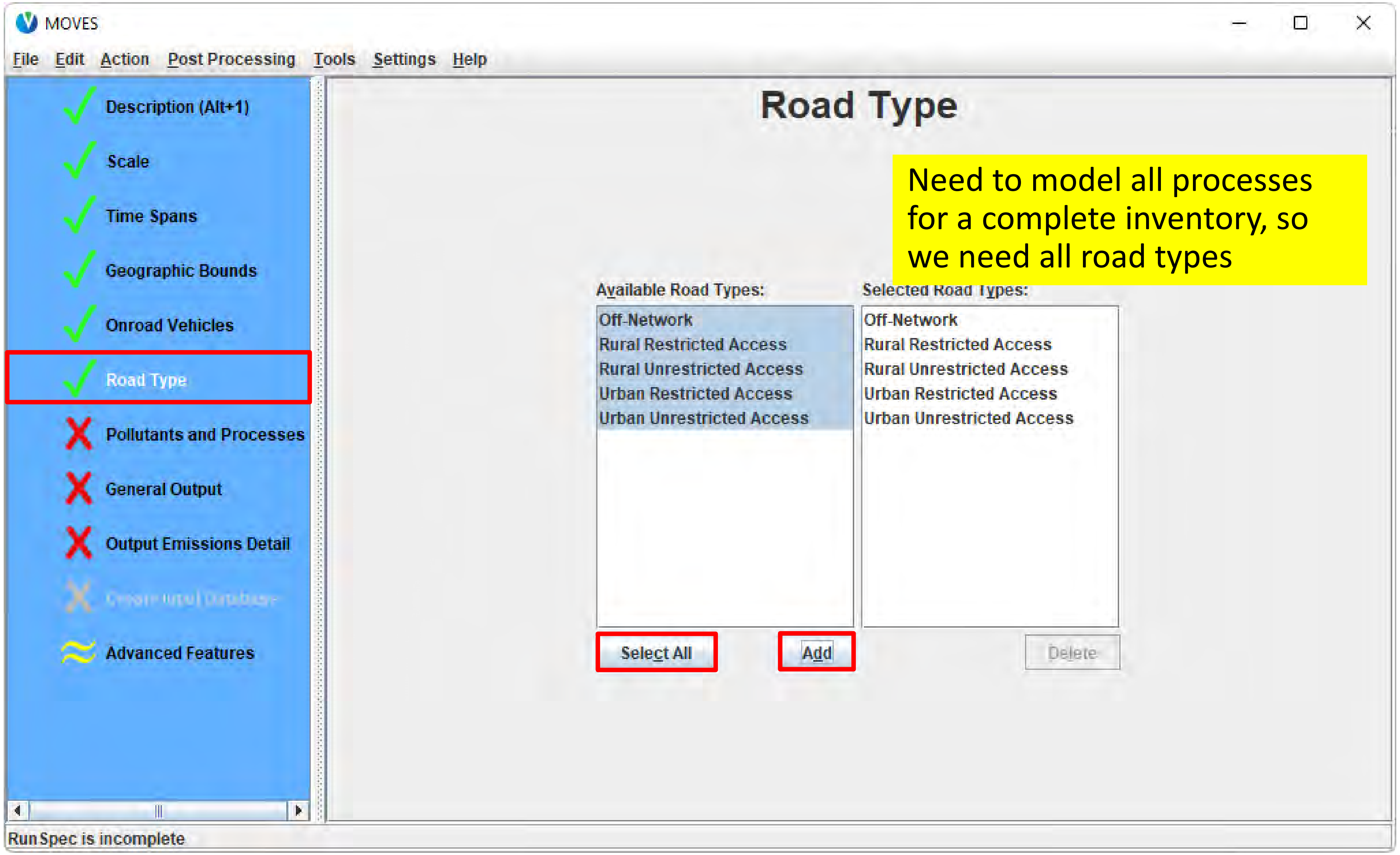


Scenario goal is to develop an inventory for Washtenaw County in Michigan

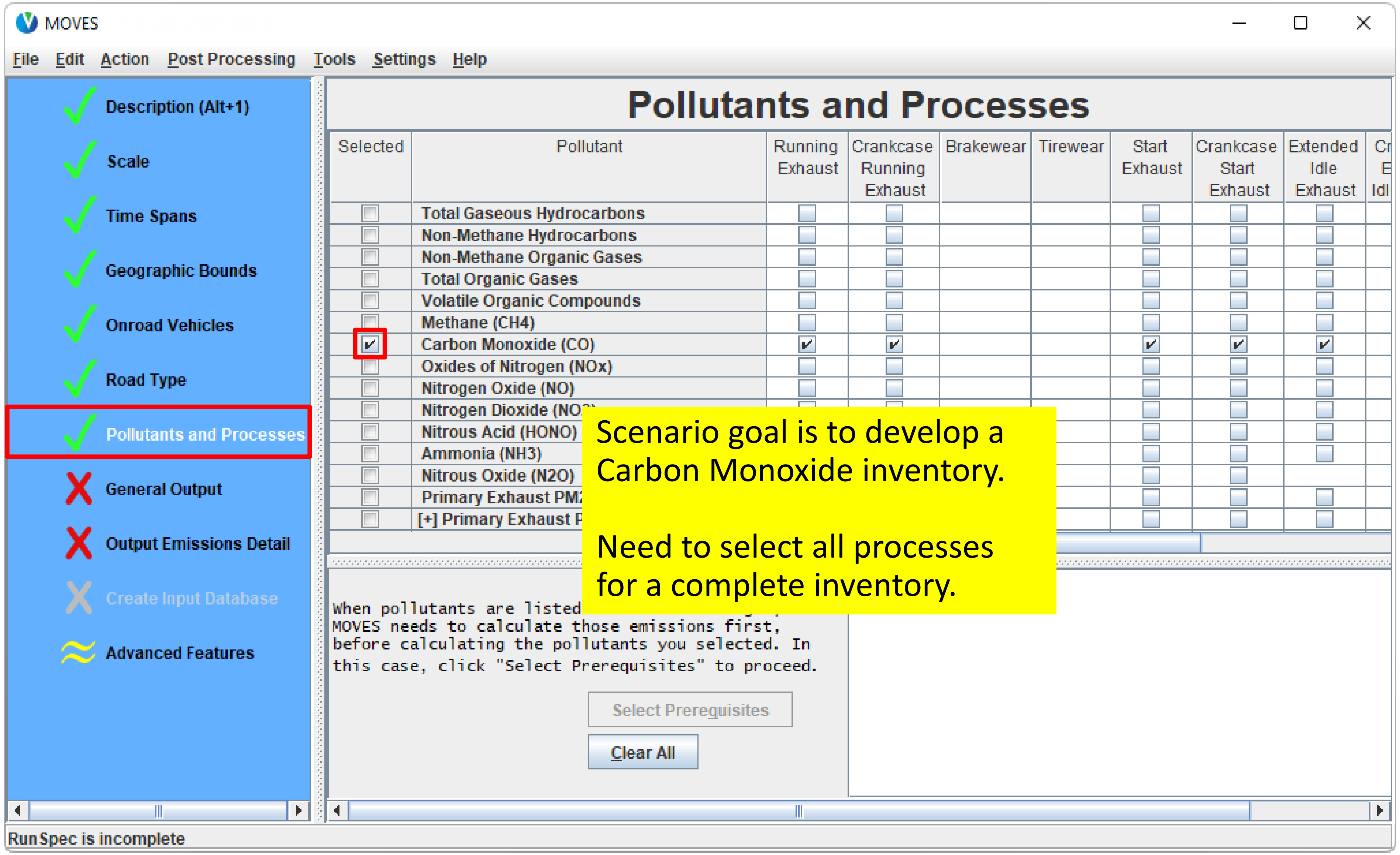
Capstone RunSpec: Onroad Vehicles



Capstone RunSpec: Road Type



Capstone RunSpec: Pollutants and Processes



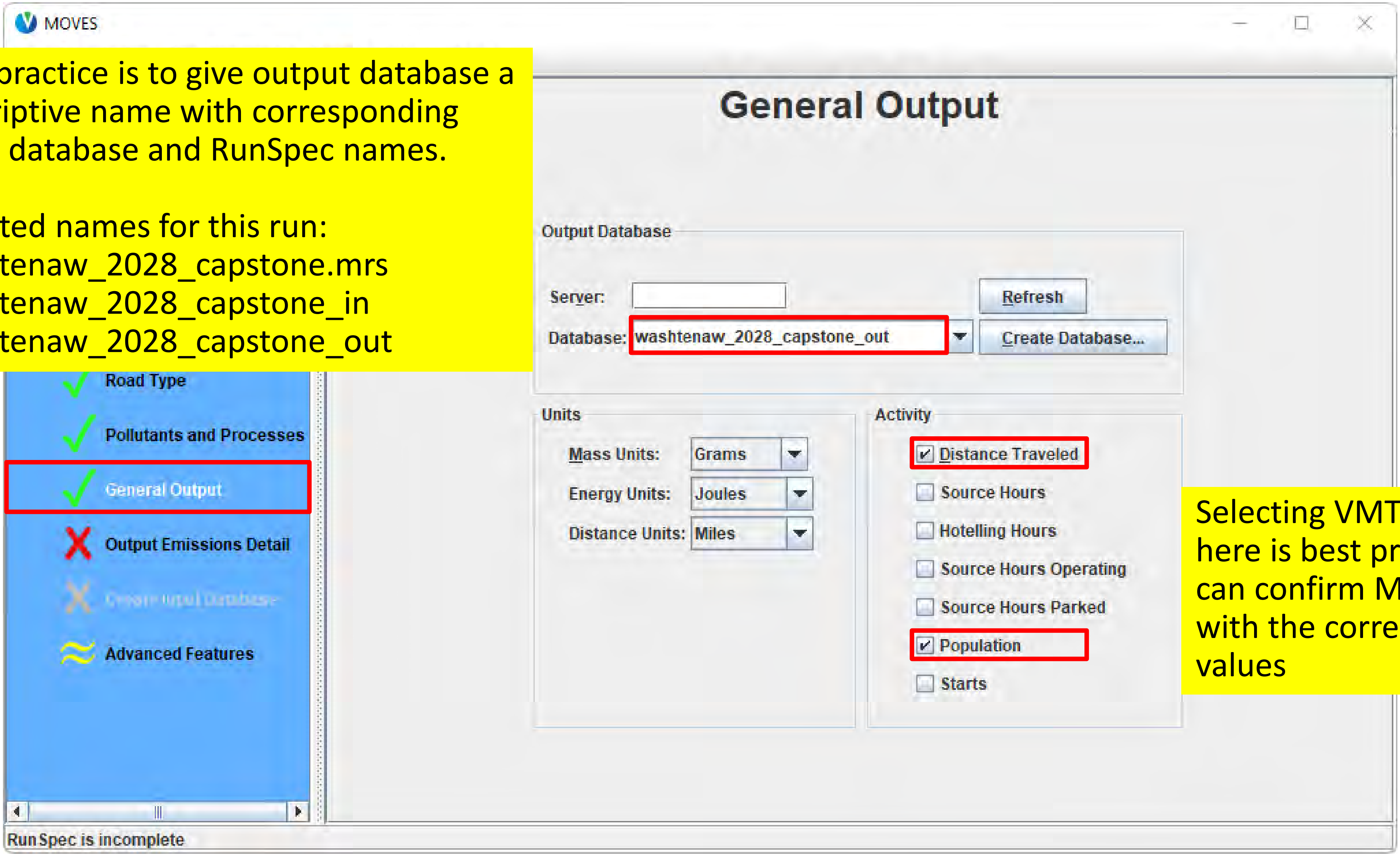
Scenario goal is to develop a Carbon Monoxide inventory.

Need to select all processes for a complete inventory.

Capstone RunSpec: General Output

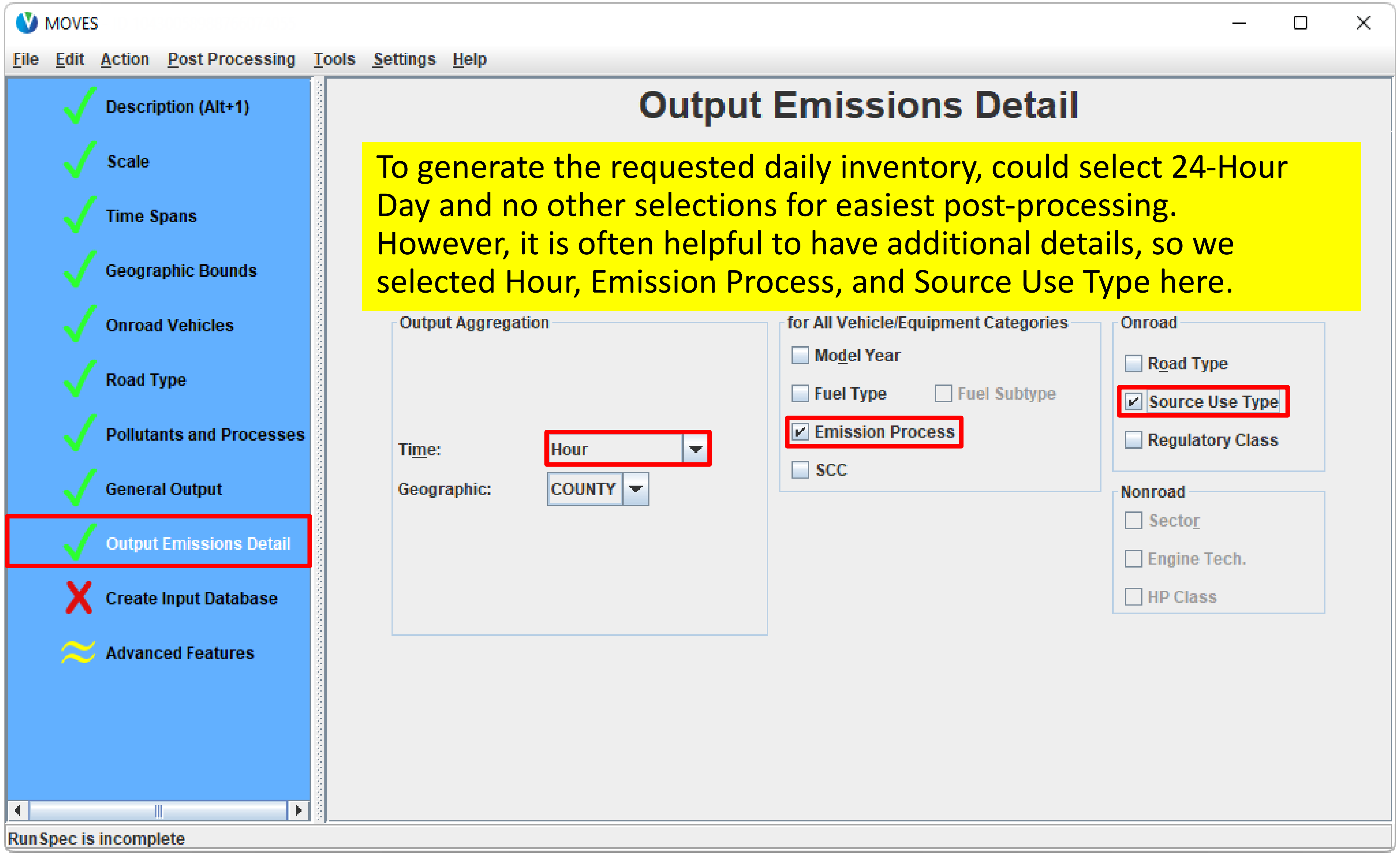
Best practice is to give output database a descriptive name with corresponding input database and RunSpec names.

Selected names for this run:
washtenaw_2028_capstone.mrs
washtenaw_2028_capstone_in
washtenaw_2028_capstone_out

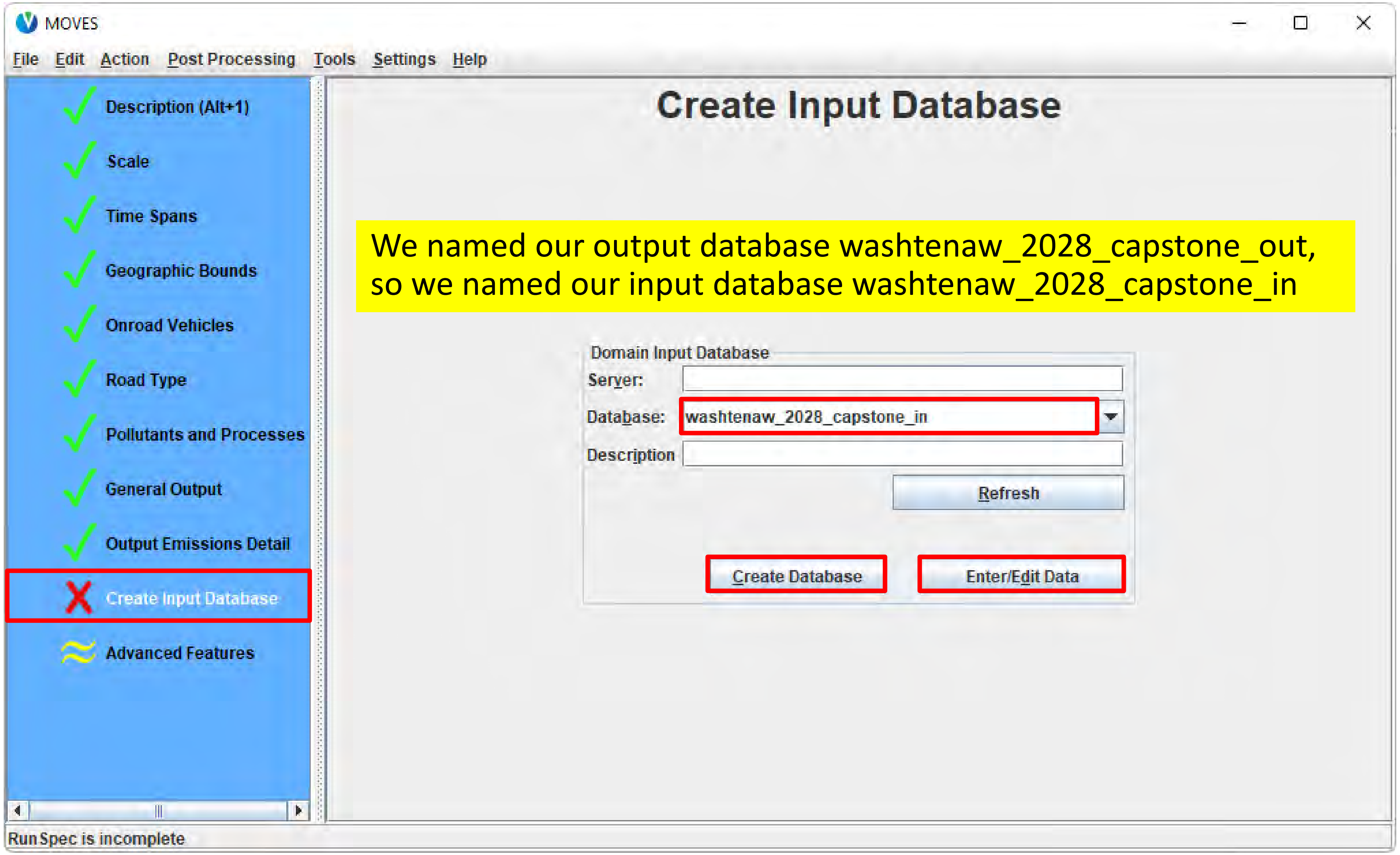


Selecting VMT and VPOP here is best practice so you can confirm MOVES ran with the correct input values

Capstone RunSpec: Output Emissions Detail



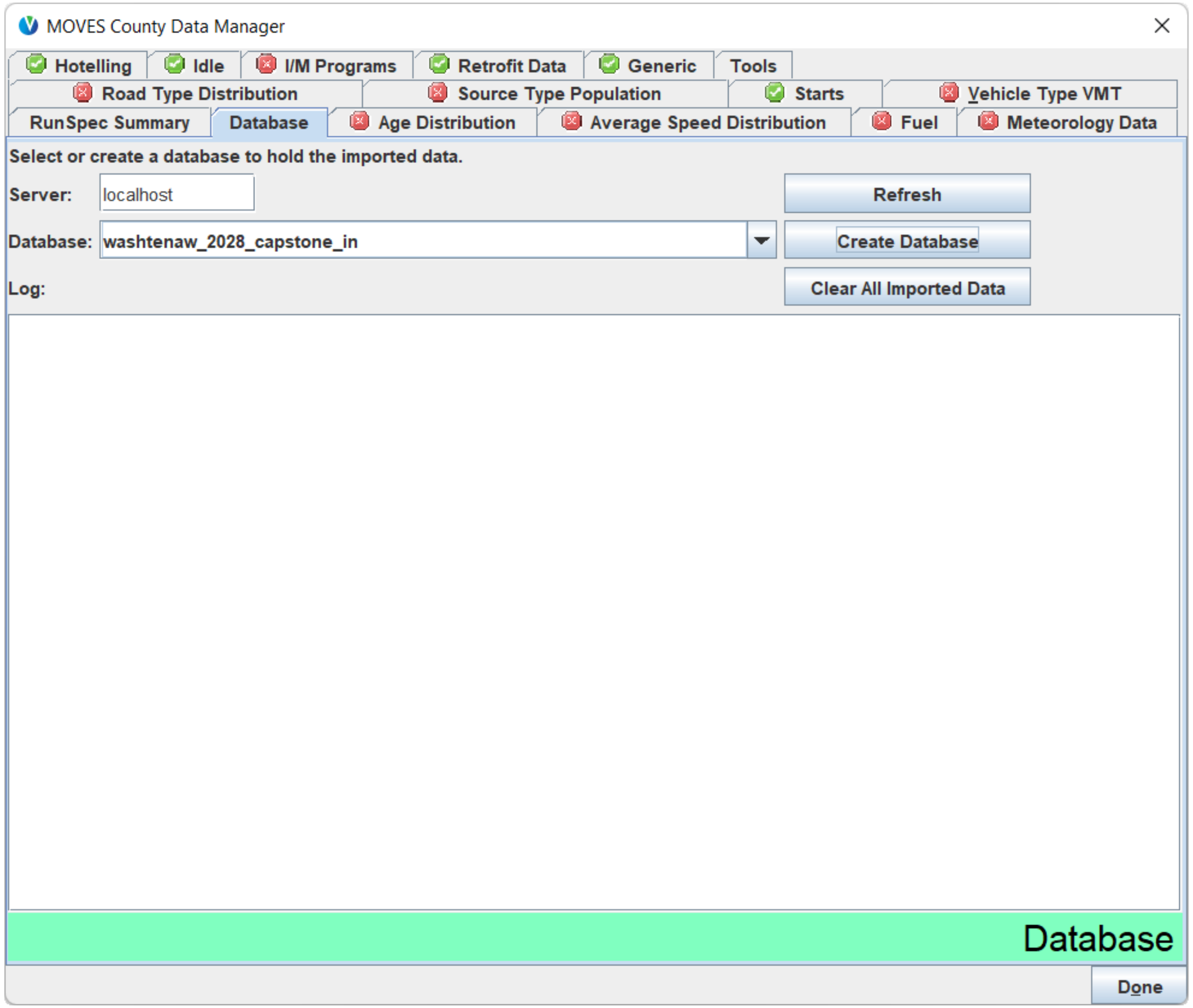
Capstone RunSpec: Create Input Database



Capstone CDM: Database Tab

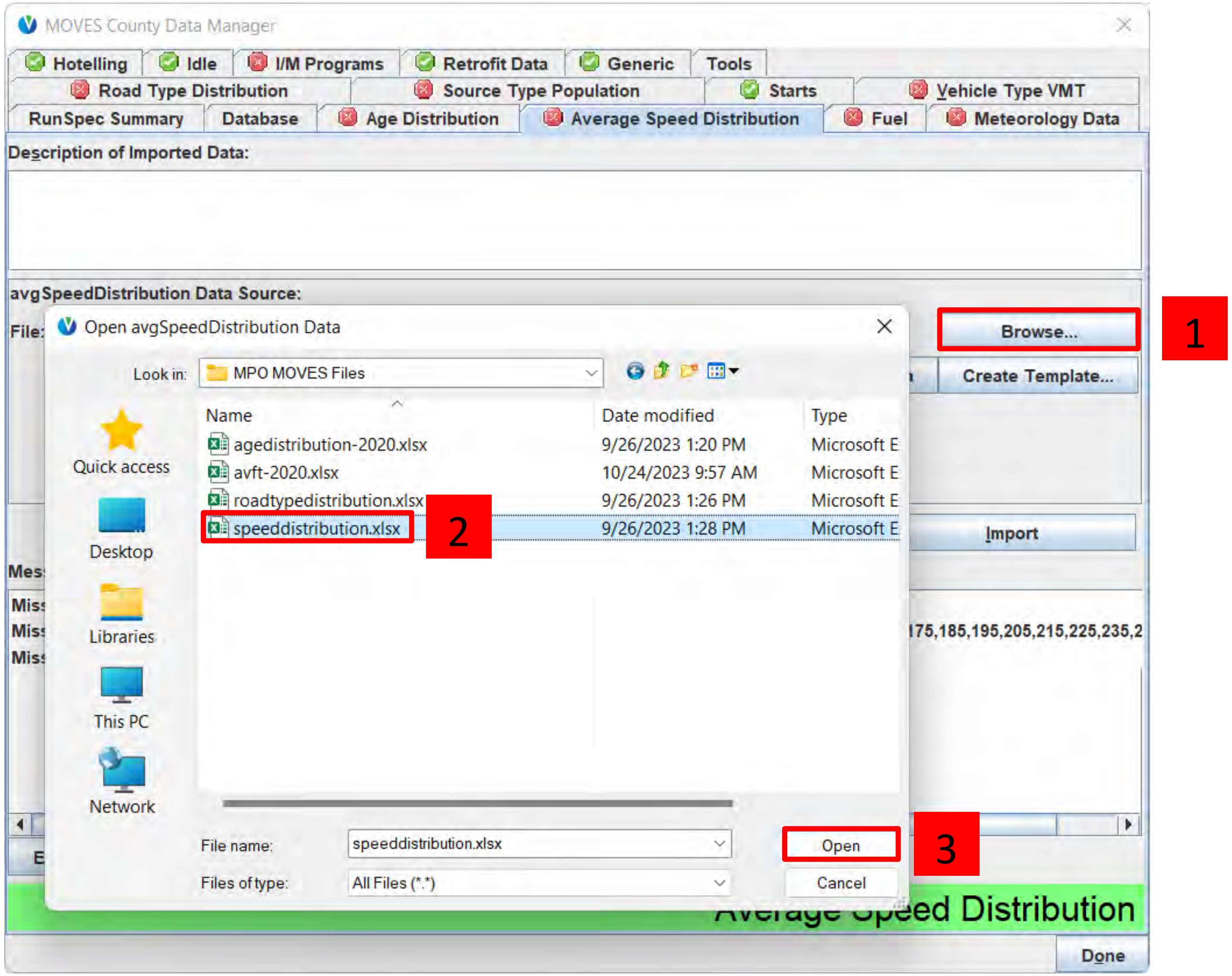
If you clicked "Create Database" in the main GUI, there is nothing to do on this tab.

Otherwise, you will need to enter the database name and click "Create Database" in the CDM before doing anything else.

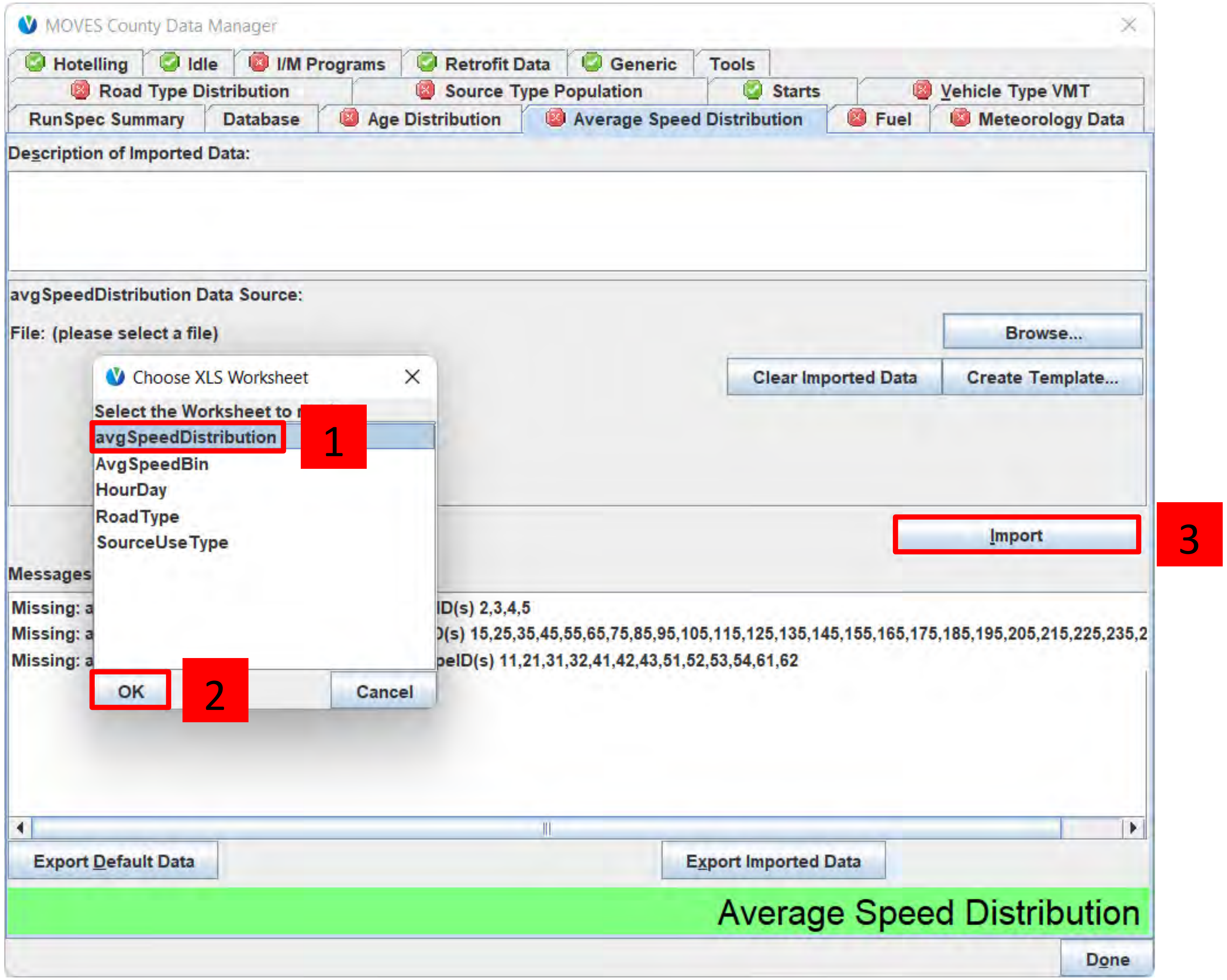


Capstone CDM: Average Speed Distribution (1)

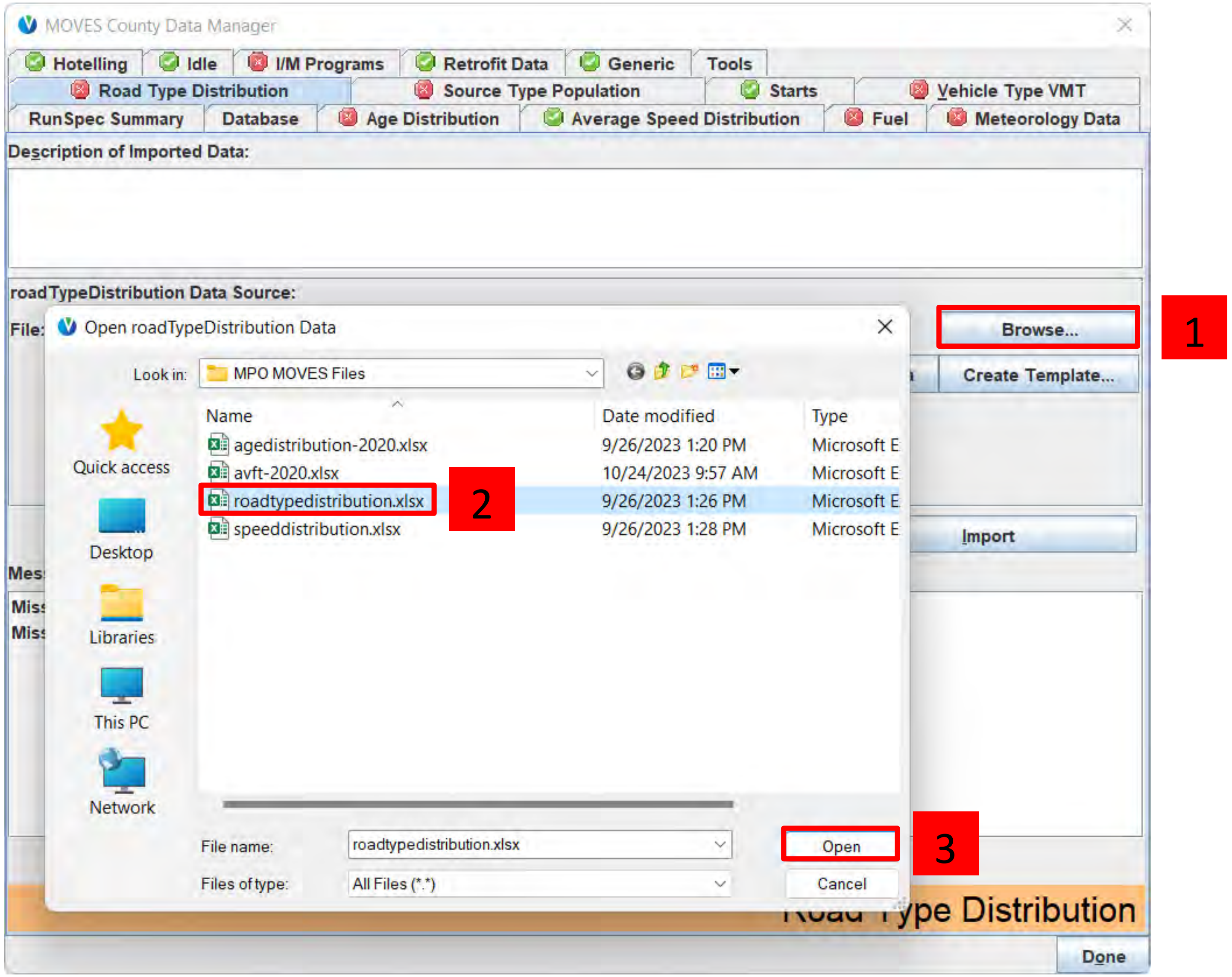
The Average Speed Distribution inputs are already formatted for MOVES, so these can be imported directly from the *speeddistribution.xlsx* file in the MPO MOVES Files folder.



Capstone CDM: Average Speed Distribution (2)

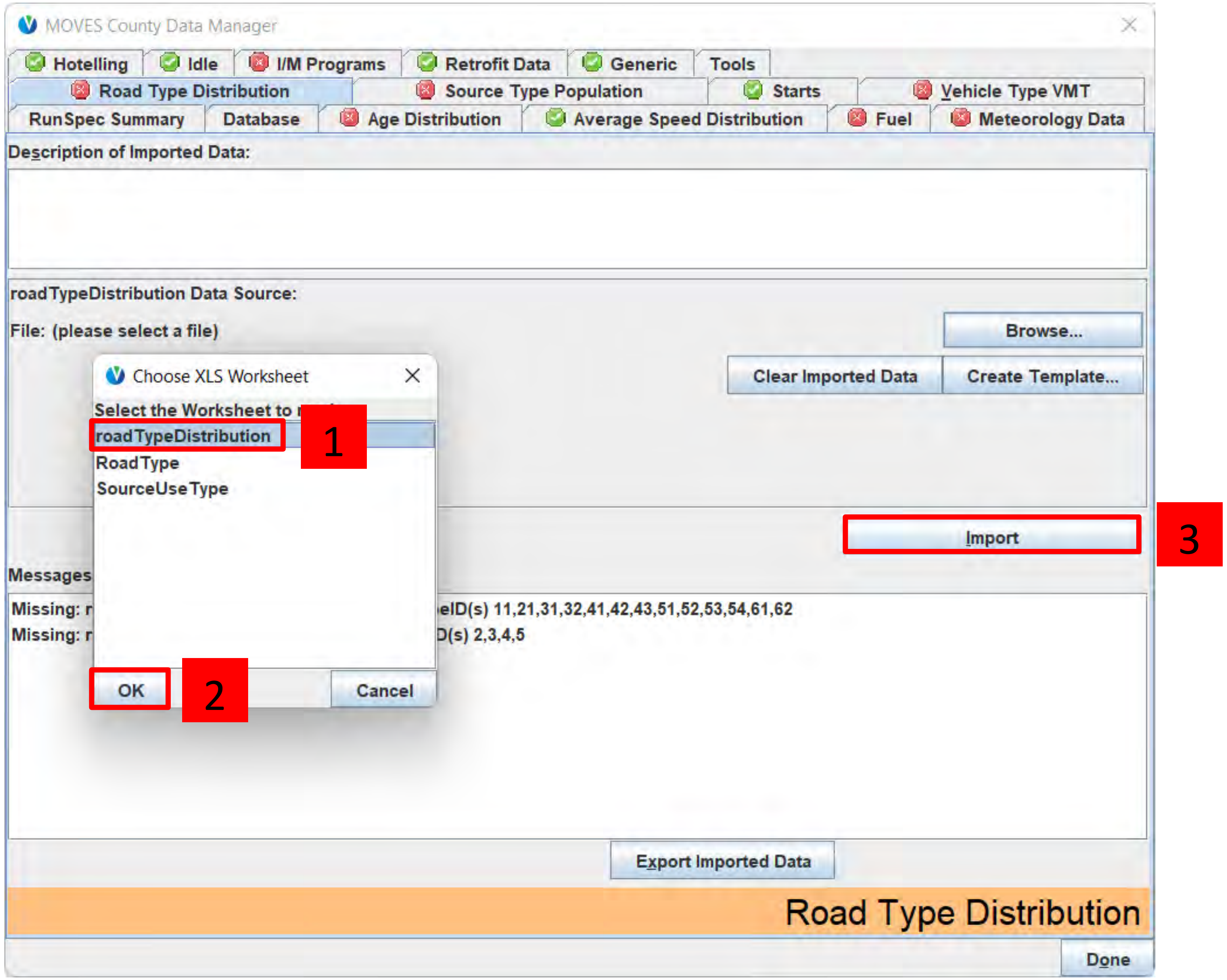


Capstone CDM: Road Type Distribution (1)



The Road Type Distribution inputs are already formatted for MOVES, so these can be imported directly from the *roadtypedistribution.xlsx* file in the MPO MOVES Files folder.

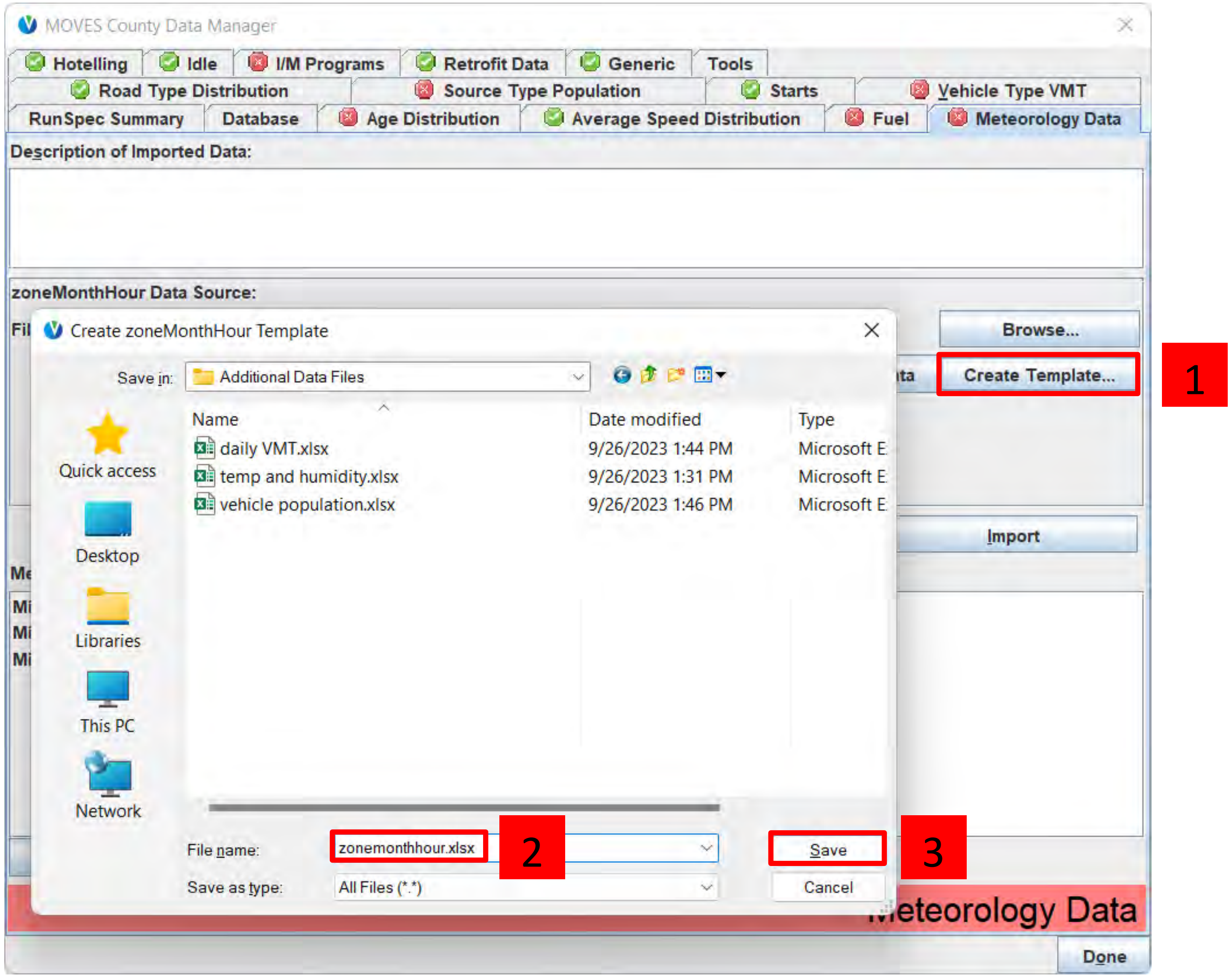
Capstone CDM: Road Type Distribution (2)



Capstone CDM: Meteorology Data (1)

The meteorology inputs are not formatted for MOVES, so we need to first make a template for the ZoneMonthHour table.

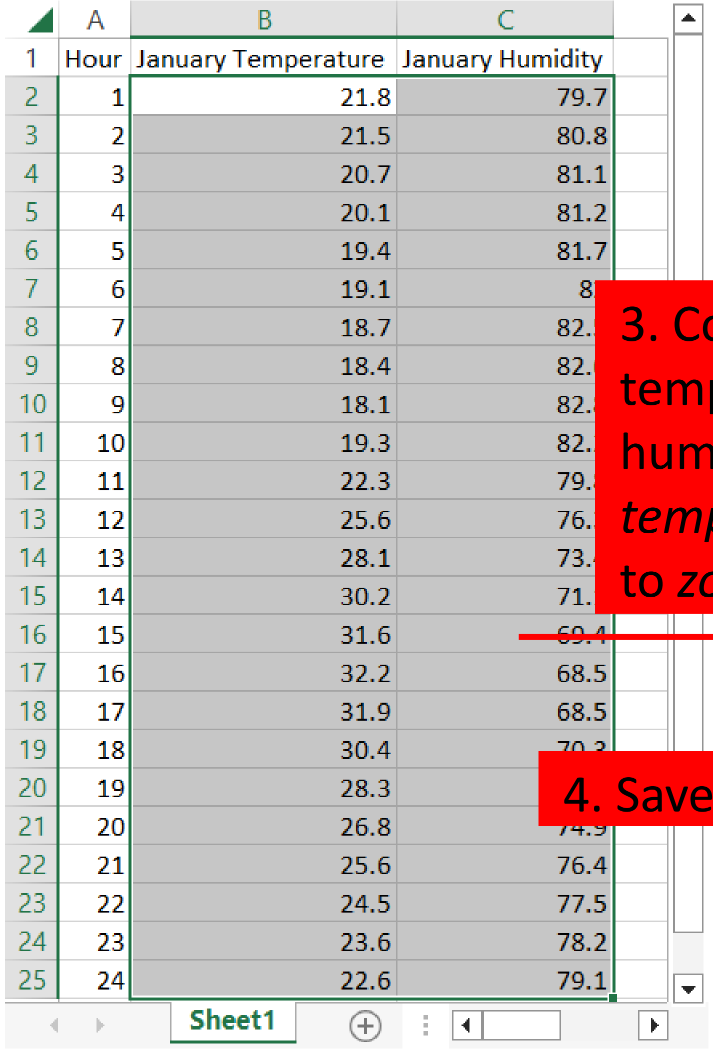
Save the template as *zonemonthhour.xlsx* to the Additional Data Files folder, since that's where the *temp and humidity.xlsx* file is located.



Capstone CDM: Meteorology Data (2)

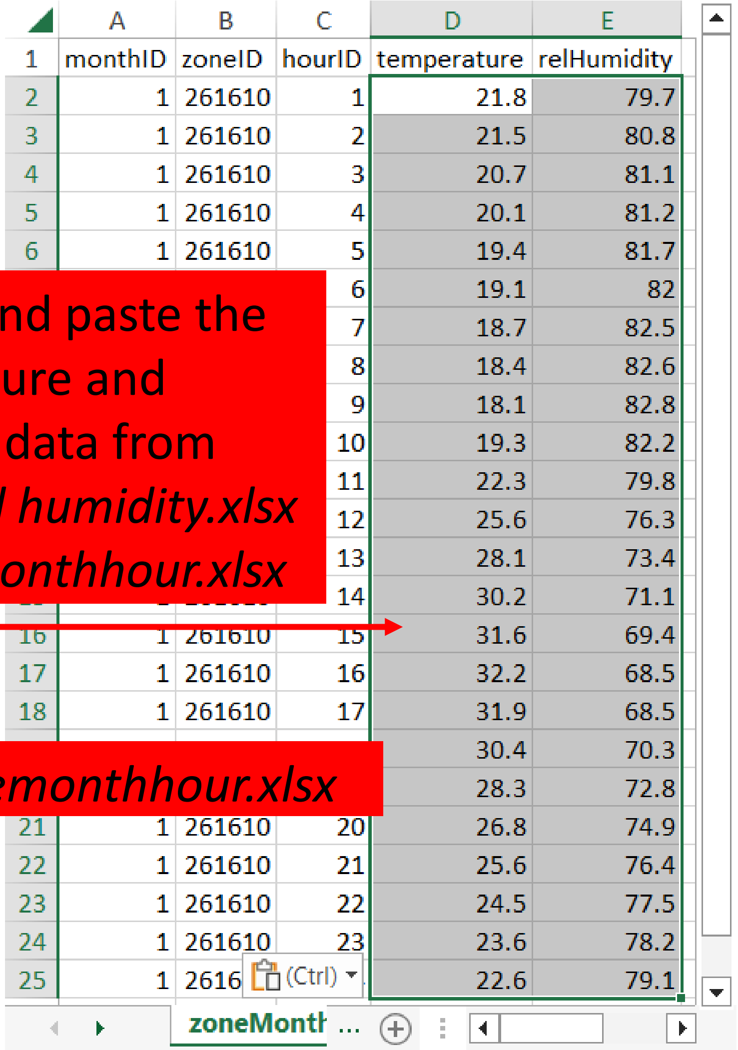
1. Open *temp and humidity.xlsx*, which contains the unformatted meteorology data
2. Open our template, *zonemonthhour.xslx*

temp and humidity.xlsx



	A	B	C
1	Hour	January Temperature	January Humidity
2	1	21.8	79.7
3	2	21.5	80.8
4	3	20.7	81.1
5	4	20.1	81.2
6	5	19.4	81.7
7	6	19.1	8
8	7	18.7	82.
9	8	18.4	82.
10	9	18.1	82.
11	10	19.3	82.
12	11	22.3	79.
13	12	25.6	76.
14	13	28.1	73.
15	14	30.2	71.
16	15	31.6	69.4
17	16	32.2	68.5
18	17	31.9	68.5
19	18	30.4	70.3
20	19	28.3	[illegible]
21	20	26.8	74.9
22	21	25.6	76.4
23	22	24.5	77.5
24	23	23.6	78.2
25	24	22.6	79.1

zonemonthhour.xlsx



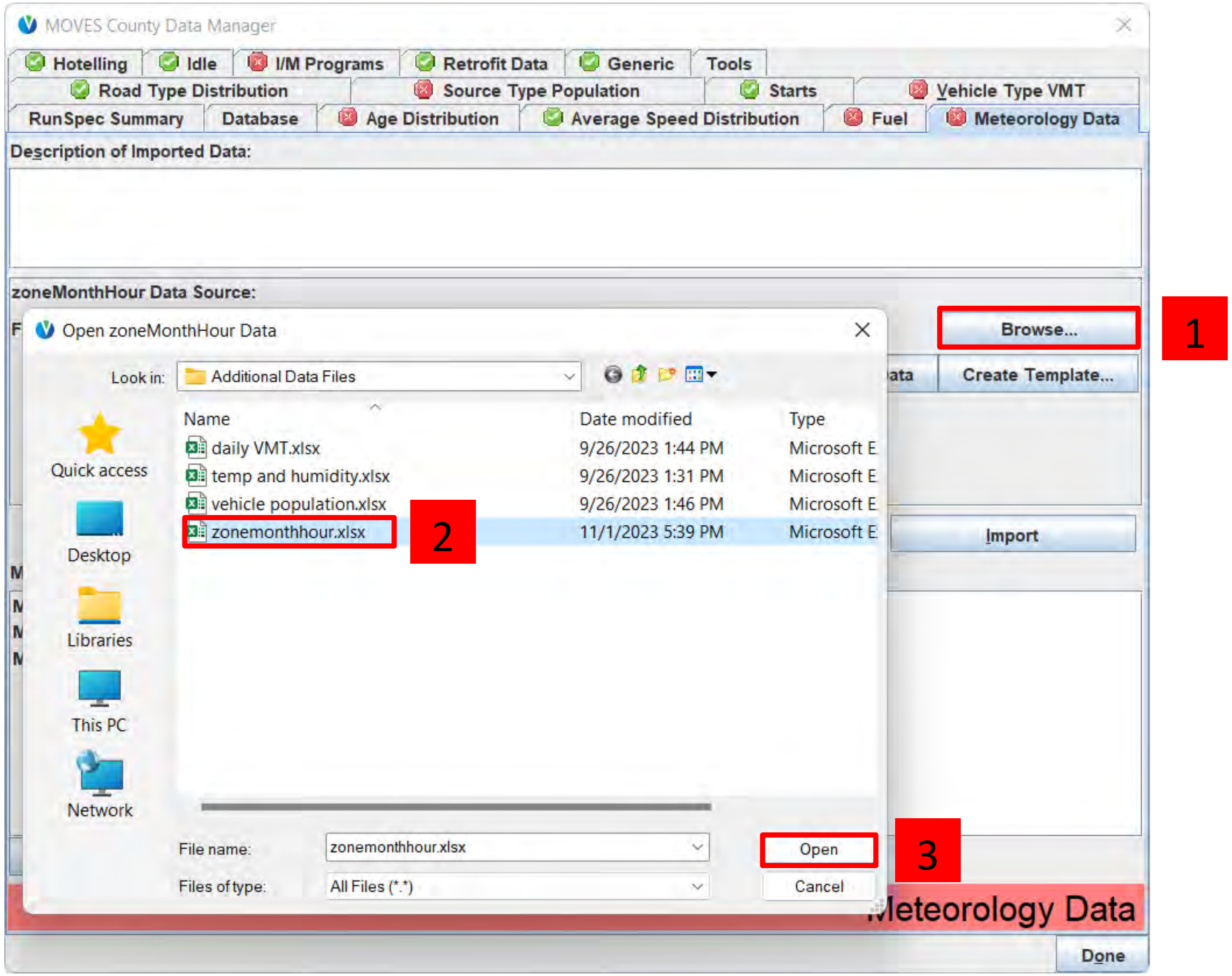
	A	B	C	D	E
1	monthID	zoneID	hourID	temperature	relHumidity
2	1	261610	1	21.8	79.7
3	1	261610	2	21.5	80.8
4	1	261610	3	20.7	81.1
5	1	261610	4	20.1	81.2
6	1	261610	5	19.4	81.7
7	[illegible]	[illegible]	6	19.1	82
8	[illegible]	[illegible]	7	18.7	82.5
9	[illegible]	[illegible]	8	18.4	82.6
10	[illegible]	[illegible]	9	18.1	82.8
11	[illegible]	[illegible]	10	19.3	82.2
12	[illegible]	[illegible]	11	22.3	79.8
13	[illegible]	[illegible]	12	25.6	76.3
14	[illegible]	[illegible]	13	28.1	73.4
15	[illegible]	[illegible]	14	30.2	71.1
16	1	261610	15	31.6	69.4
17	1	261610	16	32.2	68.5
18	1	261610	17	31.9	68.5
19	[illegible]	[illegible]	[illegible]	30.4	70.3
20	[illegible]	[illegible]	[illegible]	28.3	72.8
21	1	261610	20	26.8	74.9
22	1	261610	21	25.6	76.4
23	1	261610	22	24.5	77.5
24	1	261610	23	23.6	78.2
25	1	2616	[illegible]	22.6	79.1

3. Copy and paste the temperature and humidity data from *temp and humidity.xlsx* to *zonemonthhour.xlsx*

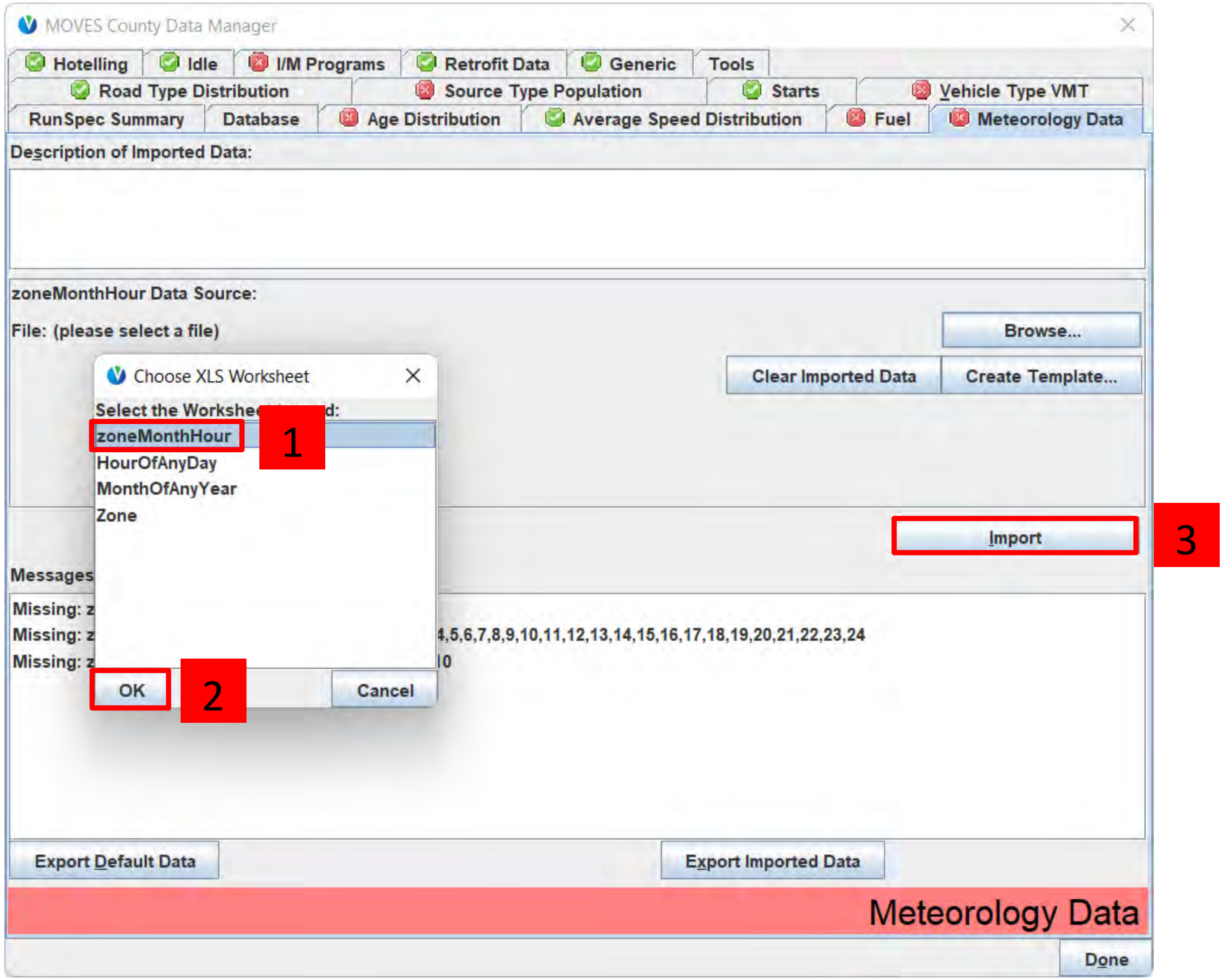
4. Save *zonemonthhour.xlsx*

Capstone CDM: Meteorology Data (3)

Now that we've formatted the meteorology inputs, we can import them from *zonemonthhour.xlsx*



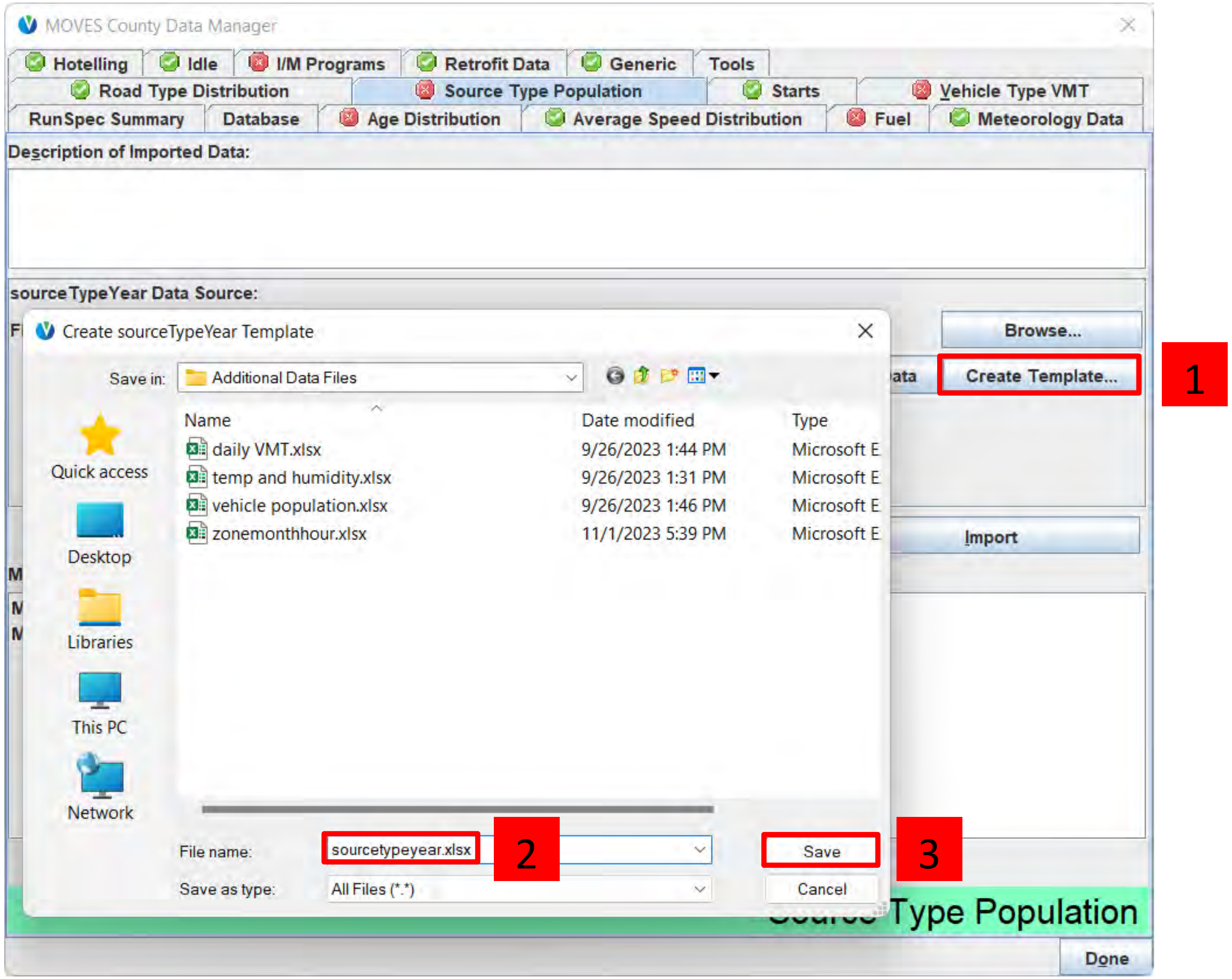
Capstone CDM: Meteorology Data (4)



Capstone CDM: Source Type Population (1)

The population inputs are not formatted for MOVES, so we need to first make a template for the SourceTypePopulation table.

Save the template as *sourcetypeyear.xlsx* to the Additional Data Files folder, since that's where the *vehicle population.xlsx* file is located.



Capstone CDM: Source Type Population (2)

1. Open *vehicle population.xlsx*, which contains the unformatted population data

2. Open our template, *sourcetypeyear.xslx*

vehicle population.xlsx

	A	B	C	D
1	MOVES Source Type	VPOP		
2	11	11010		
3	21	101451		
4	31	182567		
5	32	17883		
6	41	454		
7	42	143		
8	43	622		
9	51	83		
10	52	12145		
11	53	532		
12	54	1629		
13	61	2329		
14	62	1668		

Sheet1

3. Copy and paste the vehicle population data from *vehicle population.xlsx* to *sourcetypeyear.xlsx*

sourcetypeyear.xlsx

	A	B	C
1	yearID	sourceTypeID	sourceTypePopulation
2	2028	11	11010
3		21	101451
4		31	182567
5		32	17883
6		41	454
7		42	143
8		43	622
9		51	83
10		52	12145
11	2028	53	532
12	2028	54	1629
13	2028	61	2329
14	2028	62	1668

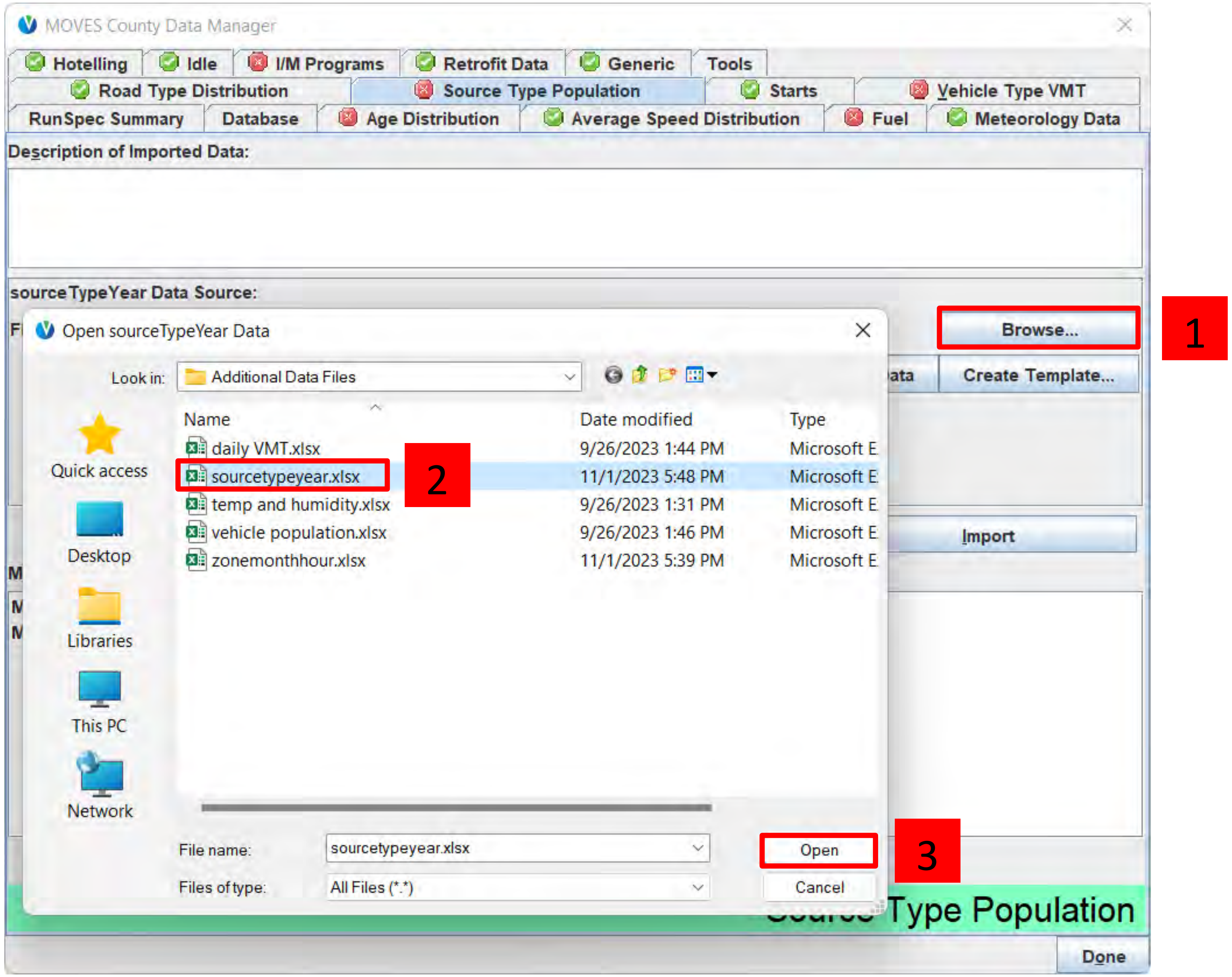
(Ctrl)

source1 ...

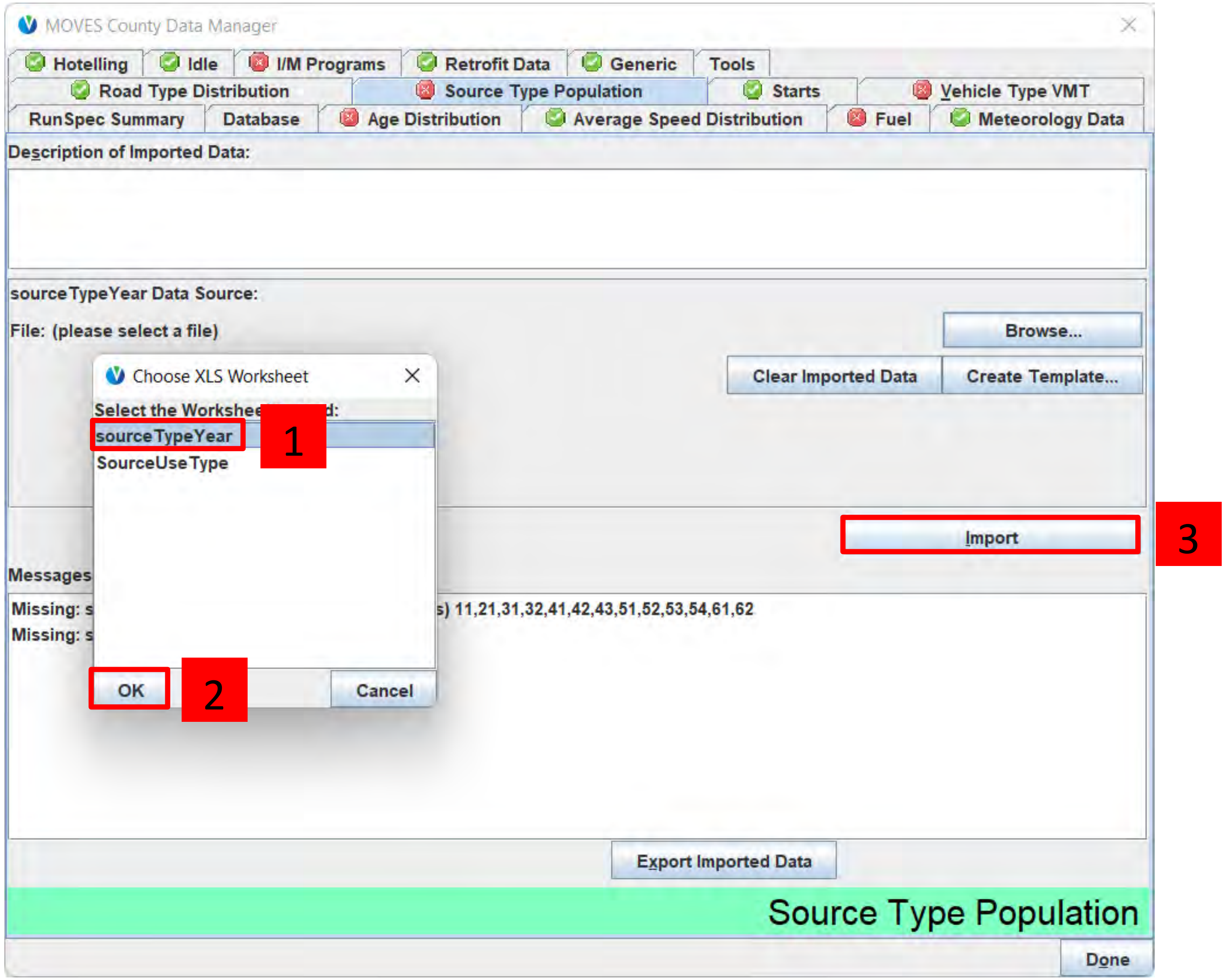
4. Save *sourcetypeyear.xlsx*

Capstone CDM: Source Type Population (3)

Now that we've formatted the vehicle population inputs, we can import them from *sourcetypeyear.xlsx*



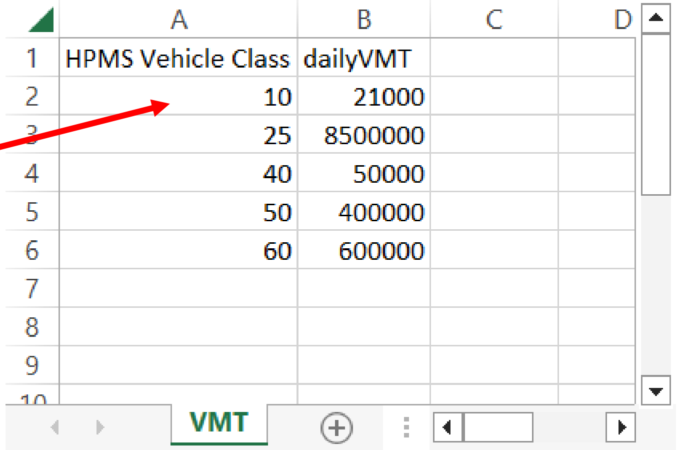
Capstone CDM: Source Type Population (4)



Capstone CDM: Creating a Plan for Vehicle Type VMT

- Open the *Additional Data Files\daily VMT.xlsx* file to see what kind of data we were provided
- From the file, we can see that we have **daily** VMT by **HPMS class**, so we will need to select the appropriate radio buttons in the CDM
- We will need to create a template to format the daily HPMS VMT data
- We do not have hourly VMT distributions, so we will need to use the default hourVMTFraction data
- Because we are using daily VMT, we do not need to input MonthVMTFraction or DayVMTFraction

Daily VMT.xlsx



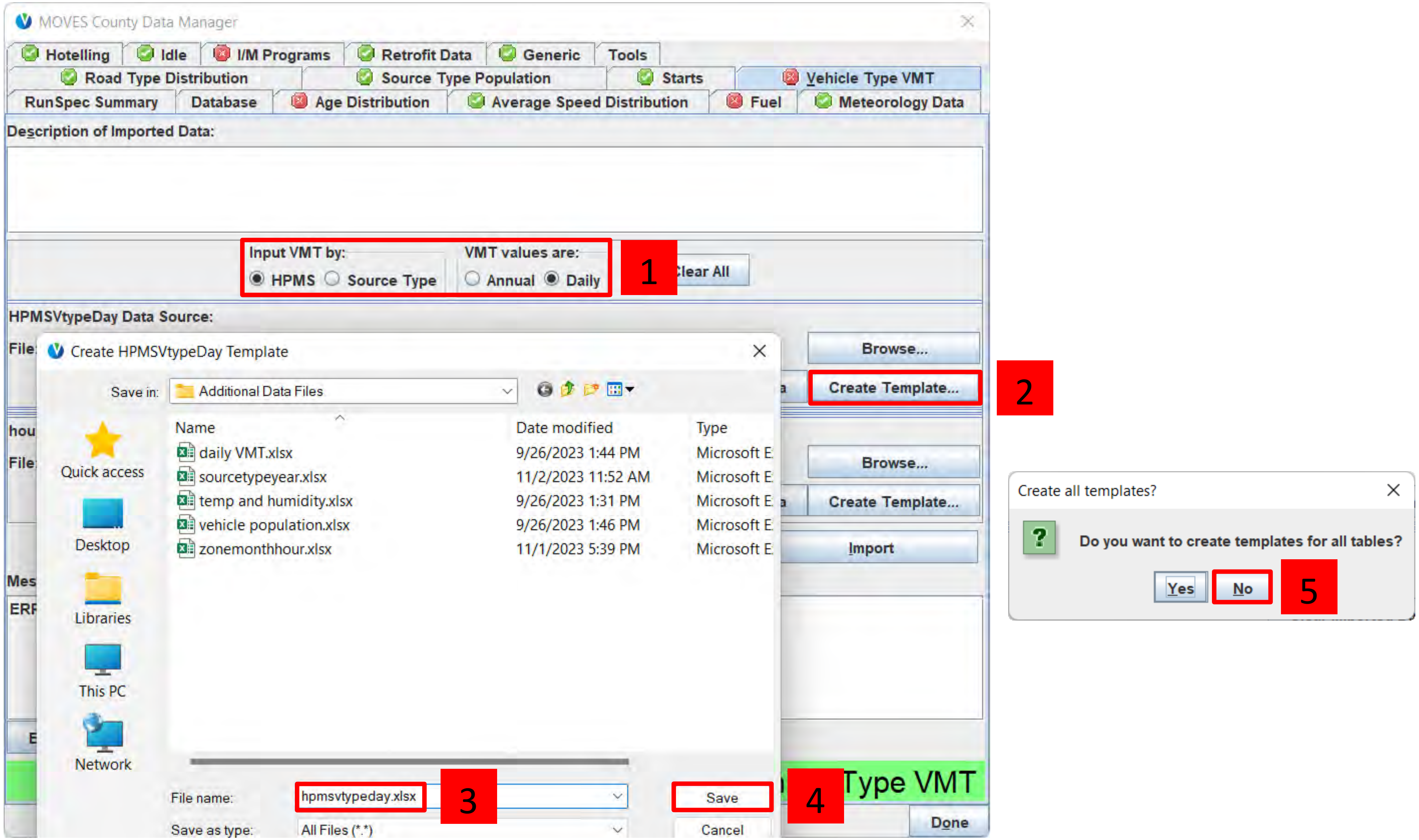
HPMS Vehicle Class	dailyVMT
10	21000
25	8500000
40	50000
50	400000
60	600000

Capstone CDM: Vehicle Type VMT (1)

After selecting HPMS and Daily, create a template for the HPMSVtypeDay table.

Save the template as *hpmsvtypeday.xlsx* to the Additional Data Files folder, since that's where the *daily VMT.xlsx* file is located.

When it asks, do not create templates for all tables because we do not need them.



Capstone CDM: Vehicle Type VMT (2)

1. Open *daily VMT.xlsx*, which contains the unformatted VMT data

2. Open our template, *hpmsvtypeday.xslx*

daily VMT.xlsx

HPMS Vehicle Class	dailyVMT
10	21000
25	8500000
40	50000
50	400000
60	600000

hpmsvtypeday.xlsx

ypeID	yearID	monthID	dayID	VMT
10	2028	1	5	21000
25	2028	1	5	8500000
40	2028	1	5	50000
50	2028	1	5	400000
60	2028	1	5	600000

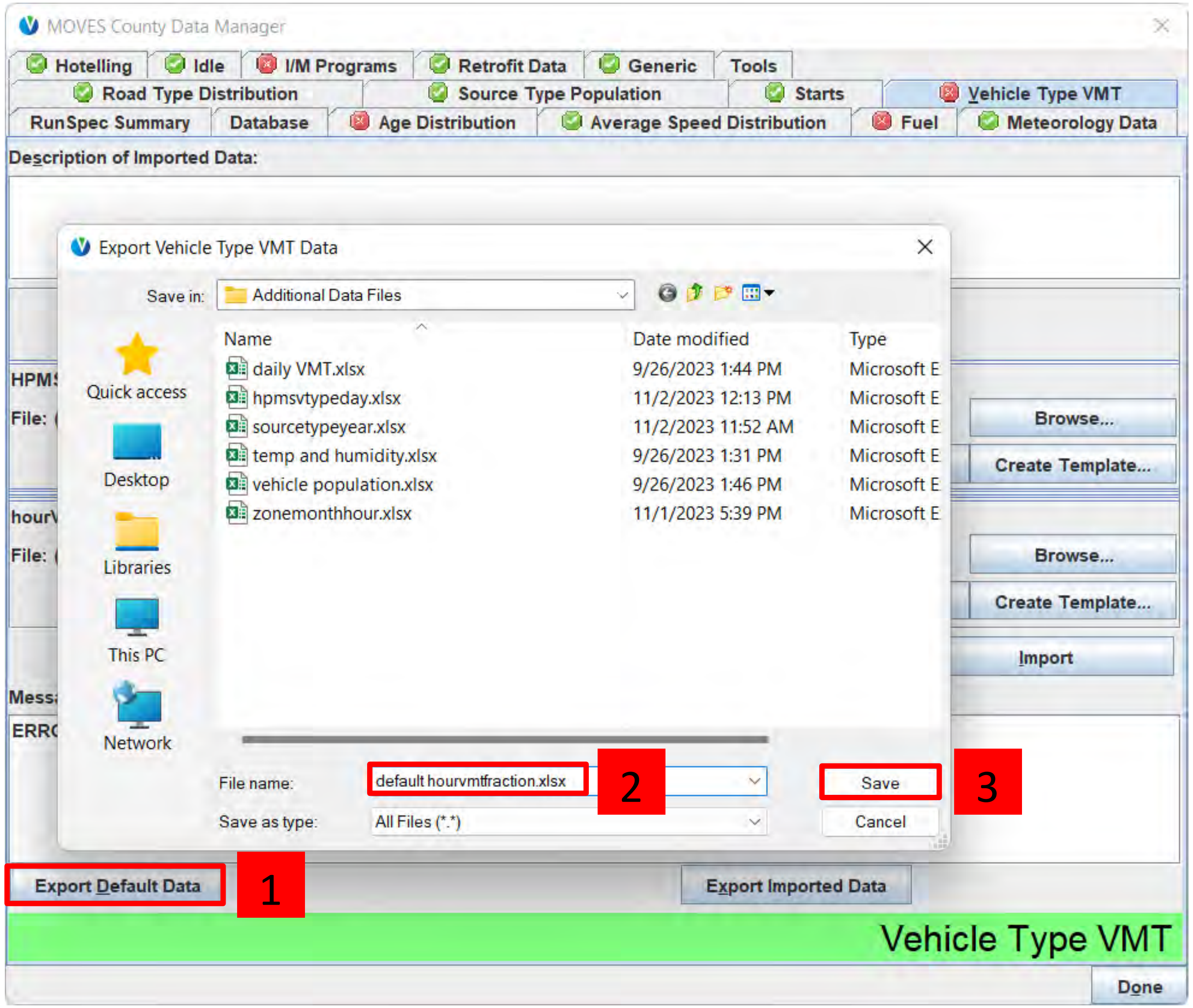
3. Copy and paste the VMT data from *daily VMT.xlsx* to *hpmsvtypeday.xlsx*

4. Save *hpmsvtypeday.xlsx*

Capstone CDM: Vehicle Type VMT (3)

We also need to export the defaults to get the default HourVMTFraction.

Save the defaults as *default hourvmtfraction.xlsx* to the Additional Data Files folder, since that's where the *daily VMT.xlsx* file is located.



Capstone CDM: Vehicle Type VMT (4)

Best practice is to always review default data before reimporting back into MOVES

1. Open *default hourvmtfraction.xlsx* to review the default data

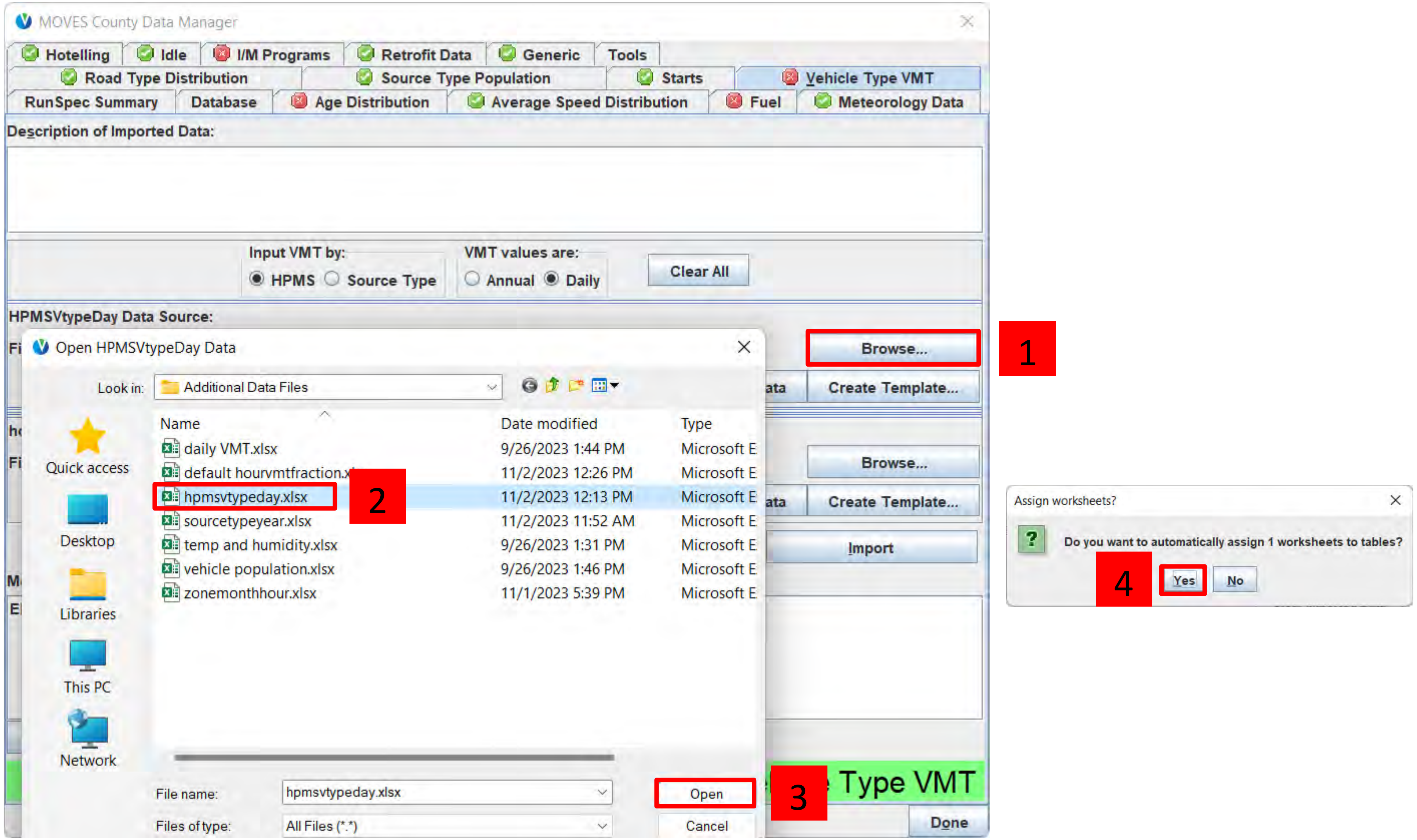
	A	B	C	D	E	F
1	sourceTypeID	roadTypeID	dayID	hourID	hourVMTFraction	
2	11	1	5	1	0.00986211	
3	11	1	5	2	0.00627248	
4	11	1	5	3	0.00505767	
5	11	1	5	4	0.00466686	
6	11	1	5	5	0.00699469	
7	11	1	5	6	0.018494	
8	11	1	5	7	0.0459565	
9	11	1	5	8	0.0696444	
10	11	1	5	9	0.0608279	
11	11	1	5	10	0.0502862	
12	11	1	5	11	0.0499351	
13	11	1	5	12	0.0543654	
14	11	1	5	13	0.0576462	
15	11	1	5	14	0.0580319	
16	11	1	5	15	0.0622554	
17	11	1	5	16	0.0710049	

SourceTypeYearVMT

Capstone CDM: Vehicle Type VMT (5)

Now it is time to import the data. Browse for the HPMSVtypeDay data source and use our template file, *hpmsvtypeday.xlsx*.

When MOVES prompts if you want to automatically assign sheets, click yes, because it is going to assign the 1 worksheet in our template to the HPMSVtypeDay data source.

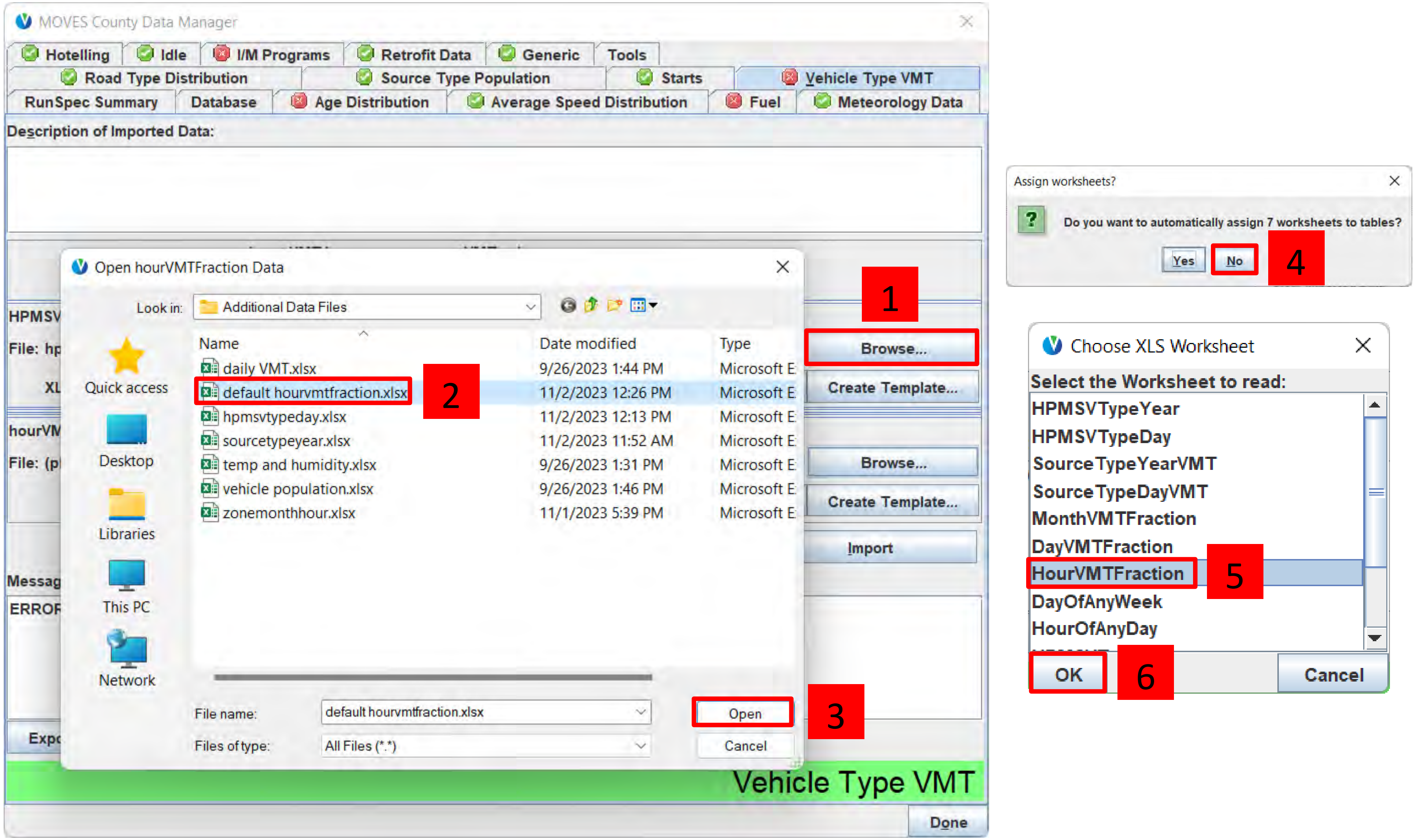


Capstone CDM: Vehicle Type VMT (6)

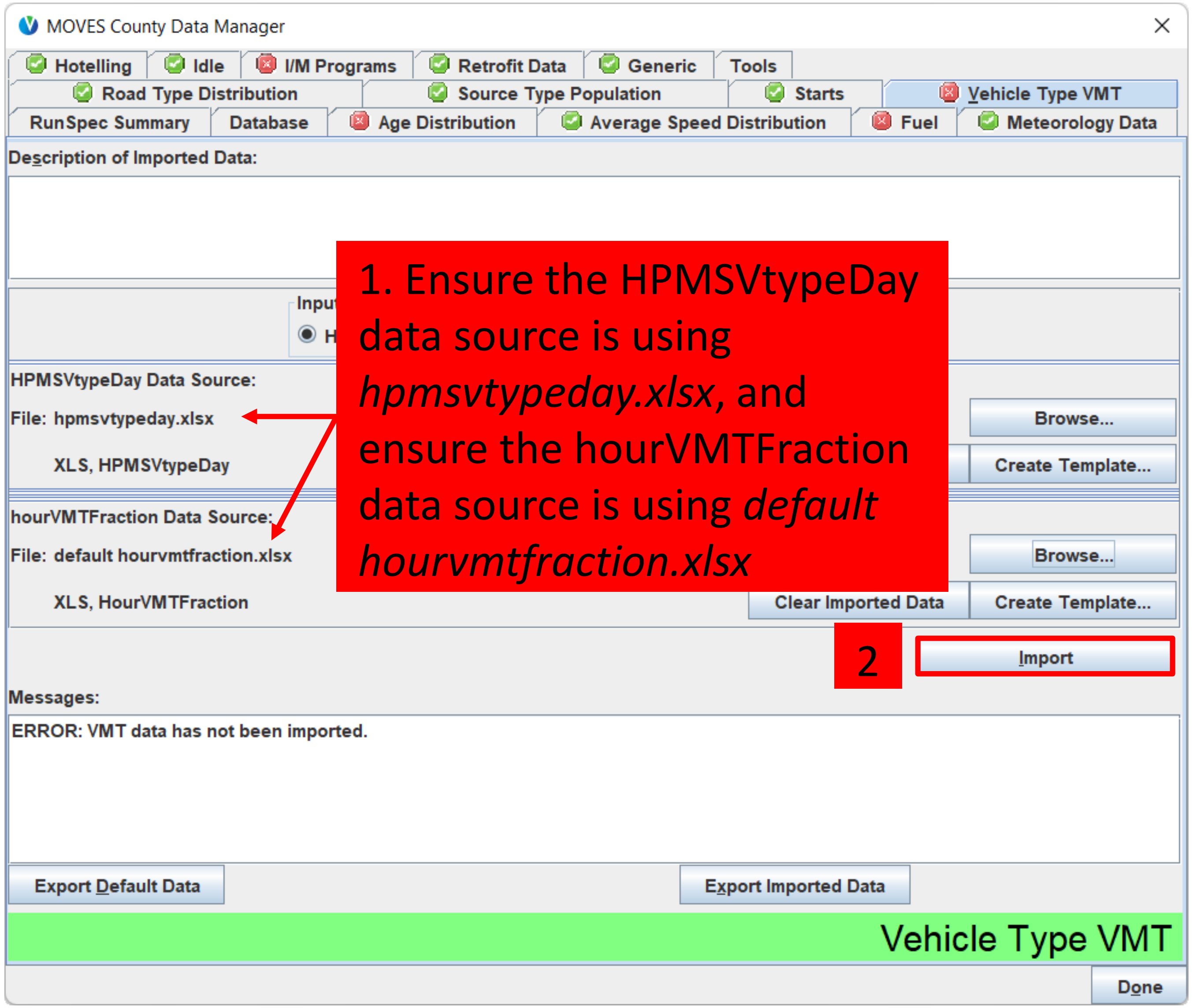
Next, browse for the hourVMTFraction data source and use *default hourvmtfraction.xlsx*.

When MOVES prompts if you want to automatically assign sheets, click no, because otherwise it will overwrite our previous selection for the HPMSVtypeDay data source.

Then, manually select the hourVMTFraction worksheet



Capstone CDM: Vehicle Type VMT (7)



Capstone CDM: Creating a Plan for Age Distribution

- Open the *MPO MOVES Files\agedistribution-2020.xlsx* file to see what kind of data we were provided
- From the file, we can see that we have correctly formatted age distributions for 2020 for all source types except 62
- We will need to export the defaults to get the national age distributions for long-haul combination trucks
- We will need to use the Age Distribution Projection Tool (available in the Tools folder of the course materials) to project the 2020 age distributions to our analysis year of 2028
- We will need to combine the results of the projection tool and the default data for importing into MOVES

agedistribution-2020.xlsx

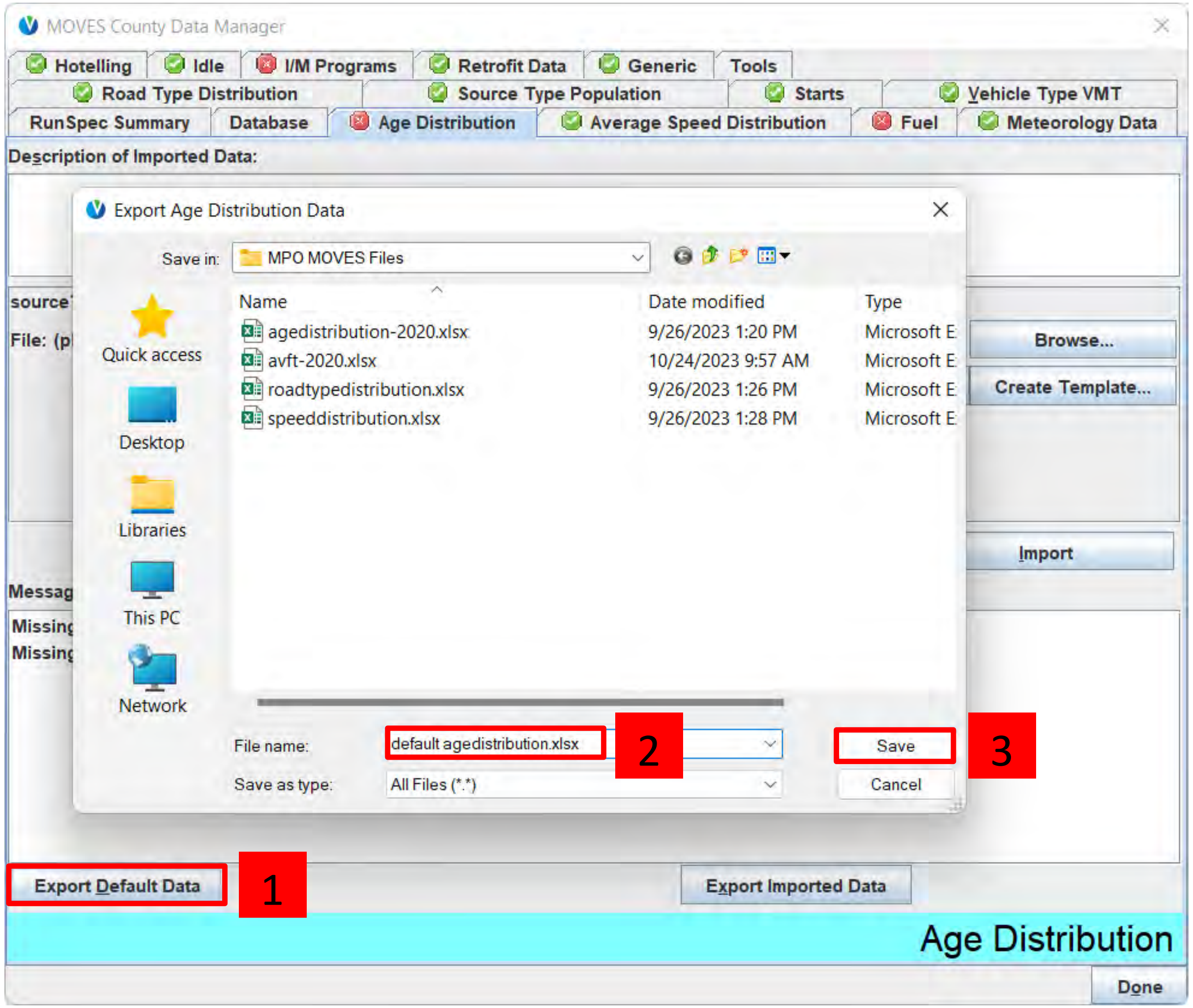
	A	B	C	D	E
1	sourceTypeID	yearID	ageID	ageFraction	
2	11	2020	0	0.07082305	
3	11	2020	1	0.065564975	
4	11	2020	2	0.066638051	
5	11	2020	3	0.066530744	
6	11	2020	4	0.06899882	
7	11	2020	5	0.05483421	
8	11	2020	6	0.03745037	
9	11	2020	7	0.036806524	
10	11	2020	8	0.035518832	
11	11	2020	9	0.022427299	
12	11	2020	10	0.015774225	
13	11	2020	11	0.038630754	
14	11	2020	12	0.04249383	
15	11	2020	13	0.043996137	
16	11	2020	14	0.04249383	
17	11	2020	15	0.039489216	
18	11	2020	16	0.037235755	
19	11	2020	17	0.041206138	
20	11	2020	18	0.027685374	
21	11	2020	19	0.029294989	
22	11	2020	20	0.024466144	

agedistrib

Capstone CDM: Age Distribution (1)

We need to export the defaults to get the national age distributions for long-haul combination trucks (62s).

Save the defaults as *default agedistribution.xlsx* to the MPO MOVES Files folder, since that's where the *agedistribution-2020.xlsx* file is located.



Capstone CDM: Age Distribution (2)

Best practice is to always review default data

1. Open *default agedistribution* review the defa data for 62s

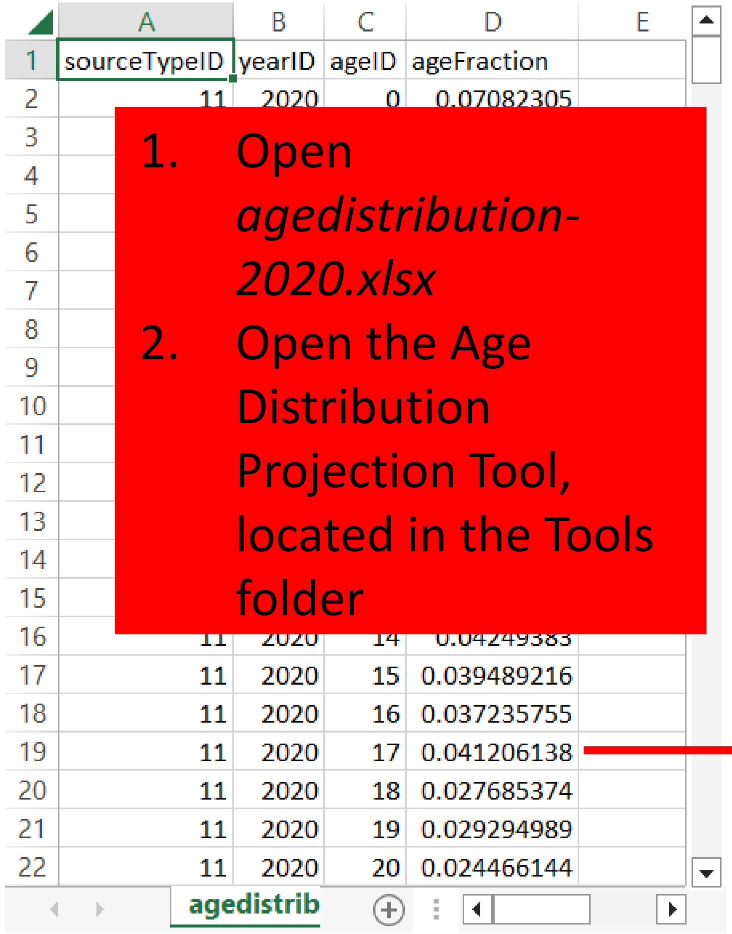
	A	B	C	D
374	62	2028	0	0.049400205
375	62	2028	1	0.049311108
376	62	2028	2	0.048410379
377	62	2028	3	0.048286599
378	62	2028	4	0.048853885
379	62	2028	5	0.048825167
380	62	2028	6	0.047421314
381	62	2028	7	0.082546529
382	62	2028	8	0.07000447
383	62	2028	9	0.069729583
384	62	2028	10	0.036300711
385	62	2028	11	0.023684545
386	62	2028	12	0.036874215
387	62	2028	13	0.032532515
388	62	2028	14	0.023739037
389	62	2028	15	0.023172844
390	62	2028	16	0.023558929
391	62	2028	17	0.012509679
392	62	2028	18	0.011402903
393	62	2028	19	0.015903087
394	62	2028	20	0.011945276
395	62	2028	21	0.038859664

SourceT ...

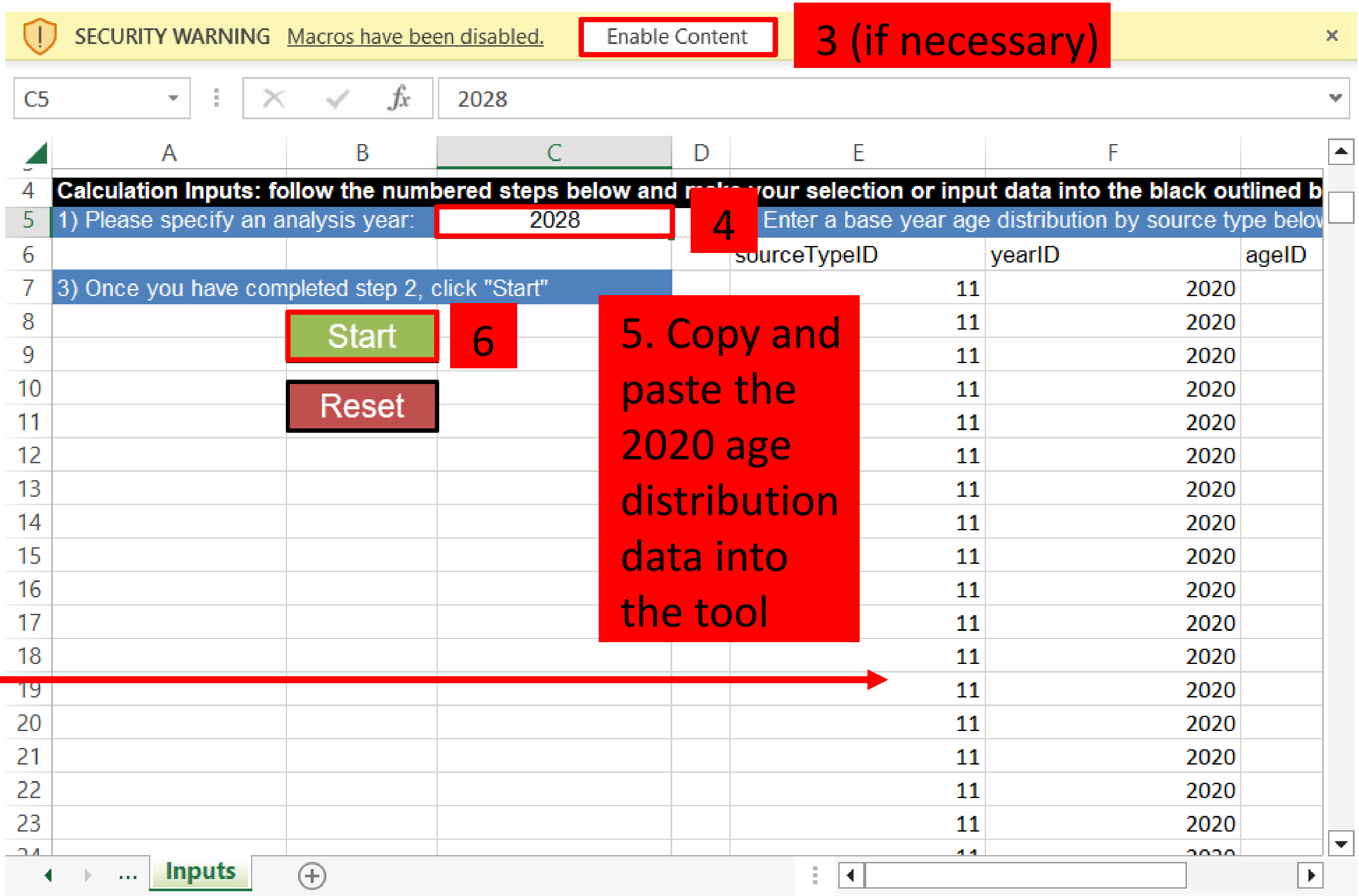
Capstone CDM: Age Distribution (3)

Next, project the 2028 age distributions

agedistribution-2020.xlsx

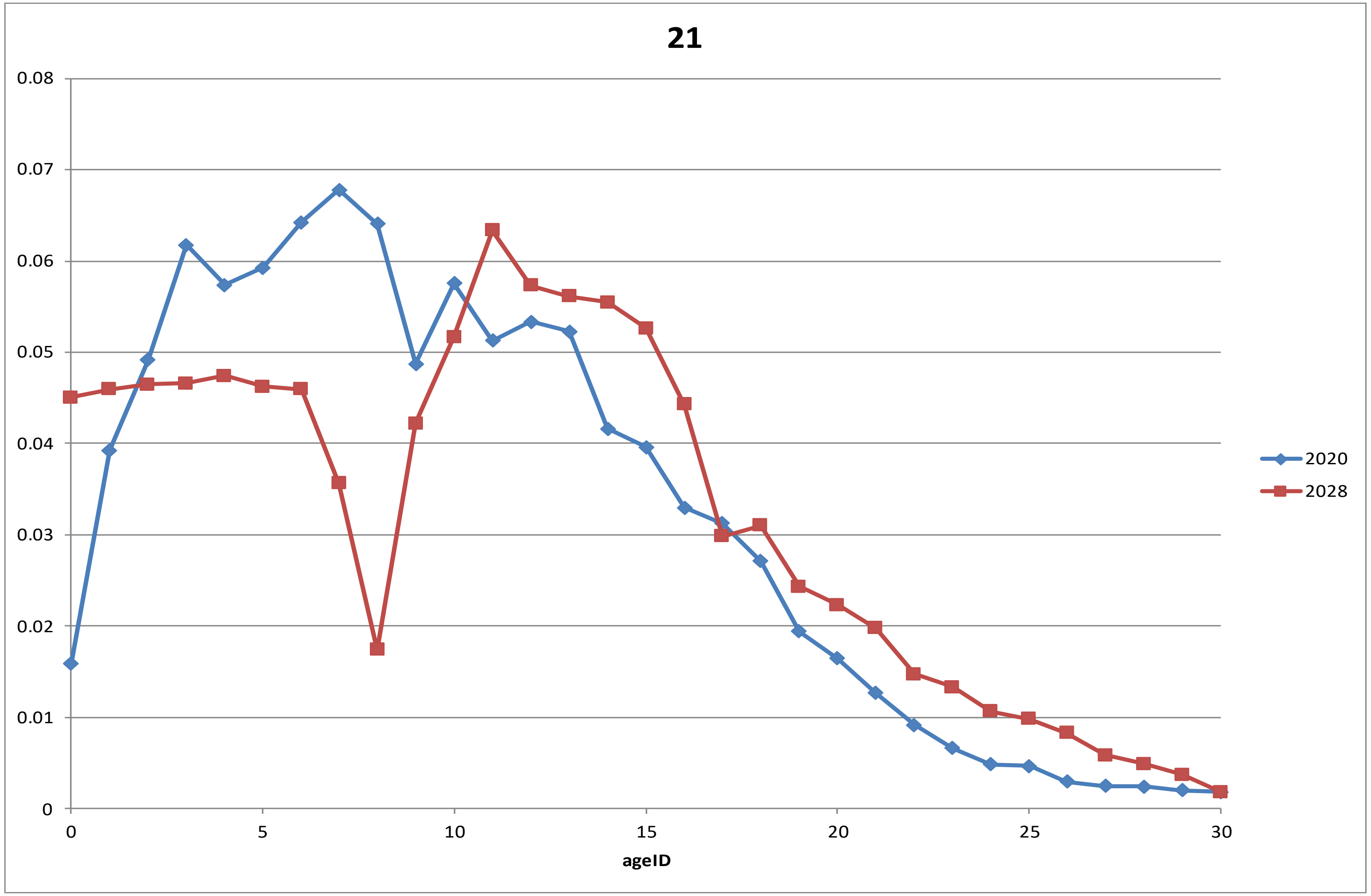


moves4-age-distribution-projection-tool-2023-08.xltm



Capstone CDM: Age Distribution (4)

Best practice is to always review the results of any tool



Capstone CDM: Age Distribution (5)

default agedistribution.xlsx

	A	B	C	D	E
373	61	2028	30	0.077697686	
374	62	2028	0	0.049400205	
375	62	2028	1	0.049311108	
376	62	2028	2	0.048410379	
377	62	2028	3	0.048286599	
378	62	2028	4	0.048853885	
379	62	2028	5		
380	62	2028	6		
381	62	2028	7		
382	62	2028	8		
383	62	2028	9		
384	62	2028	10		
385	62	2028	11		
386	62	2028	12		
387	62	2028	13		
388	62	2028	14		
389	62	2028	15	0.023172844	
390	62	2028	16	0.023558929	
391	62	2028	17	0.012509679	
392	62	2028	18	0.011402903	
393	62	2028	19	0.015903087	
394	62	2028	20	0.011945276	

SourceTy ...

SourceTypeAgeDistribution tab of Age Distribution Projection Tool

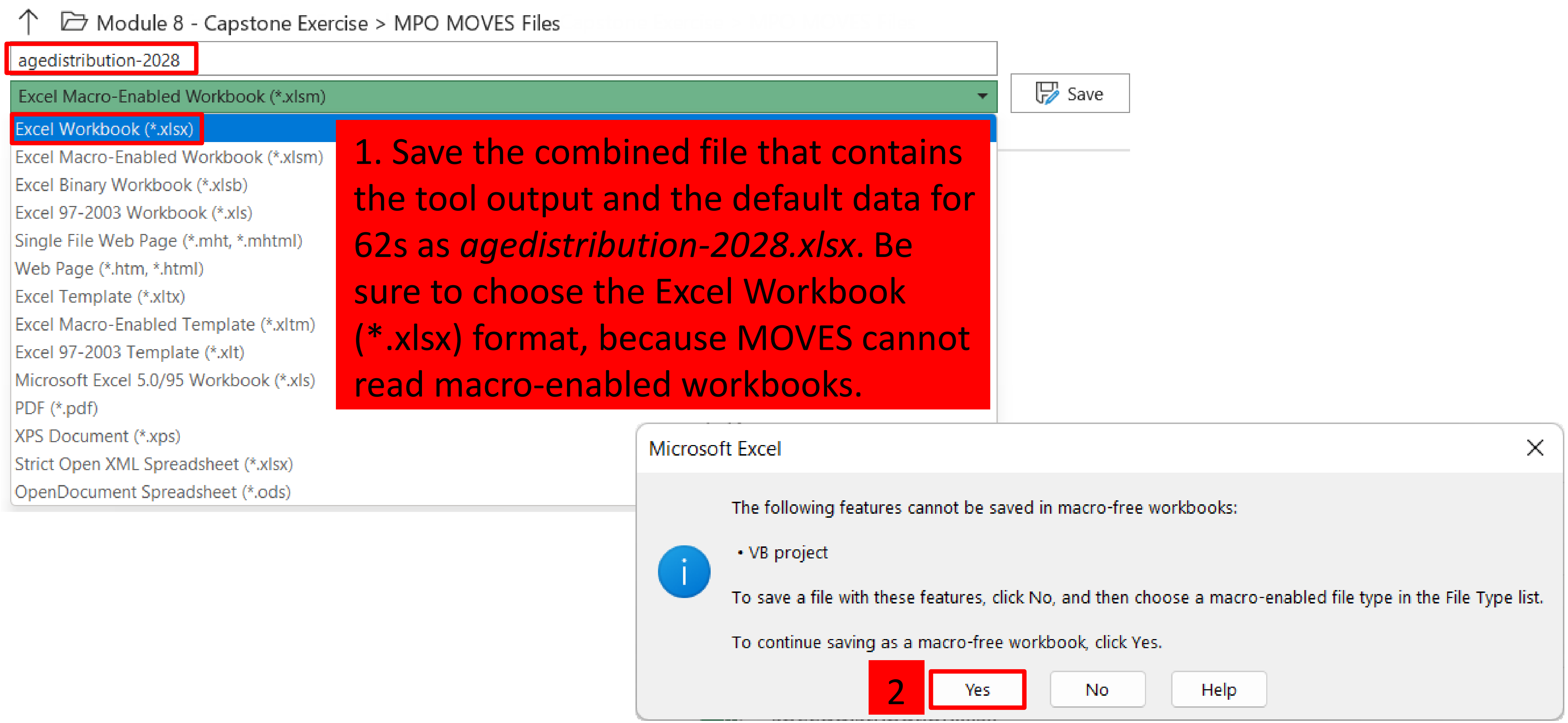
	A	B	C	D	E	F	G	H	I
372	61	2028	29	0.019869					
373	61	2028	30	0.025799					
374	62	2028	0	0.0494					
375	62	2028	1	0.049311					
376	62	2028	2	0.04841					
377	62	2028	3	0.048287					
			4	0.048854					
			5	0.048825					
			6	0.047421					
			7	0.082547					
			8	0.070004					
			9	0.06973					
			10	0.036301					
			11	0.023685					
			12	0.036874					
			13	0.032533					
388	62	2028	14	0.023739					
389	62	2028	15	0.023173					
390	62	2028	16	0.023559					
391	62	2028	17	0.01251					
392	62	2028	18	0.011403					
393	62	2028	19	0.015903					

(Ctrl)

SourceTypeAgeDistribution | Inputs | Ch ...

1. Copy and paste the default age distributions for **sourceTypeID 62** from *default agedistributions.xlsx* to the end of the tool's output on the *SourceTypeAgeDistribution* tab. Do not copy any other source types.

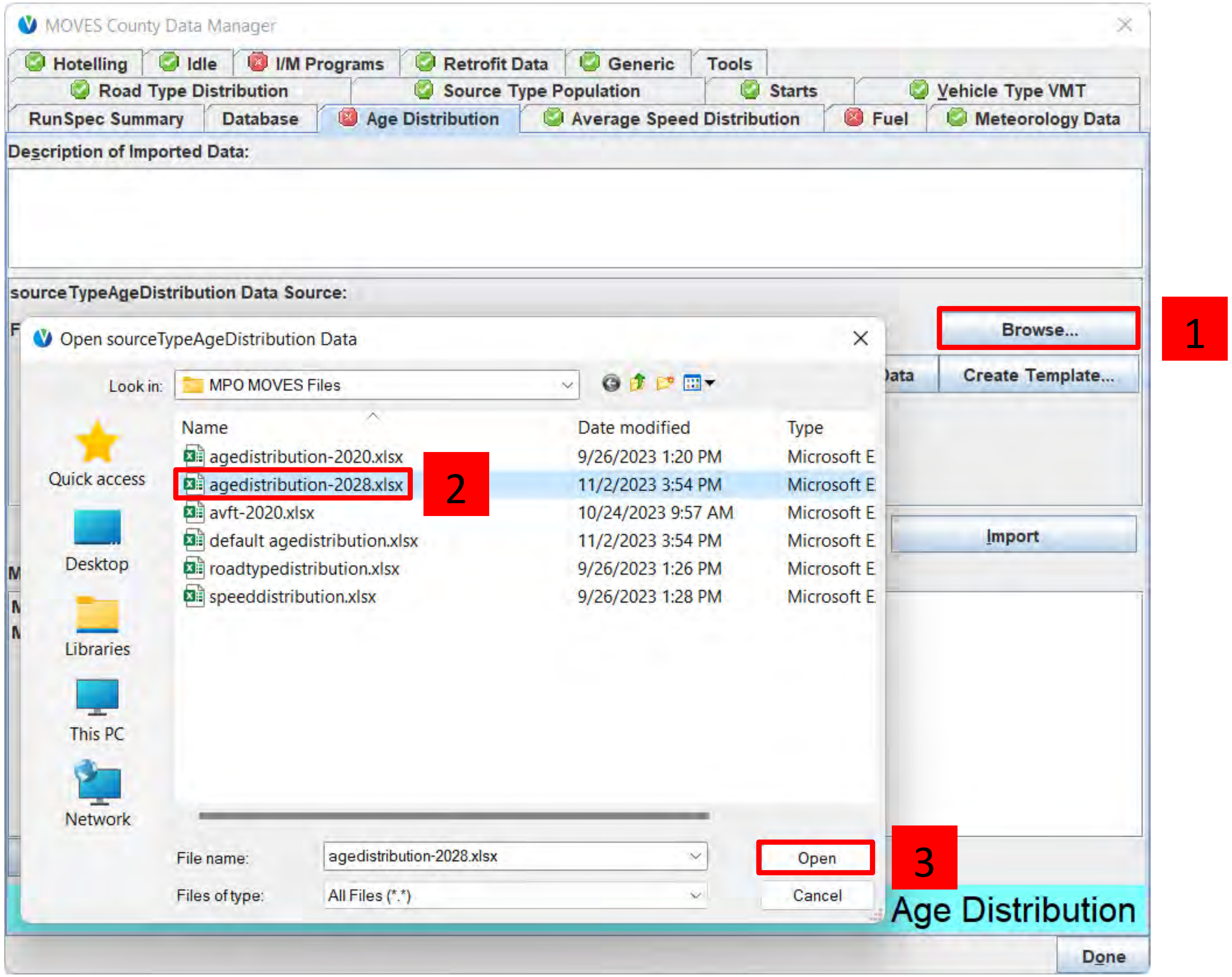
Capstone CDM: Age Distribution (6)



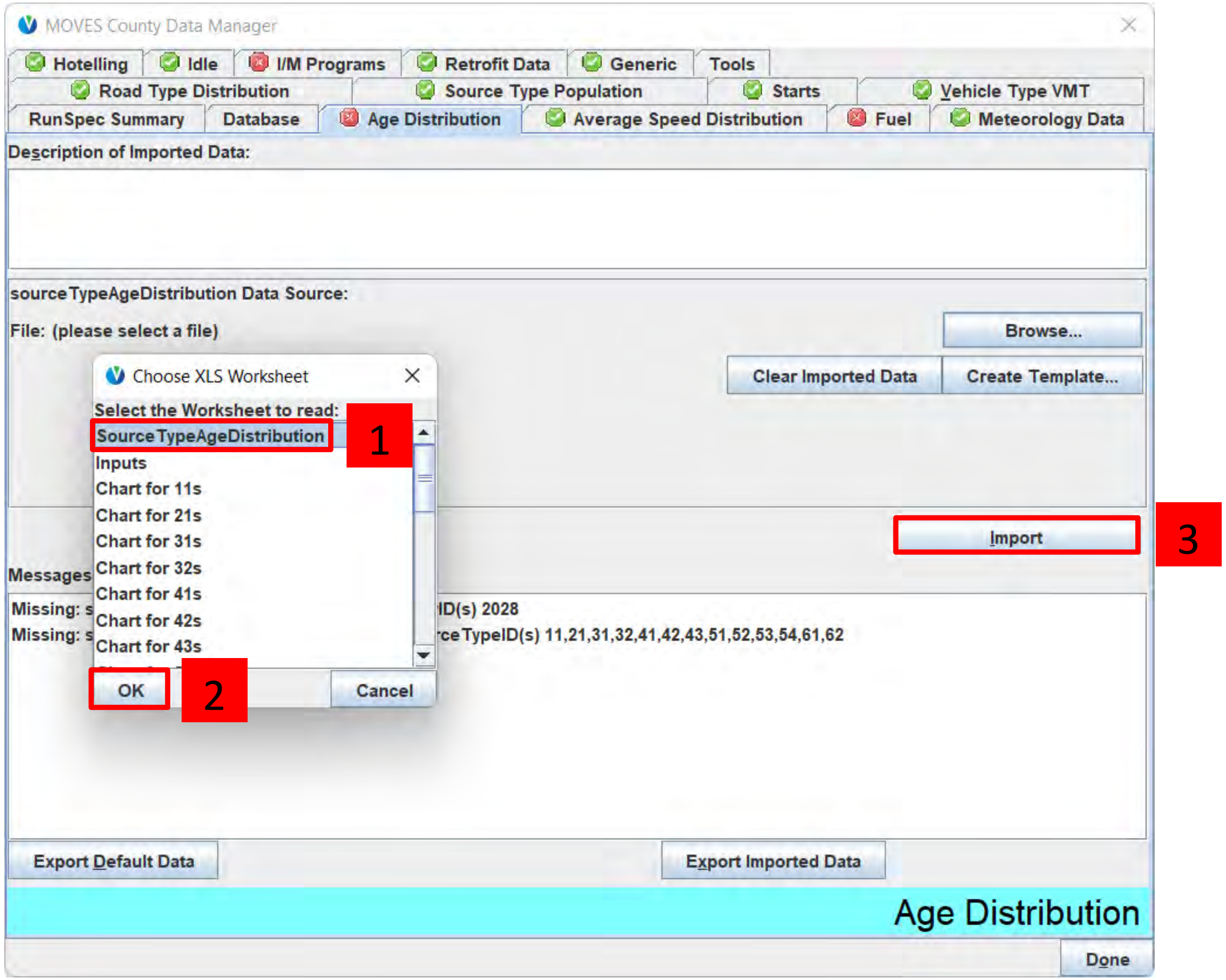
1. Save the combined file that contains the tool output and the default data for 62s as *agedistribution-2028.xlsx*. Be sure to choose the Excel Workbook (*.xlsx) format, because MOVES cannot read macro-enabled workbooks.

Capstone CDM: Age Distribution (7)

Now that we've run the projection tool and combined the results with the defaults for 62s, we are ready to load data from *agedistribution-2028.xlsx*



Capstone CDM: Age Distribution (8)



Capstone CDM: Creating a Plan for Fuels

- Open the *MPO MOVES Files\avft-2020.xlsx* file to see what kind of data we were provided on fuel type distributions
- From the file, we can see that we have a correctly formatted AVFT table for 2020
- We will use the AVFT Tool to project the 2020 fuel type distributions to our analysis year of 2028
    - We will create a Known Fractions template to correctly model the scenario where all MY2021+ refuse trucks are CNG and all MY2023+ school buses and transit buses are BEV
- For the other fuel tables, we will need to export the defaults to get the fuel supply, fuel formulation, and fuel usage fraction data

avft-2020.xlsx

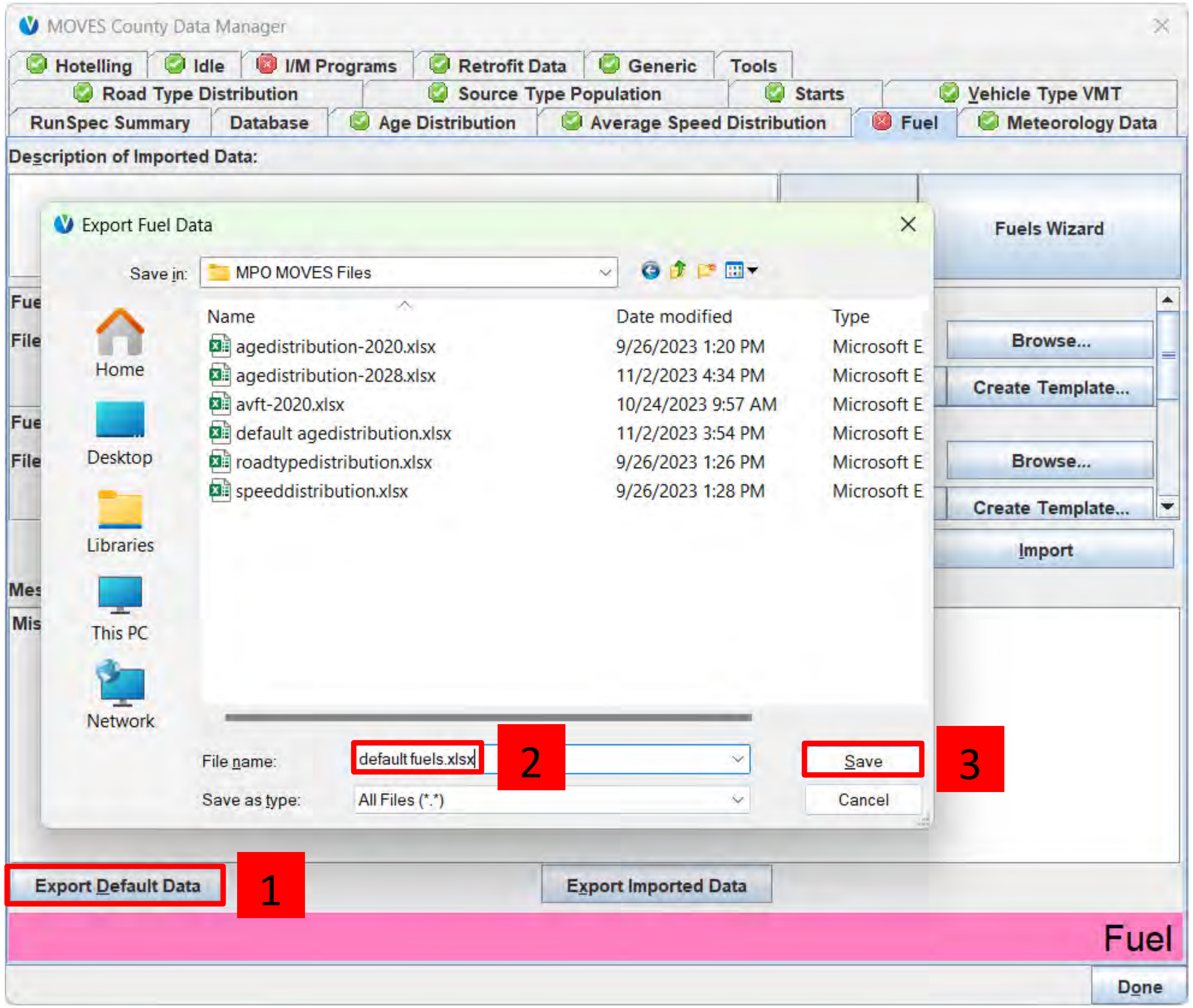
	A	B	C	D	E
166	21	2015	1	1	0.940941385
167	21	2015	2	1	0.013765542
168	21	2015	5	1	0.037892244
169	21	2015	9	30	0.007400829
170	21	2016	1	1	0.955943093
171	21	2016	2	1	0.000611901
172	21	2016	5	1	0.035337311
173	21	2016	9	30	0.008107695
174	21	2017	1	1	0.967320261
175	21	2017	2	1	0.001562944
176	21	2017	5	1	0.01733447
177	21	2017	9	30	0.013782325
178	21	2018	1	1	0.940167887
179	21	2018	2	1	0.001786033
180	21	2018	5	1	0.023932845
181	21	2018	9	30	0.034113235
182	21	2019	1	1	0.942556996
183	21	2019	5	1	0.012740277
184	21	2019	9	30	0.044702727
185	21	2020	1	1	0.940981798
186	21	2020	5	1	0.00275786
187	21	2020	9	30	0.056260342

avft-2020.xlsx

Capstone CDM: Fuel (1)

Start with exporting the defaults.

Save the defaults as *default fuels.xlsx* to the MPO MOVES Files folder, since that's where the *avft-2020.xlsx* file is located.



Capstone CDM: Fuel (2)

Best practice is to always review default data

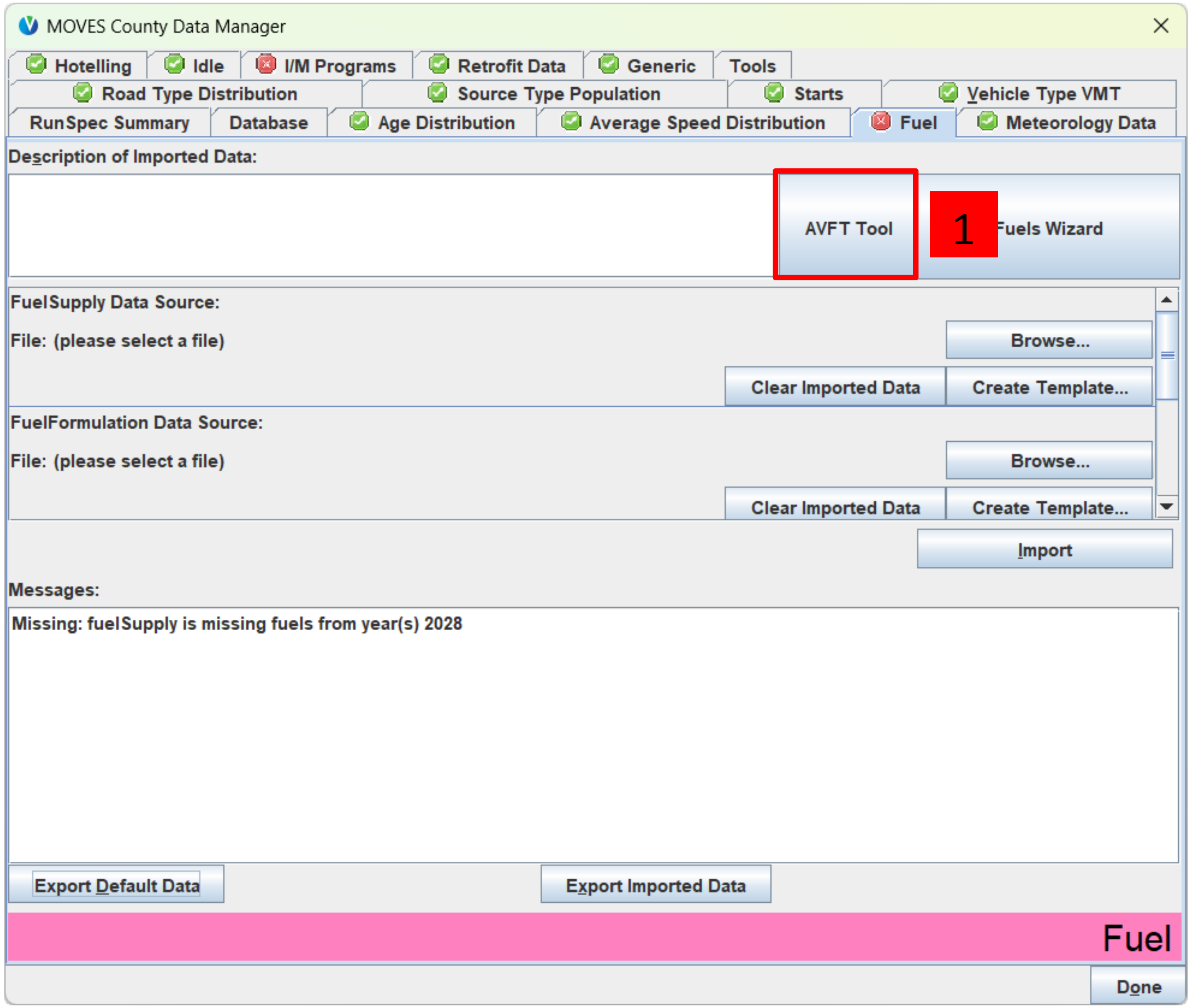
1. Open *default fuels.xlsx* to review the default data for FuelSupply, FuelFormulation, and FuelUsageFraction

fuelRegionID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
270000000	2028	1	90	1	0.5
270000000	2028	1	9115	1	0.5
270000000	2028	1	25003	1	0.5
270000000	2028	1	27001	1	0.5
270000000	2028	1	28001	1	0.5

FuelSupply | FuelFormulation | FuelUsageFraction ...

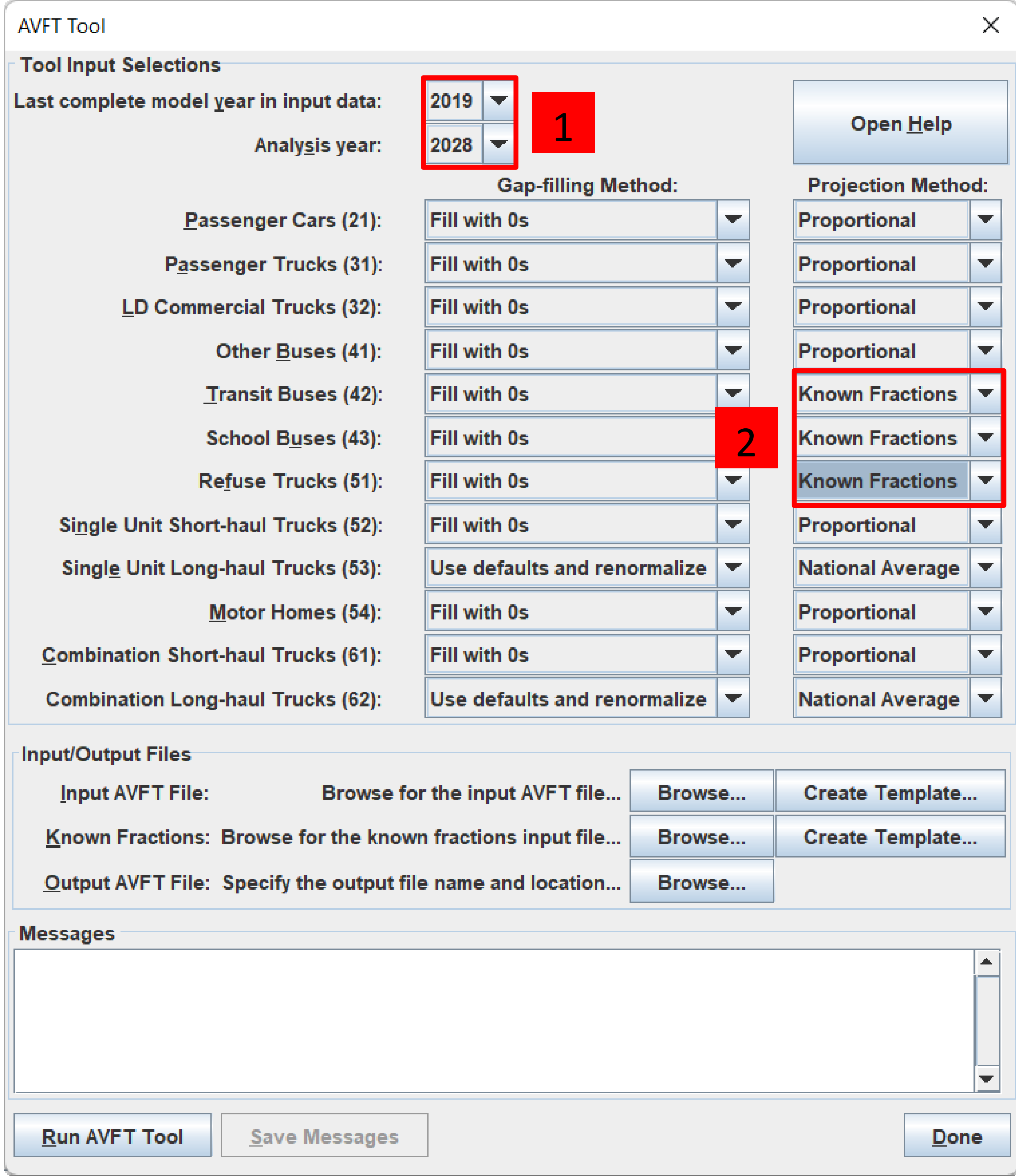
Capstone CDM: Fuel (3)

Then, open the AVFT Tool



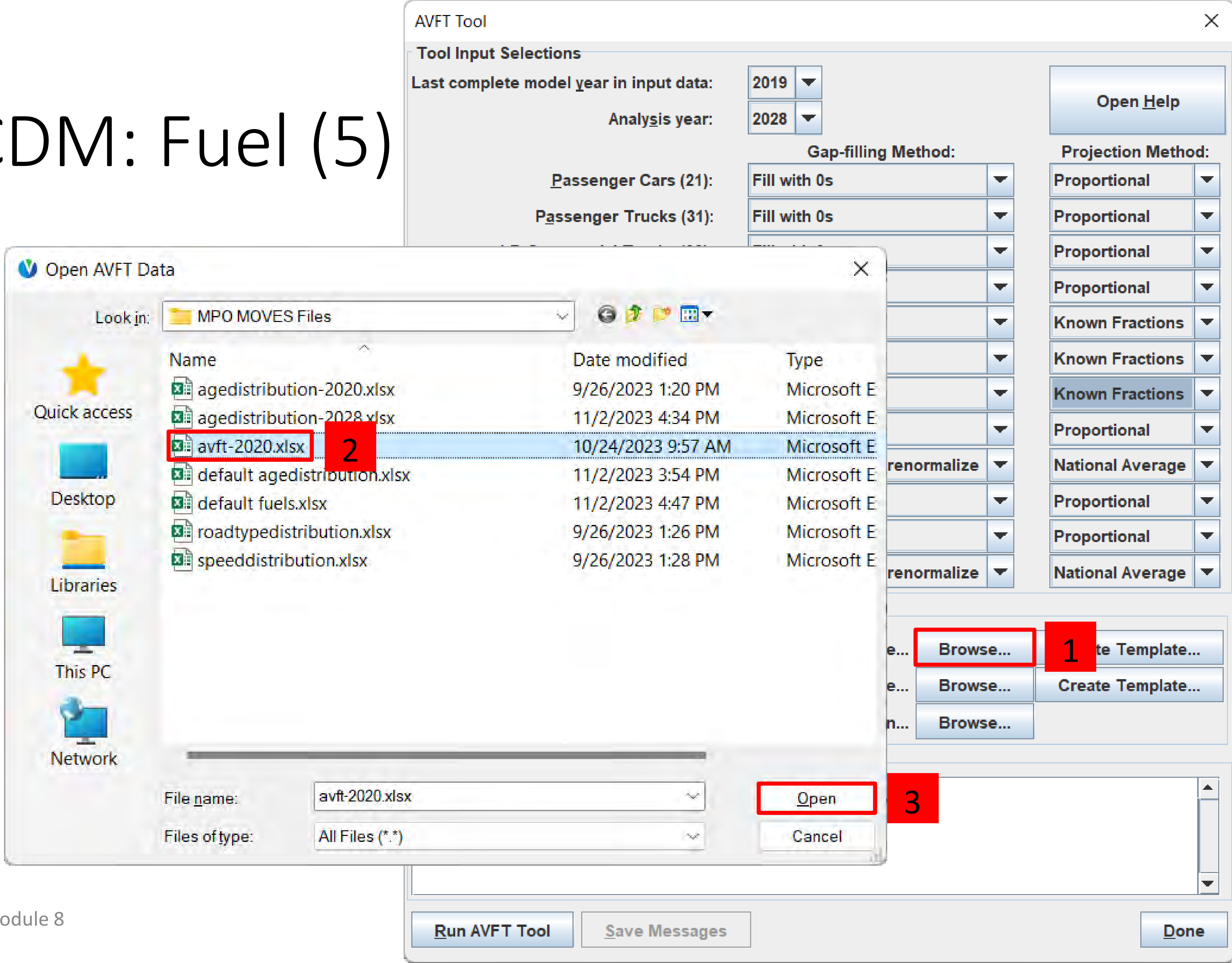
Capstone CDM: Fuel (4)

- The input data were collected on July 1, 2020, which means that the MY2020 data are incomplete. Therefore, select 2019 as the last complete model year
- Our analysis year is 2028
- Our historic data are complete for all fuel types present, so we will use the default gap filling methods for all source types
- We have known fractions for Transit Buses, School Buses, and Refuse Trucks, so we will project with the Known Fractions method for those source types
  - We will use the default projection methods for all other source types



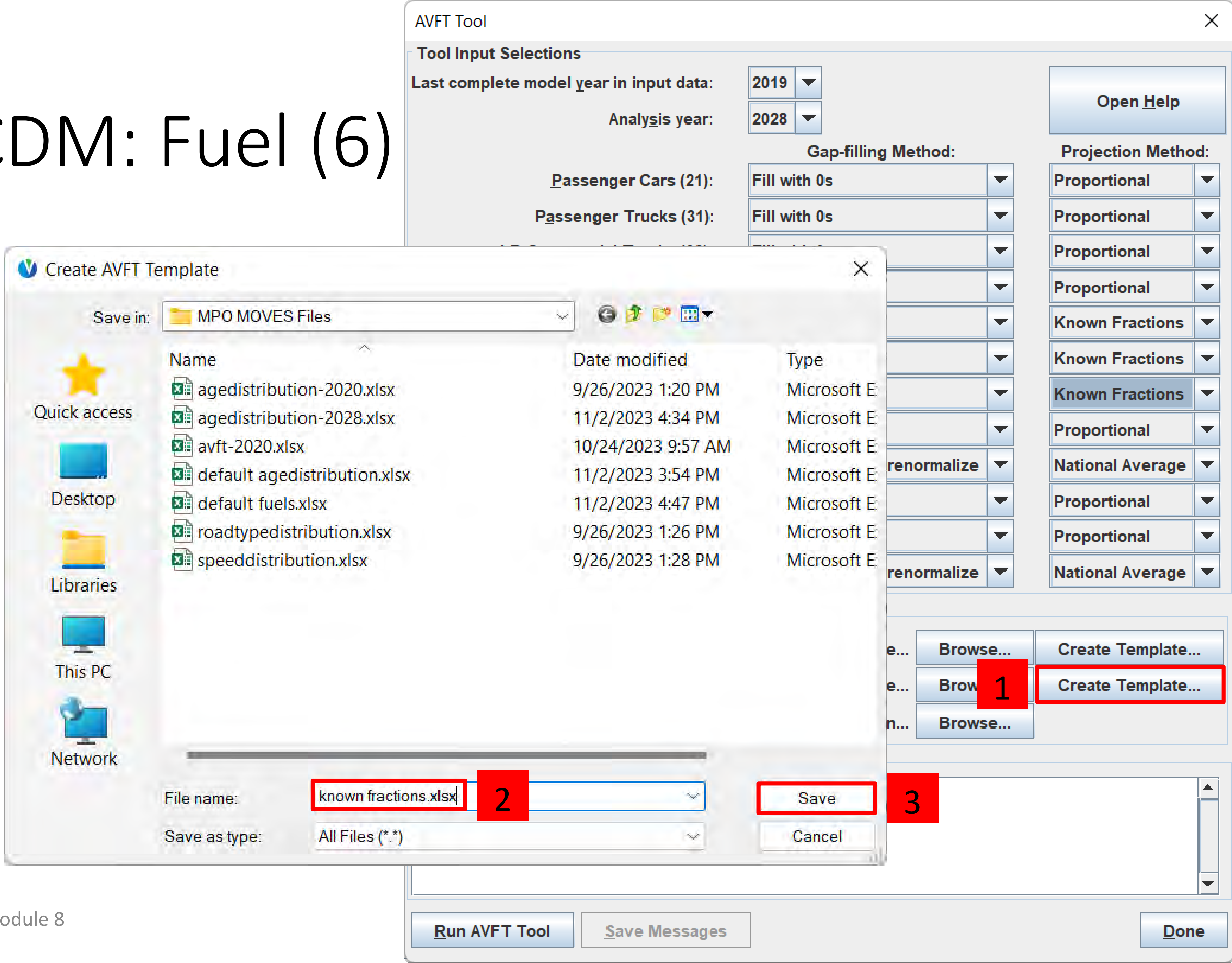
Capstone CDM: Fuel (5)

Next, specify the *avft-2020.xlsx* file in the MPO MOVES Files folder as the Input AVFT File.



Capstone CDM: Fuel (6)

Next, create a template for the Known Fractions. Call it *known fractions.xlsx*



Capstone CDM: Fuel (7)

Edit *known fractions.xlsx* to reflect the scenario where all MY2021+ refuse trucks are CNG (fuelTypeID 3) and all MY2023+ school buses and transit buses are BEV (fuelTypeID 9 and engTechID 30).

Use the decoding tabs if needed

1. Open *known fractions*.xlsx. This template contains all sourceTypeIDs, fuelTypeIDs, and engTechIDs selected in the RunSpec.

	A	B	C	D	E	F
1	sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction	
2	11		1	1		
3	21		1	1		
4	21		2	1		
5	21		5	1		
6	21		9	30		
7	31		1	1		
8	31		2	1		
9	31		5	1		
10	31		9	30		
11	32		1	1		
12	32		2	1		
13	32		5	1		
14	32		9	30		
15	41		1	1		
16	41		2	1		
17	41		3	1		
18	41		9	30		
19	41		9	40		
20	42		1	1		
21	42		2	1		

AVFT | EngineTech | F ...

2. Delete all rows for source types except 42, 43, and 51
3. Delete all rows for all non-BEV 42s and 43s
4. Delete all rows for all non CNG 51s

	A	B	C	D	E	F
1	sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction	
2	42		9	30		
3	43		9	30		
4	51		3	1		

AVFT | EngineTech | F ...

This is what your *known fractions.xlsx* should look like after completing these steps.

Capstone CDM: Fuel (8)

1. Duplicate the row for BEV transit buses (sourceTypeID 42, fuelTypeID 9, engTechID 30) so that you have enough rows to enter modelYearID values 2023-2028

2. Set the fuelEngFraction for these rows to 1 to indicate that all MY2023-MY2028 transit buses are BEV

sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction
42	2023	9	30	1
42	2024	9	30	1
42	2025	9	30	1
42	2026	9	30	1
42	2027	9	30	1
42	2028	9	30	1

AVFT | EngineTech | F ...

Capstone CDM: Fuel (9)

1. Duplicate the row for BEV school buses (sourceTypeID 43, fuelTypeID 9, engTechID 30) so that you have enough rows to enter modelYearID values 2023-2028

2. Set the fuelEngFraction for these rows to 1 to indicate that all MY2023-MY2028 school buses are BEV

sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction
42	2023	9	30	1
42	2024	9	30	1
42	2025	9	30	1
42	2026	9	30	1
42	2027	9	30	1
42	2028	9	30	1
43	2023	9	30	1
43	2024	9	30	1
43	2025	9	30	1
43	2026	9	30	1
43	2027	9	30	1
43	2028	9	30	1

AVFT EngineTech F ...

Capstone CDM: Fuel (10)

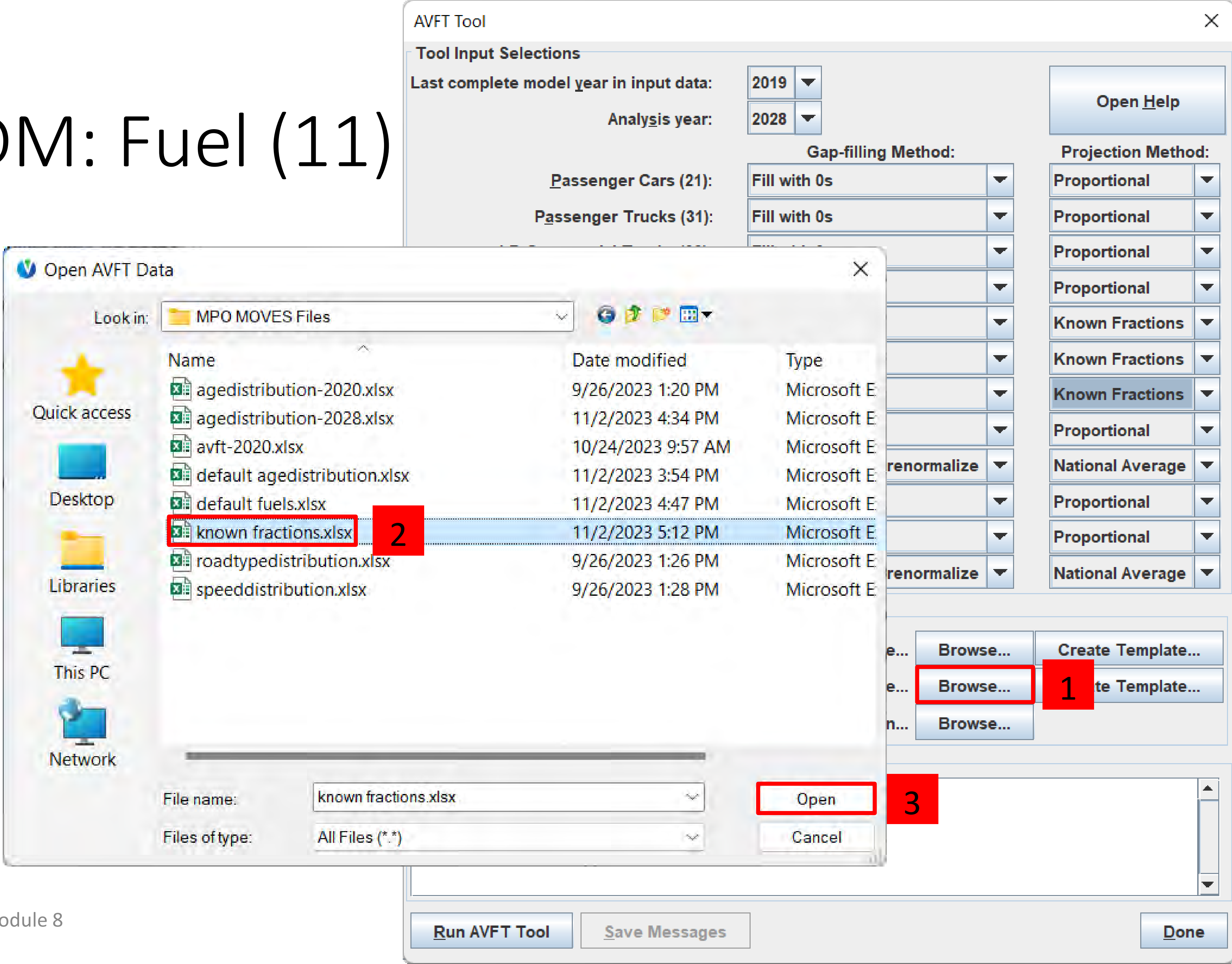
1. Duplicate the row for CNG refuse trucks (sourceTypeID 51, fuelTypeID 3, engTechID 1) so that you have enough rows to enter modelYearID values 2021-2028
2. Set the fuelEngFraction for these rows to 1 to indicate that all MY2021-MY2028 refuse trucks are CNG
3. Save *known fractions.xlsx*

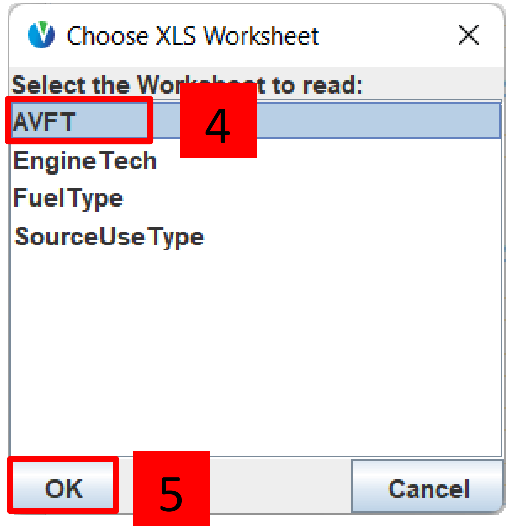
	A	B	C	D	E	F
1	sourceTypeID	modelYearID	fuelTypeID	engTechID	fuelEngFraction	
2	42	2023	9	30	1	
3	42	2024	9	30	1	
4	42	2025	9	30	1	
5	42	2026	9	30	1	
6	42	2027	9	30	1	
7	42	2028	9	30	1	
8	43	2023	9	30	1	
9	43	2024	9	30	1	
10	43	2025	9	30	1	
11	43	2026	9	30	1	
12	43	2027	9	30	1	
13	43	2028	9	30	1	
14	51	2021	3	1	1	
15	51	2022	3	1	1	
16	51	2023	3	1	1	
17	51	2024	3	1	1	
18	51	2025	3	1	1	
19	51	2026	3	1	1	
20	51	2027	3	1	1	
21	51	2028	3	1	1	

AVFT | EngineTech | F ...

Capstone CDM: Fuel (11)

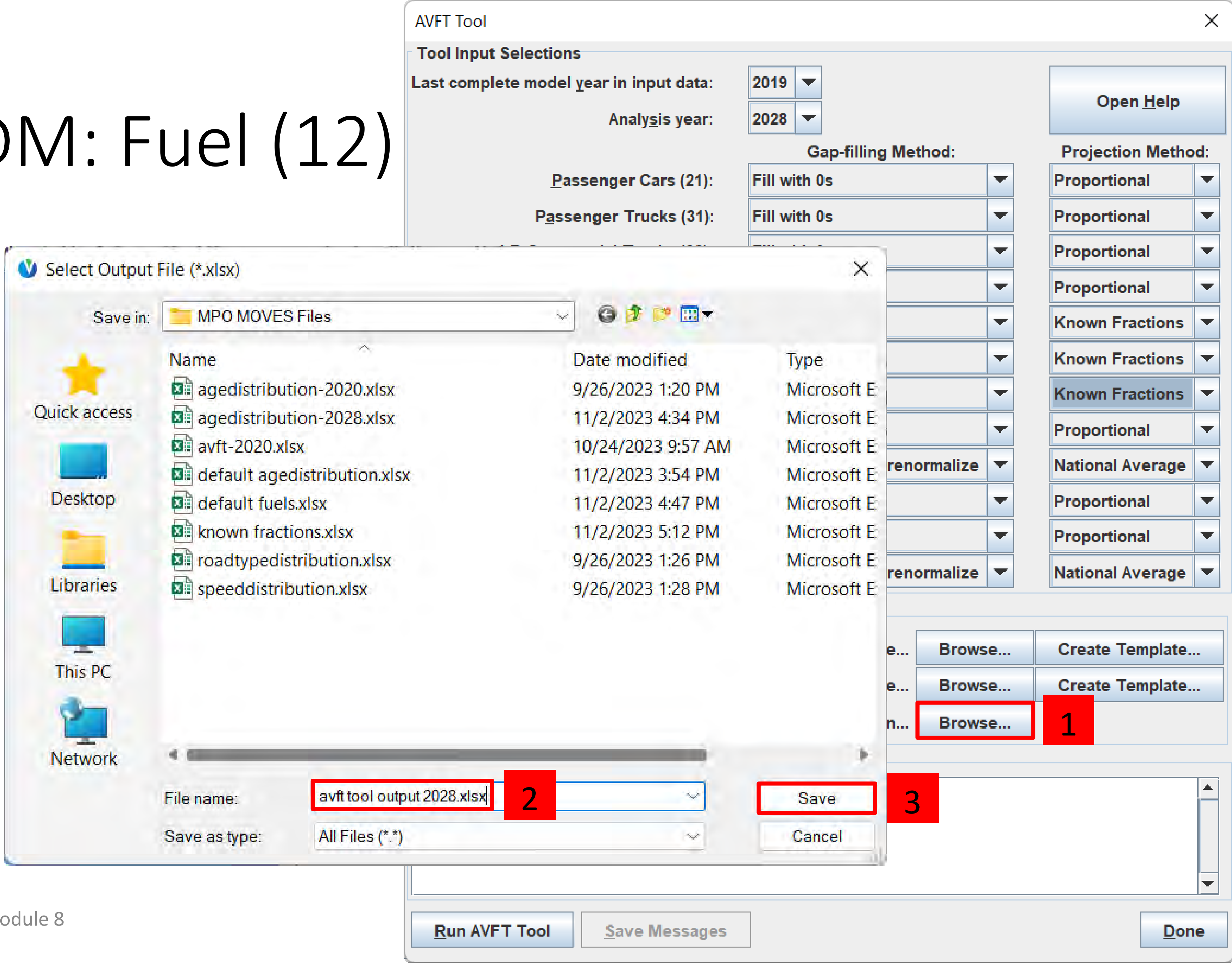
Specify the *known fractions.xlsx* file as the Known Fractions input





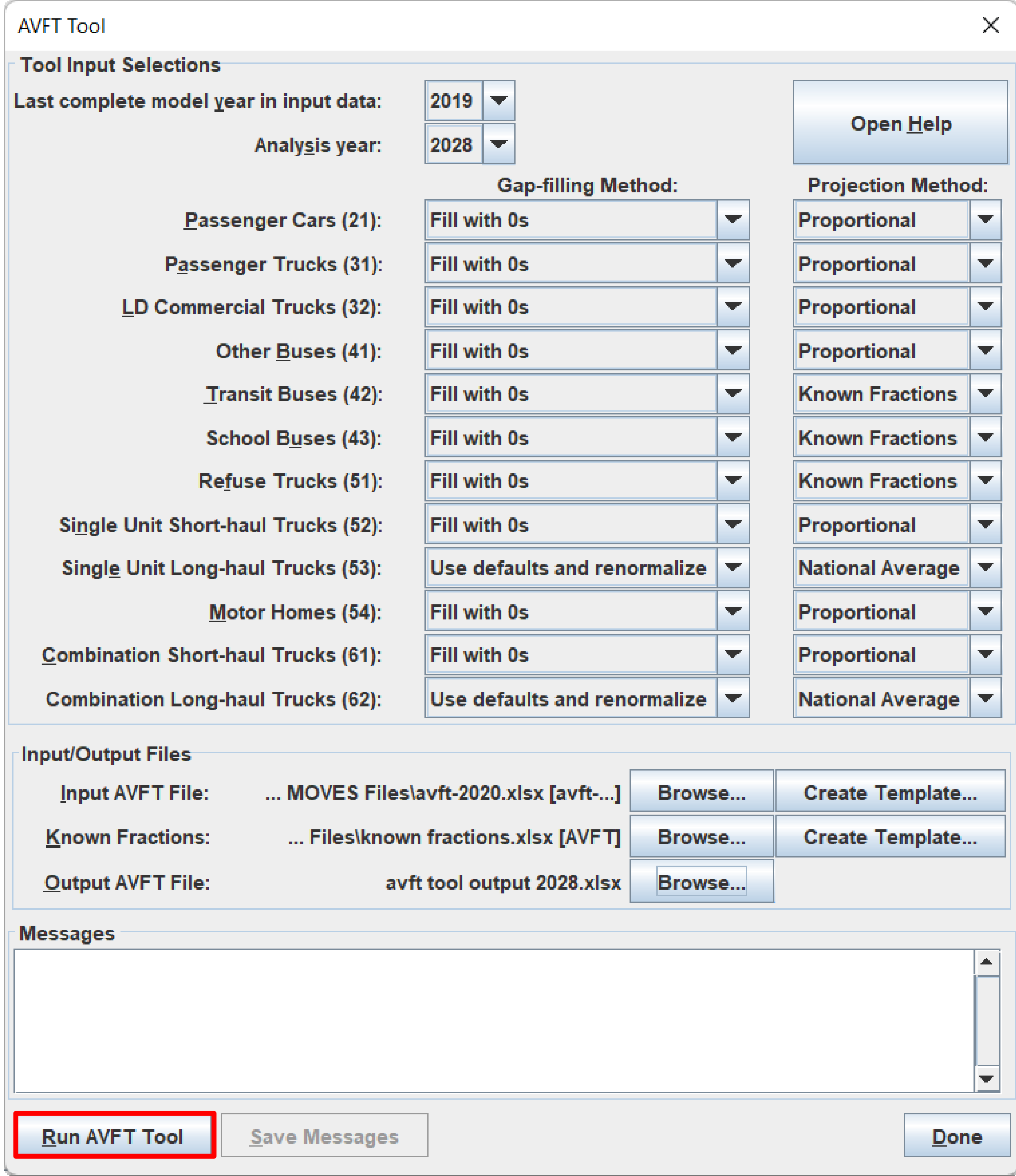
Capstone CDM: Fuel (12)

Finally, specify the output file for the AVFT Tool as *avft tool output 2028.xlsx*



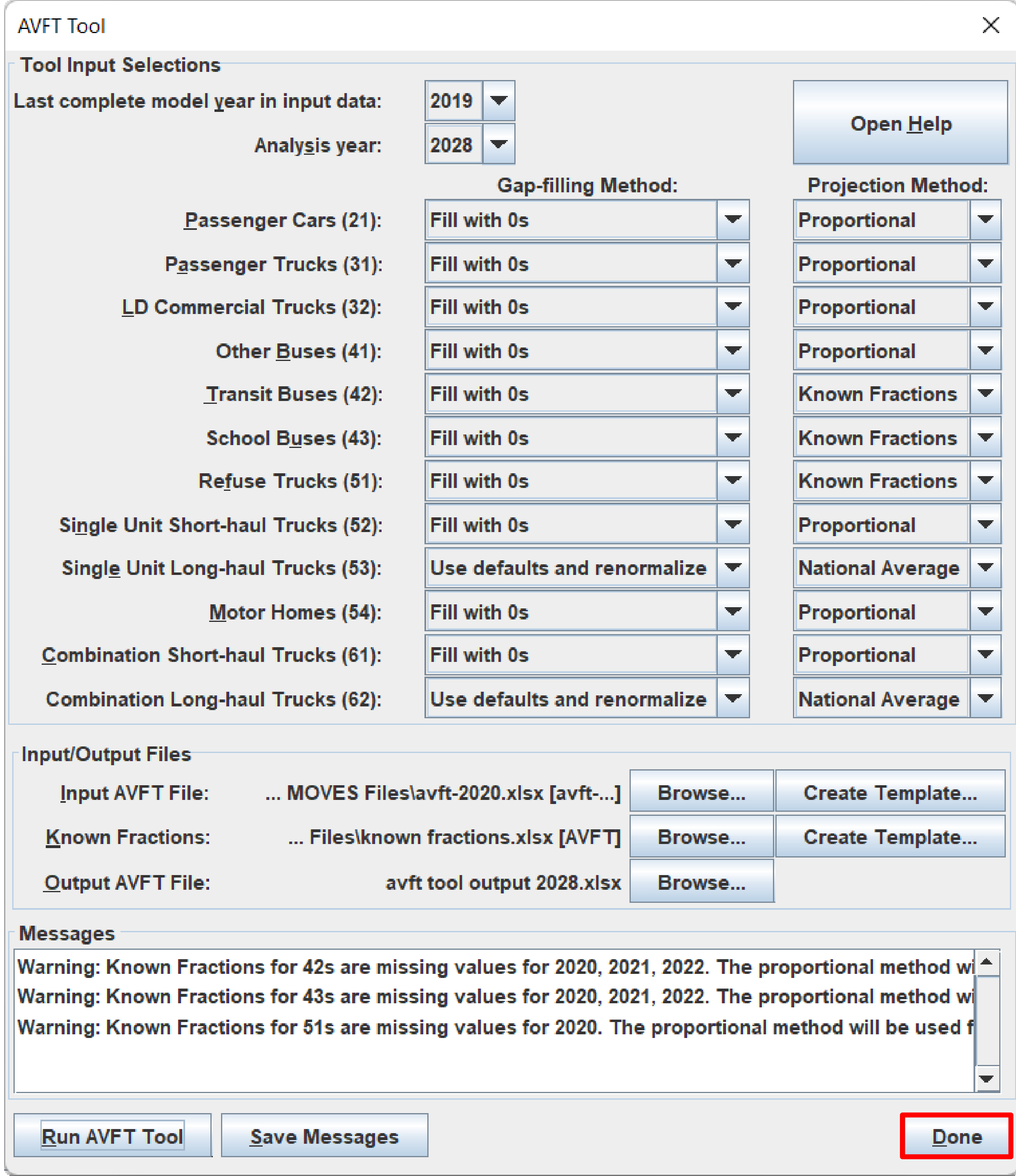
Capstone CDM: Fuel (13)

Review the AVFT Tool selections before running the tool



Capstone CDM: Fuel (14)

- After running the tool, check for error messages
- Warning messages may be OK
  - In this case, the tool is warning us that it used the proportional method for transit buses, school buses, and refuse trucks for model years before we entered the Known Fractions. This is expected.
- Click Done to close the tool

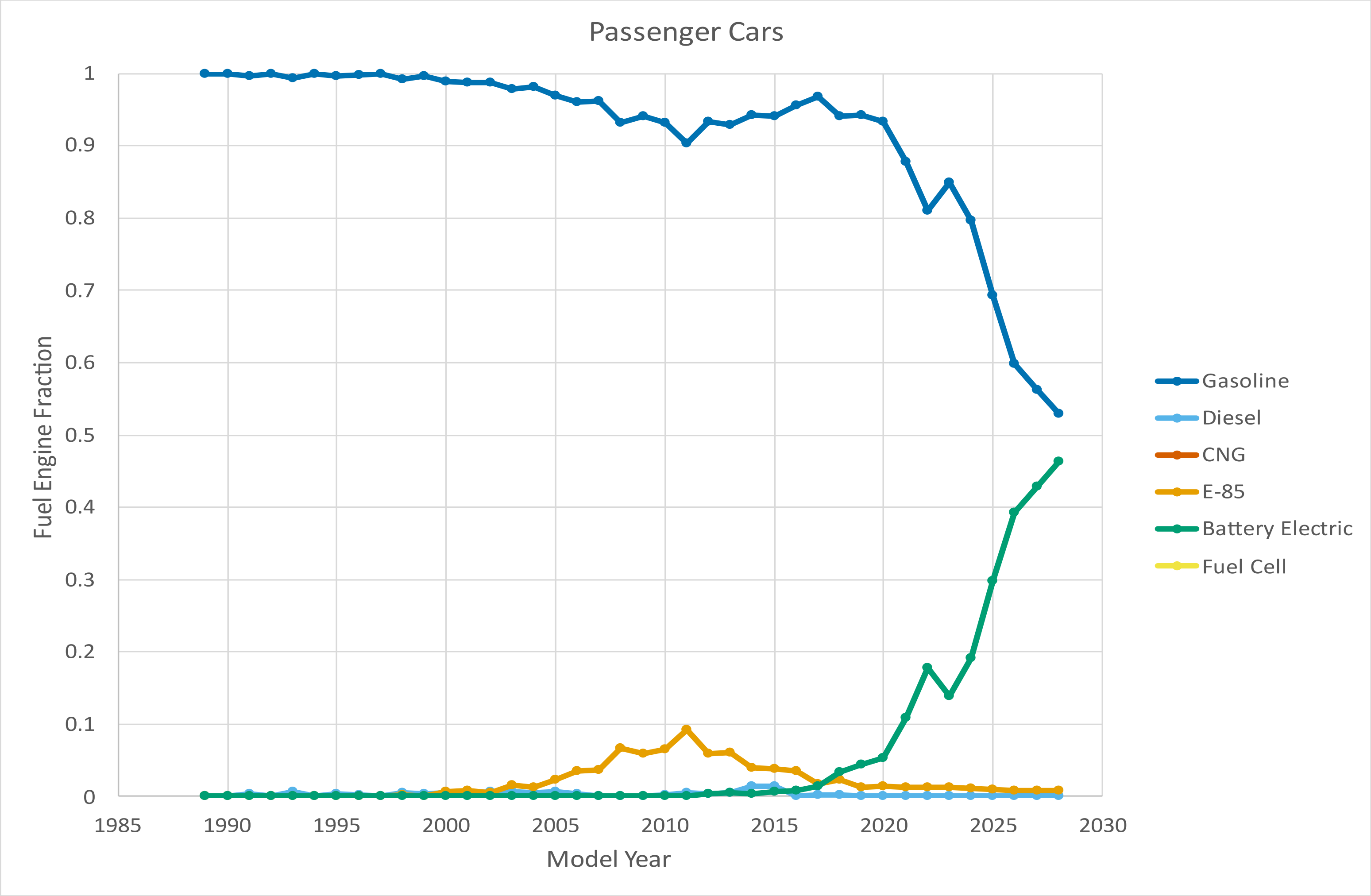


Capstone CDM: Fuel (15)

Best practice is to always review the results of any tool.

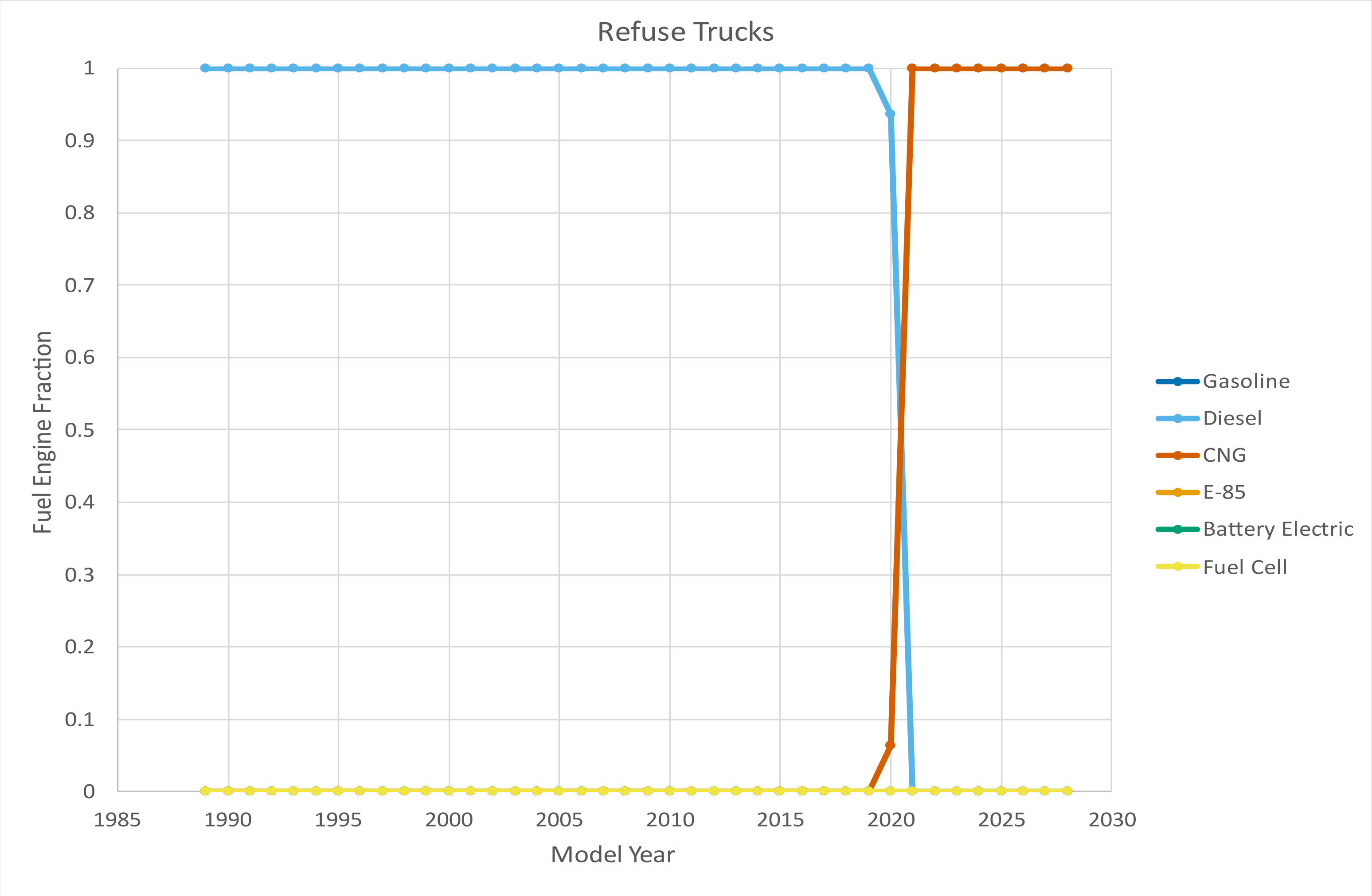
Open *avft tool output 2028.xlsx* and review results.

Note that the result charts require Excel 2021 or later to review.



Capstone CDM: Fuel (16)

In particular, review the source types that had known fractions to ensure they were modeled correctly

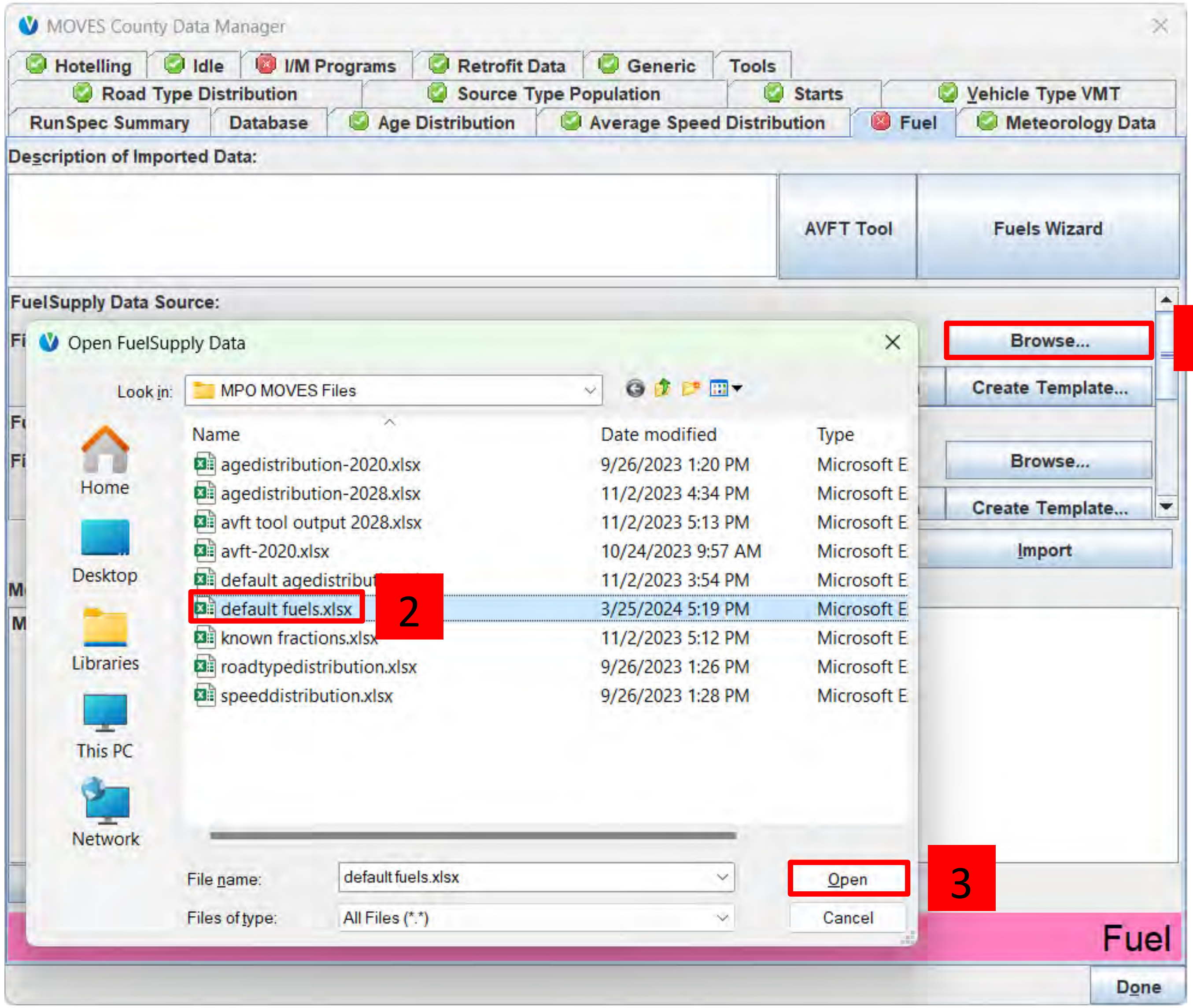


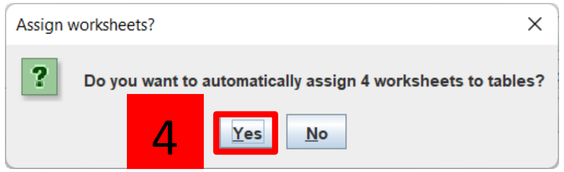
Capstone CDM: Fuel (17)

Now that we've run the AVFT Tool, we're ready to load the results into MOVES.

Reopen the CDM and first load the defaults that we exported as *default fuels.xlsx*.

When MOVES prompts if you want to automatically assign sheets, click yes, because it will save us time from having to manually select Fuel Supply, Fuel Formulation, and Fuel Usage Fraction

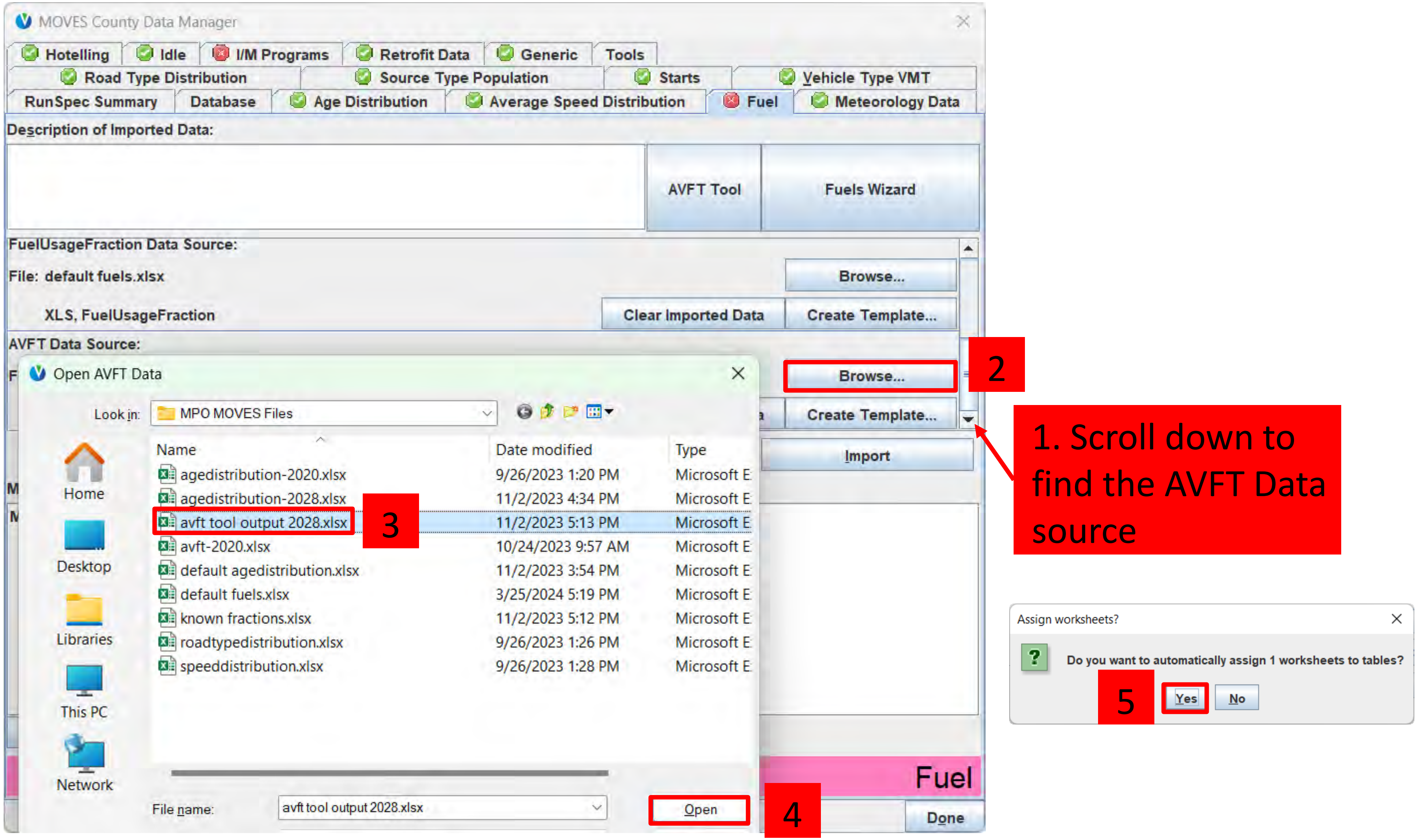




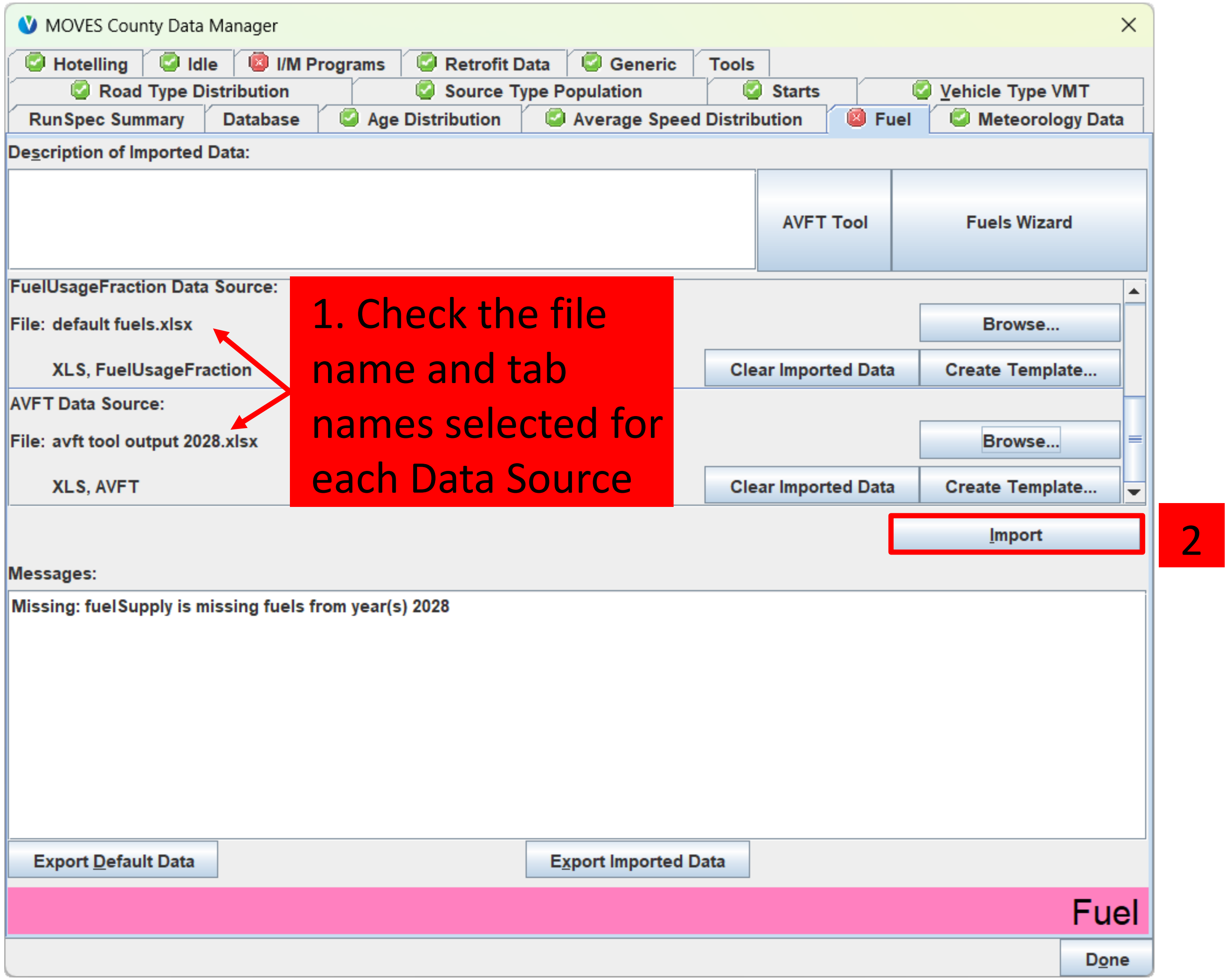
Capstone CDM: Fuel (18)

That automatically assigned all data sources. But we need to use *avft tool output 2028.xlsx* for the AVFT data source, so we'll need to manually specify that file.

When MOVES prompts if you want to automatically assign sheets, click yes, because it will only automatically assign 1 sheet, the AVFT sheet.

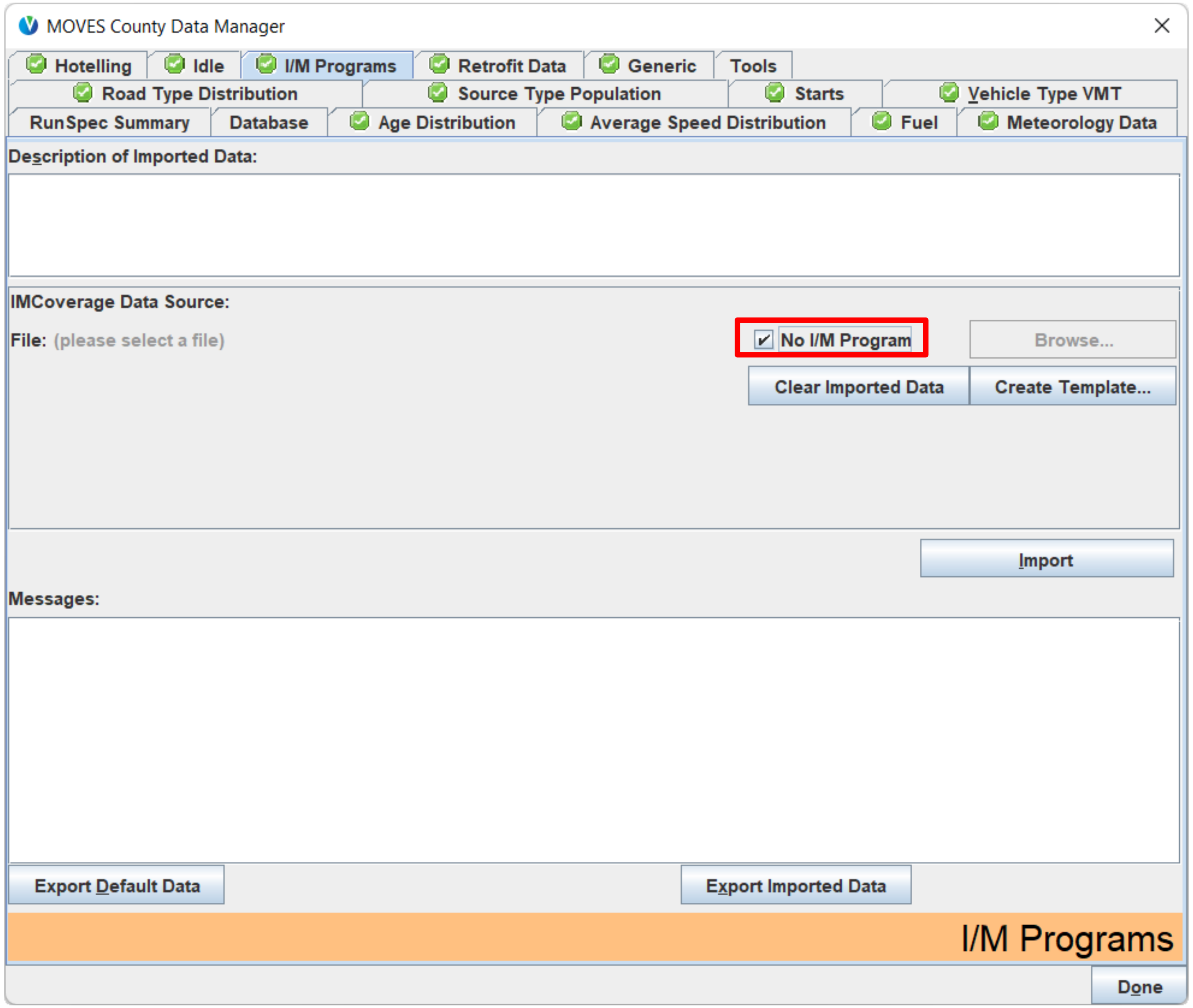


Capstone CDM: Fuel (19)



Capstone CDM: I/M Programs

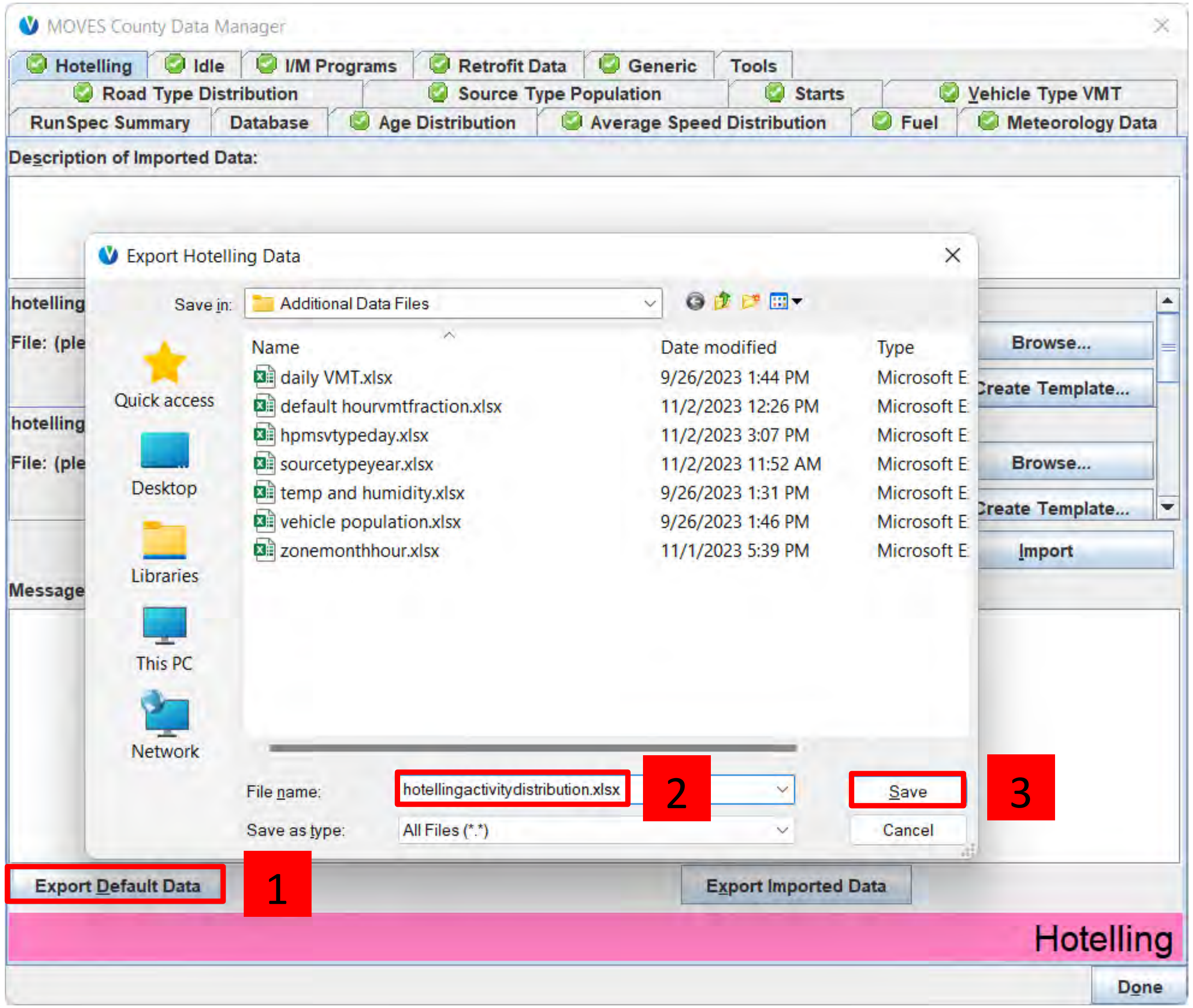
The scenario is for Washtenaw County, Michigan, which does not have an I/M program.



Capstone CDM: Creating a Plan for Hotelling

- Scenario states that all diesel MY2009 and older combination long-haul trucks will be required to use truck stop electrification (i.e., shore power)
- In MOVES, different kinds of hotelling activity are allocated using the HotellingActivityDistribution table
- To provide this input, we will export the defaults and modify them to reflect this scenario

Capstone CDM: Hotelling (1)



Capstone CDM: Hotelling (2)

Original content of the hotellingActivityDistribution tab in hotellingactivitydistribution.xlsx

	A	B	C	D	E	F	G
1	zoneID	fuelTypeID	beginModelYearID	endModelYearID	opModeID	opModeFraction	
2	261610	2	1960	2009	200	0.8	
3	261610	2	1960	2009	201	0	
4	261610	2	1960	2009	203	0	
5	261610	2	1960	2009	204	0.2	
6	261610	2	2010	2020	200	0.73	
7	261610	2	2010	2020	201	0.07	
8	261610	2	2010	2020			
9	261610	2	2010	2020			
10	261610	2	2021	2023			
11	261610	2	2021	2023			
12	261610	2	2021	2023			
13	261610	2	2021	2023			
14	261610	2	2024	2026			
15	261610	2	2024	2026			
16	261610	2	2024	2026			
17	261610	2	2024	2026			
18	261610	2	2027	2060			
19	261610	2	2027	2060			
20	261610	2	2027	2060			
21	261610	2	2027	2060			

hotellingActivityDistribution | Ag ...

Modified content

	A	B	C	D	E	F	G
1	zoneID	fuelTypeID	beginModelYearID	endModelYearID	opModeID	opModeFraction	
2	261610	2	1960	2009	200	0	
3	261610	2	1960	2009	201	0	
4	261610	2	1960	2009	203	1	
5	261610	2	1960	2009	204	0	
6	261610	2	2010	2020	200	0.73	
7	261610	2	2010	2020	201	0.07	
8			2010	2020	203	0	
9			2010	2020	204	0.2	
10			2021	2023	200	0.48	
11			2021	2023	201	0.24	
12			2021	2023	203	0	
13			2021	2023	204	0.28	
14			2024	2026	200	0.4	
15			2024	2026	201	0.32	
16			2024	2026	203	0	
17			2024	2026	204	0.28	
18			2027	2060	200	0.36	
19			2027	2060	201	0.32	
20			2027	2060	203	0	
21			2027	2060	204	0.32	

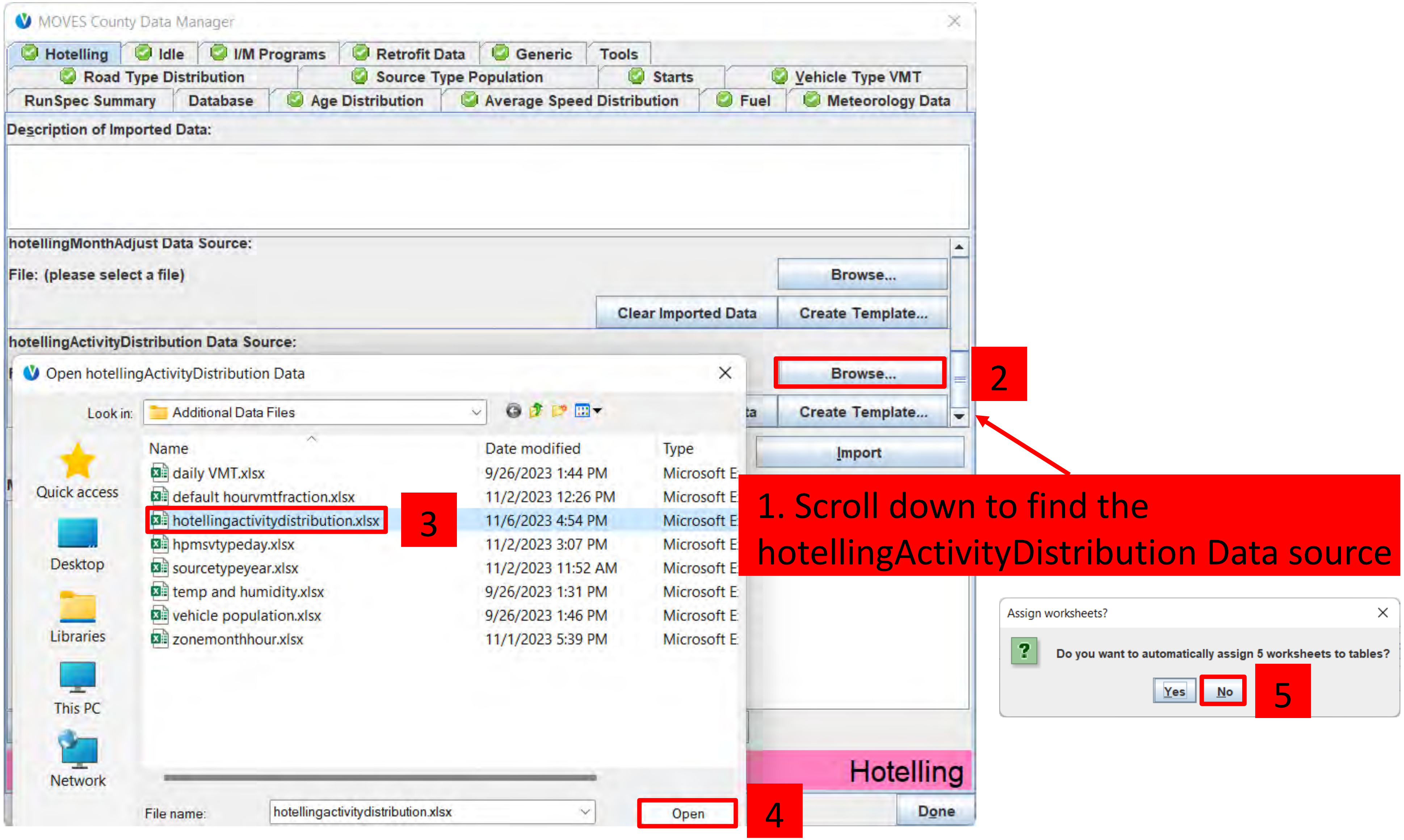
hotellingActivityDistribution | Ag ...

Find the rows associated with fuelTypeID 2 (diesel) and have a model year range from 1960-2009. Change the opModeFraction to 1 for opModeID 203 (shore power) and 0 for the other opModeIDs, then save. Do not change any other values.

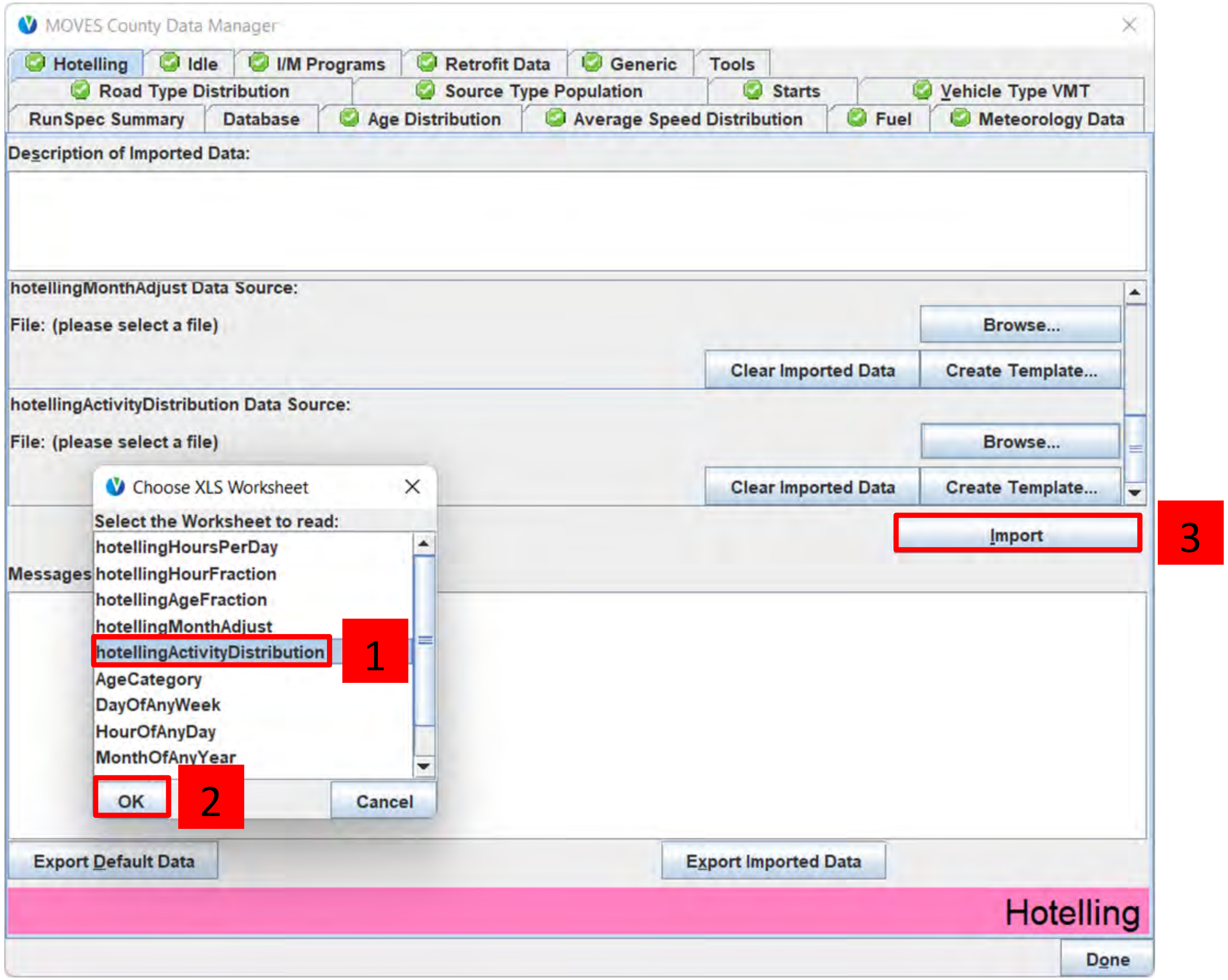
Capstone CDM: Hotelling (3)

After updating the hotelling activity distribution to reflect 100% shore power for MY2009 and earlier diesel trucks, we need to import the data.

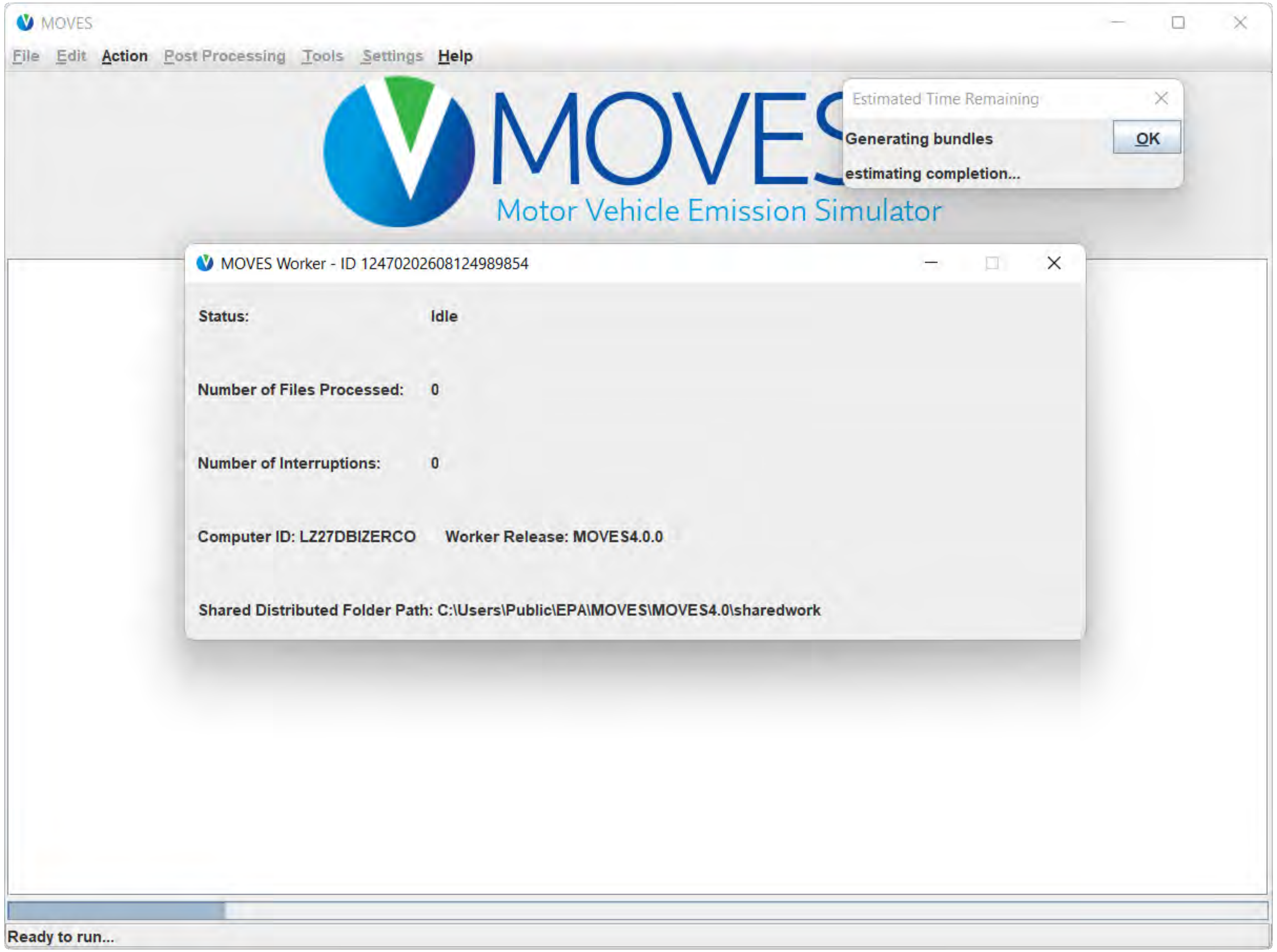
When MOVES prompts if you want to automatically assign sheets, click No, because we only want to import data from one tab of our file.



Capstone CDM: Hotelling (4)



Capstone: Run MOVES



Capstone: Post-Process the Results

```
SELECT MOVESRunID, yearID, monthID, dayID, pollutantID,
 SUM(emissionQuant) AS grams
FROM washtenaw_2028_capstone_out.movesoutput
GROUP BY MOVESRunID, yearID, monthID, dayID,
 pollutantID;
```

movesoutput (1r × 6c)

MOVESRunID	yearID	monthID	dayID	pollutantID	grams
1	2028	1	5	2	30604863.149166677

Capstone: Extra Credit

These steps are not shown, but should be performed for best practices:

- Check `moveserror` for any error messages
- Check that `movesactivityoutput` has the correct VMT and population values
- Document your run by saving the RunSpec file, input and output databases, tool inputs and results, along with a narrative description of:
  - Data and analysis used to populate the input database
  - Any other methods and assumptions, including methods and files used to post-process output

Module 8 Questions?

MOVES

Motor Vehicle Emission Simulator

Module 9:
Modeling Nonroad Emissions

MOVES

Motor Vehicle Emission Simulator

EPA

Module 9 Overview

- Past, present, and future of modeling nonroad emissions
- Overview of Nonroad in MOVES4
- Instruction and hands-on demonstration of Nonroad in MOVES
  - Instructional slides are intermingled with the exercise

Module 9 Key References

- MOVES4 Technical Guidance: Using MOVES to prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA-420-B-23-011), August 2023
  - Section 5 covers Nonroad
- Port Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions
  - Guidance covers how to use MOVES-Nonroad to estimate emissions of cargo handling equipment and recreational marine sectors
- MOVES4 Nonroad Cheat Sheet
  - Found within the MOVES4 GUI's Help menu
  - Also on GitHub

History of Modeling Nonroad Emissions

- NONROAD
  - A predecessor to MOVES that estimated emissions from nonroad equipment
  - Draft release in 1998
  - Final version was NONROAD2008
- MOVES2014
  - Incorporated standalone NONROAD2008 into MOVES framework
  - MOVES2014a: Added VOC, TOG, NMHC, NMOG, plus about 60 air toxics, more output aggregation options, and updated fuels
  - MOVES2014b: Updated equipment growth estimates for every sector, diesel Tier 4 emission rates, and post-processing scripts
- MOVES3 & MOVES4
  - Fixed minor bugs
  - Updated fuel information

Nonroad Guidance

- Which model should I use?
  - Use MOVES4 for nonroad inventory development
- What data should I use?
  - It is acceptable to use default nonroad fleet and activity data for SIPs and other regulatory submissions
  - You can use local fleet and activity data if available. Contact us at mobile@epa.gov with questions about how to do this

Future of Nonroad Modeling

- Future revisions may include:
  - New emissions, activity, and fleet data
  - New algorithms for calculating emissions
  - New design
- Still in the early planning stages for additional revisions
  - Timetable is not yet determined
- Goal is for MOVES to be a comprehensive model that covers most types of mobile sources in a consistent way

Overview of Nonroad in MOVES (1)

- Heavy reliance on national defaults applied at the county level
  - Local activity and fleet data can be hard to develop
  - MOVES-Nonroad uses surrogates (construction activity, acreage farmed, etc.) to allocate national data to the county level
- MOVES-Nonroad produces inventory output
  - Emission rates can be derived using post-processing scripts
- MOVES-Nonroad inventory output is for a single day with no hourly detail or other aggregation options
  - Post-processing scripts may be used if aggregation to a longer time period is needed

Overview of Nonroad in MOVES (2)

- Nonroad equipment divided into 12 sectors with 91 equipment types
  - Not included: locomotives, commercial marine, and aircraft
- Pollutants and Processes detail more limited than for onroad
- See MOVES documentation and access to MOVES source code on [GitHub]

MOVES-Nonroad Sectors:
- Construction
- Agriculture
- Industrial
- Lawn & Garden
- Logging
- Railroad Maintenance
  - *Excludes locomotives*
- Recreational Vehicles
- Pleasure Craft
  - *Recreational marine only; excludes commercial marine vessels*
- Airport ground support
  - *Excludes aircraft*
- Oil field
- Underground mining

Building a Nonroad RunSpec with a Hands-On Exercise

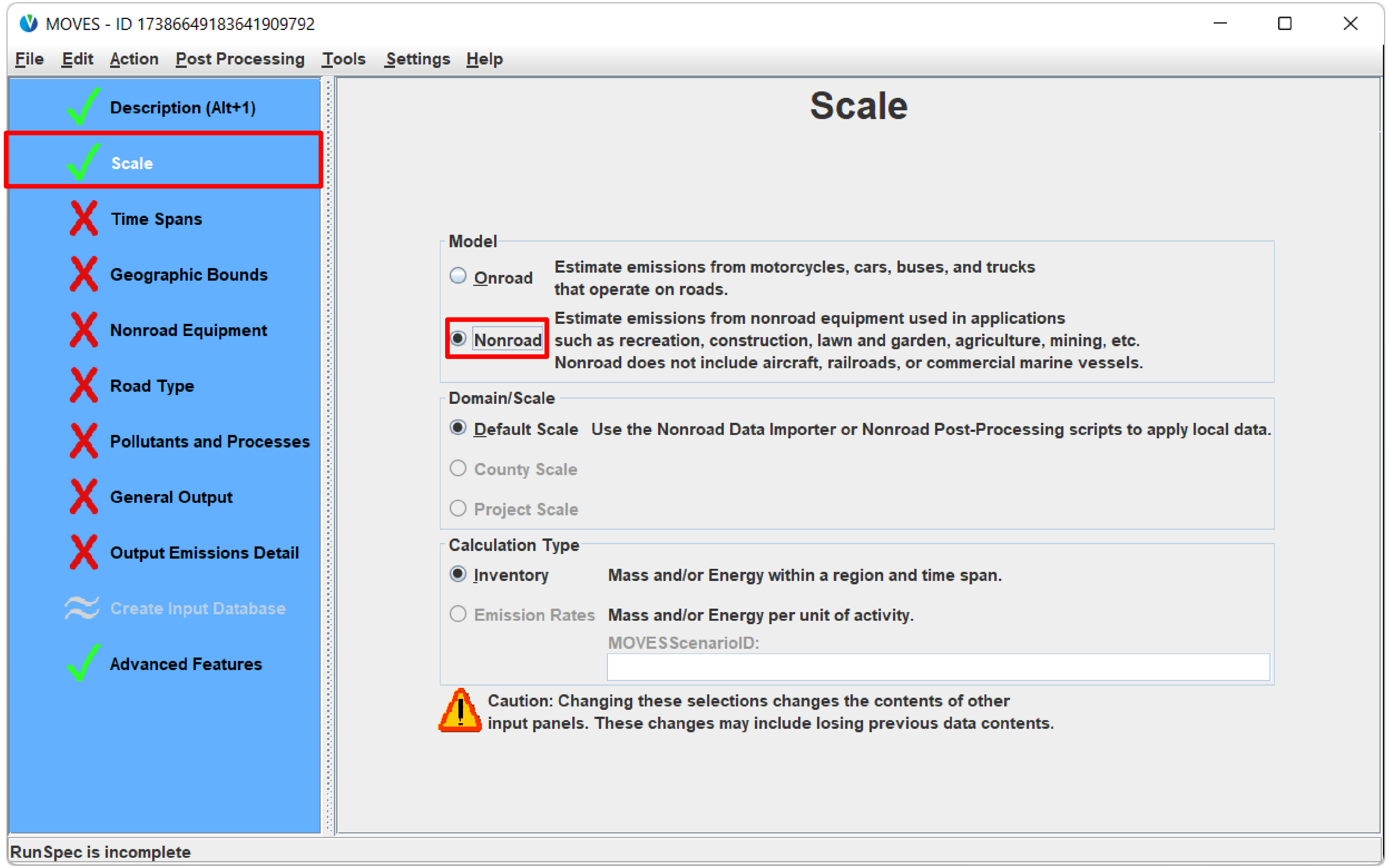
Nonroad Hands-On Exercise Overview

- The goal of the exercise is to estimate an emission inventory for a construction site in Washtenaw County, Michigan on a July 2023 weekday
- We have specific equipment populations that we will use in our calculations (provided on later slides)
- Approach:
  1. Create and populate a new RunSpec
  2. Run MOVES and a post-processing script
  3. Calculate inventory in Excel

Nonroad RunSpec: Scale

- Select “Nonroad” on the Scale panel to enable the Nonroad model options
- “Default” is only option for Scale
  - For the most part, Nonroad relies on default data
  - However, a few local inputs are available for input via the Nonroad Data Importer
- “Inventory” is only option for Calculation Type
  - Several scripts are available in the Post Processing menu to calculate emission factors from inventory results

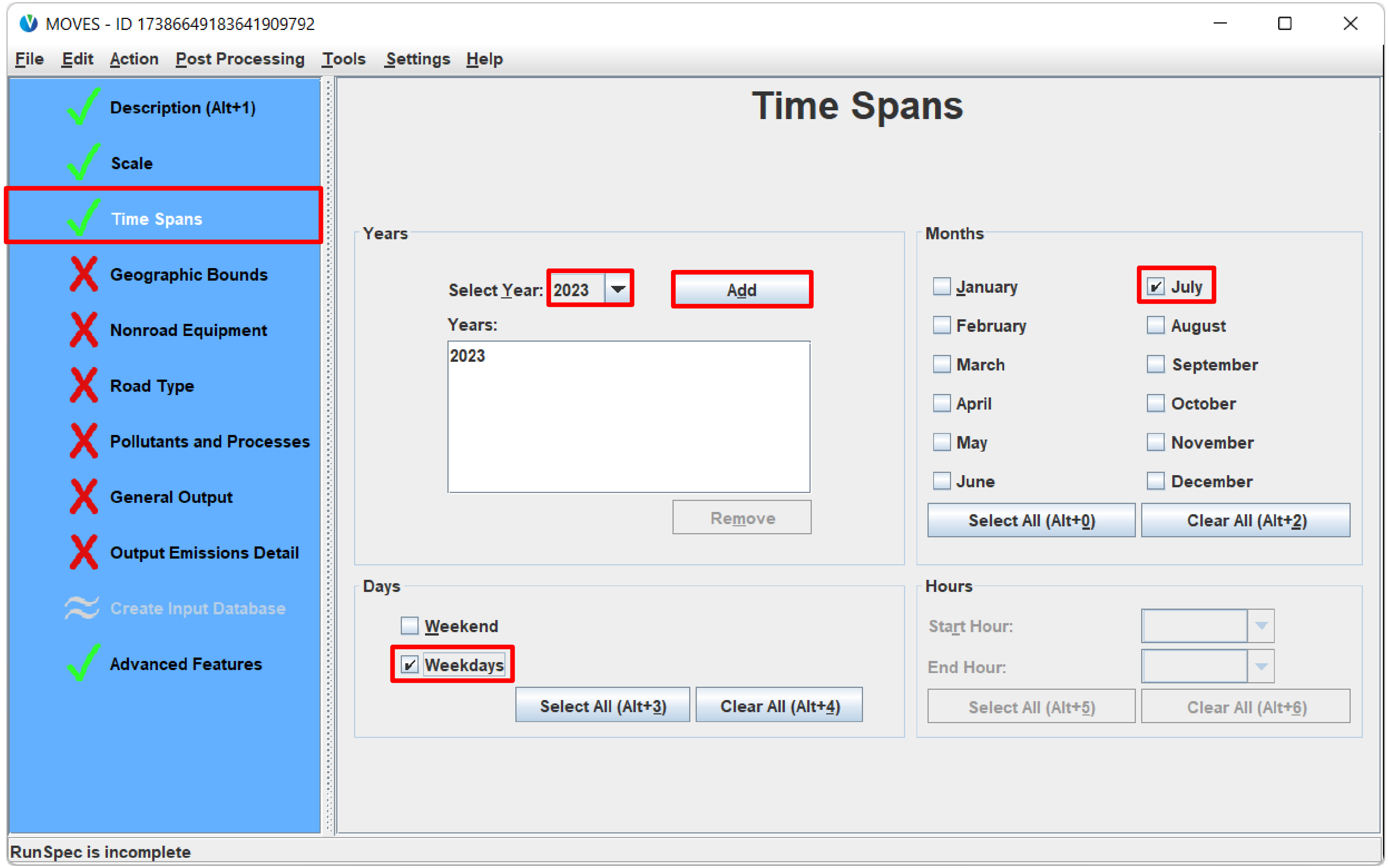
Nonroad Exercise: Scale



Nonroad RunSpec: Time Spans

- Nonroad emissions in MOVES are calculated on a daily basis
  - No options for running individual hours
  - No temporal preaggregation options on the Advanced Features Panel
- For the exercise, select:
  - 2023
  - July
  - Weekdays

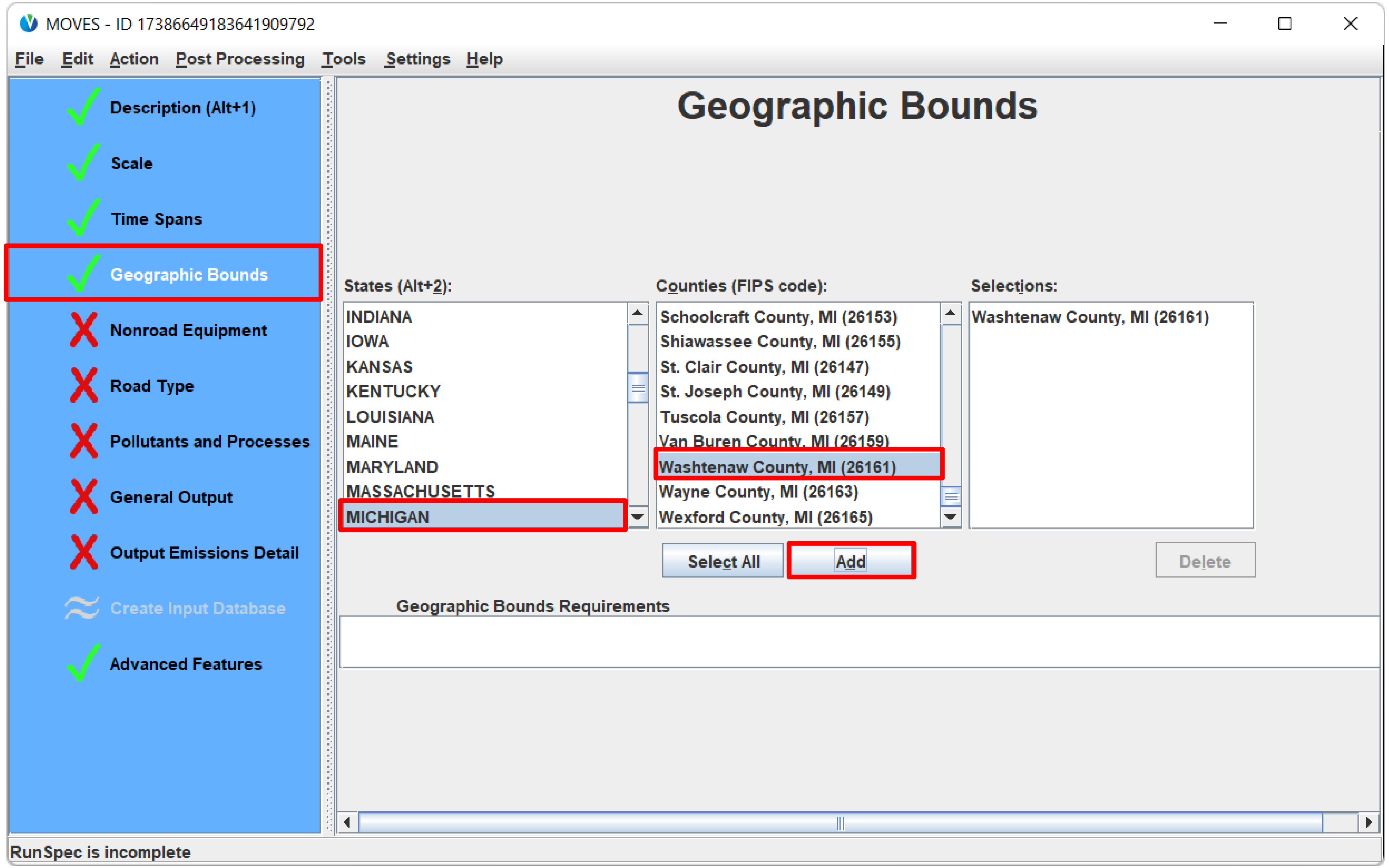
Nonroad Exercise: Time Spans



Nonroad RunSpec: Geographic Bounds

- Select county or counties of interest
  - Can run multiple counties in a single run
- Nation preaggregation is available on Advanced Features Panel
  - If this is selected, no further selections are necessary on the Geographic Bounds Panel
  - Note: State pre-aggregation is not an option for Nonroad
- For the exercise, select:
  - Michigan
  - Washtenaw County

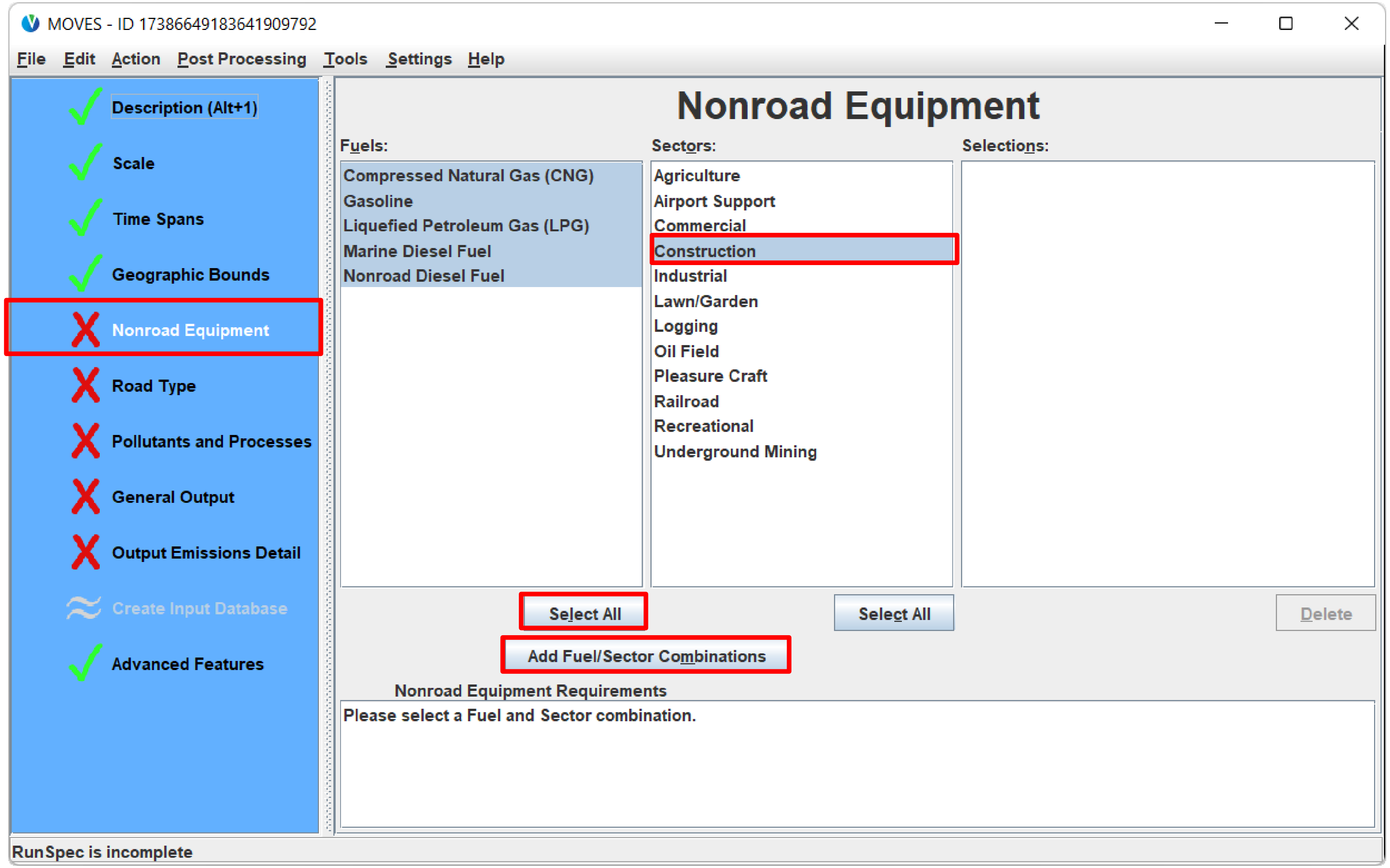
Nonroad Exercise: Geographic Bounds



Nonroad RunSpec: Nonroad Equipment

- Nonroad allocates activity to each sector in a county based on various surrogates:
  - Farmed acreage for agriculture, construction starts for construction, etc.
- To model a complete nonroad inventory, select all fuel types and all sectors
  - However, to manage output file size and post-processing time, you may want to divide sectors between multiple runs
- For this exercise, select all fuel types and only the Construction sector

Nonroad Exercise: Nonroad Equipment



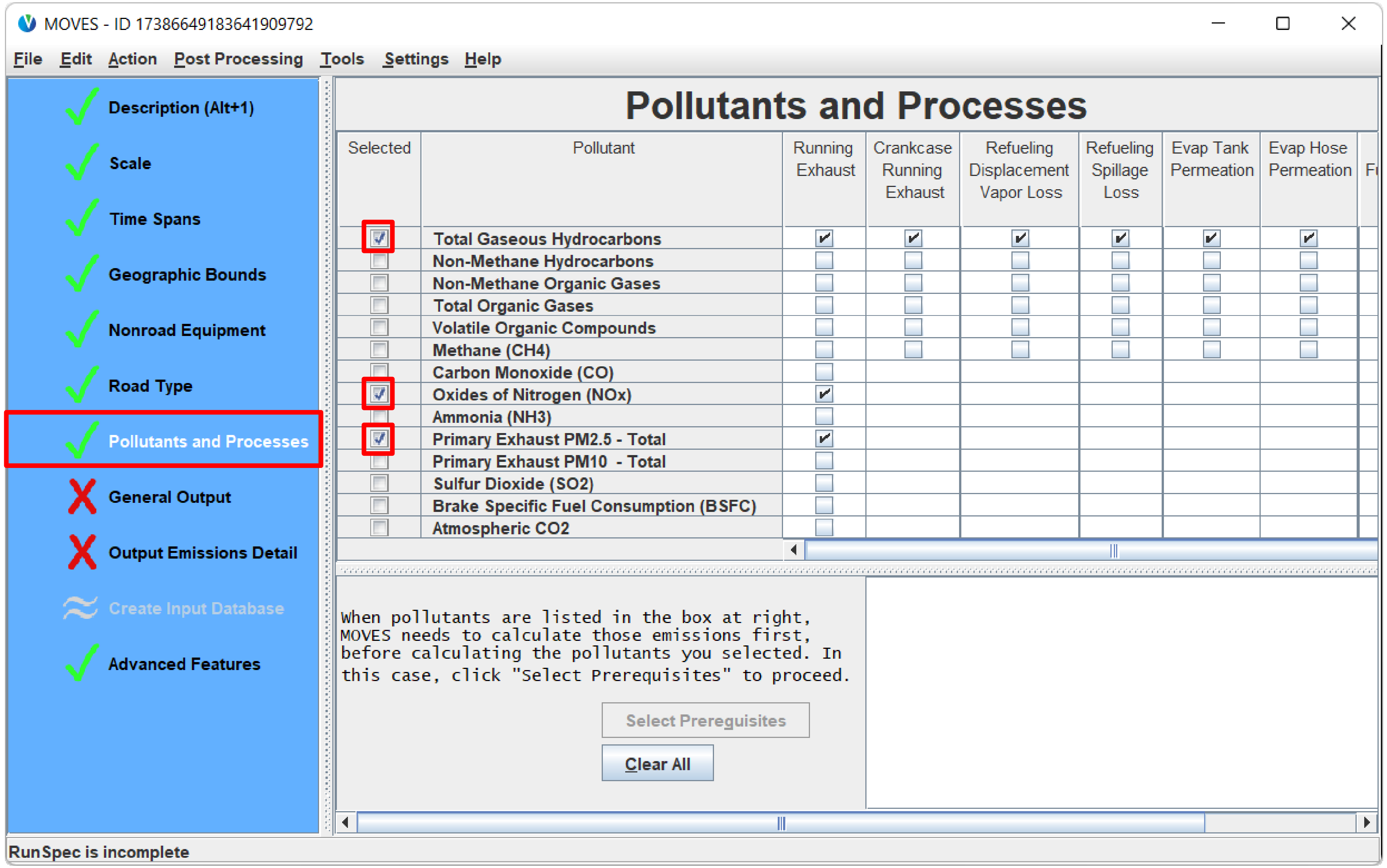
Nonroad RunSpec: Road Type

- Doesn't apply to Nonroad
- Click on Road Type in navigation panel to get green check

Nonroad RunSpec: Pollutants and Processes

- Nonroad has different pollutant/process selections than onroad
  - All primary criteria pollutants are included
  - Does not model nitrous oxide (N_2O, a greenhouse gas)
  - Less speciation detail than onroad
  - Less differentiation by process than onroad
- For this exercise, select all processes for:
  - Total Gaseous HC
  - Oxides of Nitrogen
  - Primary Exhaust PM2.5

Nonroad Exercise: Pollutants and Processes



Nonroad RunSpec: General Output (1)

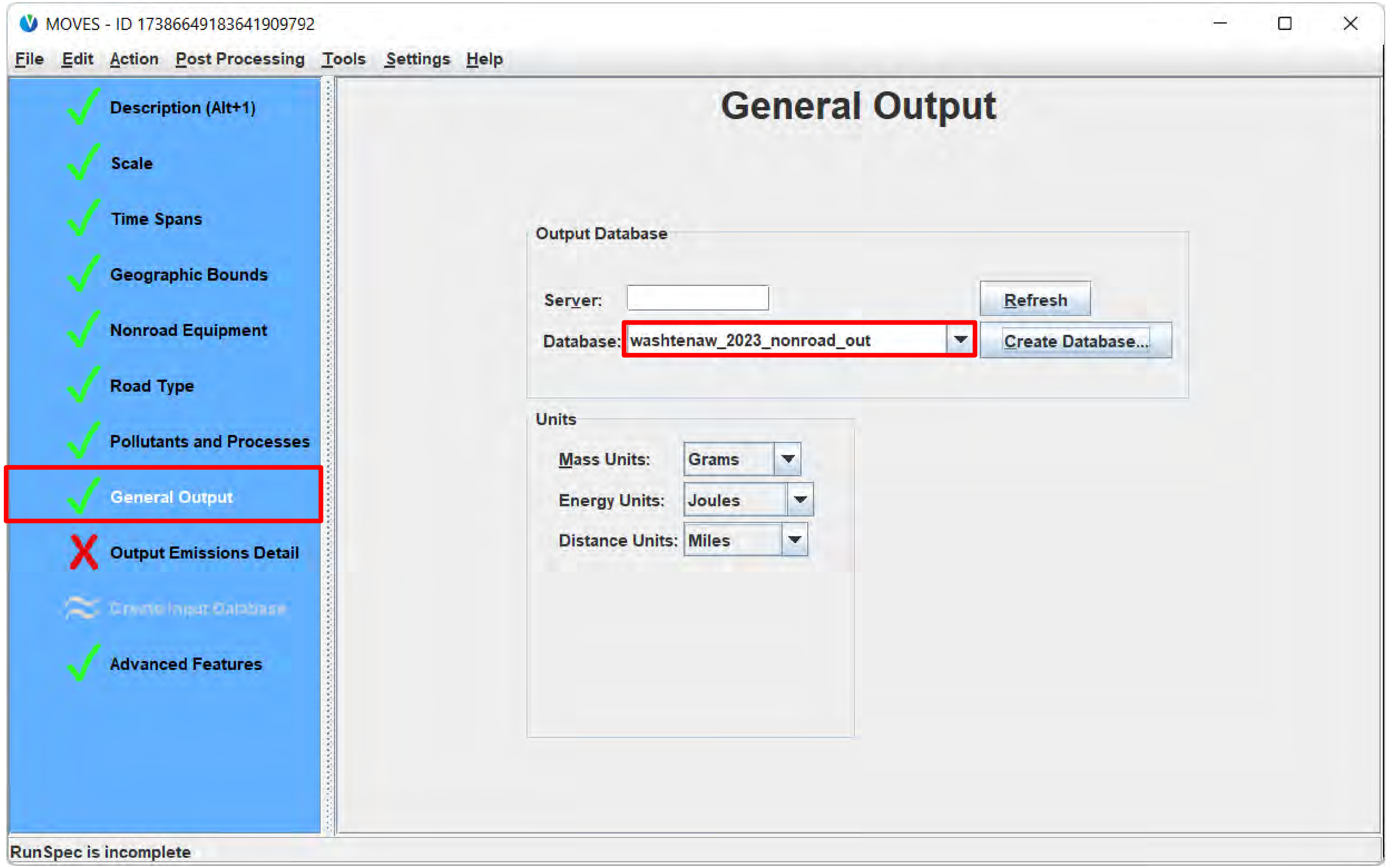
- The only required input on this panel is the name of the output database
  - Tip: end output database names with "_out" to clearly indicate they contain output
  - Enter a unique name to have MOVES make a new output database, unless you want to use one already made
- You can store output from multiple MOVES runs (i.e., multiple RunSpecs) in the same database
  - Data is stored in the same tables as onroad
  - Not recommended to store onroad and nonroad output in the same database because they use different columns

Nonroad RunSpec: General Output (2)

- There are no activity selections on this panel
- However, Nonroad output always includes the following activity measures:

Activity Output Options	Notes
Source Hours	Hours of equipment activity
Population	Number of equipment (not people)
Average Horsepower	Average rated engine size in horsepower
Load Factor	A factor between 0 and 1 representing average engine power output as a fraction of the rated engine size

Nonroad Exercise: General Output



Nonroad RunSpec: Output Emissions Detail (1)

- All output will be for a 24-hour day
  - No other temporal aggregation options
- The emissions will be reported as daily emissions for each day type, month, and year selected in the RunSpec
- These are "typical days"
- If both day types are run:
  - Summing across both day types will NOT result in weekly or monthly emissions
  - You must multiply the daily emissions by the number of times those day types occur to calculate weekly or monthly emissions

Nonroad RunSpec: Output Emissions Detail (2)

- Nonroad output can be differentiated by some of the same categories as onroad:
  - Model year
  - Fuel type
    - Nonroad also has the ability to report fuel subtype. For example, it can distinguish emissions from equipment using gasoline with various ethanol content (E0 vs E10)
  - Emission process
  - SCC
    - Nonroad SCCs uniquely identify equipment types and fuel types. Select this option if you want results by equipment type

Nonroad RunSpec: Output Emissions Detail (3)

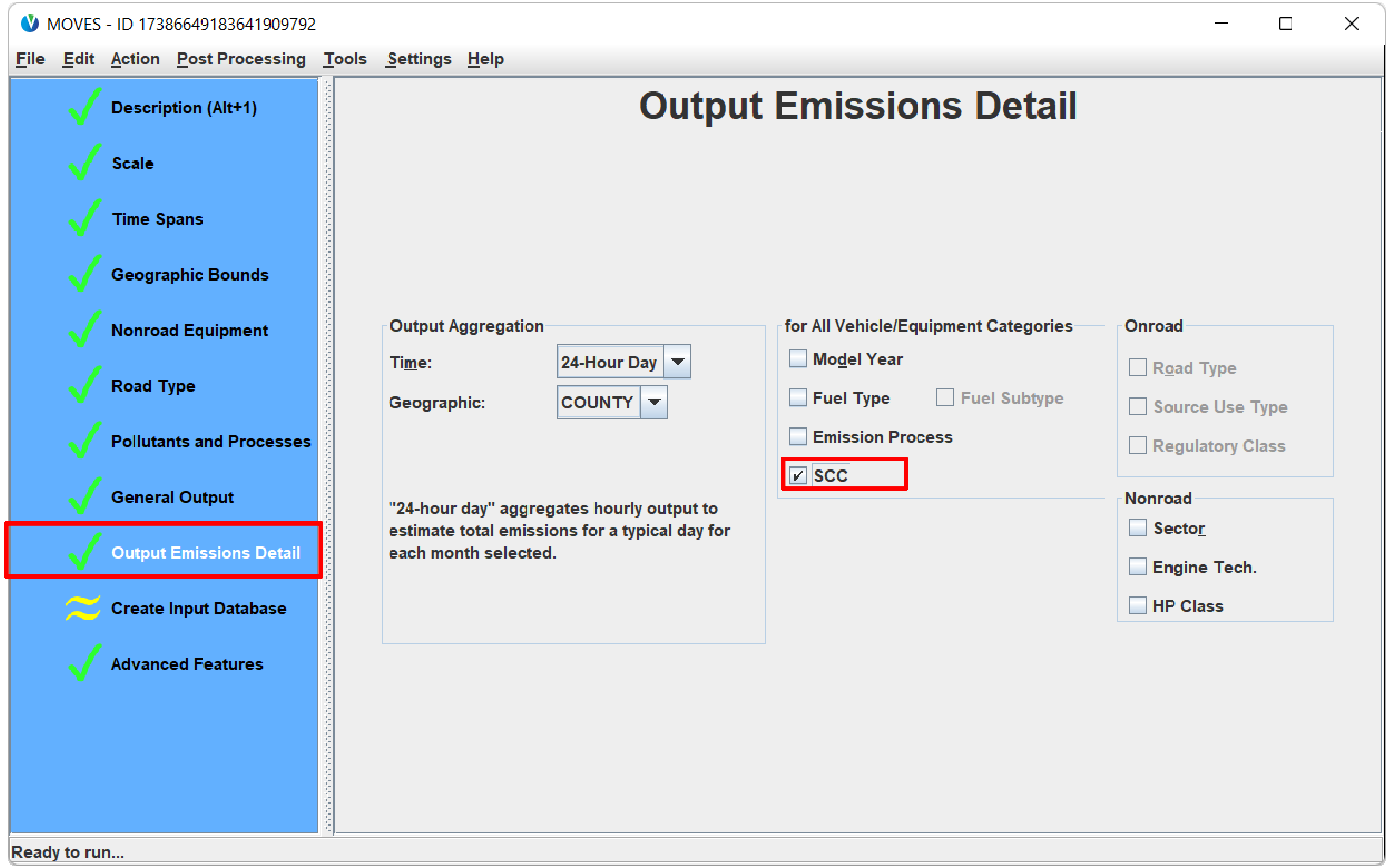
- Nonroad output can also include the following detail:
  - Sector
    - This corresponds to the sectors listed on the Nonroad Equipment Panel
  - Engine technology
    - If selected, emissions will be estimated by regulatory tier (e.g., diesel Tier 4)
  - Horsepower class
    - Emissions will be estimated for the 18 horsepower range bins in MOVES nonroad

hpID	Description	hpID	Description	hpID	Description
1	0 < hp <= 1	**40**	25 < hp <= 40	**600**	300 < hp <= 600
3	1 < hp <= 3	**50**	40 < hp <= 50	**750**	600 < hp <= 750
6	3 < hp <= 6	**75**	50 < hp <= 75	**1000**	750 < hp <= 1000
11	6 < hp <= 11	**100**	75 < hp <= 100	**1200**	1000 < hp <= 1200
16	11 < hp <= 16	**175**	100 < hp <= 175	**2000**	1200 < hp <= 2000
25	16 < hp <= 25	**300**	175 < hp <= 300	**3000**	2000 < hp <= 3000

Nonroad RunSpec: Output Emissions Detail (4)

- Nonroad emissions output can be very granular: If you select all checkboxes and had all sectors selected, the output table for this one-day, one-county run would contain 391,196 rows
- Recommendation: If you plan to use a post-processing script, read the script documentation and select only the details necessary for the script to run
- For this exercise:
  - Select SCC

Nonroad Exercise: Output Emissions Detail



Running the Nonroad Hands-on Exercise

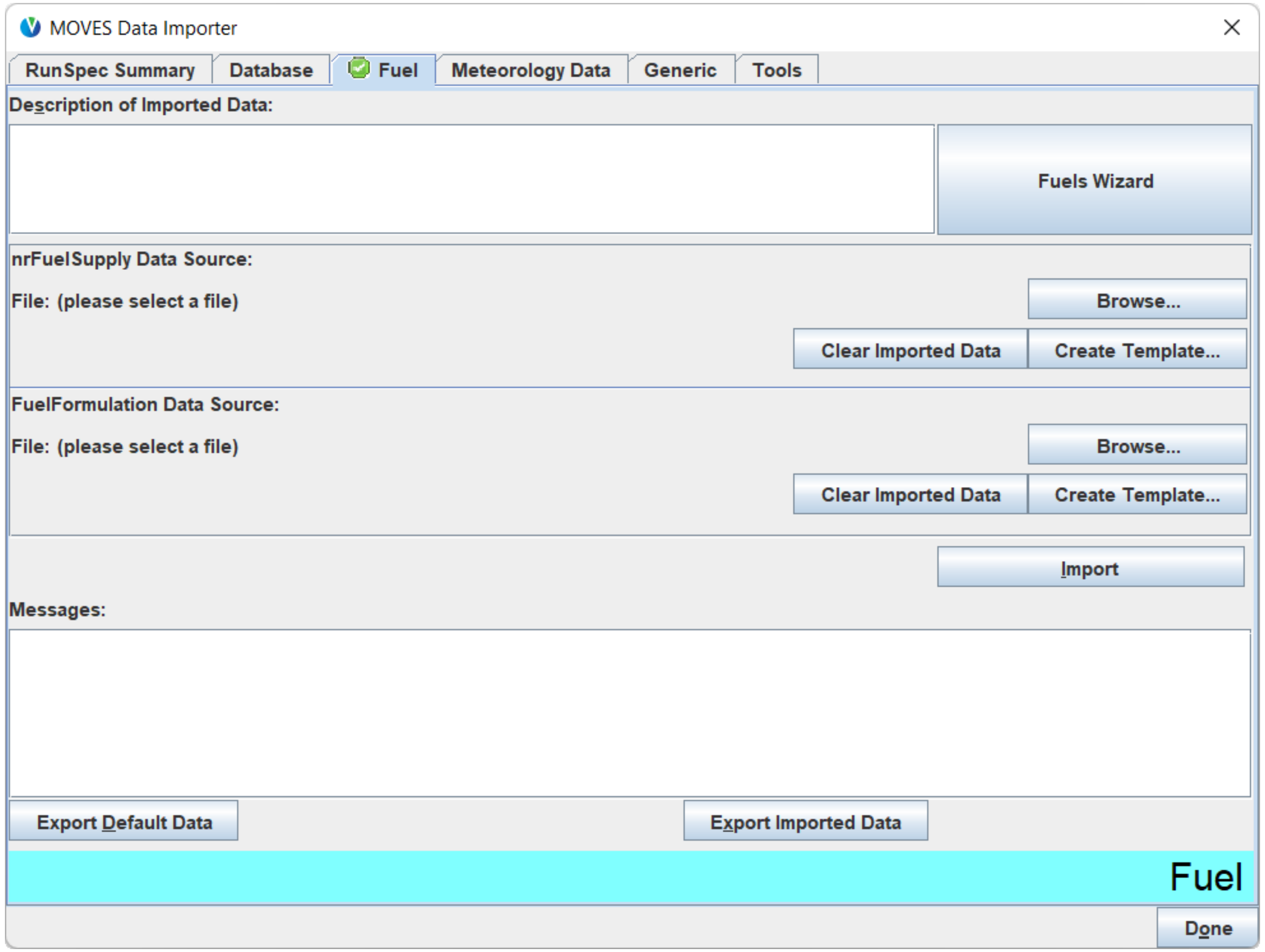
- We are now ready to run MOVES
  - While MOVES is running, we will discuss optional input data for Nonroad, advanced features, and post-processing scripts
- Save and run your RunSpec now
  - The same recommendations for naming RunSpecs apply to Nonroad runs

Nonroad RunSpec: Create Input Database

- Optional for Nonroad
- Only available once all other panels have green checks
- Limited input options:
  - Meteorology
  - Fuels
  - Generic
- Enter the Nonroad Data Importer the same way as with onroad:
  - Click “Enter/Edit Data”, give your database a name, and click “Create Database”

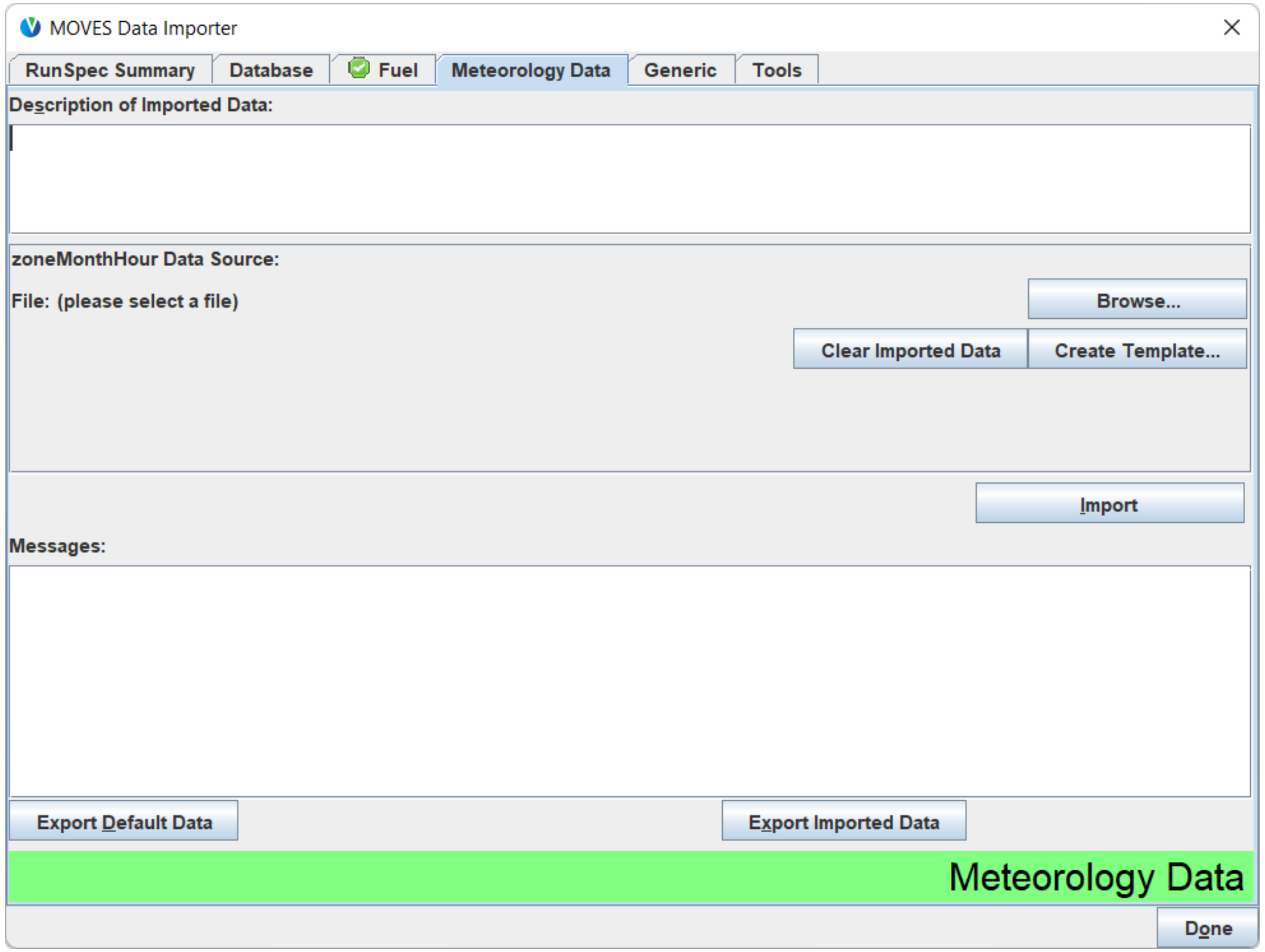
Nonroad Data Importer: Fuel

- Unlike onroad, nonroad only has two tables:
  - nrFuelSupply
  - FuelFormulation
- The same fuels guidance for onroad applies to nonroad
- Note that nonroad has different fuelTypeIDs for some fuels



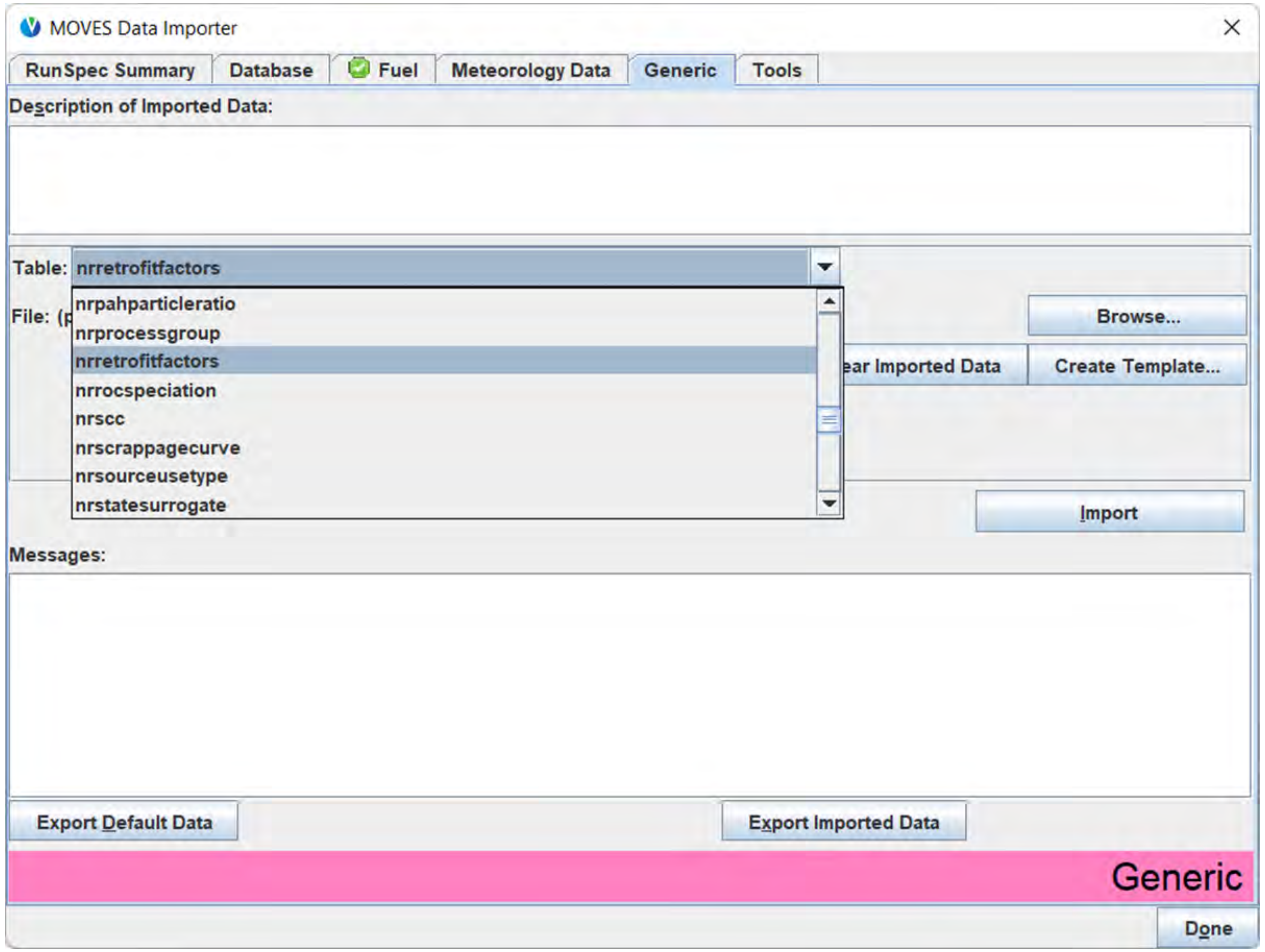
Nonroad Data Importer: Meteorology

- Nonroad has access to the same default meteorology data as onroad
- Important: If estimating both onroad and nonroad inventories, use the same meteorology data for both runs



Nonroad Data Importer: Generic

- If modeling a nonroad retrofit program using the Nonroad Retrofit Tool, you'll use this tab to import the nrretrofitfactors table
- This tab also provides access to all other nonroad tables, which typically begin with "nr" (e.g. nrengtechfraction)
  - These tables are difficult to use
  - Consult with EPA before changing these tables
  - When using local activity data, best practice is to multiply by emission factors generated with MOVES post-processing scripts



Nonroad RunSpec: Advanced Features Panel

- This panel will not be used in most cases, however:
  - If you want to do a national run, indicate that here
  - Input Data Sets selection can be used to import optional nonroad input databases. Optional nonroad input databases can be created on the previous panel, but are automatically specified here
- Note:
  - "Masterloopable", aggregation, and default database options toward the bottom of the panel are for EPA diagnostic work only and are not covered in this course. Recommend you do not use

Nonroad Post Processing Scripts

- Post processing menu contains scripts to process nonroad output into different forms
  - These are only available if you have loaded a Nonroad RunSpec
- 6 Inventory scripts (by county, by equipment type, and by sector)
  - These scripts consolidate inventory output. Often better to just choose desired output with “Output Emissions Detail” in RunSpec
- 1 Population script (by sector and SCC)
- 10 Emission factor scripts
  - Emission factors per horsepower-hour, per operating hour, and per vehicle
  - If you have local activity data, use these scripts to produce emission factors at the relevant level of detail
    - Produces emission factors are specific to year, month, and day type

Nonroad Post Processing Scripts: Emission Factors (1)

Script Title	Description	Select in Output Emissions Detail Panel	To Calculate an Inventory
EmissionFactors_per_hphr_by_*Equipment*.sql	Produces an output table which reports the emission results in g/hp-hour for each *equipment type*	SCC	Multiply emission factors produced by script by total hp-hours for appropriate equipment type
EmissionFactors_per_hphr_by_*Equipment_and_Horsepower*.sql	Produces an output table which reports the emission results in g/hp-hour for each *equipment type and horsepower class*	SCC, HP Class	Multiply emission factors produced by script by total hp-hours for appropriate equipment type and horsepower class
EmissionFactors_per_hphr_by_*SCC*.sql	Produces an output table which reports the emission results in g/hp-hour for each *SCC*	SCC	Multiply emission factors produced by script by total hp-hours for appropriate SCC
EmissionFactors_per_hphr_by_*SCC_and_ModelYear*.sql	Produces an output table which reports the emission results in g/hp-hour for each *SCC, horsepower class, and model year*	SCC, HP Class, Model Year	Multiply emission factors produced by script by total hp-hours for appropriate SCC, horsepower class, and model year

Note: In general, hp-hours = rated horsepower × load factor × total hours per equipment × number of equipment operating

Default load factor assumptions are available in Appendix A of the *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* technical report: http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081RV.pdf.

Sales-weighted mean rated horsepower values for each equipment by type/horsepower category are available in Appendix A of the *Nonroad Engine Population Estimates* technical report: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081T6.pdf.

Nonroad Post Processing Scripts: Emission Factors (2)

Script Title	Description	Select in Output Emissions Detail Panel	To Calculate an Inventory
EmissionFactors_per_OperatingHour_by_*Equipment*.sql	Produces an output table which reports the emission results in g/hour for each *equipment type*	SCC	Multiply emission factors produced by script by total hours of operation (i.e., operating hours) for appropriate equipment type
EmissionFactors_per_OperatingHour_by_*Equipment_and_Horsepower*.sql	Produces an output table which reports the emission results in g/hour for each *equipment type and horsepower class*	SCC, HP Class	Multiply emission factors produced by script by total hours of operation for appropriate equipment type and horsepower class
EmissionFactors_per_OperatingHour_by_*SCC*.sql	Produces an output table which reports the emission results in g/hour for each *SCC*	SCC	Multiply emission factors produced by script by total hours of operation for appropriate SCC
EmissionFactors_per_OperatingHour_by_*SCC_and_ModelYear*.sql	Produces an output table which reports the emission results in g/hour for each *SCC* and *model year*	SCC, Model Year	Multiply emission factors produced by script by total hours of operation for appropriate SCC and model year

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

operating hours = hours of operation per equipment × number of equipment operating

Nonroad Post Processing Scripts: Emission Factors (3)

Script Title	Description	Select in Output Emissions Detail Panel	To Calculate an Inventory
EmissionFactors_per_ Vehicle_by _*Equipment*.sql	Produces an output table which reports the emission results in g/vehicle per day for each *equipment type*	SCC	Multiply emission factors produced by script by total number of vehicle-days for appropriate equipment type
EmissionFactors_per_ Vehicle_by _*Equipment_and* _*Horsepower*.sql	Produces an output table which reports the emission results in g/vehicle per day for each *equipment type and horsepower class*	SCC, HP Class	Multiply emission factors produced by script by total number of vehicle-days for appropriate equipment type and horsepower class
EmissionFactors_per_ Vehicle_by_*SCC*.sql	Produces an output table which reports the emission results in g/vehicle per day for each *SCC*	SCC	Multiply emission factors produced by script by total number of vehicle-days for appropriate SCC

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

vehicle-days = number of equipment operating × number of days of operation

Using Nonroad Post Processing Scripts

- Emission factor scripts can have very long run times depending on the size of the output database
- If you need emission factors:
  - Reduce the size of your output database by choosing just the amount of detail you need in the Output Emissions Detail panel
  - Only select sectors for which you have appropriate activity data
  - Delete equipment types for which you don’t have activity information from the output file before running the script

Manually Deleting Results for Unneeded Equipment Types

- SQL can be used to manually delete equipment types
- For example, if you only had activity data for Pavers (`NREquipTypeID`=6) and Rollers (`NREquipTypeID`=9) in the Construction sector, the following script could be run on your output database in SQL to reduce output to only Pavers and Rollers before running an emission factors script:

Should match the name of *your* output database

```
DELETE output_db.movesoutput FROM output_db.movesoutput
JOIN movesdb20230615.nrscc USING (SCC)
JOIN movesdb20230615.nrequipmenttype USING (NREquipTypeID)
WHERE NREquipTypeID NOT IN (6, 9);
```

- Use Nonroad Cheat Sheet to determine `NREquipTypeIDs`

Before Deleting Records

- We recommend making a copy of your original movesoutput table before deleting records:

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

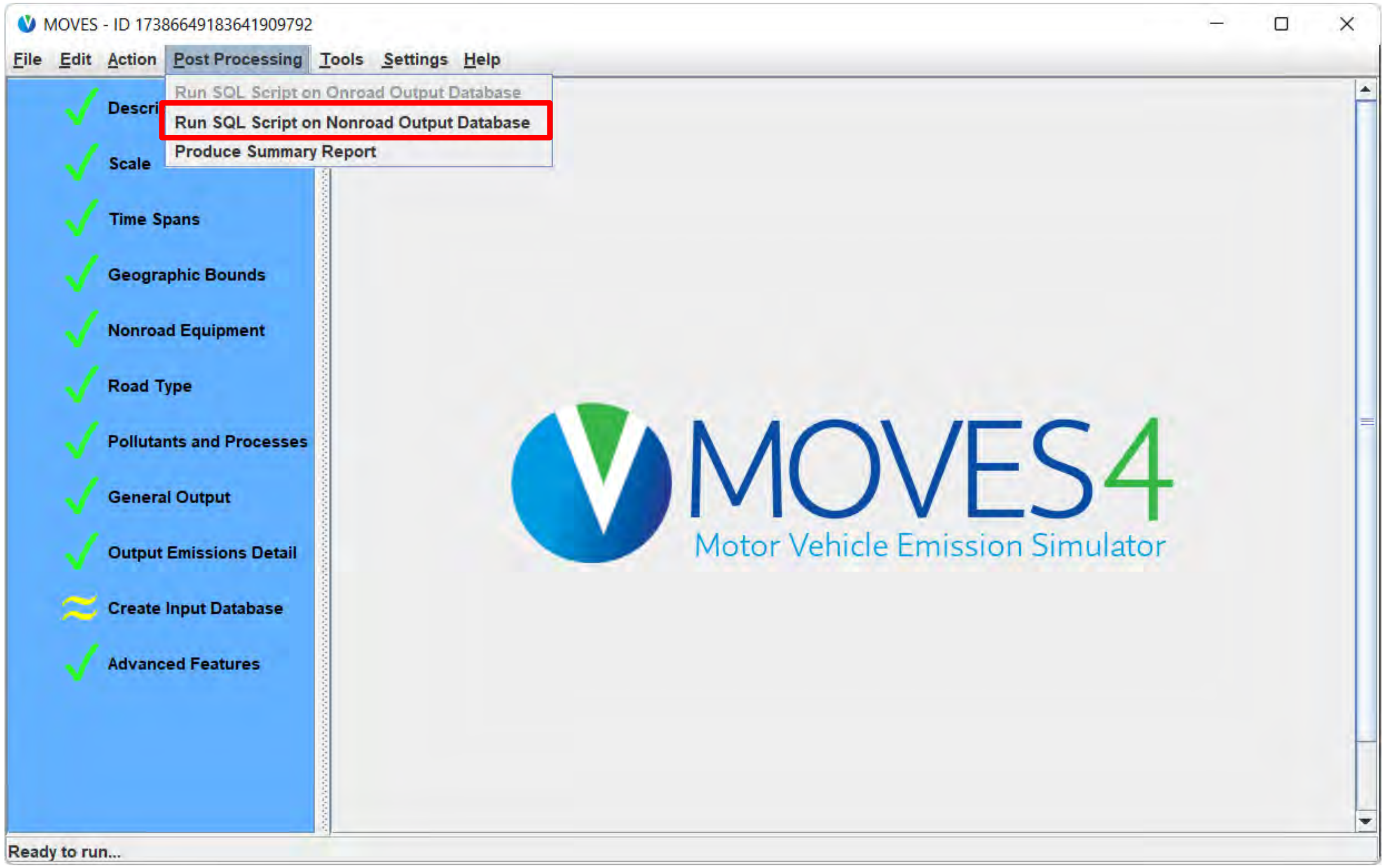
Nonroad Exercise: Example Daily Inventory

- How could you calculate a daily NOx inventory for a construction site with the following diesel equipment operating?
  - 1 paver
  - 5 signal boards
  - 2 cement mixers
  - 3 excavators
  - 1 grader
  - 10 skid steer loaders

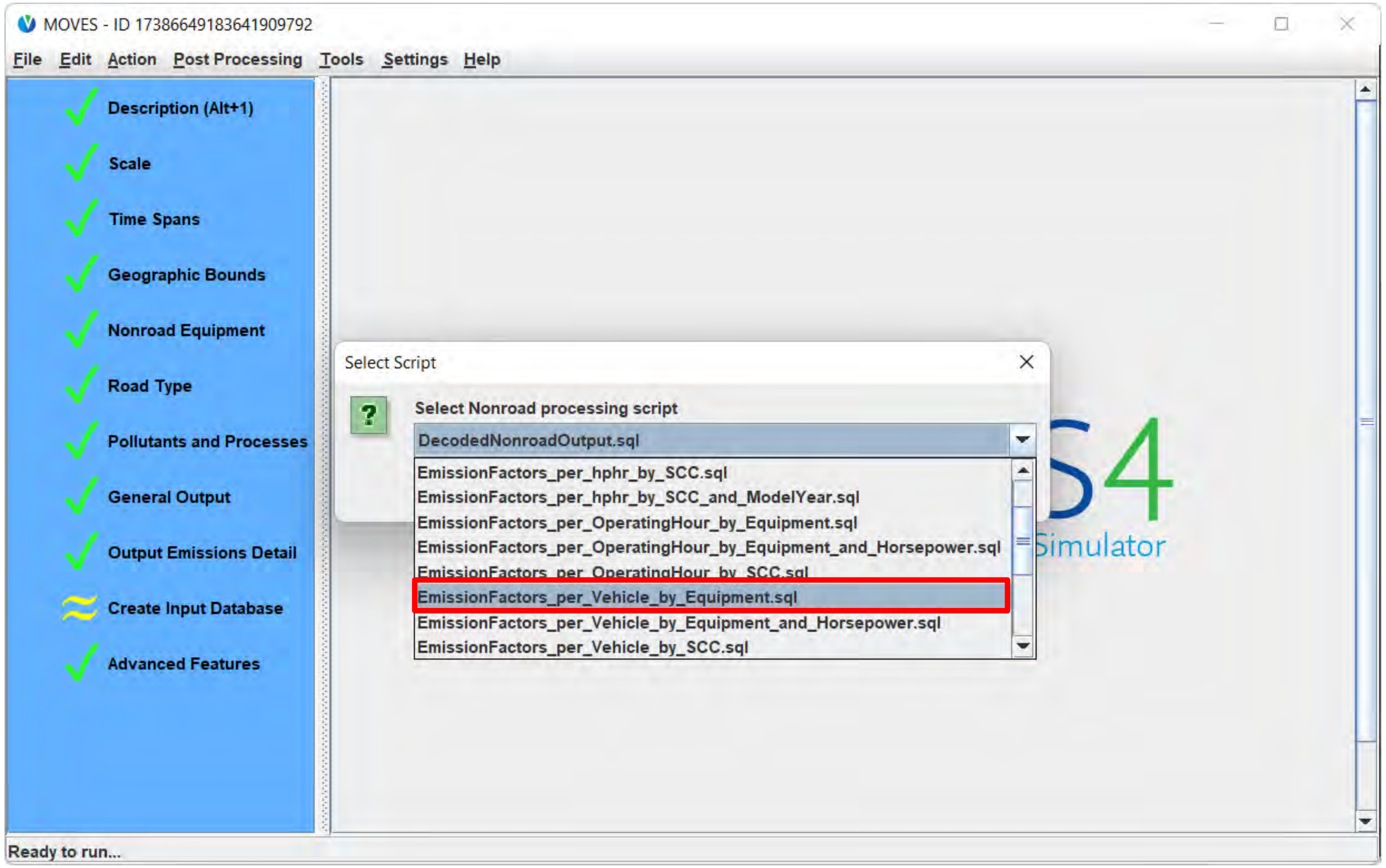
Nonroad Exercise: Example Daily Inventory Knowledge Check

- How could you calculate a daily NOx inventory for a construction site with the following diesel equipment operating?
  - 1 paver
  - 5 signal boards
  - 2 cement mixers
  - 3 excavators
  - 1 grader
  - 10 skid steer loaders
- Since activity is "number of equipment" and we don't have additional detail about the equipment, run the EmissionFactors_per_Vehicle_by_Equipment.sql script
  - Note: the output of this run is not large enough to warrant deleting rows as shown earlier

Nonroad Exercise: Running a Nonroad Post Processing Script (1)

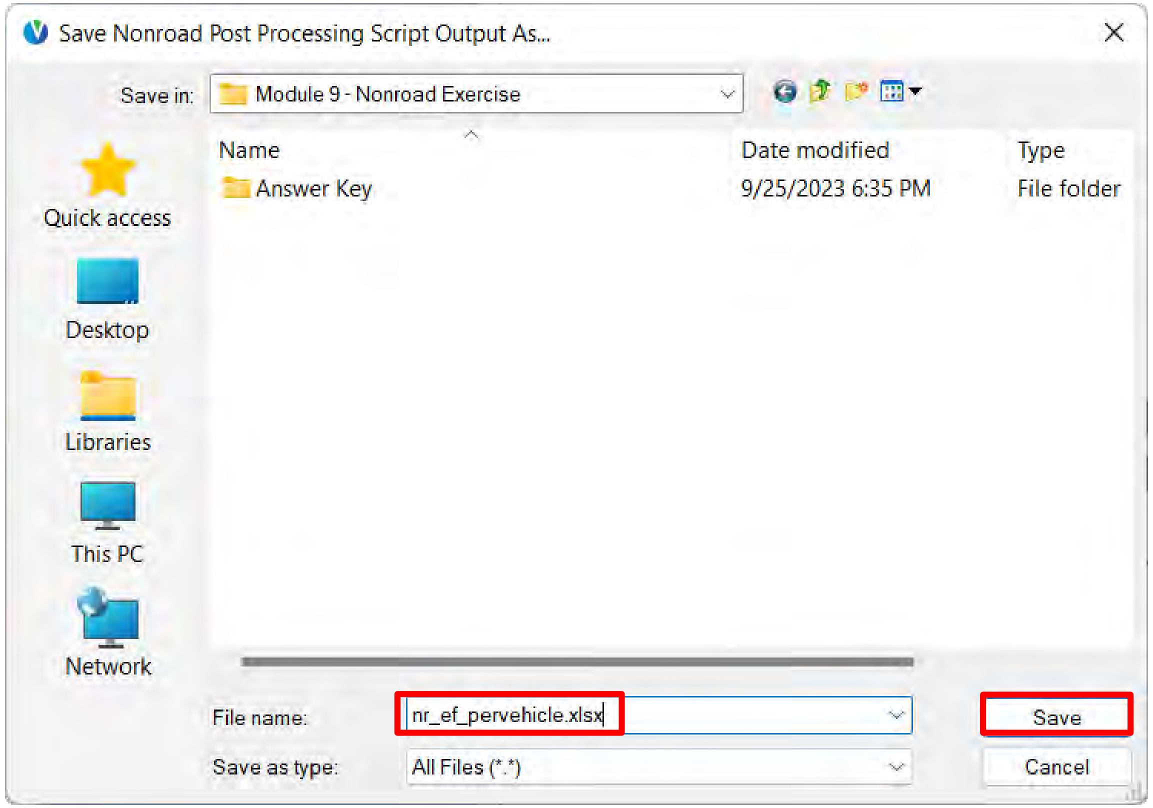


Nonroad Exercise: Running a Nonroad Post Processing Script (2)



Nonroad Exercise: Running a Nonroad Post Processing Script (3)

- All nonroad post-processing scripts produce an Excel output file for easy post-processing
- Remember to give the file name the .xlsx extension



Nonroad Exercise: Calculating an Inventory from Post-Processing Emission Rates

- Filter the resulting file for diesel (fuelTypeID 23), NOx (pollutantID 3), and the equipment provided in the list:
  - 1 paver
  - 5 signal boards
  - 2 cement mixers
  - 3 excavators
  - 1 grader
  - 10 skid steer loaders
- Enter the number of equipment in a new column in the table
- Multiply the emission factors by the number of equipment and sum

Nonroad Exercise: Results

- Correct result: **2,893.197 g NOx**
- See *nr_ef_pervehicle.xlsx* in the Module 9 - Nonroad Exercise\Answer Key folder

	equipDescription	fuelType	pollutant	emissionRa	emissionRateUni	Activity	Inventory
9	Pavers	23	3	206.4703293	g/vehicle per day	1	206.4703
54	Signal Boards/Light Plants	23	3	70.91902962	g/vehicle per day	5	354.5951
87	Cement & Mortar Mixers	23	3	52.99043425	g/vehicle per day	2	105.9809
138	Skid Steer Loaders	23	3	143.8968937	g/vehicle per day	10	1438.969
162	Excavators	23	3	208.2656216	g/vehicle per day	3	624.7969
165	Graders	23	3	162.3848264	g/vehicle per day	1	162.3848
179							
180						**Total**	**2893.197**

Sheet1

Produce Summary Report: Nonroad Output

- MOVES' Post Processing 'Produce Summary Report' feature can be used to report inventory output only, for selected emission processes and pollutants, by the following categories:
  - Fuel type
  - Model year
  - SCC
  - MOVES run
  - Day type
  - Time/location identifiers (month, state, county)
- Feature covered in detail in Module 2

Module 9 Questions?

MOVES
Motor Vehicle Emission Simulator

Module 10:
Modeling Greenhouse Gases

MOVES
Motor Vehicle Emission Simulator

EPA

Module 10 Overview

- Options for using MOVES to model greenhouse gas (GHG) emissions
- Exercise: Using the Default Scale for a GHG analysis with local VMT and vehicle population
  - Purpose is to demonstrate how this information is included
- This module does not repeat information from earlier modules – if you are starting here, you may need to refer to earlier modules

Module 10 Key References

- *MOVES Greenhouse Gas Guidance: Using MOVES for Estimating State and Local Inventories of On-Road GHG Emissions and Energy Consumption*
  - Section 2 is useful for considering different approaches when emissions are estimated for a non-regulatory purpose
  - See EPA's Estimating Greenhouse Gas Emissions webpage for latest version
- *MOVES4 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity*
  - Section 3 describes setting up a RunSpec with MOVES4
  - Available at: https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

Greenhouse Gas and Energy Usage Analyses

- MOVES can be used to:
- Produce onroad or nonroad inventories for
  - the entire U.S.
  - an individual state or multiple states
  - an individual county (or a partial county) or multiple counties, such as a metropolitan region
- Create GHG emissions inventories and estimate energy use
  - GHG inventories are usually annual
- Estimate GHG impacts of a variety of strategies:
  - travel efficiency strategies – those that affect mode choice, e.g., transit service expansion or addition of bike/pedestrian infrastructure
  - vehicle and fuel strategies – those that affect type of vehicles used, e.g., incentives for electric vehicle purchase

Using MOVES for GHG Analyses

- MOVES can be used at any scale to estimate GHG emissions:
  - Use County Scale if you have local data (Module 3)
  - Use Default Scale if you need to rely on default data (Module 2)
    - EPA recommends including local information for at least VMT and vehicle population
    - The exercise in this module illustrates a Default Scale run with local VMT and vehicle population data
  - Project Scale (Module 7) can also be used to estimate GHG emissions
    - However, Project Scale runs produce emissions for one specific hour at a time. If an annual inventory is needed, it may be easier to use County or Default Scales

Greenhouse Gas and Energy Usage

- MOVES can model any of the following GHGs or energy, with selections on the Pollutants and Processes Panel:
  - Carbon dioxide, CO_2
  - Methane, CH_4
  - Nitrous oxide, N_2O
  - Elemental carbon (equivalent to black carbon, under “Primary Exhaust $PM_{2.5}$ – Species” on the panel)
  - Total Energy Consumption
  - CO_2 Equivalent – next slide

CO_2 Equivalent

- MOVES can also provide GHG emissions in terms of "CO_2 Equivalent:"
  - The sum product of any of the three greenhouse gases selected (CO_2, methane, and nitrous oxide) multiplied by their global warming potential, expressed in units of CO_2
  - Does not include black carbon
- If only CO_2 is chosen,
  - CO_2 equivalent = CO_2 emissions
- If CO_2 and methane are chosen,
  - CO_2 equivalent = CO_2 emissions + 25×(CH_4 emissions)
- If all 3 are chosen,
  - CO_2 equivalent = CO_2 emissions + 25×(CH_4 emissions) + 298×(N_2O emissions)

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

Introduction to the Default Scale Data Importer

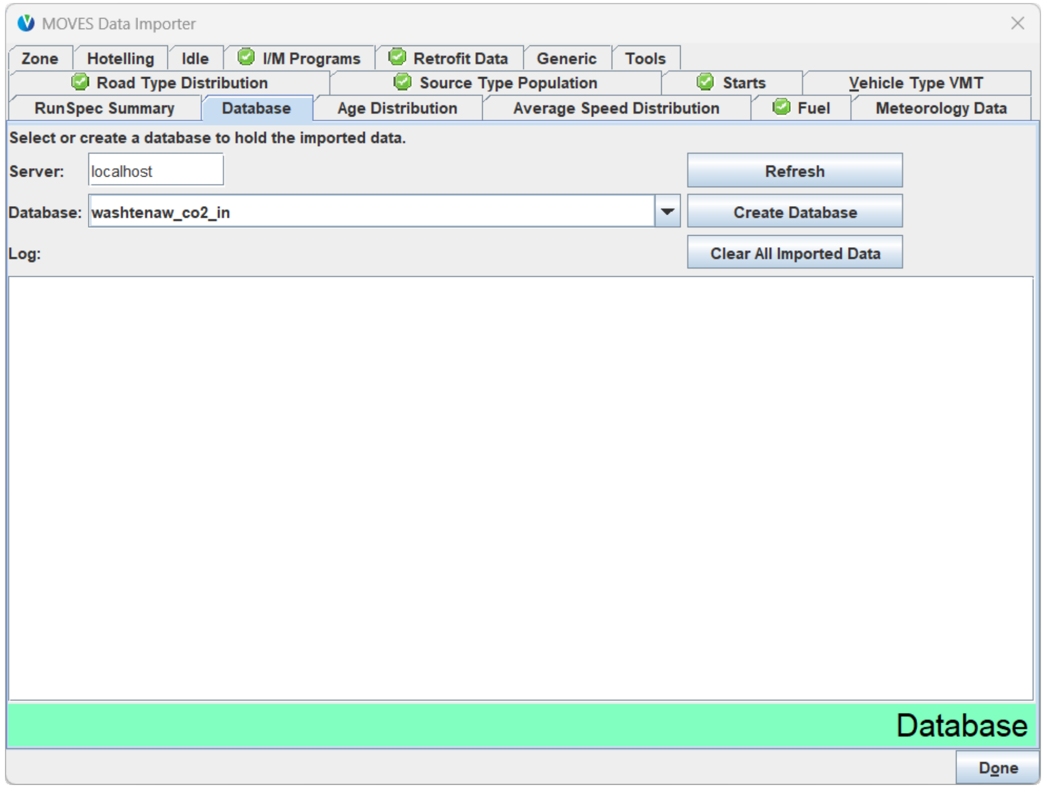
MOVES

Motor Vehicle Emission Simulator

What is the Default Scale Data Importer?

- The Data Importer is used with Default Scale to facilitate entering data into an input database
  - Same function as the County Data Manager at County Scale (Refer to Module 3 for more information)
  - The data in the input database is used by MOVES when executing the run

- The Data Importer takes the form of a separate Graphical User Interface (GUI) that is used in conjunction with the MOVES Main GUI
  - When the importer is open, the MOVES Main GUI is frozen and no changes can be made to the RunSpec
  - Nothing done in the importer will affect the selections in the RunSpec



Default Scale Data Importer Manager Functions

- At the Default Scale, using the Data Importer is optional
  - Needed when you want to include local information in a Default Scale run, e.g., local information for VMT and vehicle population
- Use the Data Importer to replace default information for the run for one or more inputs, by either:
  - Creating a table template, in which you will enter local data, or
  - Exporting default data to a table to modify with local data
- Work with the resulting file in Excel, then “Import” worksheets into the importer
  - Data are not entered directly in the importer
  - You can add a description of imported data within the importer to document data sources
- Using the Data Importer ensures the input tables are properly formatted
- Since the Data Importer works just like the County Data Manager, see Module 3 for more information/instruction

Default Scale Data Importer: One Additional Tab

- The Data Importer has the same set of tabs as the County Data Manager and as of MOVES4.0.1, one additional tab: Zone
  - This module does not cover all tabs; see Module 3
- The Zone Tab makes it possible for the modeler to allocate local VMT and vehicle population within the Default Scale
  - Which allows you to enter local VMT and vehicle population
- In MOVES4.0.0 and earlier versions, any VMT and vehicle population input in the Data Importer are applied to the nation as a whole
  - No practical method to input VMT or vehicle population for the area being modeled in these earlier MOVES versions

Importing Local VMT and Vehicle Population Data into the Data Importer (1)

- To include local VMT, modelers would need to supply **all three** of the following inputs:
  - Zone: ZoneRoadType and Zone tables
  - Vehicle Type VMT: VMT for one or more counties or states (see Module 3 for details)
  - Source Type Population: vehicle population for the area being modeled (see Module 3 for details)

- All three are needed; modelers cannot supply data for just one or two of these inputs

Importing Local VMT and Vehicle Population Data into the Data Importer (2)

- 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 allocate 100% of the VMT and vehicle population the modeler supplies to the selected county

Importing Local VMT and Vehicle Population Data into the Data Importer (3)

- If more than one county is selected in the RunSpec:
  - Supply VMT and vehicle population inputs that reflect the combined VMT and vehicle populations for all selected counties
  - Calculate each individual county's proportion of the combined VMT
    - These fractions should sum to 1
  - In ZoneRoadType, supply each county’s fraction in the “SHOAllocFactor” column using the same value for each road type
  - In Zone, supply each county’s fractions in the "AllocFactor" columns
- 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

Hands-on Exercise:
Default Scale GHG Run with Local VMT and Vehicle Population Data

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Motor Vehicle Emission Simulator

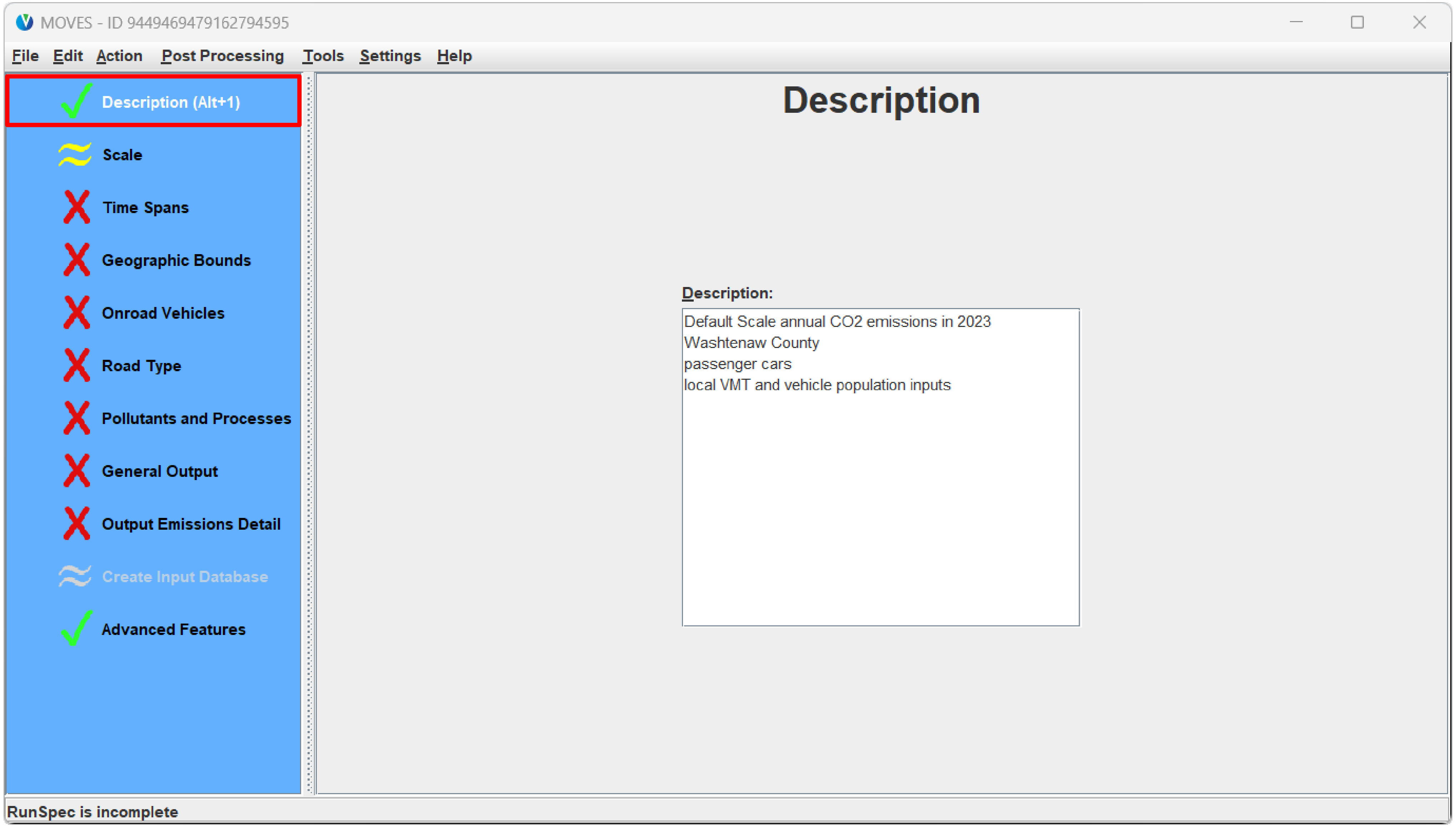
GHG Exercise Overview

- This exercise is similar to the exercises done in Modules 2 and 3:
- Model annual CO_2 emissions from passenger cars in Washtenaw County, 2023
  - Module 2 and 3 exercises estimated daily July NOx emissions from passenger cars in Washtenaw County
  - We're using the same passenger car population of 200,000
  - We're using the same daily VMT for passenger cars:
    - Weekday (dayID 5) = 5,000,000
    - Weekend day (dayID 2) = 4,000,000
    - We will assume these weekday and weekend day VMT apply to all months
- NOTE: This exercise scenario is intentionally simplified to facilitate learning, limit complexity, and reduce MOVES run time
  - E.g., a run to calculate an onroad CO_2 inventory should include all vehicle types

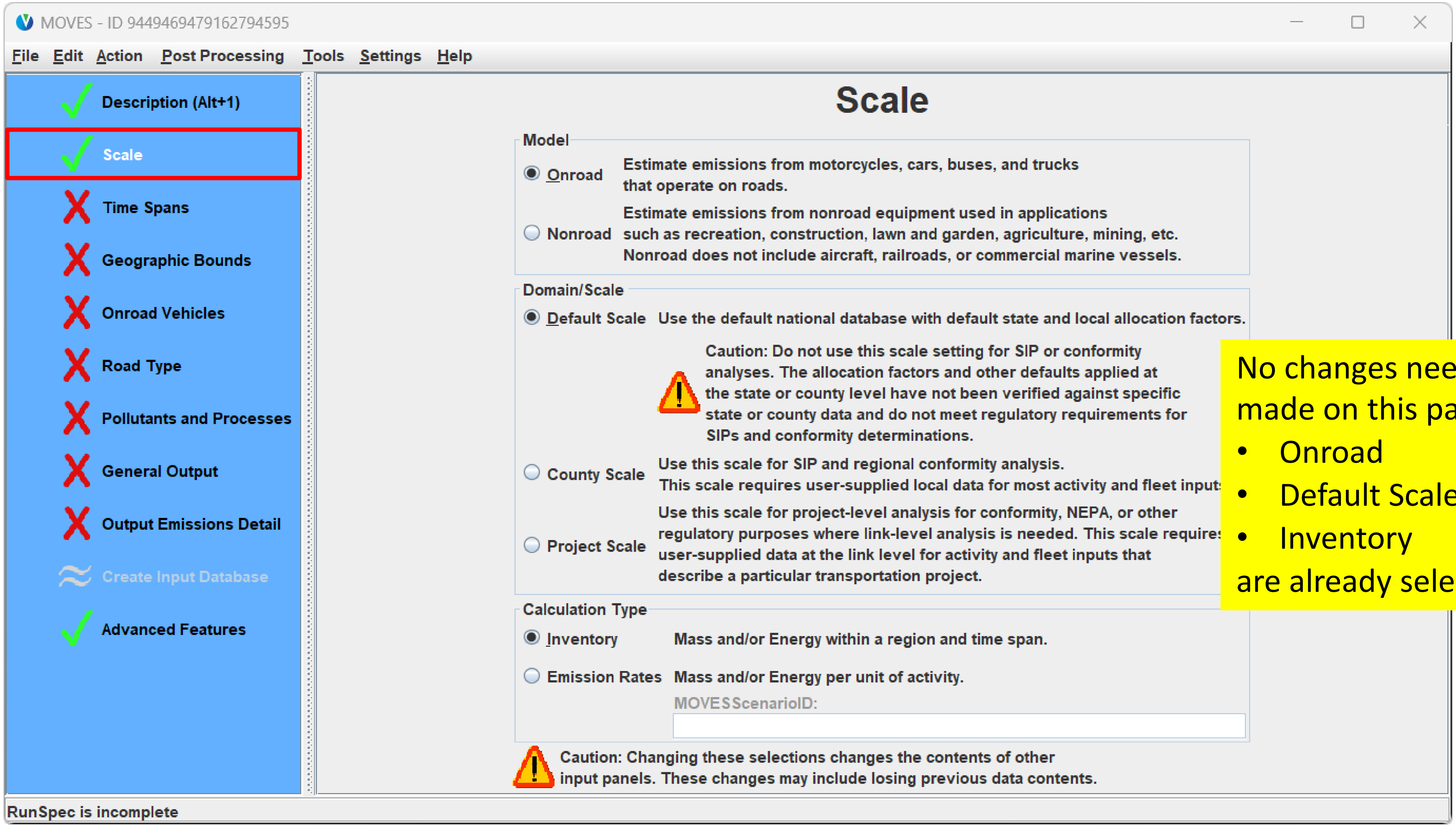
GHG Exercise Step 1: Building the RunSpec

How much CO2 was emitted from passenger cars in Washtenaw County, Michigan in the year 2023?

GHG Exercise: Description Panel



GHG Exercise: Scale Panel

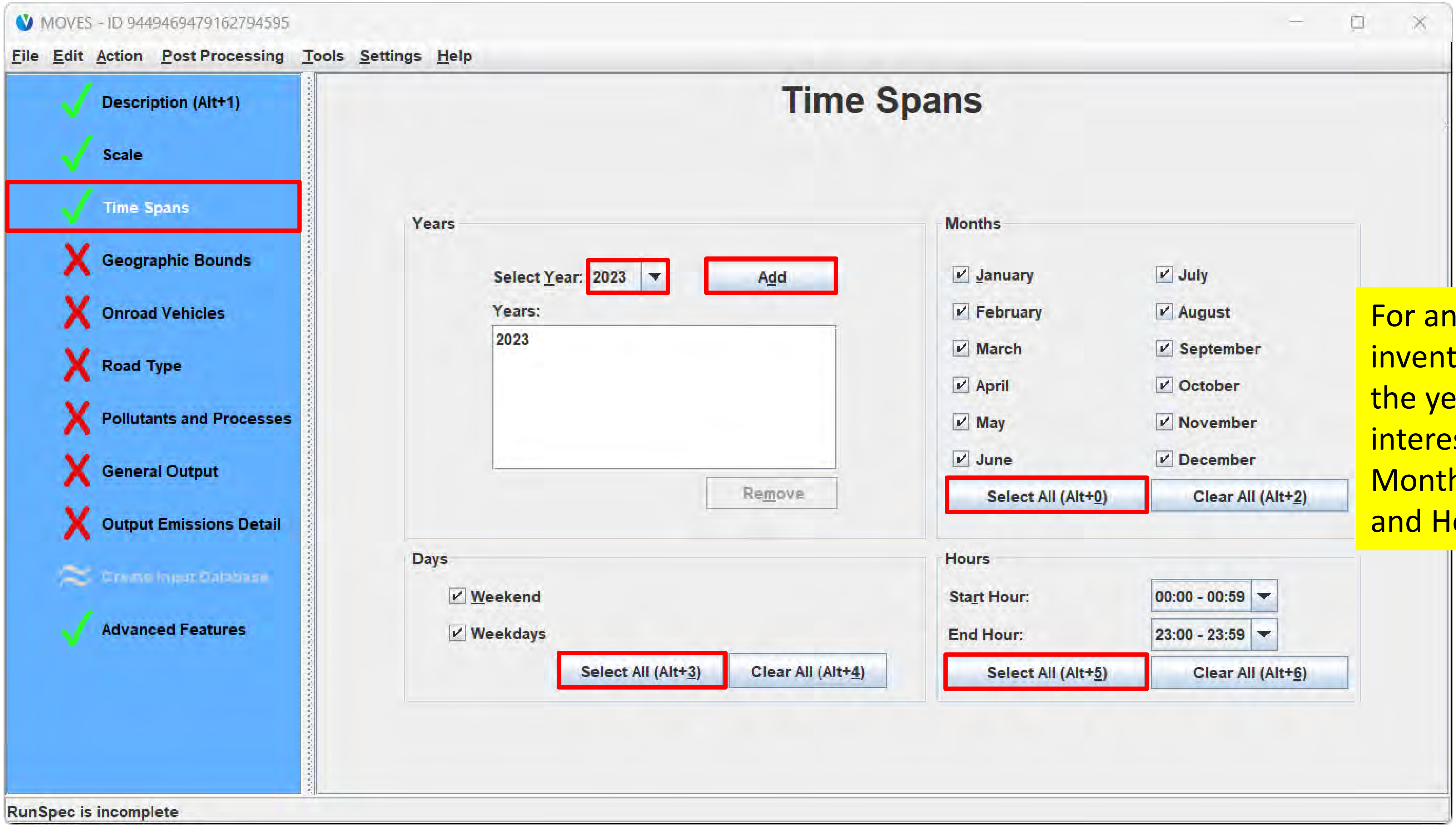


No changes need to be made on this panel:

- Onroad
- Default Scale
- Inventory

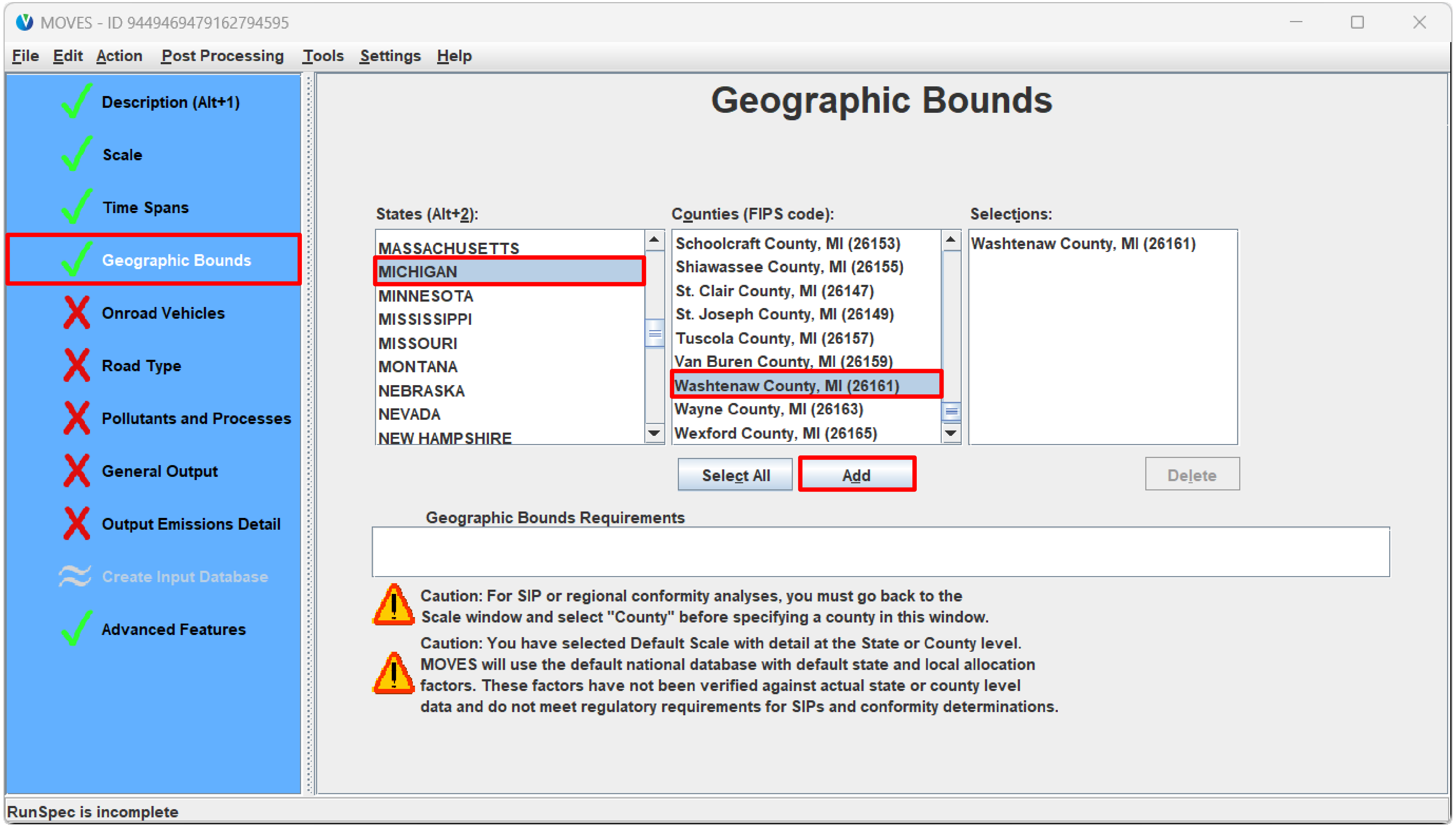
are already selected

GHG Exercise: Time Spans Panel

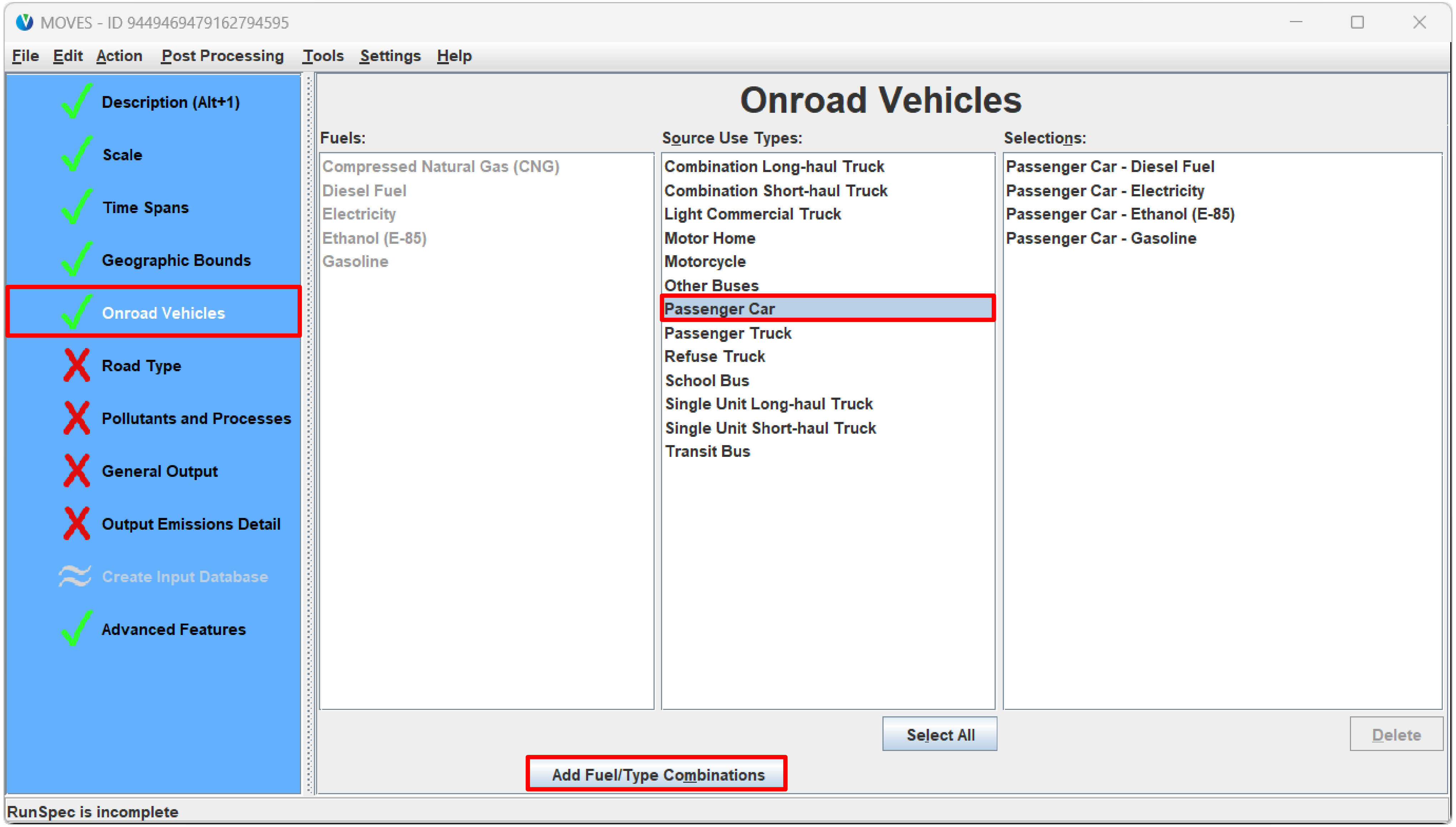


For an annual inventory, select the year of interest and all Months, Days, and Hours

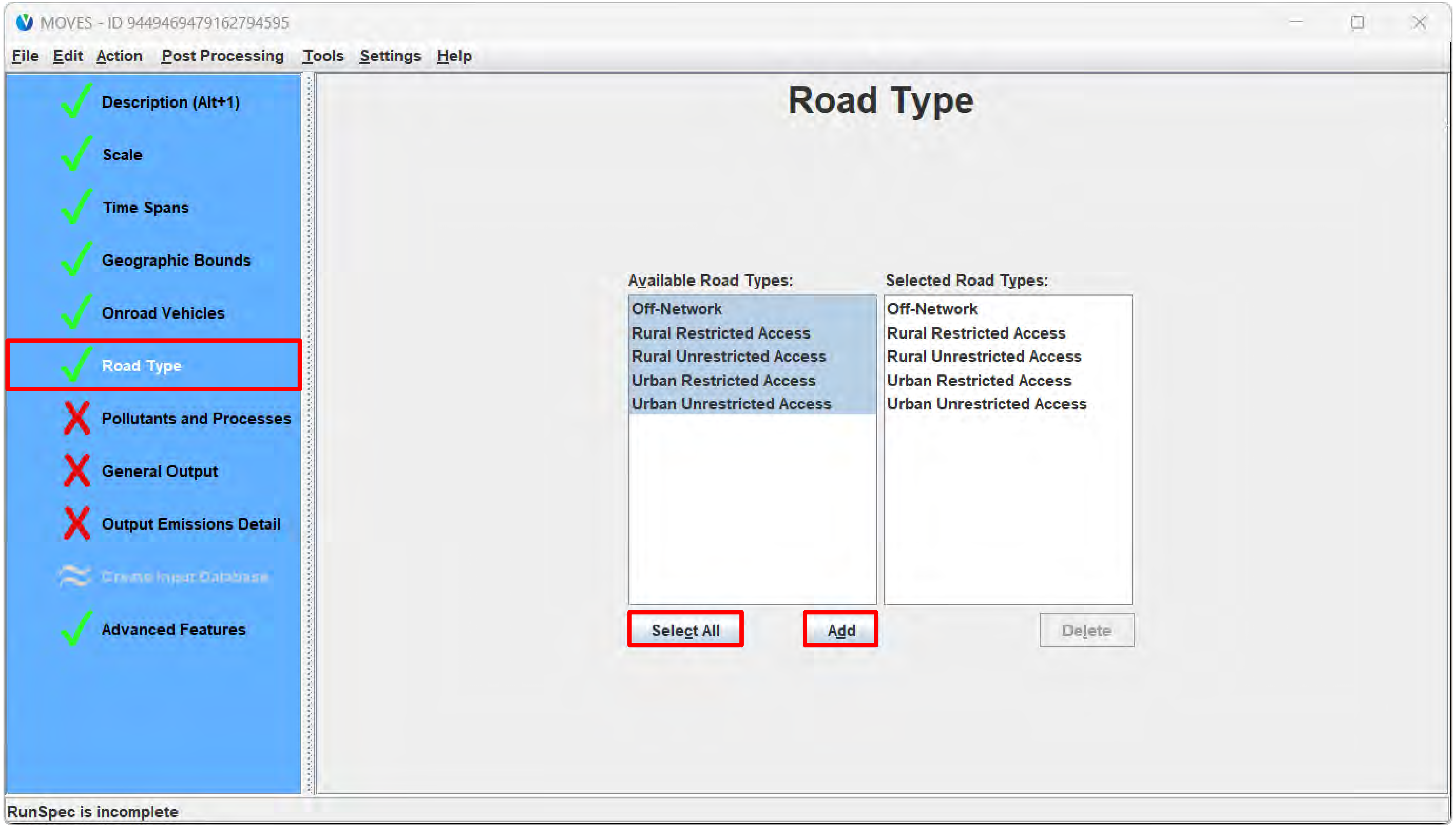
GHG Exercise: Geographic Bounds Panel



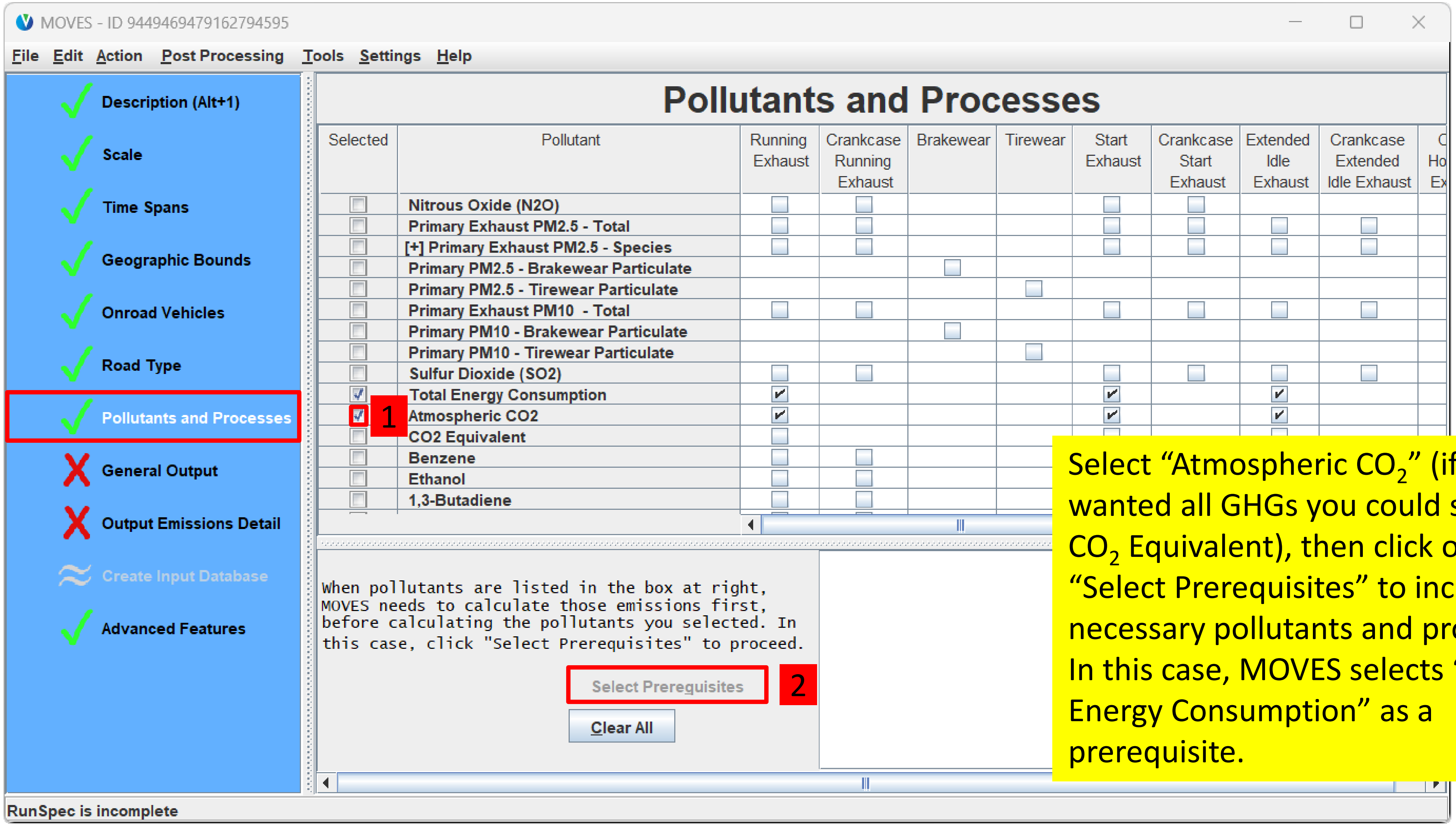
GHG Exercise: Onroad Vehicles Panel



GHG Exercise: Road Type Panel

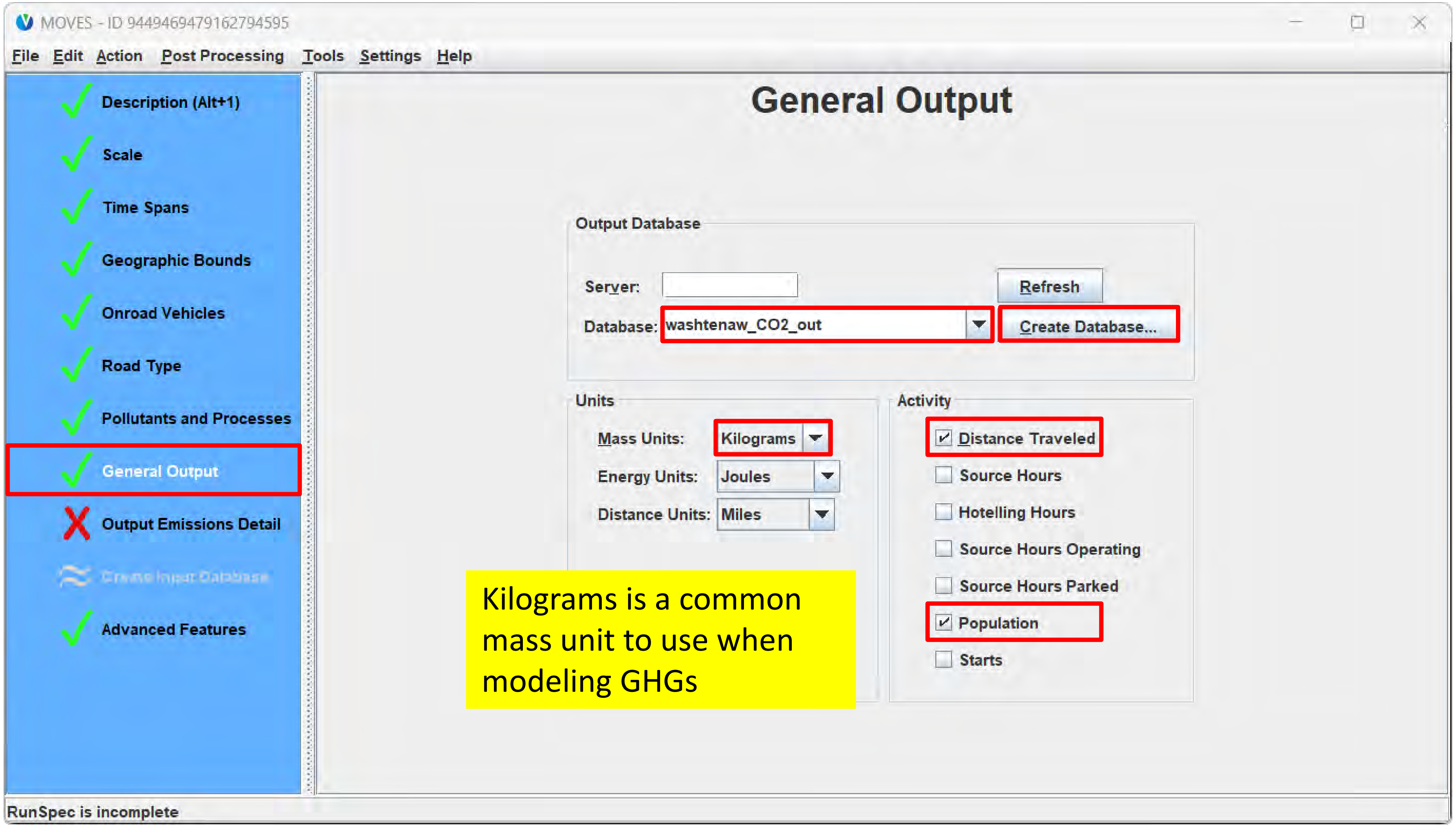


GHG Exercise: Pollutants and Processes



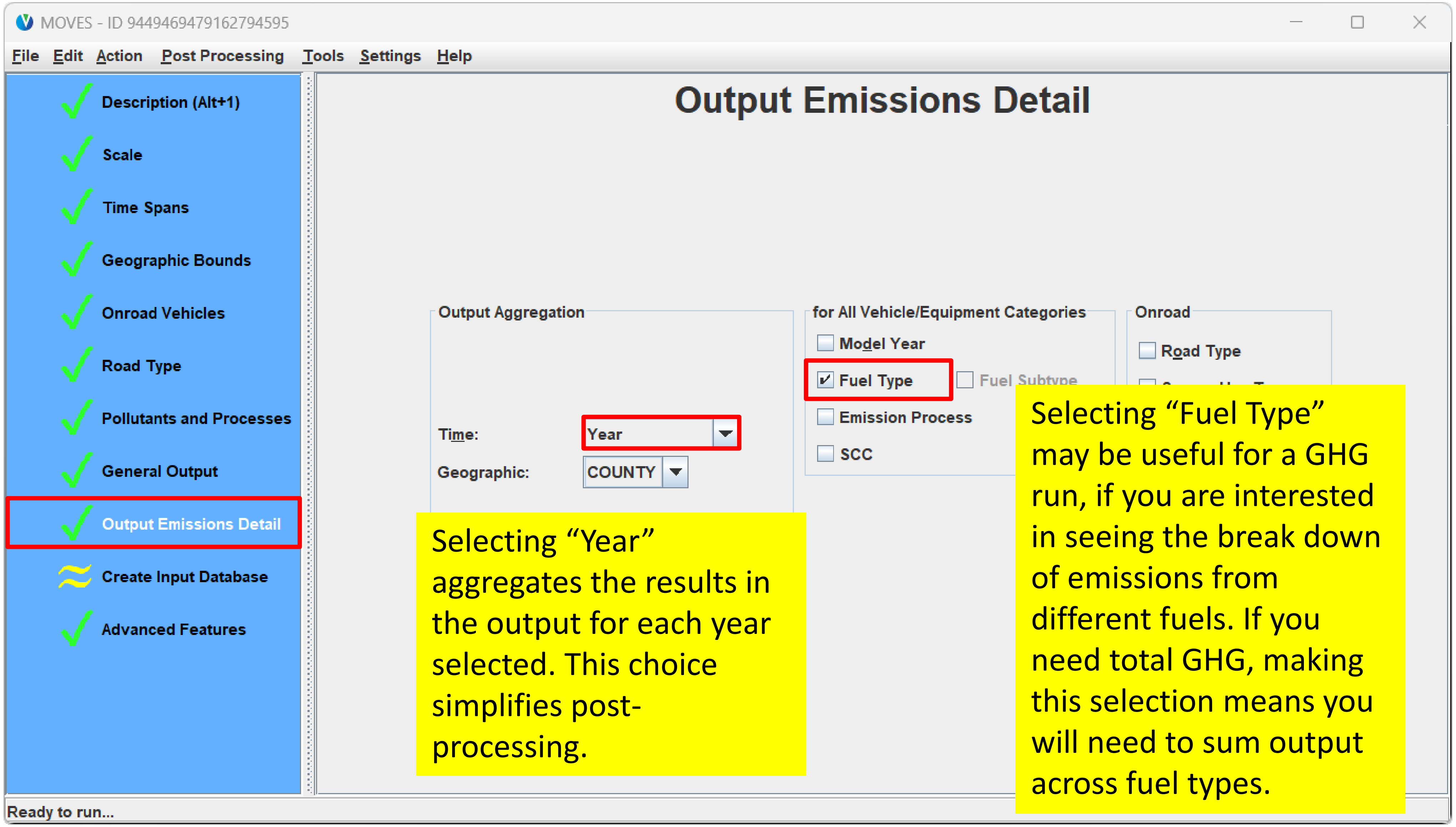
Select “Atmospheric CO_2” (if you wanted all GHGs you could select CO_2 Equivalent), then click on “Select Prerequisites” to include all necessary pollutants and processes. In this case, MOVES selects “Total Energy Consumption” as a prerequisite.

GHG Exercise: General Output Panel



Kilograms is a common mass unit to use when modeling GHGs

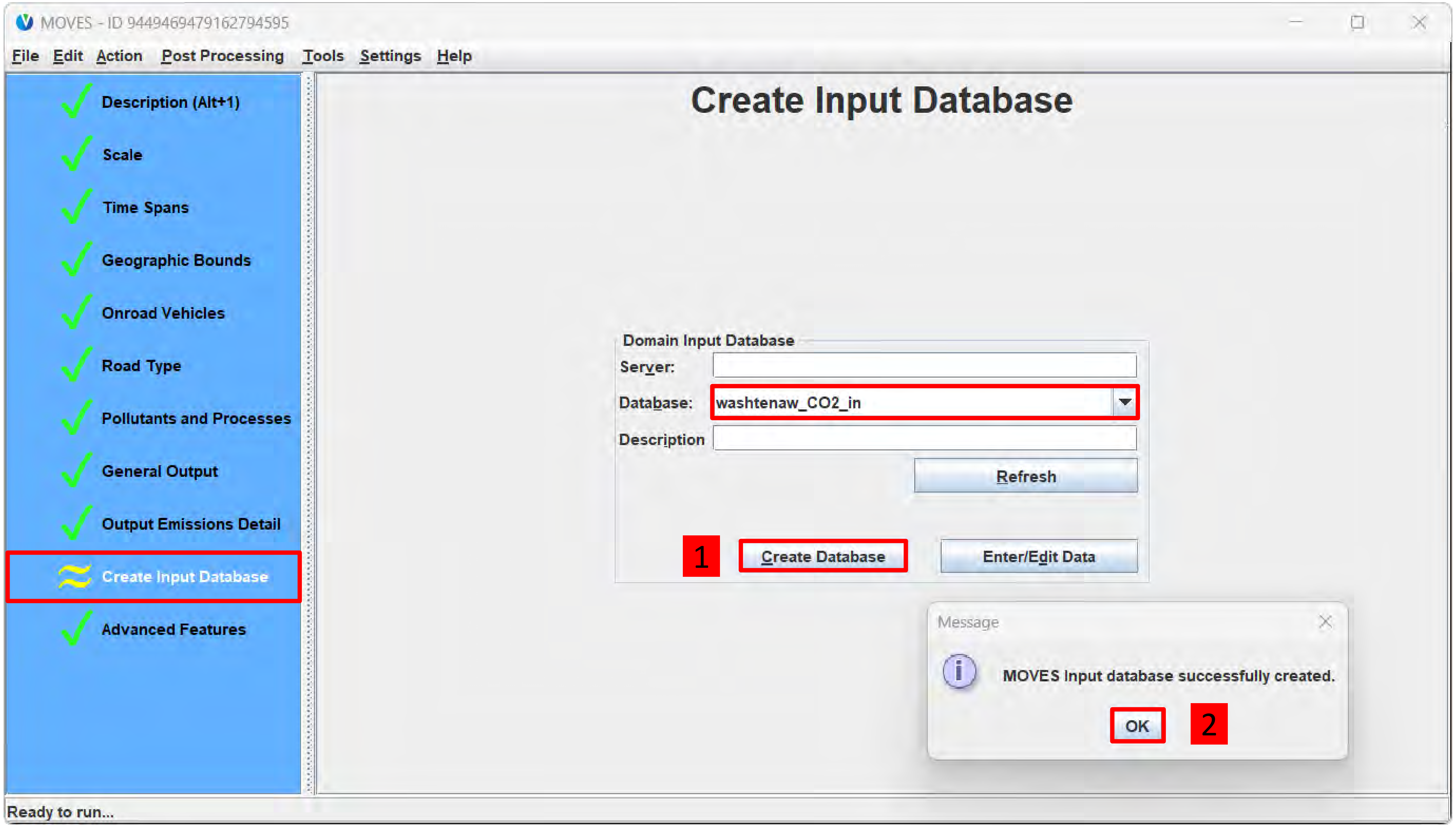
GHG Exercise: Output Emissions Detail



Selecting "Year" aggregates the results in the output for each year selected. This choice simplifies post-processing.

Selecting "Fuel Type" may be useful for a GHG run, if you are interested in seeing the break down of emissions from different fuels. If you need total GHG, making this selection means you will need to sum output across fuel types.

GHG Exercise: Create Input Database



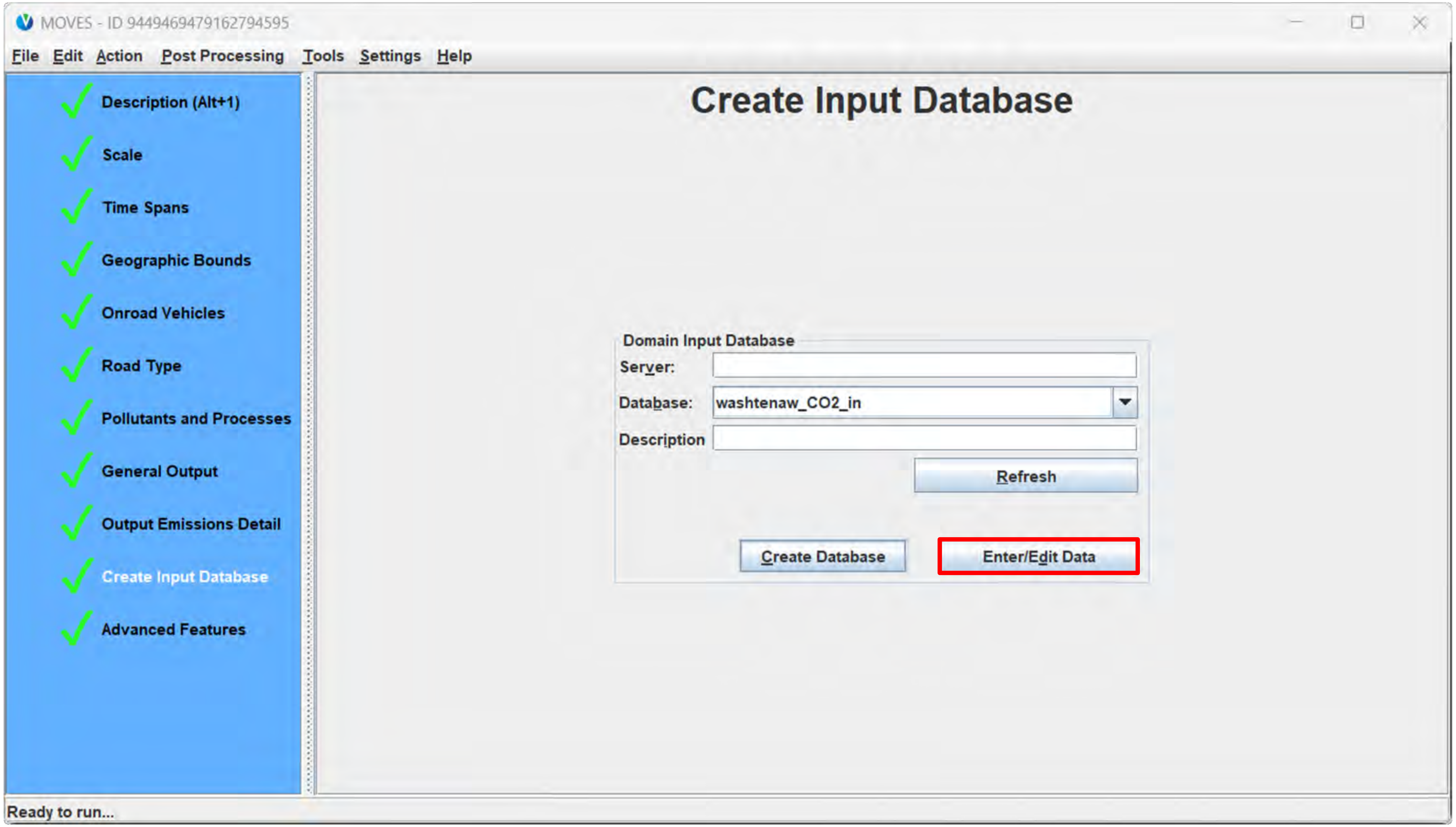
GHG Exercise: Saving the RunSpec

- Best Practice
  - Relate the RunSpec name to input/output database names
  - Save the RunSpec in its own folder, alongside any input files or output post-processing scripts

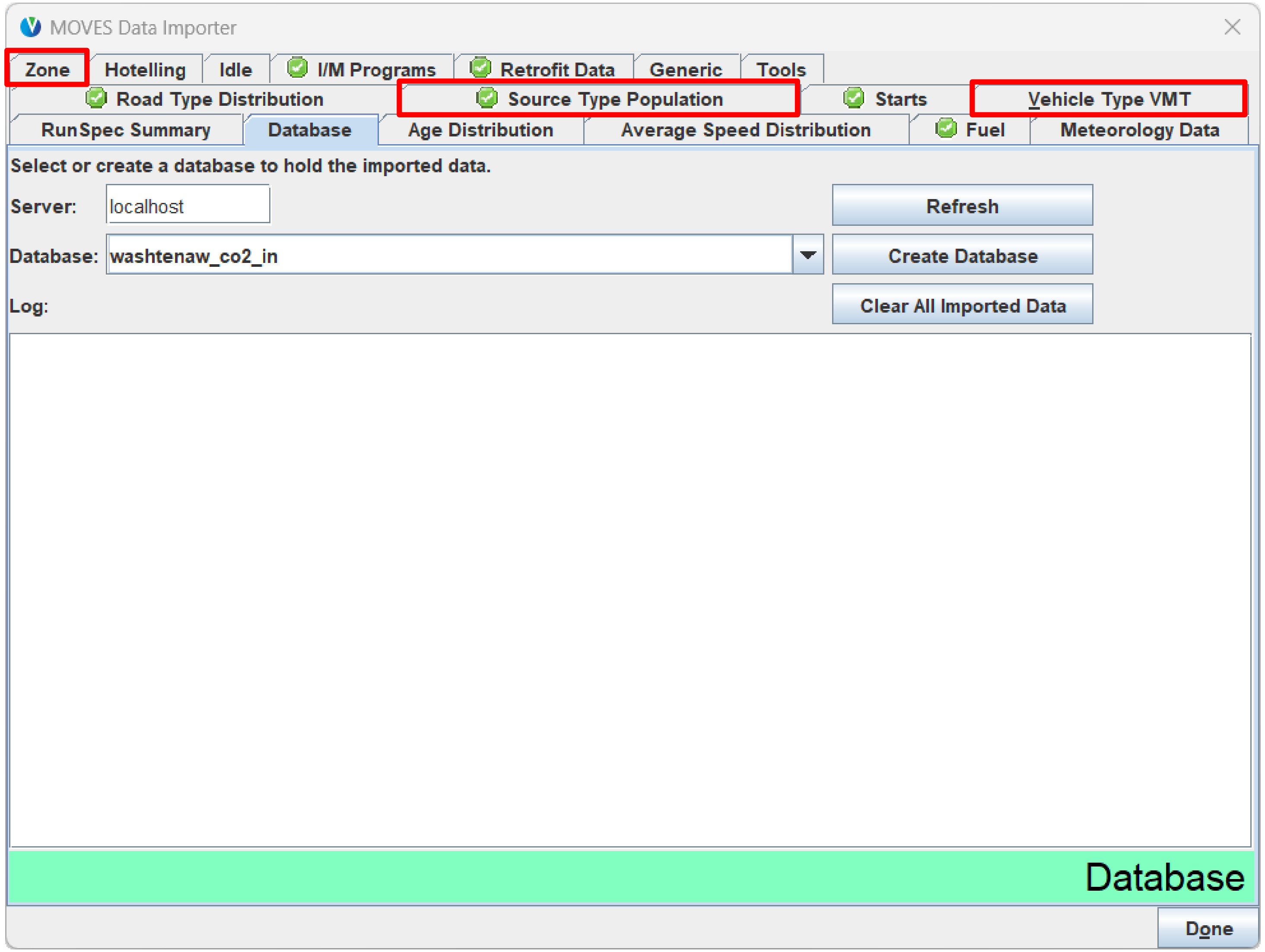
- Saving our RunSpec for this exercise:
  - We named the output database "washtenaw_CO2_out"
  - We named the input database "washtenaw_CO2_in"
  - Save the RunSpec as: "washtenaw_CO2.mrs" in a new folder:
    - From File menu, select Save As…
    - Create a new folder (somewhere easy to find, such as on your Desktop).
      - Ours is called "Module 10 - Default Scale GHG Exercise"
    - Name the RunSpec file "washtenaw_CO2.mrs"
    - Click Save

GHG Exercise Step 2: Including Local Information through the Data Importer

GHG Exercise: Open the Data Importer



GHG Exercise: Default Scale Data Importer



- We named the database when we completed the RunSpec
- We need to add information to 3 tabs:
  - Zone
  - Source Type Population
  - Vehicle Type VMT
- In this example, we are relying on MOVES default information for the other tabs

Zone Tab

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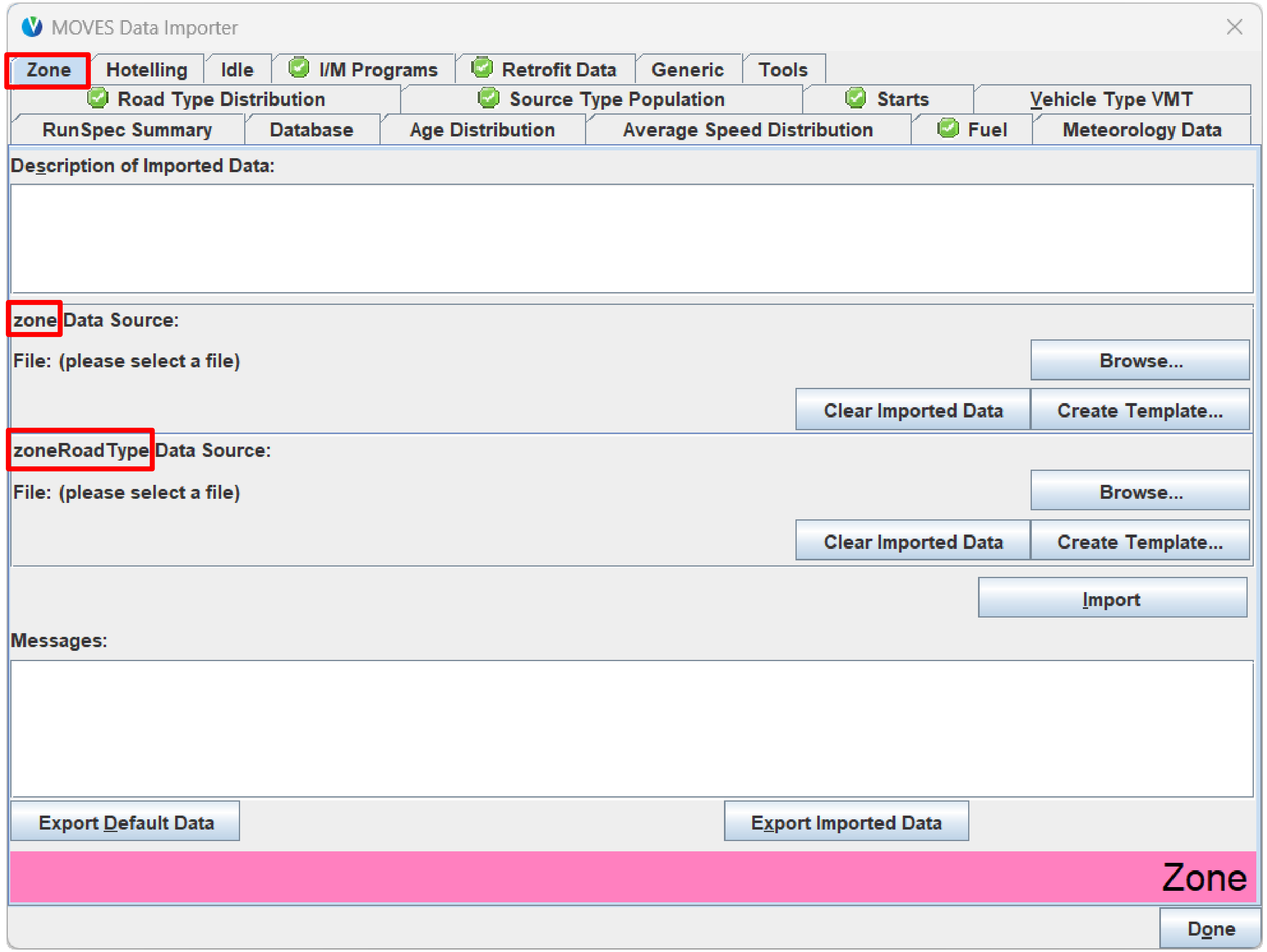
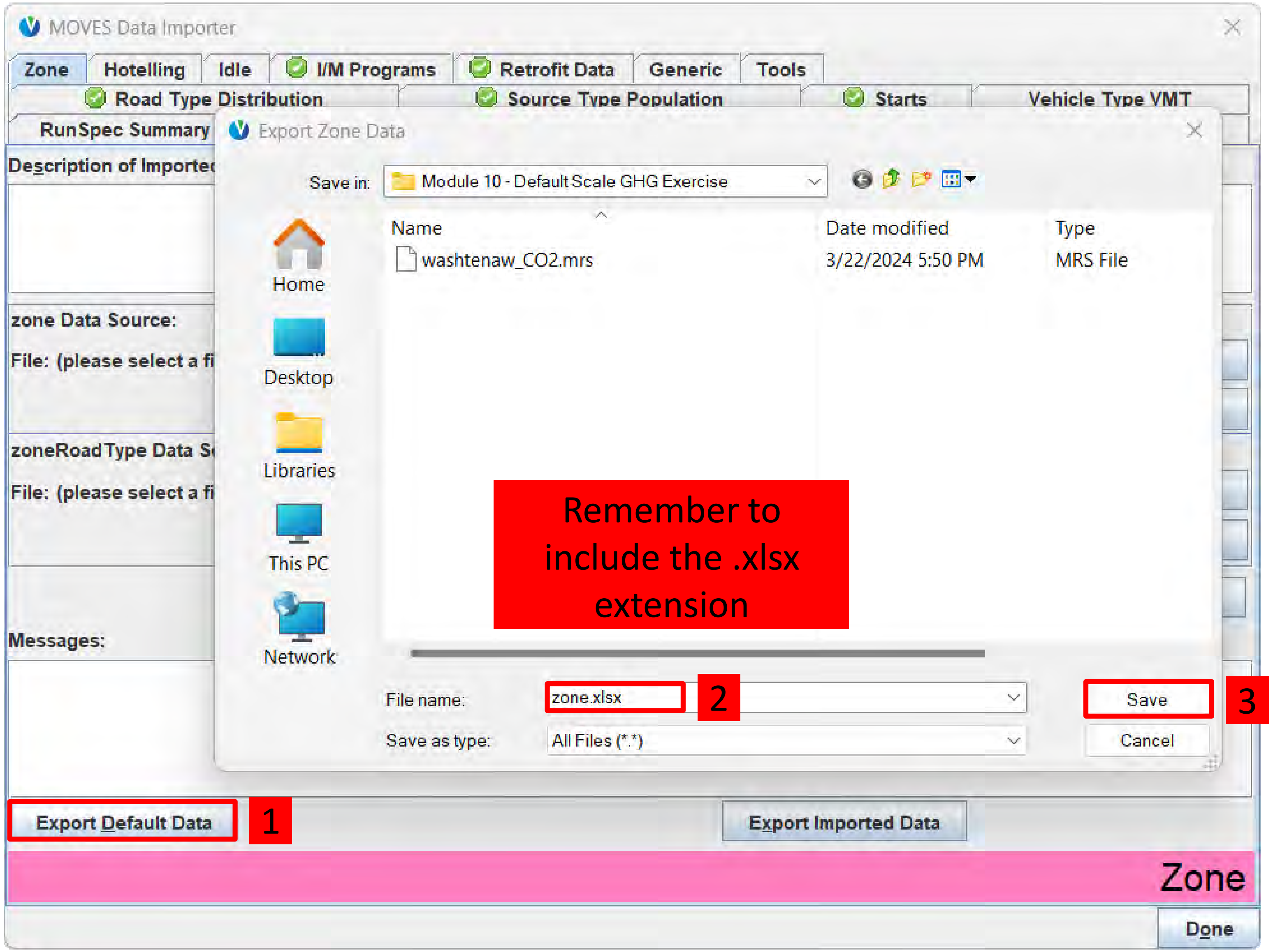
GHG Exercise: Zone Tab



- Clicking on a tab shows the importer for that tab
- This importer has two tables:
  - Zone
  - ZoneRoadType

Export Zone Default Data



Export the default data to an Excel spreadsheet

Zone default data includes Zone and ZoneRoadType

- Reminder: 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
  - Edit the Zone Table to include 1.0 for all of the "AllocFactor" columns
- This will allocate 100% of the vehicle population and VMT the modeler supplies to the selected county
- Open the Excel file

Edit the Zone input

zoneID	countyID	startAllocFactor	idleAllocFactor	SHPAllocFactor
261610	26161	0.001122533	0.001122533	0.001122533

zone | zoneroadtype | County | RoadType

Change all “AllocFactor” columns to 1

zoneID	countyID	startAllocFactor	idleAllocFactor	SHPAllocFactor
261610	26161	1	1	1

zone | zoneroadtype | County | RoadType

Note, zoneID = 10x countyID

- The default “AllocFactor” indicates what fraction of national activity (e.g. start activity) is occuring in Washtenaw County
- Changing these to 1 means for our run, 100% of the activity is occuring in Washtenaw County
    - In other words, 100% of vehicles in the run are in Washtenaw County

Edit the ZoneRoadType input

zoneID	roadTypeID	SHOAllocFactor
261610	3	0.000644397
261610	5	0.001045393
261610	2	0.001310337
261610	4	0.001645628

zone | zoneroadtype | County | RoadType

1. Change all "SHOAllocFactors" to 1

zoneID	roadTypeID	SHOAllocFactor
261610	3	1
261610	5	1
261610	2	1
261610	4	1

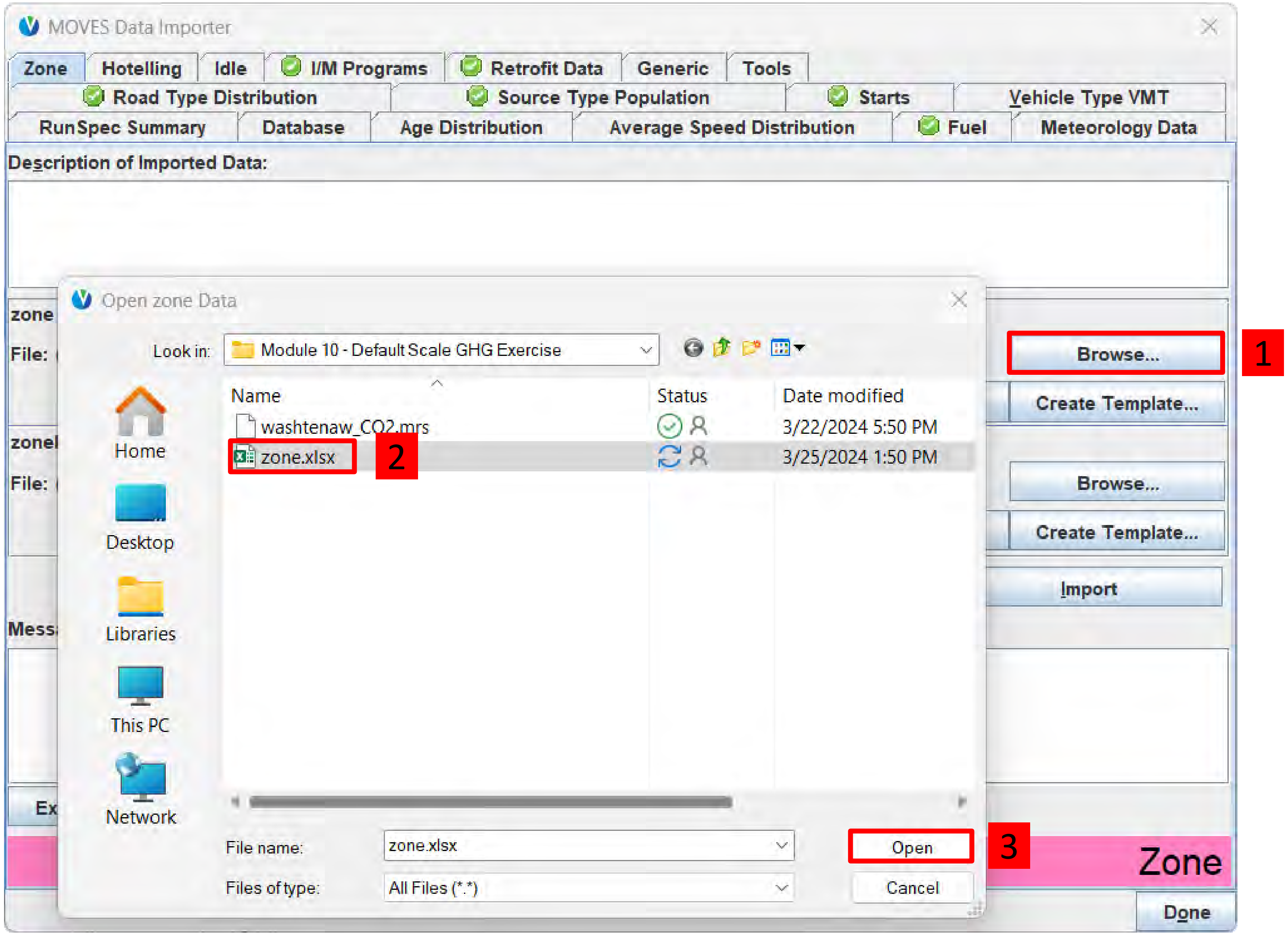
zone | zoneroadtype | County | RoadType

2. Save this Excel file, then close it

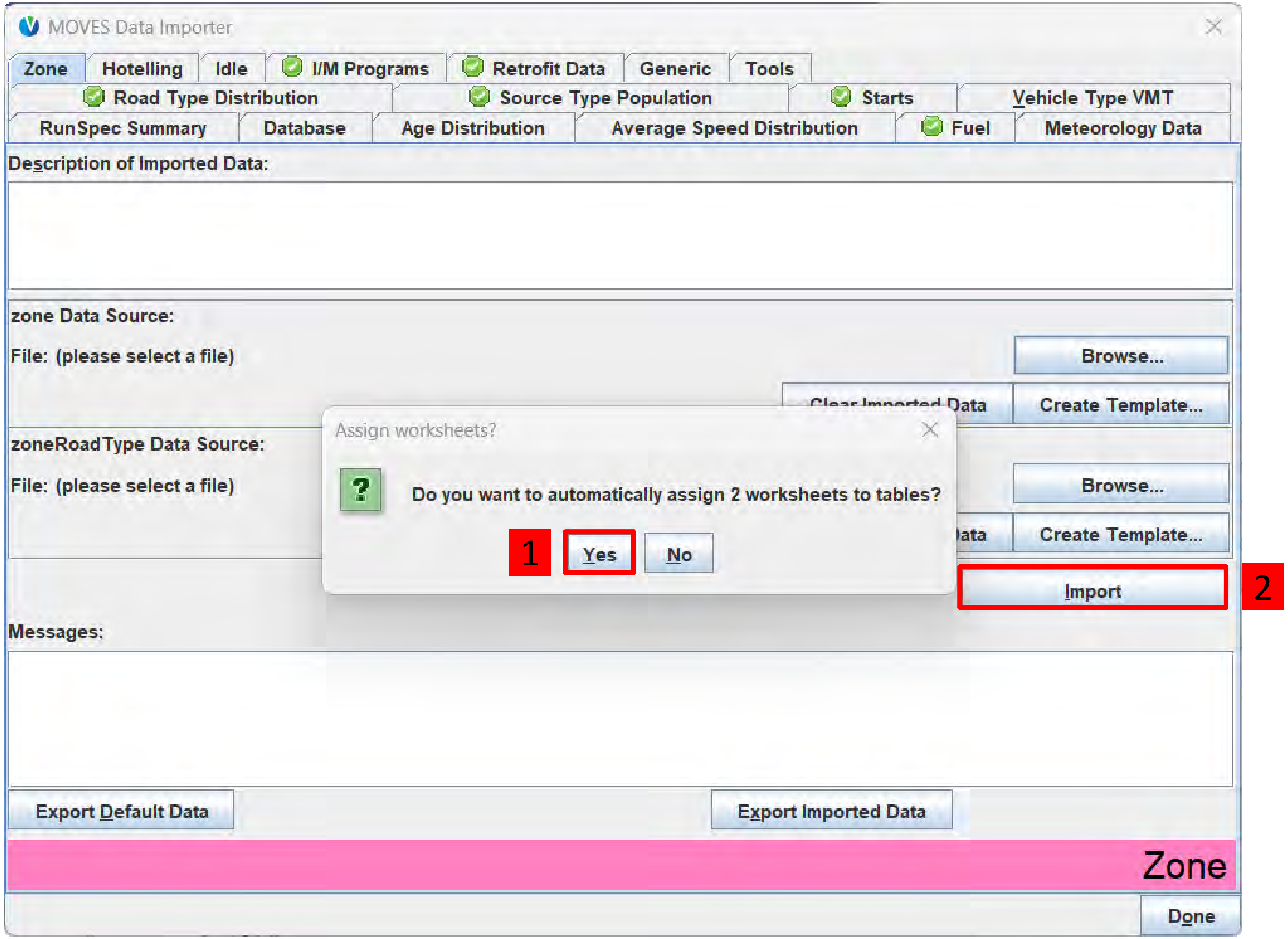
Use the RoadType tab in the template file (or use the cheat sheet) to decode the roadTypeID field

- The default "SHOAllocFactor" indicates what fraction of national time that vehicles are on a particular road type is occuring in Washtenaw County
- Changing these to 1 means for our run, 100% of driving is occuring in Washtenaw County

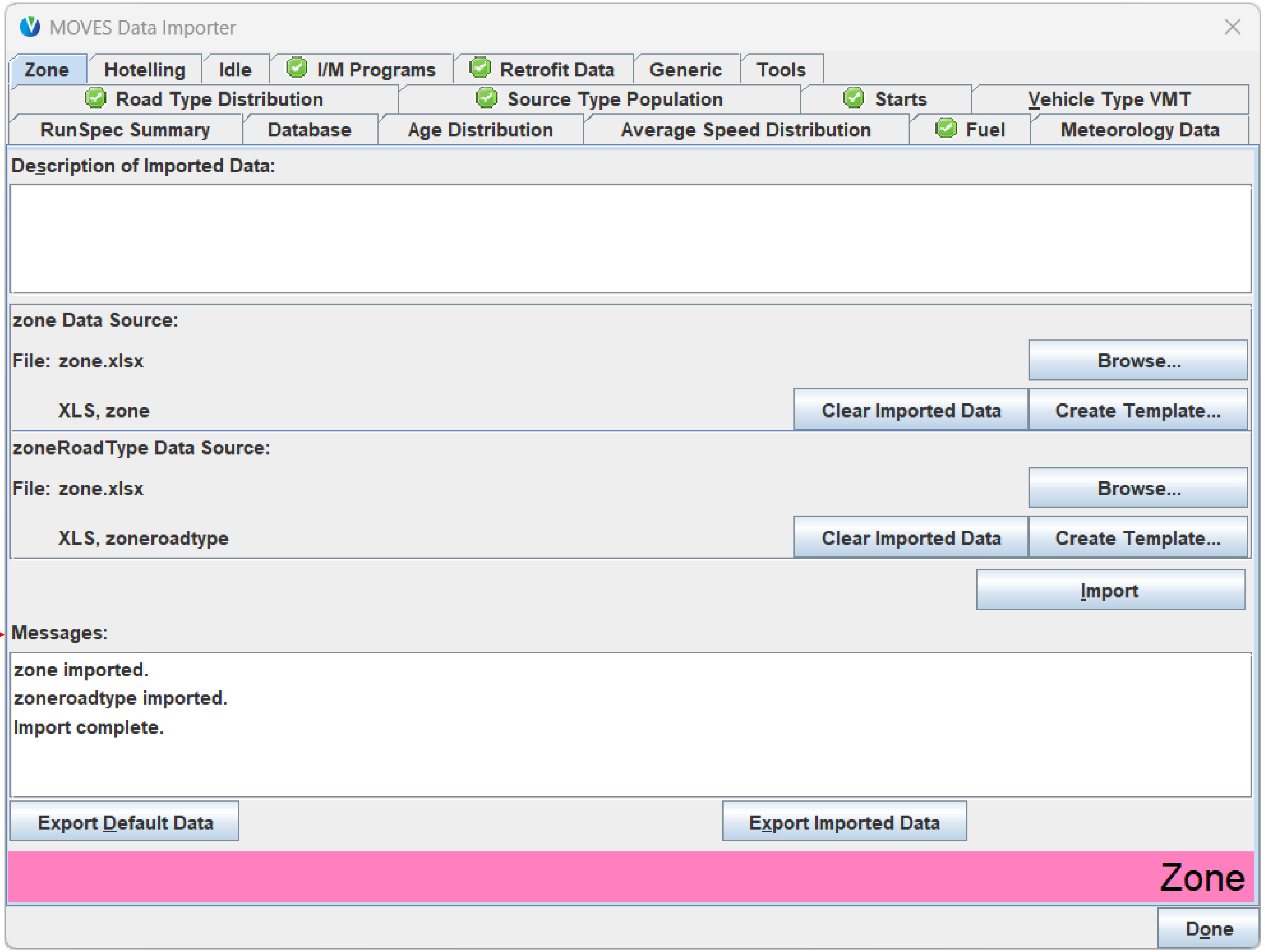
Import Zone (1)



Import Zone (2)



Check for Zone Errors

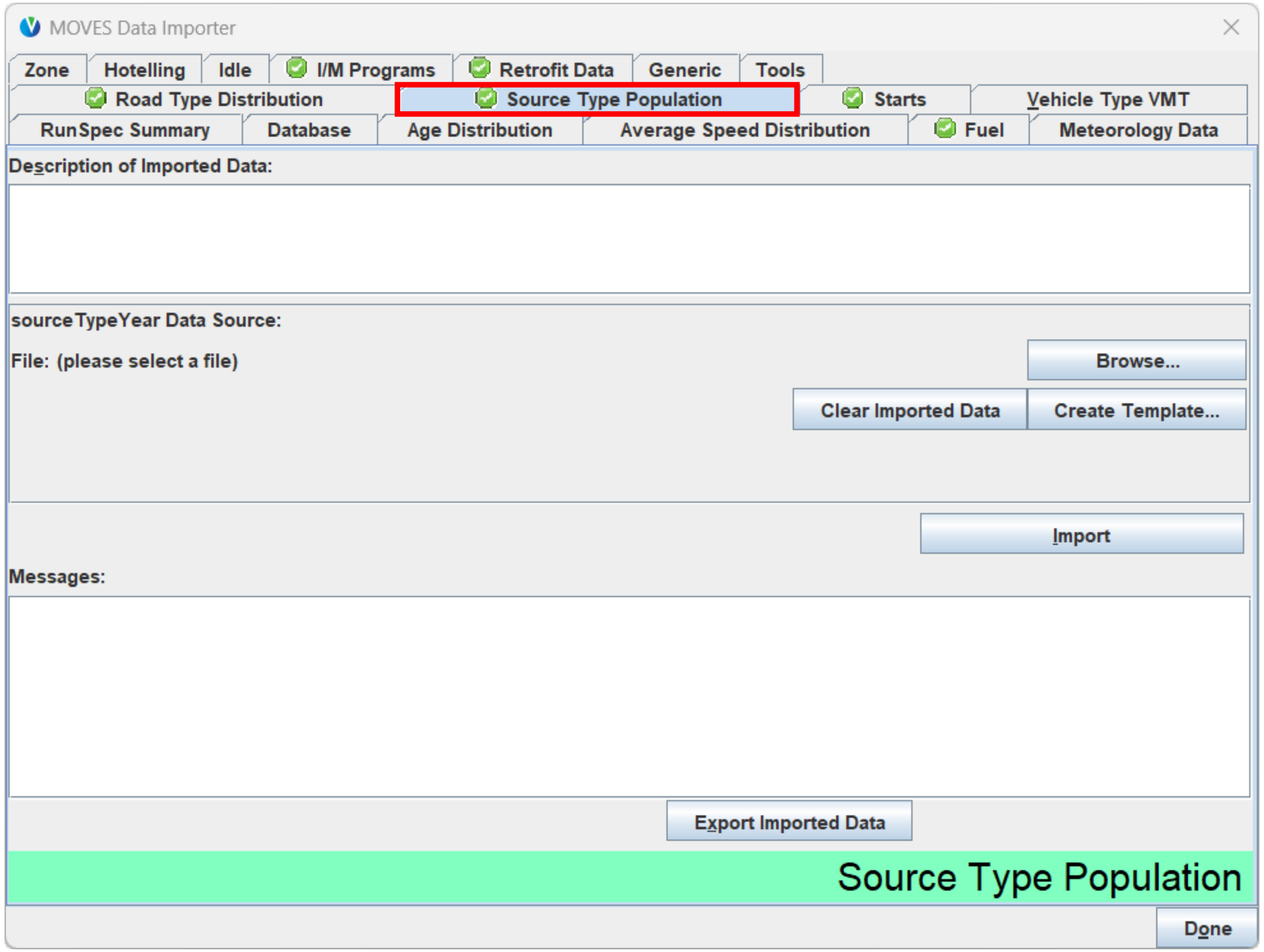


Any errors will appear in the Messages list

Default Data Importer
Source Type Population Tab

Default Data Importer: Source Type Population

- The Source Type Population tab has one table to populate: *SourceTypeYear*
- This table needs the number of vehicles of each "source type" (vehicle type) in the county being modeled
- MOVES uses vehicle population when estimating start and evaporative emissions
- There is no default data for this input, so you need to create a template and fill it out
- Refer to Module 3 for information about filling out the Source Type Population template



Source Type Population: GHG Guidance (1)

- Section 4.5 of MOVES GHG Guidance
- Historic local population data are recommended
  - Based on vehicle registration data for instance
- Vehicle population growth must be handled outside the model
  - Vehicle population for future years can be scaled in proportion to expected VMT or human population growth

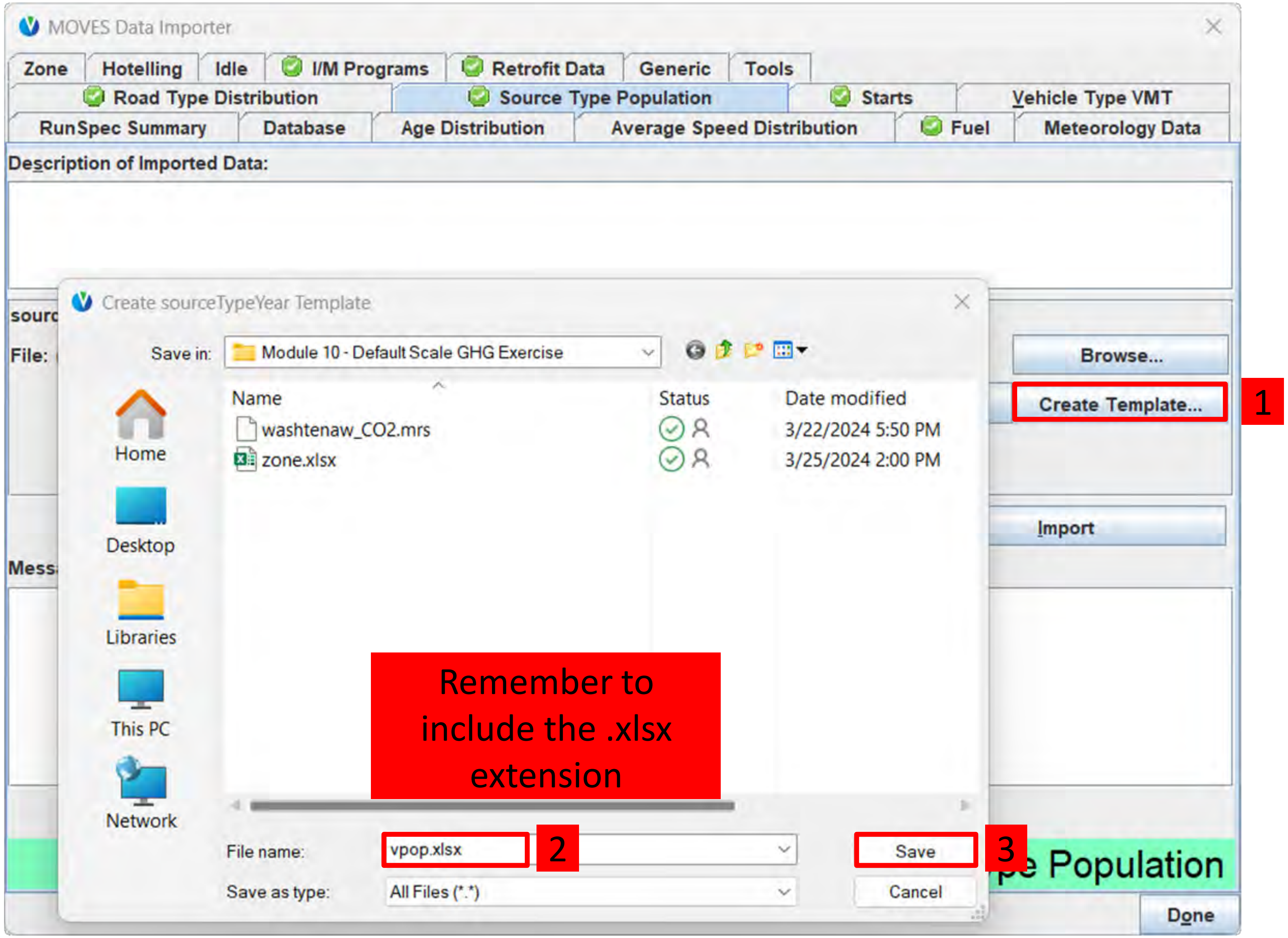
Source Type Population: GHG Guidance (2)

- Only local vehicles need to be included in population
  - Local vehicles are those that have a significant portion of their starts and parked hours in the county
  - Vehicles that only pass through the county (do not park or start) do not have to be included in population, but their VMT must be included in the Vehicle Type VMT tab
- Sources of population data
  - Use local registration data for motorcycles, passenger cars, and light trucks
  - Use data from transit agencies, school districts, and refuse haulers for buses and refuse trucks
  - If information is not available for other vehicle classes, their local population can be estimated by using the ratio of MOVES national default population to MOVES national default VMT and then applying that same ratio to local VMT

Source Type Population: GHG Exercise

- We have passenger car populations from local registration data (same as in Module 2):
  - 200,000 passenger cars
- Instructions for importing vehicle population into the Data Importer:
  1. Create a template from the Source Type Population tab
  2. Enter and save local population data in Excel
  3. Browse for the data file in the Data Importer
  4. Select the correct worksheet
  5. Import the worksheet into the Data Importer
  6. Check for errors

GHG Exercise: Create Source Type Population Template



GHG Exercise: Fill out Source Type Population Template

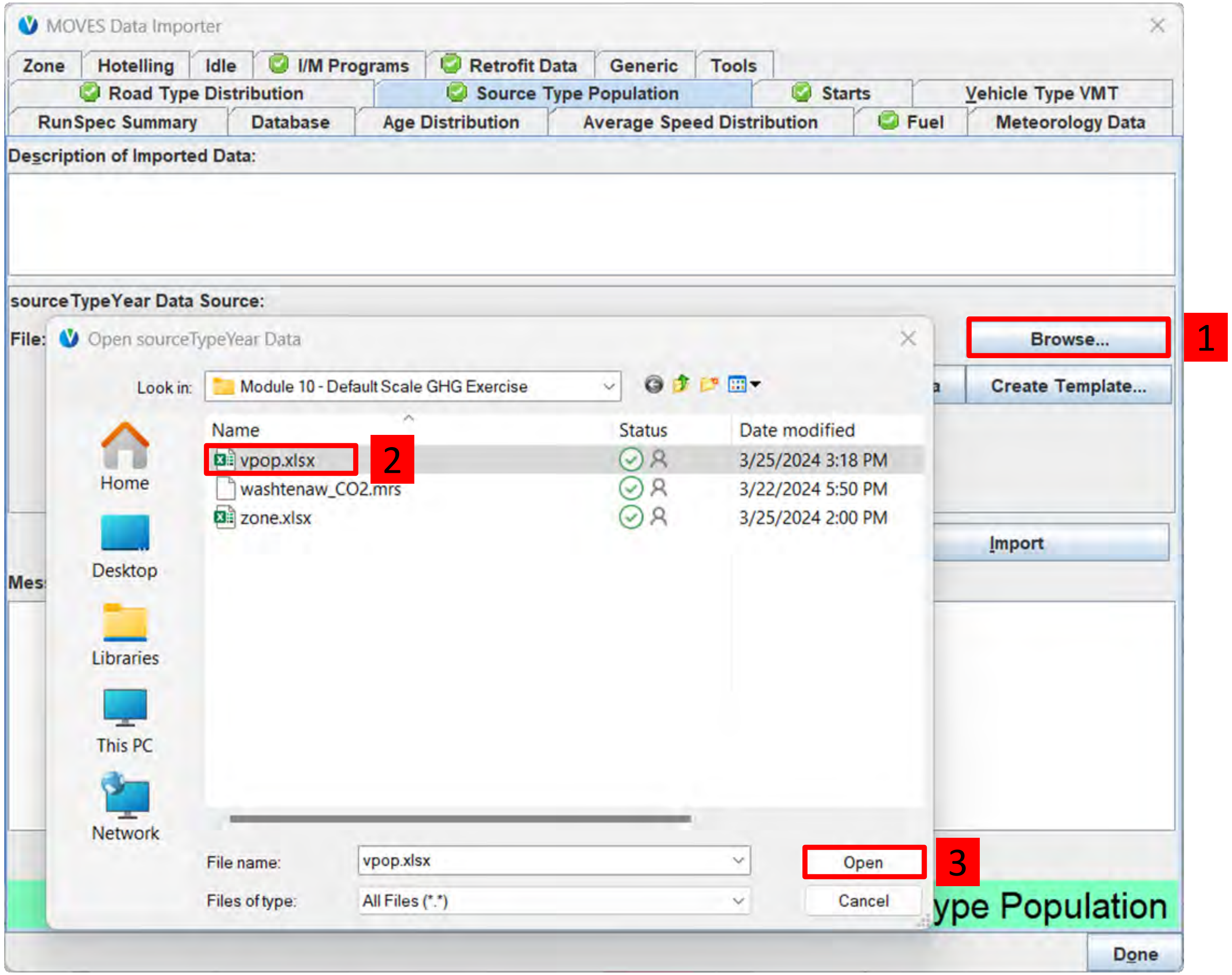
- In Windows Explorer, find the template you just created and open it
- Enter a vehicle population of 200,000 as the "sourceTypePopulation" next to the sourceTypeID 21 to indicate how many passenger cars are in this scenario

yearID	sourceTypeID	sourceTypePopulation
2023	21	200000

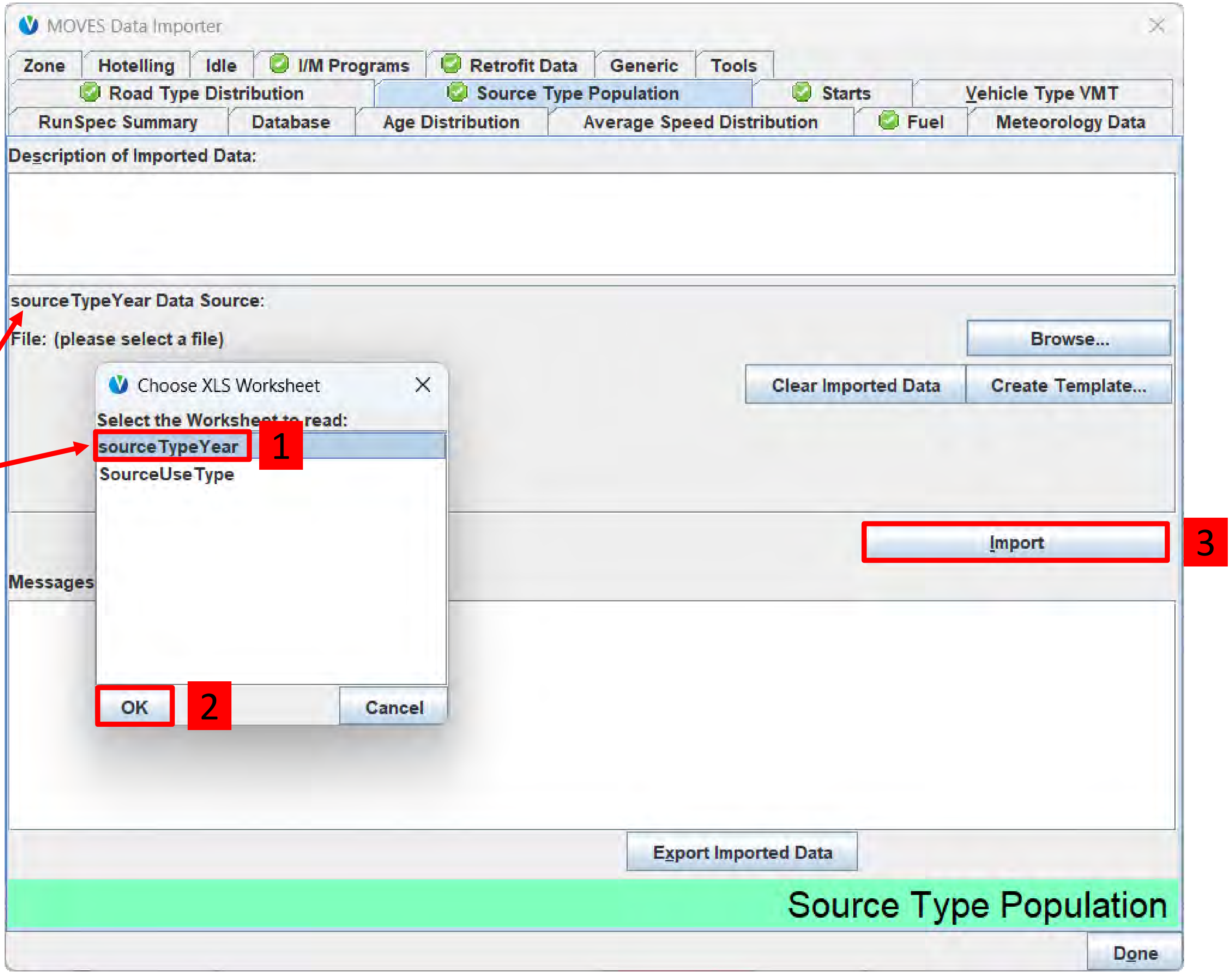
sourceTypeYear SourceUseType ...

- Save and close when done

GHG Exercise: Import the Source Type Population (1)

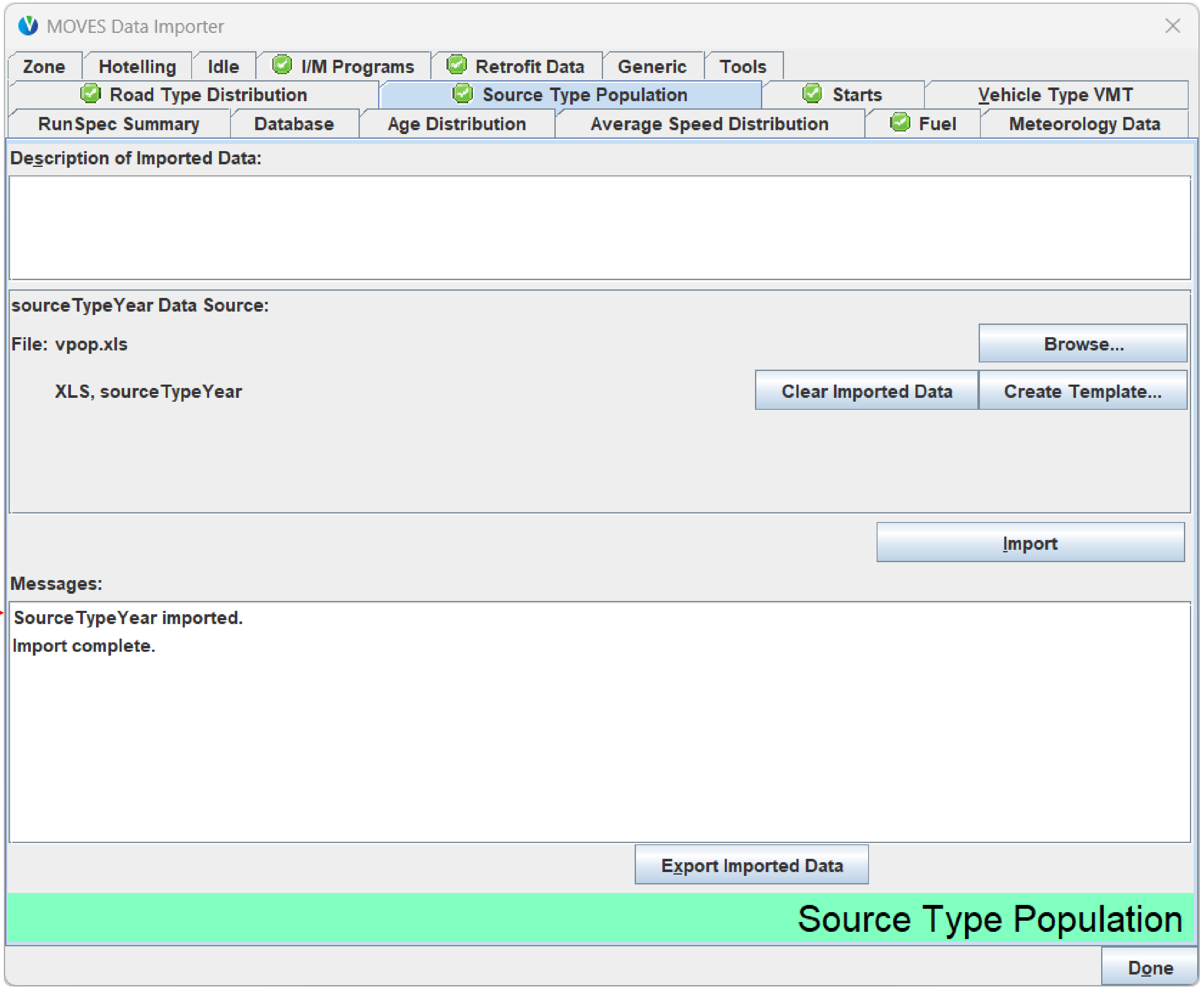


GHG Exercise: Import the Source Type Population (2)



Match the worksheet name to the Data Source name

GHG Exercise: Check for Source Type Population Errors



Any errors will appear in the Messages list

Default Data Importer Vehicle Type VMT Tab

Default Data Importer Vehicle Type VMT

- MOVES uses VMT to calculate emissions for all running and refueling processes
- VMT input is also used to allocate emissions by month, day type (weekday or weekend), and hour
- MOVES allows VMT to be entered in different forms:
  - VMT by HPMS class or VMT by MOVES source type
  - Annual VMT or daily VMT
- Refer to Module 3 for information about filling out the Vehicle Type VMT template

Vehicle Type VMT: GHG Guidance (1)

- Section 4.7 of MOVES GHG Guidance
- Local VMT data are recommended for a GHG analysis
- Enter VMT by either HPMS Class or by Source Type:
  - Use HPMS Class if you don’t have enough detail to disaggregate to Source Type
  - Use Source Type if you have that data and want more control over how MOVES allocates VMT

Vehicle Type VMT: GHG Guidance (2)

Enter either Annual or Daily VMT:

- Use Annual if you want to model multiple months and day types with different VMT fractions in a single run
  - Local VMT, month, day, and hour fractions should be used if available; otherwise, defaults are acceptable
  - Entering annual VMT and the correct month and daily VMT fractions for the entire year allows the same files to be used to model any month or day
  - Use EPA's AADVMT Converter Tool to convert local Daily VMT to Annual VMT if necessary (must have VMT by HPMS class to use the tool)
- Use Daily if that is the form your VMT is in and the VMT is appropriate for the month and day type you are modeling

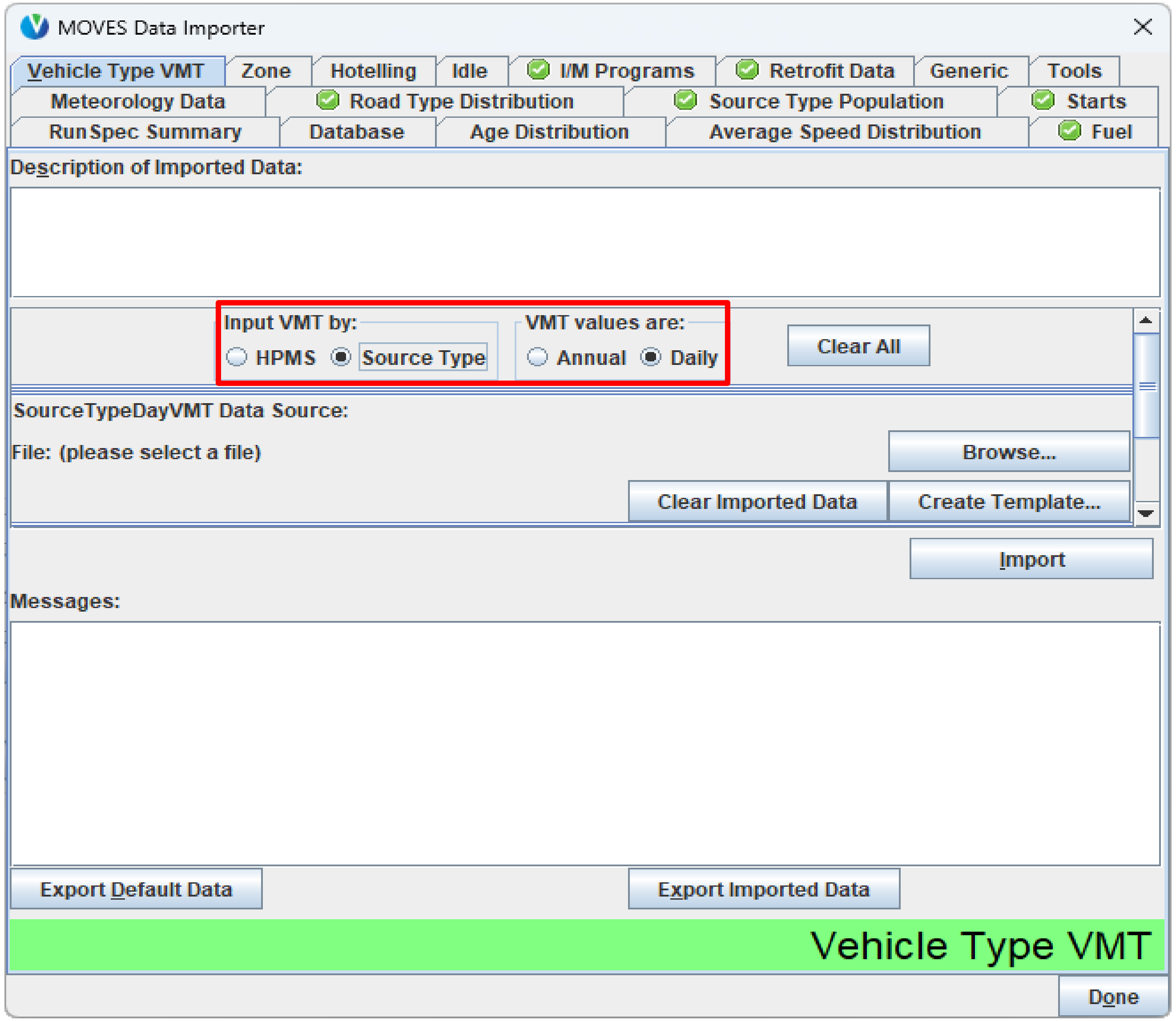
Vehicle Type VMT: GHG Guidance (3)

- Recommend using the same approach (HPMS or source type, annual or daily VMT) for any analysis that compares two or more cases
  - Avoid causing differences in results due to differences in the way VMT is allocated
  - For GHG analyses, consult with other agencies as appropriate to find the latest VMT information and to agree on a common approach or to minimize differences caused by different approaches

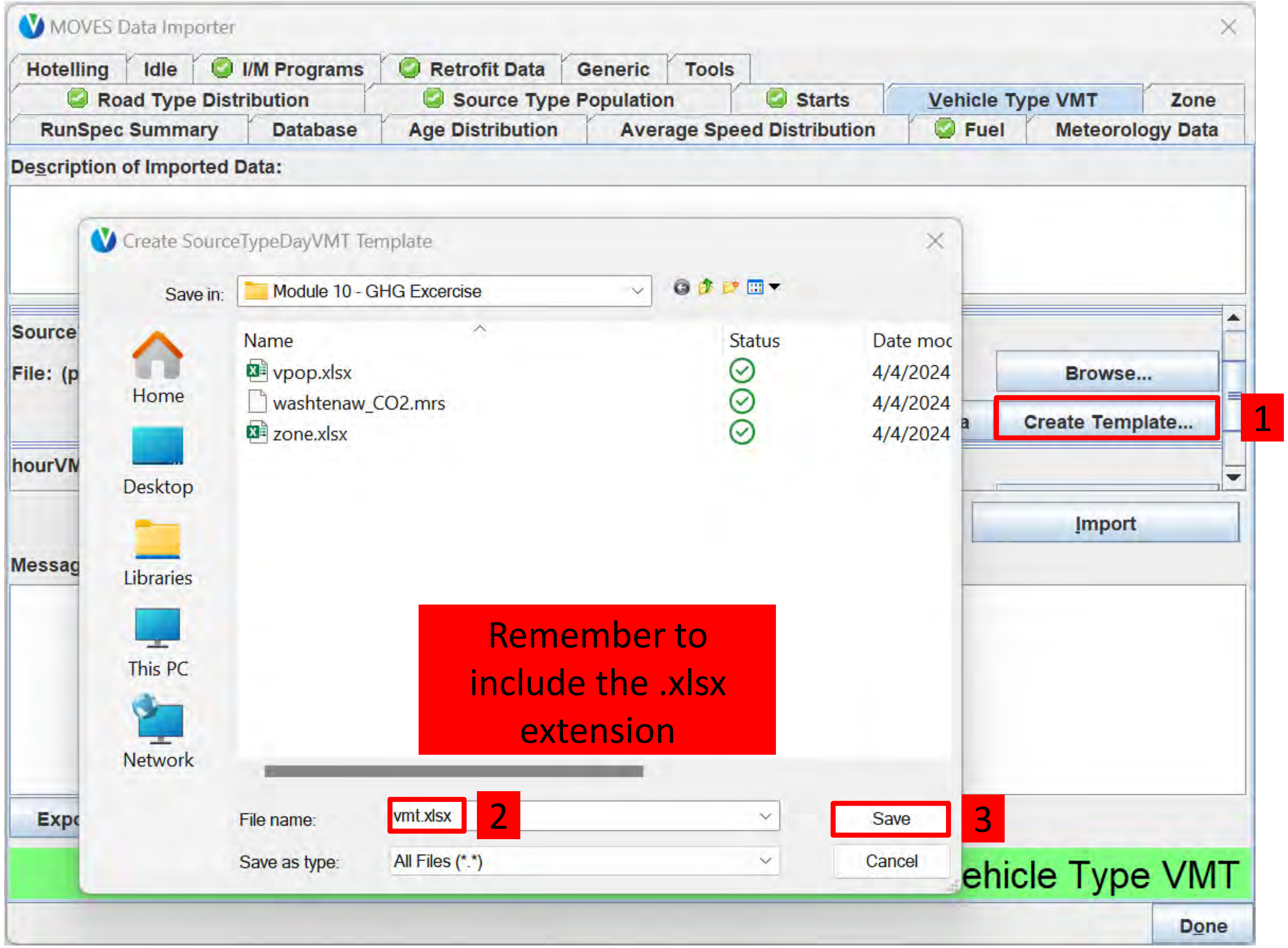
Vehicle Type VMT: GHG Exercise Overview

- We know daily VMT for weekdays and weekend days in Washtenaw County from the earlier modules:
  - Passenger cars (sourceTypeID 21)
  - Weekday (dayID 5) = 5,000,000
  - Weekend day (dayID 2) = 4,000,000

GHG Exercise: Create Vehicle Type VMT Template (1)



GHG Exercise: Create Vehicle Type VMT Template (2)



GHG Exercise: Fill out Vehicle Type VMT Template

- In Windows Explorer, find the template you just created and open it
- In the “SourceTypeDayVMT” sheet, enter a VMT of 4,000,000 for all dayID 2 (weekend days) and 5,000,000 for all dayID 5 (weekdays) to indicate passenger car VMT in this scenario, for all 12 months

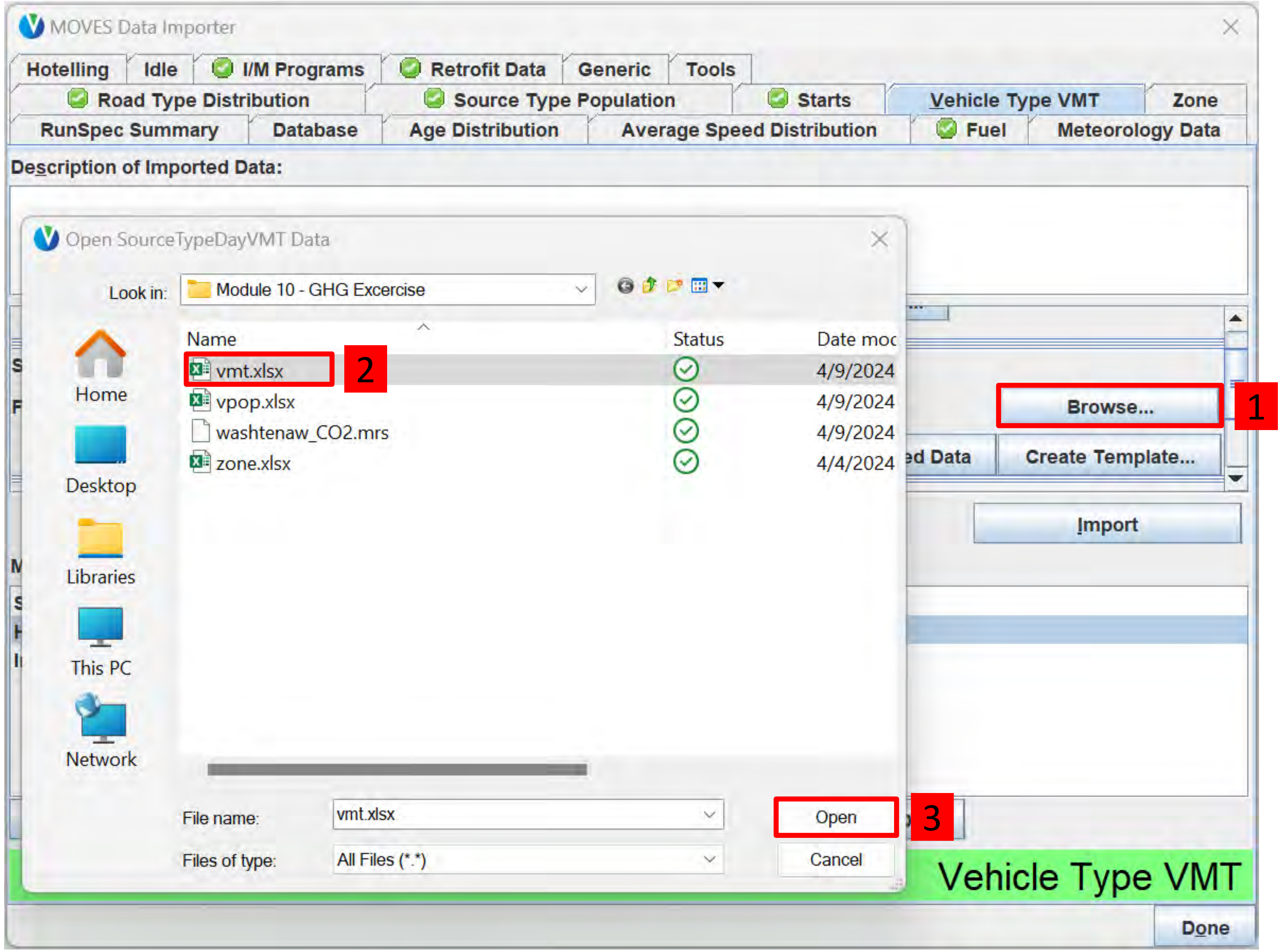
	A	B	C	D	E
1	sourceTyp	yearID	monthID	dayID	VMT
2	21	2023	1	2	4000000
3	21	2023	1	5	5000000
4	21	2023	2	2	4000000
5	21	2023	2	5	5000000

... SourceTypeDayVMT | monthVMTFraction

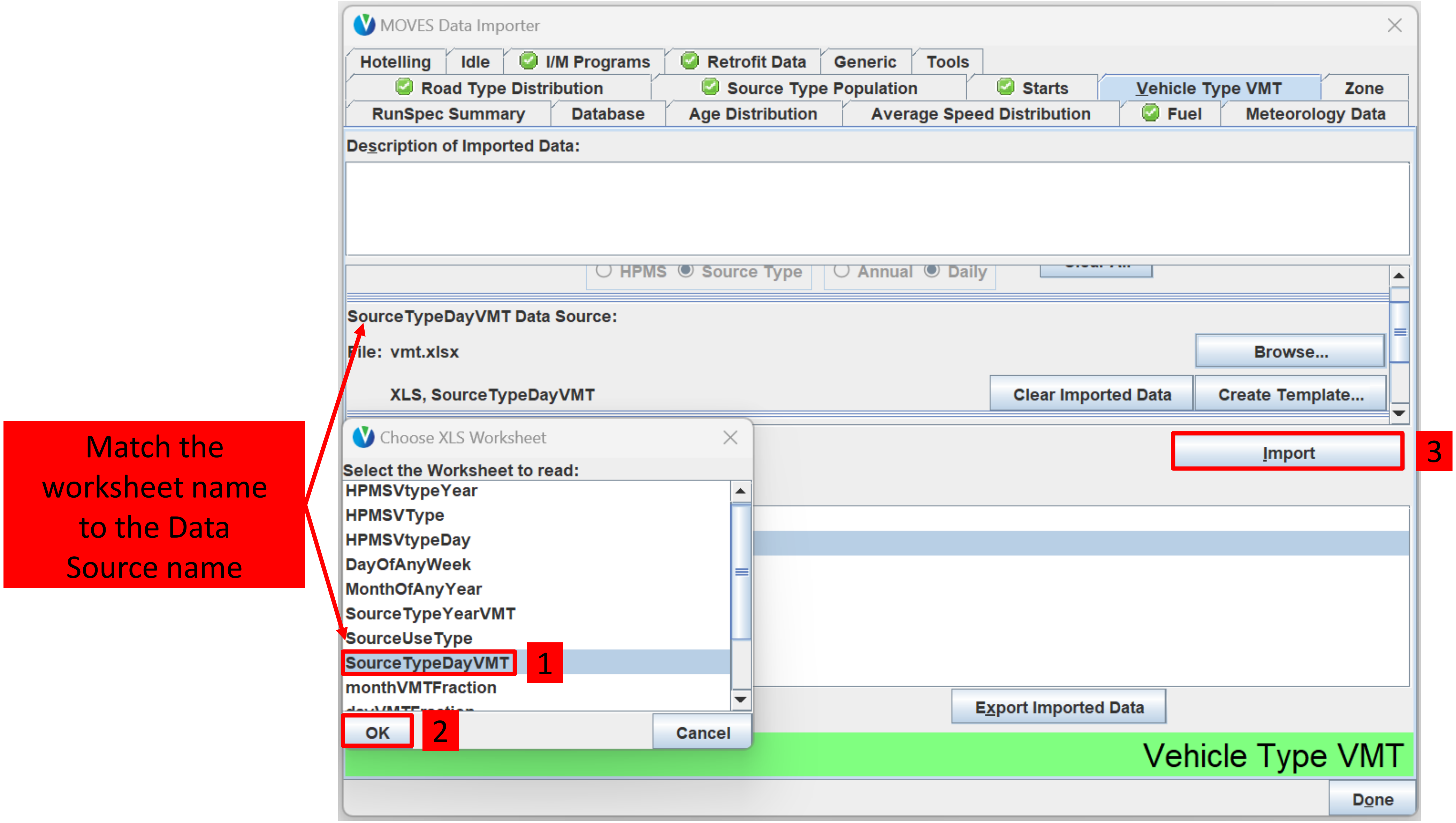
For this exercise, enter the same dayID 2 and dayID 5 VMT for all 12 months (only January and February shown)

- Save and close when done

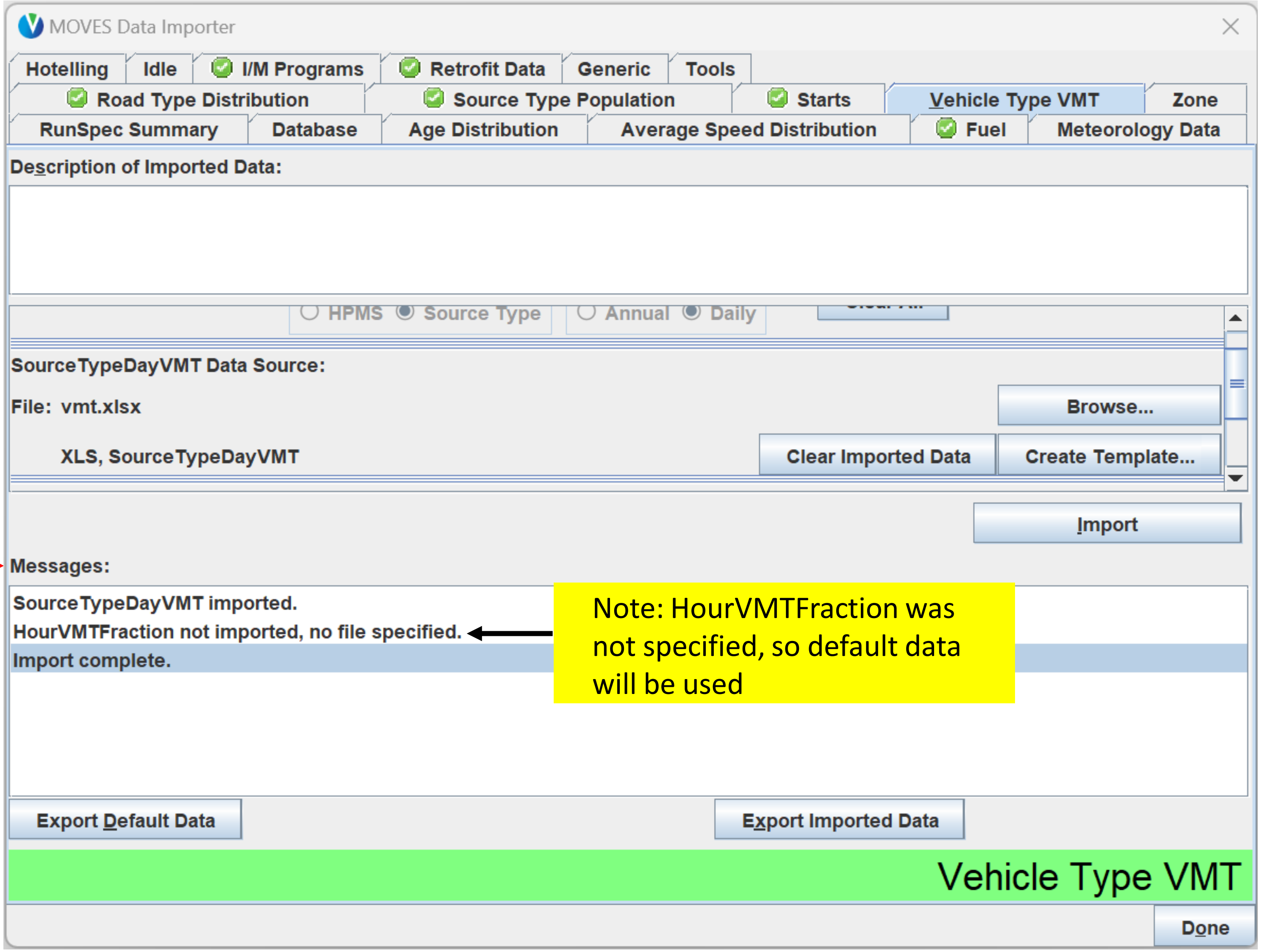
GHG Exercise: Import the Vehicle Type VMT (1)



GHG Exercise: Import the Vehicle Type VMT (2)



GHG Exercise: Check for Vehicle Type VMT Errors



Any errors will appear in the Messages list

GHG Exercise: Running MOVES

- MOVES needs your action to begin the run
- Instructions for our Default Scale Run Exercise:
  - Click the Action Menu
  - Click "▶ Execute" menu item
    - Note: this option is only available when your RunSpec has all green checks
  - When prompted to save the run specification, click "No" as we have already saved the RunSpec
  - NOTE: Executing the RunSpec will open a new window. This window will display any warning or error messages MOVES encounters, along with a status bar and a dialog box that estimates time remaining
    - This run should take less than 10 minutes

GHG Exercise Results

- You can view results from this run with either
  - the Summary Reporter, covered in Module 2, or
  - HeidiSQL, covered in Module 4
- Results are provided by pollutant (CO_2, energy consumption), and fuel type
  - For total CO_2, CO_2 of each fuel type is summed
- Total CO_2 from passenger cars for all fuel types in Washtenaw County in 2023 from MOVES = 572,100,728 kilograms

Module 10 Questions?

Module 11: Special Cases and Additional Examples

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Module 11 Overview

- Using Emission Rates mode to create a lookup table of rates by temperature
- Accessing MOVES output in Excel
- Note: This module may be expanded in the future with additional examples not covered in other modules

Building a Rates Lookup Table

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Building a Rates Lookup Table Overview (1)

- The modeling strategy discussed in Module 6 Emission Rates uses specific diurnal temperature profiles that reflect actual conditions
- If you need to model a wide range of temperatures and humidities (for example, over a wide geographic area), you may be limited when using only typical diurnal profiles
- An advanced approach is to create a rates lookup table by temperature and humidity
  - With this approach, the month and hour fields lose their regular meaning and become arbitrary IDs

Building a Rates Lookup Table Overview (2)

- Involves making certain selections in the RunSpec and using the meteorology tab of the CDM to define temperatures:
  - Each month selected in the RunSpec provides you 24 temperature "slots" (one for each hour of the day)
  - These slots can hold temperatures in 1 degree increments, to get running rates at each specific temperature
  - Or, a month's slots can hold a daily temperature profile, needed for start, hotelling, and evaporative fuel vapor venting rates
  - Determine how many months to select in the RunSpec based on the number of temperature slots needed to represent all the rates you need

Building a Rates Lookup Table: Running Rates

- For running rates (RatePerDistance table):
- Determine the temperature range for which you want rates, and how many months are needed in the RunSpec (each month = 24 temperatures)
  - For example, if the temperature range of interest is 50 to 97° F, 48 temperature slots are needed; 2 months can accommodate all of them
  - July Hour 1: 50 degrees
  - July Hour 2: 51 degrees … (and so on, one degree per slot until…)
  - August Hour 24: 97 degrees
- A rate will be produced for each temperature – in this case, the hourID value is not relevant for the results
- MonthID (the month(s) chosen in the RunSpec) affects the fuels MOVES assumes, but otherwise does not affect the rates
  - This is because you are defining the temperatures

Building a Rates Lookup Table: Diurnal Profiles

- For start and hotelling rates (RatePerVehicle table) and evaporative fuel vapor venting (RatePerProfile table):
- Determine the number of diurnal profiles you need; each month selected can accommodate one diurnal profile
- Input a realistic diurnal profile for the 24 hours, since both temperature and hour of day impact these emission rates, e.g.:
  - September Hour 1 – 50.1 degrees
  - September Hour 2 – 51.6 degrees
  - September Hour 3 – 54.4 degrees, etc.
- A rate will be produced for each temperature/hourID
- MonthID (the month(s) chosen in the RunSpec) affect the fuels MOVES assumes, but otherwise does not affect the rates
  - because you are defining the temperatures

Building a Rates Lookup Table in a Single Run

- You can get the following all in one run:
  - running rates (RatePerDistance table)
  - start and hotelling rates (RatePerVehicle table)
  - resting evaporative rates (RatePerProfile table)

if you:

- Use some months to define one degree temperature intervals, for running rates
- Use other months to define daily temperature profiles, for start, hotelling, and resting evaporative rates
- Use specific months to have MOVES assume the right fuels

Building a Rates Lookup Table Example

Example of an annual inventory, with six months selected in RunSpec:

Winter rates:

- Use months 12 and 1 to cover the winter temperature range for rateperdistance rates
  - E.g., 0 degrees through 47 degrees, in 1 degree intervals
- Use month 2 to define a typical winter daily temperature profile for ratepervehicle and rateperprofile rates
- Confirm that months 12-2 have correct winter fuel properties

Summer rates:

- Use month 6 and 7 to cover the summer temperature range for rateperdistance rates
  - E.g., 48 degrees through 95 degrees in 1 degree intervals
- Use month 8 to define a typical summer daily temperature profile for ratepervehicle and rateperprofile rates
- Confirm that months 6-8 have correct summer fuel properties

Building a Rates Lookup Table Discussion

- What if you need more temperature slots for summer, but you run out of summer months in the RunSpec?

- What if you need more temperature slots, period?

Building a Rates Lookup Table Knowledge Check

- What if you need more temperature slots for summer, but you run out of summer months in the RunSpec?
  - You can use any of the 12 months – just be sure to edit the fuel supply table so that summertime fuel formulations are used in all months (in the Fuel tab of the CDM)
- What if you need more temperature slots, period?
  - You would need to do multiple runs

Accessing MOVES Output in Excel

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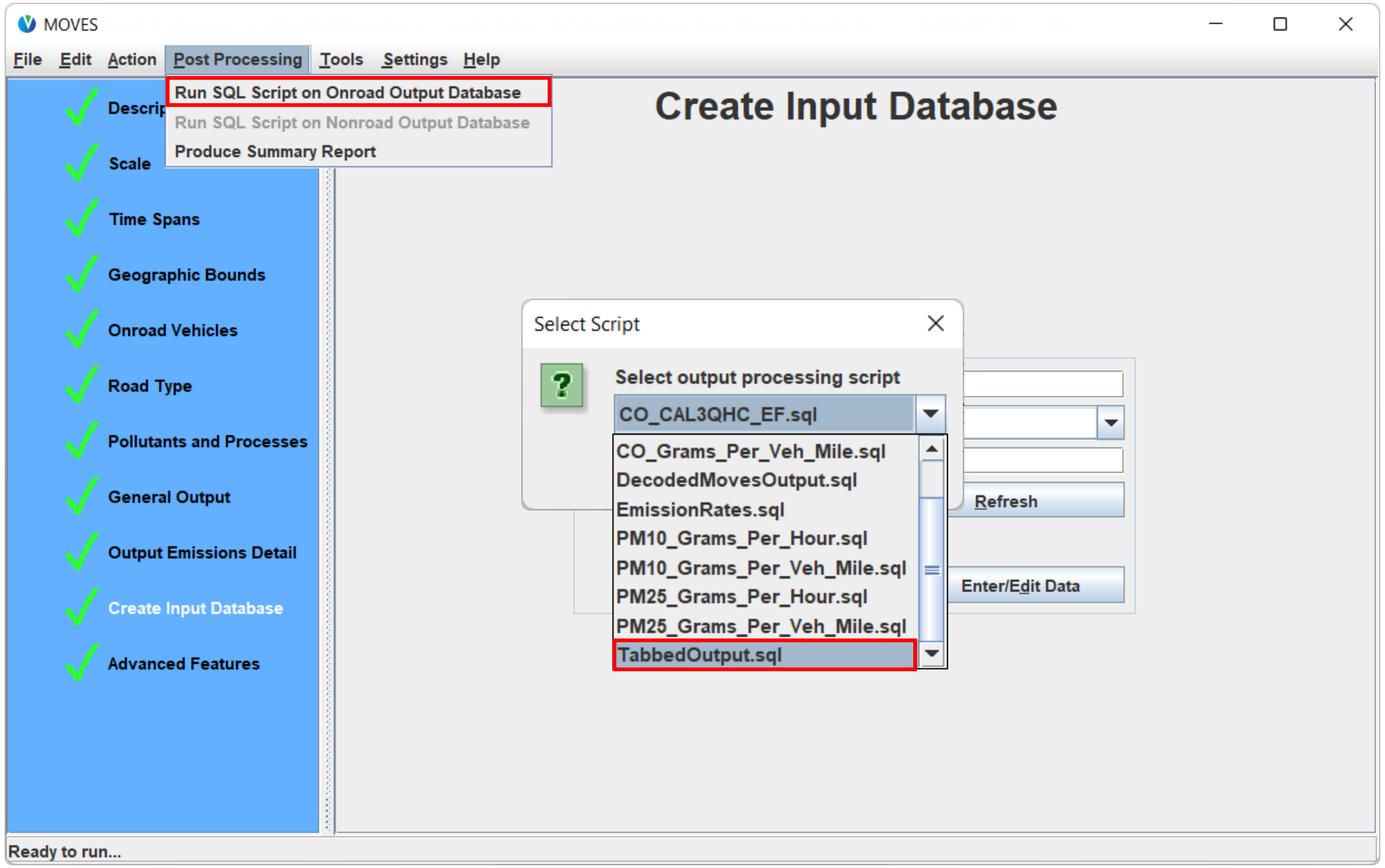
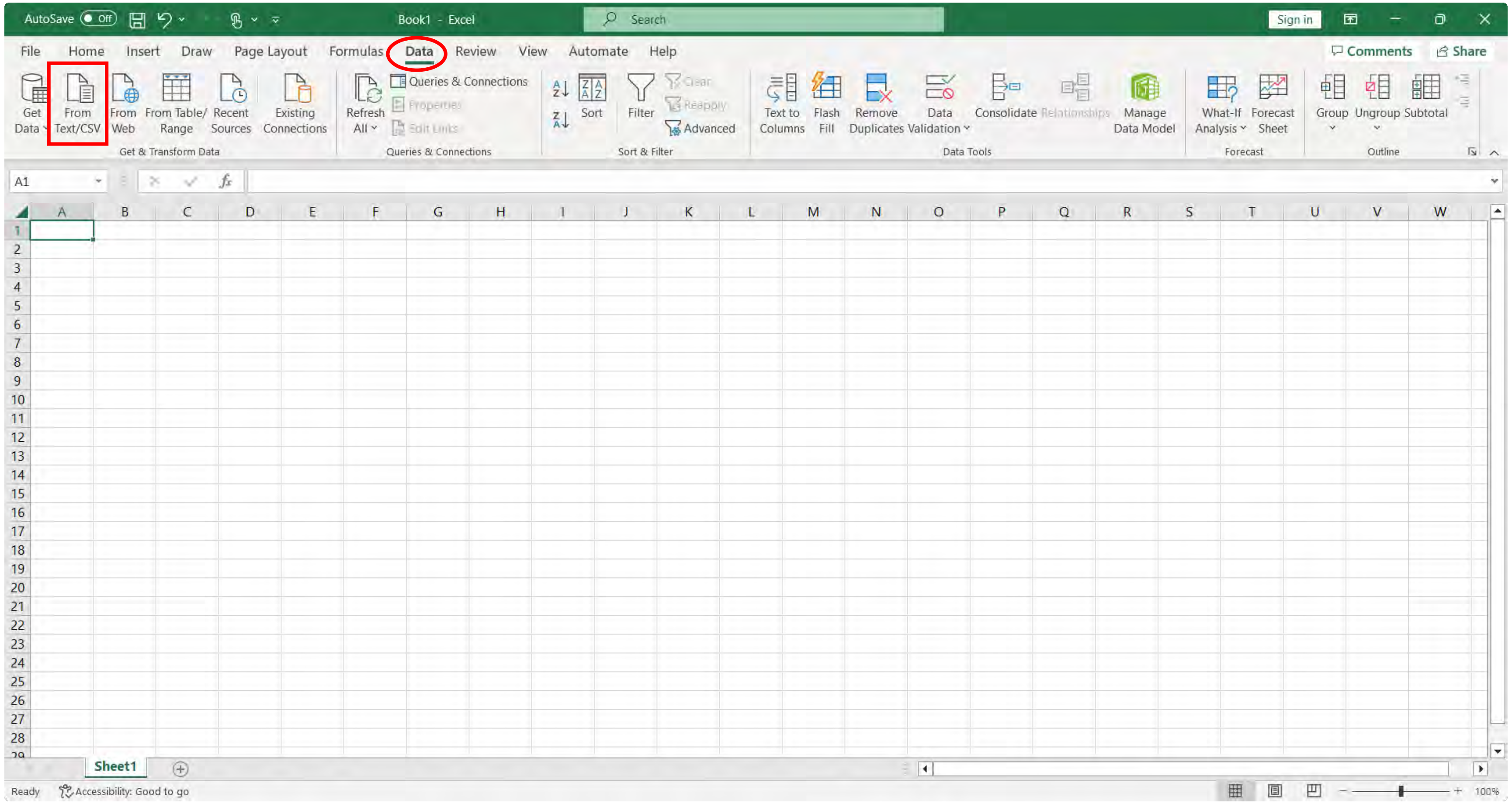
Accessing MOVES Output in Excel Overview

- After running MOVES, open the Post Processing menu and select “Run SQL Script on Onroad Output Database”
- Select “TabbedOutput” and click “OK” in the documentation pop-up. When MOVES is done exporting the data, you will get another pop-up
- In Excel, navigate to the Data ribbon and click the “From Text/CSV” icon
  - Excel will prompt you to select a file to load
  - Navigate to your MariaDB data directory. You may have a shortcut on your desktop to help you find it
  - Open your output database’s directory
  - Select which file you want to load. Your options will be the MovesOutput, MovesActivityOutput, or the MovesRun table
- Excel will show you a preview of your data. Click “Load”

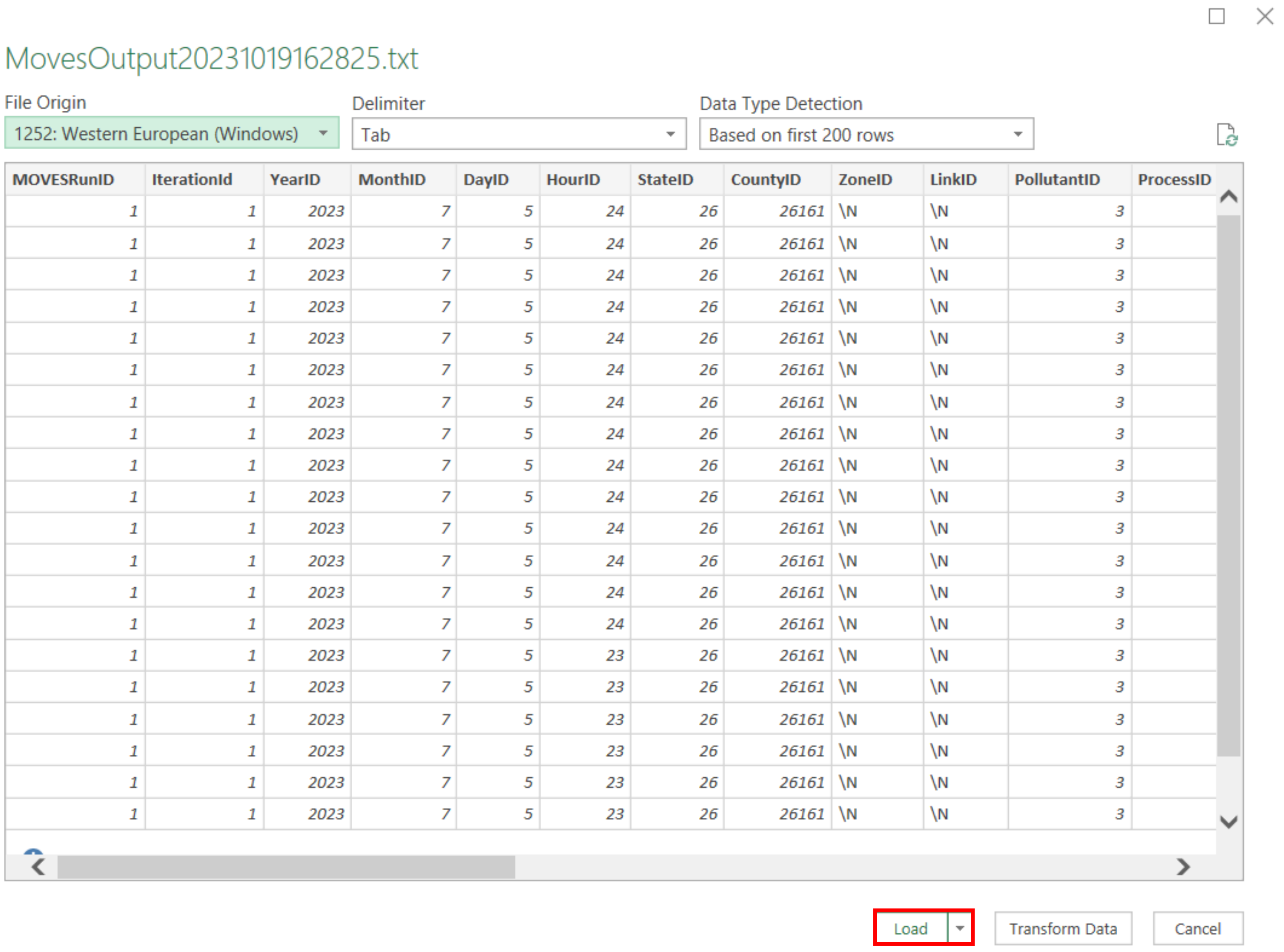
Export data using the TabbedOutput Post-Processing Script



In Excel, use the From Text/CSV option



After selecting a file, click “Load”



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1	1	2023	7	5	24	26	26161	\N	\N	3	
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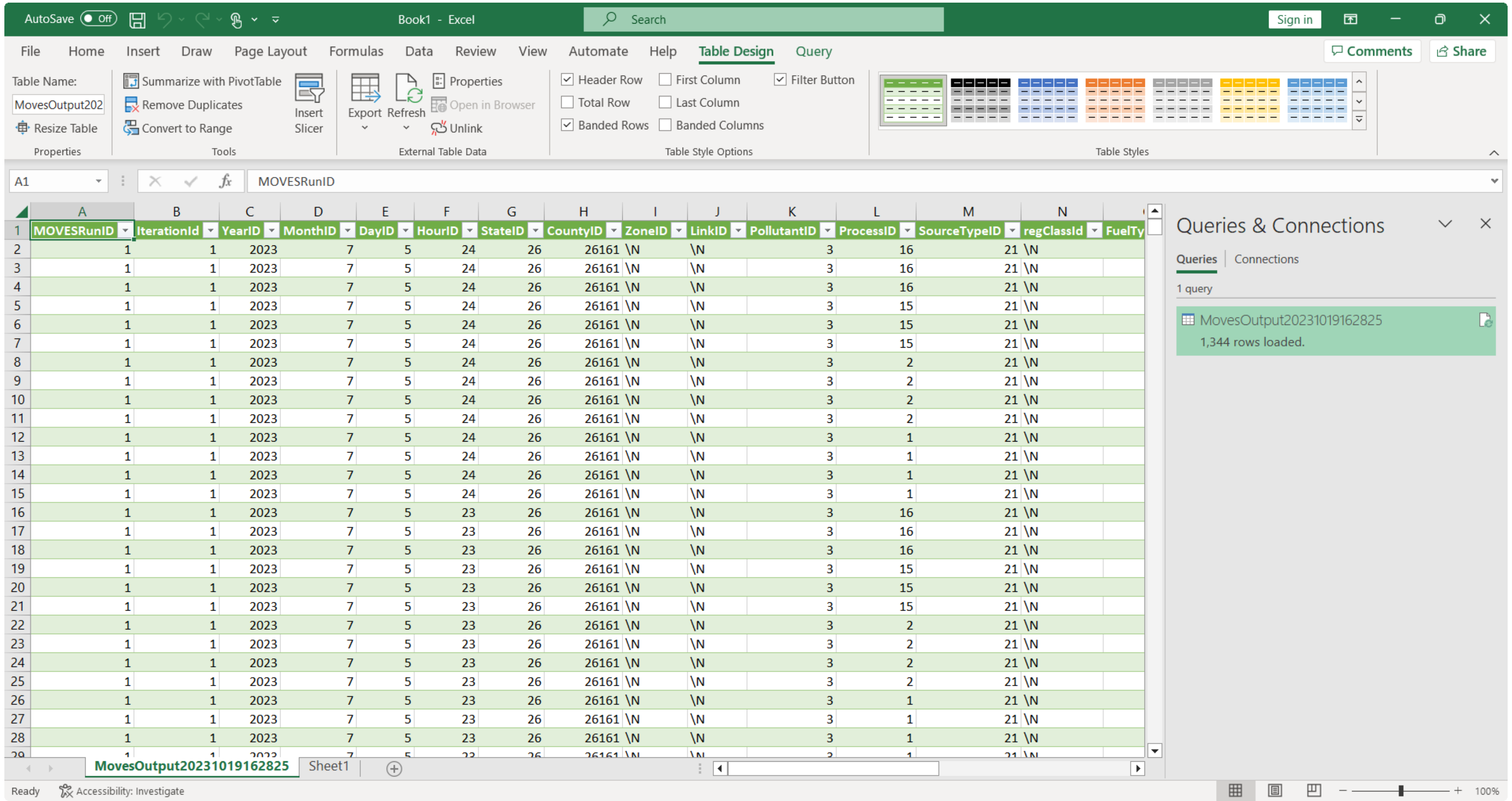
1	1	2023	7	5	23	26	26161	\N	\N	3	
1	1	2023	7	5	23	26	26161	\N	\N	3	

Data loaded in Excel



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1	1	2023	7	5	23	26	26161	\N	\N	3	1	21	\N	

Course Wrap-up

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For more information after this class

Visit:
www.epa.gov/moves

Final Thoughts

- To join the MOVES listserv, go to:
  www.epa.gov/moves/forms/epa-mobilenews-listserv

- Questions?
  - Check out our FAQ page: www.epa.gov/moves/frequent-questions-about-moves-and-related-models

  - Contact us: mobile@epa.gov

- If you have feedback on this training, please contact us at the email above

Thank You

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