User's Guide for Estimating Methane and Nitrous Oxide Emissions From Mobile Combustion Using the State Inventory Tool

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This section of the User's Guide provides instruction on using the Mobile Combustion module of the State Inventory Tool (SIT), and describes the methodology used for estimating greenhouse gas (GHG) emissions from highway and non-highway vehicles at the state level.

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1.1 Getting Started

The Mobile Combustion module was developed using Microsoft® Excel 2000. While the module will operate with older versions of Excel, it functions best with Excel 2000 or later. If you are using Excel 2007, instructions for opening the module will vary as outlined in the Excel basics below. Some of the Excel basics are outlined in the sections below. Before you use the Mobile Combustion module, make sure your computer meets the system requirements. In order to install and run the Mobile Combustion module, you must have:

- IBM-PC compatible computer with the Windows 95 operating system or later;
- Microsoft® Excel 1997 or later, with calculation set to automatic and macros enabled;
- Hard drive with at least 20MB free; and
- Monitor display setting of 800 x 600 or greater.

Microsoft Excel Settings

Excel 2003 and Earlier: For the SIT modules to function properly, Excel must be set to automatic calculation. To check this setting, launch Microsoft Excel before opening the Mobile Combustion module. Go to the Tools menu and select "Options..." Click on the "Calculations" tab and make sure that the radio button next to "Automatic" is selected, and then click on "OK" to close the window. The security settings (discussed next) can also be adjusted at this time.

Excel 2007: For the SIT modules to function properly, Excel must be set to automatic calculation. Go to the Formulas ribbon and select "Calculation Options." Make sure that the box next to the "Automatic" option is checked from the pop-up menu.

Microsoft Excel Security

Excel 2003 and Earlier: Since the SIT employs macros, you must have Excel security set to medium (recommended) or low (not recommended). To change this setting, launch Microsoft Excel before opening the Mobile Combustion module. Once in Excel, go to the Tools menu, click on the Macro sub-menu, and then select "Security" (see Figure 1). The Security pop-up box will appear. Click on the "Security Level" tab and select medium. When set to high, macros are automatically disabled; when set to medium, Excel will give you the choice to enable macros; when set to low, macros are always enabled.

When Excel security is set to medium, users are asked upon opening the module whether to enable macros. Macros must be enabled in order for the Mobile Combustion module to work. Once they are enabled, the module will open to the control worksheet. A message box will appear welcoming the user to the module. Clicking on the "x" in the upper-right-hand corner of the message box will close it.

Excel 2007: If Excel's security settings are set at the default level a Security Warning appears above the formula box in Excel when the Mobile Combustion module is initially opened. The Security Warning lets the user know that some active content from the spreadsheet has been disabled, meaning that Excel has prevented the macros in the spreadsheet from functioning. Since SIT needs macros in order to function properly, the user must click the "Options" button in the security message and then select, "Enable this content" in the pop-up box. Enabling the macro content for the SIT in this way only enables macros temporarily in Excel but does not change the macro security settings. Once macros are enabled, a message box will appear welcoming the user to module. Click on the “x” in the upper right-hand corner to close the message box.

If the Security Warning does not appear when the module is first opened, it may be necessary to change the security settings for macros. To change the setting, first exit out of the Mobile Combustion module and re-launch Microsoft Excel before opening the Mobile Combustion module. Next, click on the Microsoft Excel icon in the top left of the screen. Scroll to the bottom of the menu and select the “Excel Options” button to the right of the main menu. When the Excel Options box appears, select “Trust Center” in left hand menu of the box. Next, click the gray “Trust Center Settings” button. When the Trust Center options box appears, click “Macro Settings” in the left hand menu and select “Disable all macros with notification.” Once the security level has been adjusted, open the Stationary Combustion module and enable macros in the manner described in the preceding paragraph.

Viewing and Printing Data and Results

The Mobile Combustion module contains some features to allow users to adjust the screen view and the appearance of the worksheets when they are printed. Once a module has been opened, you can adjust the zoom by going to the Module Options Menu, and either typing in a zoom percentage or selecting one from the drop down menu. In addition, data may not all appear on a single screen within each worksheet; if not, you may need to scroll up or down to view additional information.

You may also adjust the print margins of the worksheets to ensure that desired portions of the Mobile Combustion module are printed. To do so, go to the File menu, and then select “Print Preview.” Click on “Page Break Preview” and drag the blue lines to the desired positions (see Figure 2). To print this view, go to the File menu, and click “Print.” To return to the normal view, go to the File menu, click “Print Preview,” and then click “Normal View.”

Figure 1. Changing Security Settings

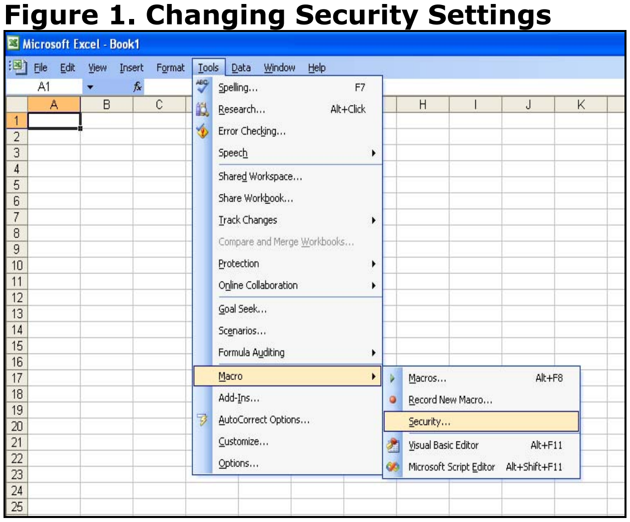
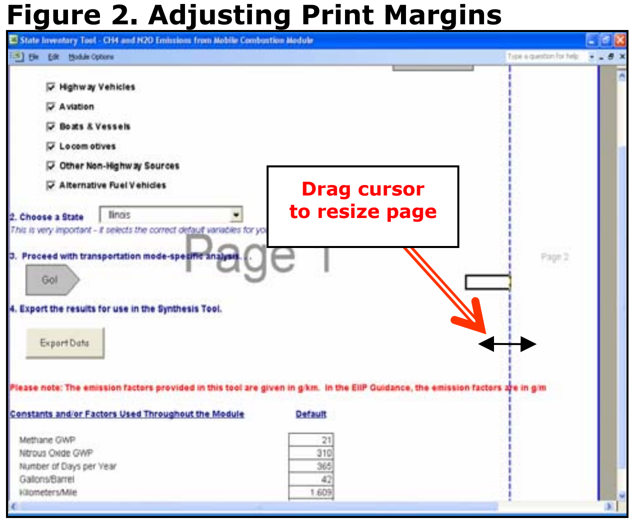


Figure 2. Adjusting Print Margins



1.2 Module Overview

This User's Guide accompanies and explains the Mobile Combustion module of the SIT. The SIT was developed in conjunction with EPA's Emissions Inventory Improvement Program (EIIP). Prior to the development of the SIT, EPA developed the States Workbook for estimating greenhouse gas emissions. In 1998, EPA revisited the States Workbook and expanded it to follow the format of EIIP guidance documents for criteria air pollutants. The result was a comprehensive, stepwise approach to estimating greenhouse gas emissions at the state level. This detailed methodology was appreciated by states with the capacity to devote considerable time and resources to the development of emission inventories. For other states, the EIIP guidance was overwhelming and impractical for them to follow from scratch. EPA recognized the resource constraints facing the states and developed the SIT. The ten modules of the SIT corresponded to the EIIP chapters and attempted to automate the steps states would need to take in developing their own emission estimates in a manner that was consistent with prevailing national and state guidelines.

Since most state inventories developed today rely heavily on the tools, User's Guides have been developed for each of the SIT modules. These User's Guides contain the most up-to-date methodologies that are, for the most part, consistent with the Inventory of U.S. Greenhouse Gas Emissions and Sinks. Volume VIII of the EIIP guidance is a historical document that was last updated in August 2004, and while these documents can be a valuable reference, they contain outdated emissions factors and in some cases outdated methodologies. States can refer to Volume VIII of the EIIP guidance documents if they are interested in obtaining additional information not found in the SIT or the companion User's Guide.

Box 1: State Mobile Combustion Data Sources

In-state sources, such as state highway agencies, should be consulted first. Otherwise, default data provided by the Mobile Combustion module may be used.

The Mobile Combustion module calculates methane (CH_4) and nitrous oxide (N_2O) emissions from highway vehicles, aviation, boats and vessels, locomotives, other non-highway sources, and alternative fuel vehicles. This module also includes optional calculations of carbon dioxide (CO_2) from these sources, which are also calculated in the CO_2 from Fossil Fuel Combustion (CO_2FFC) module. The Mobile Combustion module-based CO_2 calculations provide detail by transportation mode not available in the CO_2FFC module.

For highway vehicles, it calculates emissions based on vehicle miles traveled (VMT) for eight types of control technologies: three-way catalyst, early three-way catalyst, oxidation catalyst, non-catalyst, low-emission vehicle, advanced, moderate, and uncontrolled; and for seven classes of vehicles, using the Federal Highway Administration (FHWA) vehicle classifications. For other transportation types, emissions are based on fuel consumption in gallons or British thermal units (BTU). While the module provides default data for most inputs, if you have access to more comprehensive data sources, they should be used in place of the default data (see Box 1 for suggestions of possible data sources). If using outside data sources, or for a more thorough understanding of the tool, please refer to the following discussion of data requirements and methodology.

Although there is virtually no CH_4 in either gasoline or diesel fuel, CH_4 is emitted as a combustion product that is influenced by fuel composition, combustion conditions, and control technologies. Depending on the control technologies used, CH_4 emissions may also result from hydrocarbons passing unburned or partially burned through the engine, and then be affected by any post-combustion control of hydrocarbon emissions, such as catalytic converters. For highway vehicles, the emissions of unburned hydrocarbons, including CH_4, are generally lowest in uncontrolled engines when the air/fuel ratio is high or "lean," which means that there is excess oxygen available relative to the quantity of hydrogen and carbon present. However, such conditions favor the formation of nitrogen oxides, which are a major air pollutant and key component in the formation of smog. In modern three-way closed loop catalyst highway vehicles, the lowest emissions are achieved when hydrogen, carbon, and oxygen are present in the ideal combination for complete combustion. Conditions favoring high CH_4 emissions include aggressive driving, low speed operation, and cold start operation. Poorly tuned highway vehicle engines may have a particularly high output of CH_4.

Emissions are also strongly influenced by the engine type and the fuel combusted. N_2O formation in internal combustion engines is not yet well understood, and data on these emissions are scarce. It is believed that N_2O emissions come from two distinct processes. In the first process, during combustion in the cylinder, N_2O is formed as nitrogen oxide interacts with combustion intermediates such as NH and NCO. The N_2O is then removed very rapidly in the post-flame gas by the reaction between N_2O and hydrogen. While a significant amount of N_2O may be formed in the flame, it can only survive if there is very rapid quenching of the flame, which is not common. Thus, only small amounts of N_2O are produced as engine-out emissions.

The second N_2O-forming process occurs during catalytic after-treatment of exhaust gases. The output of N_2O from the catalyst is highly temperature dependent. Prigent and De Soete (1989) showed that as the catalyst warms up after a cold start, N_2O levels increase greatly (to 4.5 times the inlet value) at around 360°C. The emissions then decrease to the inlet level as the catalyst reaches a temperature of 460°C. Above this temperature there is less N_2O exiting the catalyst than entering it. These results demonstrate that N_2O is formed primarily during cold starts of catalyst-equipped vehicles. This explains why N_2O emissions data for the Federal Test Procedure (which includes a cold-start phase) are much higher than data for the U.S. Highway Fuel Economy Test (which does not include a cold start phase).

Emissions of CH_4 and N_2O from non-highway mobile sources have received relatively little study. Non-highway sources include jet aircraft, gasoline-fueled piston aircraft, agricultural and construction equipment, railway locomotives, boats, and ships. Except for aircraft (fueled by jet fuel or gasoline), all of these sources are typically equipped with diesel engines.

In 2013, additional updates were made to the mobile combustion module to improve disaggregation of CO_2 estimates, and compliment the CO_2 from Fossil Fuel Combustion module. An explanation of these updates can be found in Section 1.5, "Explanation of Mobile Combustion Module Updates."

1.2.1 Data Requirements

To calculate GHG emissions from mobile combustion, the data listed in Table 1 are required inputs (again, note that defaults are available for most of these data).

Table 1. Required Data Inputs for the Mobile Combustion Module

Module Worksheet	Input Data Required
4a Highway Vehicles - Emission Factors and VMT	CH_4 and N_2O emission factors (g/km traveled) for each type of control technology State total VMT, 1990-present, for all vehicle types
4b Highway Vehicles - Allocating VMT by Model Year	Annual vehicle mileage accumulation (miles) for each model year in use Age distribution of vehicles (%) in the current year
4c Highway Vehicles - Allocating Control Technology by Model Year	Percentage of vehicles with each control type, 1960-present
5 Aviation Factors and Fuel Consumption	Energy contents (kg/million BTU) for kerosene jet fuel, naphtha jet fuel, and aviation gasoline N_2O and CH_4 emission factors (g/kg fuel) for each type of fuel Aviation fuel consumption (million BTU), 1990-present
6 Marine Factors and Fuel Consumption	Density factors (kg/gal) for residual fuel, distillate fuel, and motor gasoline N_2O and CH_4 emission factors (g/kg fuel) for each type of fuel Marine fuel consumption (gallons), 1990-present
7 Locomotive Factors and Fuel Consumption	Density factors (kg/gal or ton) for residual fuel, diesel fuel, and coal N_2O and CH_4 emission factors (g/kg fuel) for each type of fuel Locomotive fuel consumption (gal or tons), 1990-present
8 Other Non-Highway Factors and Fuel Consumption	Density factors (kg/gal) for diesel and gasoline N_2O and CH_4 emission factors (g/kg fuel) for diesel and gasoline tractors, construction equipment, snowmobiles, and other equipment Fuel consumption (gal), 1990-present, for the above types of equipment
9 Alternative Fuel Vehicles Factors and VMT	CH_4 and N_2O emission factors (g/km traveled) for each type of alternative fuel (methanol, ethanol, LPG, LNG, CNG) State total VMT, 1990-present, for alternative fuel vehicles

1.2.2 Tool Layout

Since there are multiple sections to complete within the Mobile Combustion module, it is important to have an understanding of the module's overall design. The layout of the module and the purpose of its worksheets are presented in Figure 3.

Figure 3. Flow of Information in the Mobile Combustion Module*

Control Worksheet

1. Select Modes of Transport
2. Choose a State
3. Select Optional CO_2 Calculations
4. - 11. Proceed to Calculation Worksheets
12. View Summary Data
13. Export Data

Mode-Specific Worksheets

4a. Highway Vehicles - Emission Factors and VMT Worksheet
↓ Enter emission factors and VMT for highway vehicles
4b. Highway Vehicles - Allocating VMT by Model Year Worksheet
↓ Enter annual mileage accumulation and age distribution by model year
4c. Highway Vehicles - Allocating Control Technology by Model Year Worksheet
↓ Enter percent of vehicles with each type of pollution control by year
5. Aviation Worksheet
↓ Enter energy contents, emission factors, and aviation fuel consumption
6. Marine Worksheet
↓ Enter density factors, emission factors, and marine fuel consumption
7. Locomotive Worksheet
↓ Enter density factors, emission factors, and locomotive fuel consumption
8. Other Non-Highway Worksheet
↓ Enter density factors, emission factors, and other non-highway fuel consumption
9. Alternative Fuel Vehicles Worksheet
↓ Enter emission factors and VMT for alternative-fuel highway vehicles
10. Highway CO_2 Worksheet
↓ Review highway CO_2 calculations
11. Non-Highway CO_2 Worksheet
↓ Review non-highway CO_2 calculations

Summary Data

↕ Presented in both table and graphical formats in $MMTCO_2E$

Uncertainty

Review information on uncertainty associated with the default data

* These worksheets are the primary worksheets used in the Mobile Combustion module; subsequent worksheets are used to populate the default data and are provided for informational purposes only.

1.3 Methodology

This section provides a guide to using the Mobile Combustion module of the SIT to estimate GHG emissions from the following types of vehicles (or transportation modes): highway vehicles, airplanes, boats, trains, non-highway equipment (e.g. tractors and snowmobiles), and alternative-fuel highway vehicles. The module estimates CH_4, N_2O, and CO_2 emissions from mobile sources using activity data, information on the combustion technologies used, and information on the type of emission control technologies employed during and after combustion. Operating conditions during combustion also have an impact on emissions, and are reflected in the emission factor. The basic approach for estimating emissions is presented in Equation 1, but variations on this equation will be discussed in subsequent sections, following this general methodology discussion.

Equation 1. General Mobile Combustion Equation

$$\text{Emissions} = \Sigma(EF_{abc} \times Activity_{abc})$$

Where,

EF = emissions factor (e.g., grams/kilometer traveled);
Activity = activity level measured in the units appropriate to the emission factor (e.g., miles);
a = fuel type (e.g., diesel or gasoline);
b = vehicle type (e.g., passenger car, light duty truck, etc.); and
c = emission control type (if any)

The Mobile Combustion module automatically calculates emissions once you have entered the required data on the control and transportation mode worksheets. The tool provides default data for all parameters.

There are six general steps involved in estimating emissions using the Mobile Combustion module: (1) select relevant modes of transport; (2) select a state; (3) select an option to conduct optional CO_2 calculations; (4) complete highway vehicle worksheets; (5) complete aviation worksheet; (6) complete marine worksheet; (7) complete locomotives worksheet; (8) complete other non-highway worksheet; (9) complete alternative fuel vehicles worksheet; (10) review highway CO_2 emissions worksheet; (11) review off-road CO_2 emissions worksheet; (12) review summary information; and (13) export data.

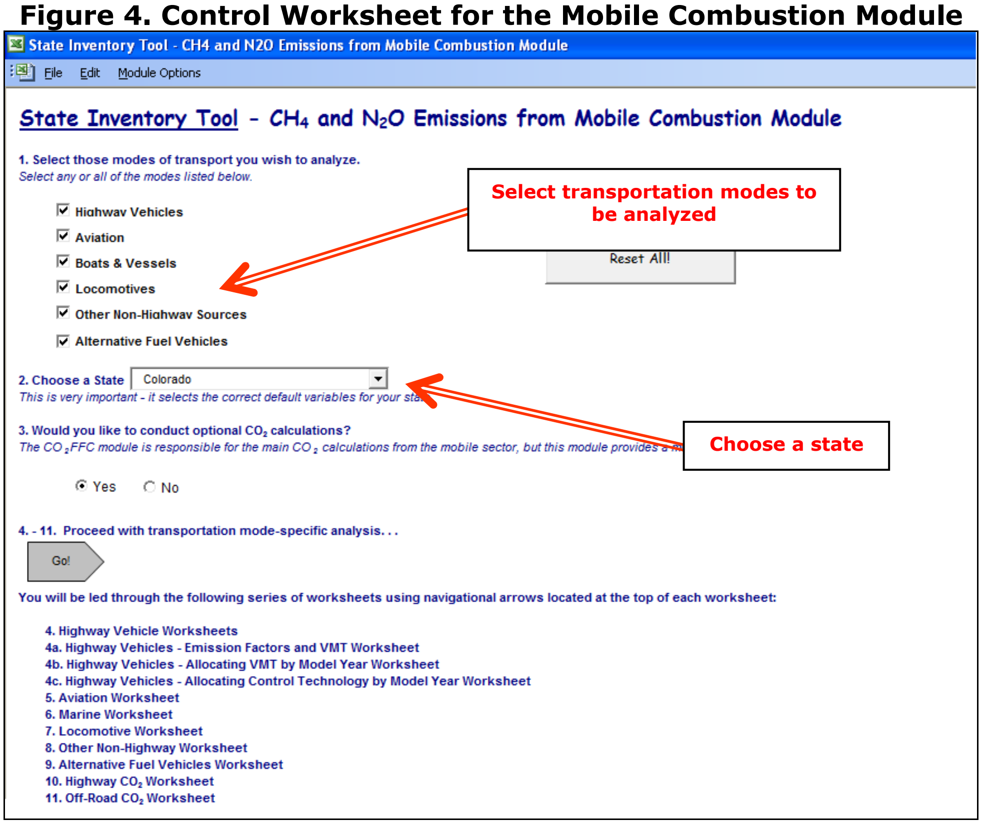
Step (1) Select Modes of Transport

In order for the emissions calculations to be successful, the user must choose the desired transportation modes. Once these selections are made, information on other modes will automatically drop out of the navigation scheme, saving time and streamlining the analysis.

Step (2) Choose a State

Next, select the state you are interested in evaluating. By selecting a state, the rest of the tool will automatically reset to reflect the appropriate state default data and assumptions for use in subsequent steps of the tool. Figure 4 shows the control worksheet with these two steps completed.

Figure 4. Control Worksheet for the Mobile Combustion Module



Step (3) Decide on an option to conduct CO_2 calculations

This module will estimate CH_4 and N_2O emissions, and CO_2 emission calculations are optional. The CO_2FFC module is responsible for the main CO_2 calculations from the mobile sector, but this module provides a mode-specific analysis through a different emission estimation approach; the CO_2FFC module calculations emissions using fuel consumption data and this module calculates emissions using mode-specific activity data already used in this module.

Selecting "Yes" will allow you to walk through the CO_2 calculations worksheets later in the module. Selecting "No" will allow you to skip steps 10 and 11.

Step (4) Complete the Sector Worksheets for Highway Vehicles

The gray arrow in on the control worksheet takes you to the first of the mode-specific worksheets.

The calculation of CH_4 and N_2O emissions from highway vehicles follows a complicated methodology. The module breaks highway vehicles into the following categories: heavy-duty diesel vehicles (HDDV), heavy-duty gasoline vehicles (HDGV), light-duty diesel trucks (LDDT), light-duty diesel vehicles (LDDV), light-duty gasoline trucks (LDGT), light-duty gasoline vehicles (LDGV), and motorcycles (MC). Emissions depend heavily on the type of emissions control technology used in the vehicle; the type of control technology used generally correlates with year of vehicle manufacture.

Due to the number of factors involved, the steps for estimating CH_4 and N_2O emissions from highway vehicles are spread out over three worksheets. The steps necessary to complete these worksheets are as follows: (1) enter emission factors for each control technology and vehicle class; (2) enter the vehicle miles traveled for each vehicle type, by year; (3) distribute vehicle miles traveled by vehicle age and enter age distribution for vehicles on the road, by year; and (4) enter percentage of vehicles with each control technology, by vehicle type. To complete these worksheets, follow the steps as explained below. Keep in mind that the tool provides default data for these parameters.

Step (4a) Highway Vehicles - Emission Factors and VMT Worksheet

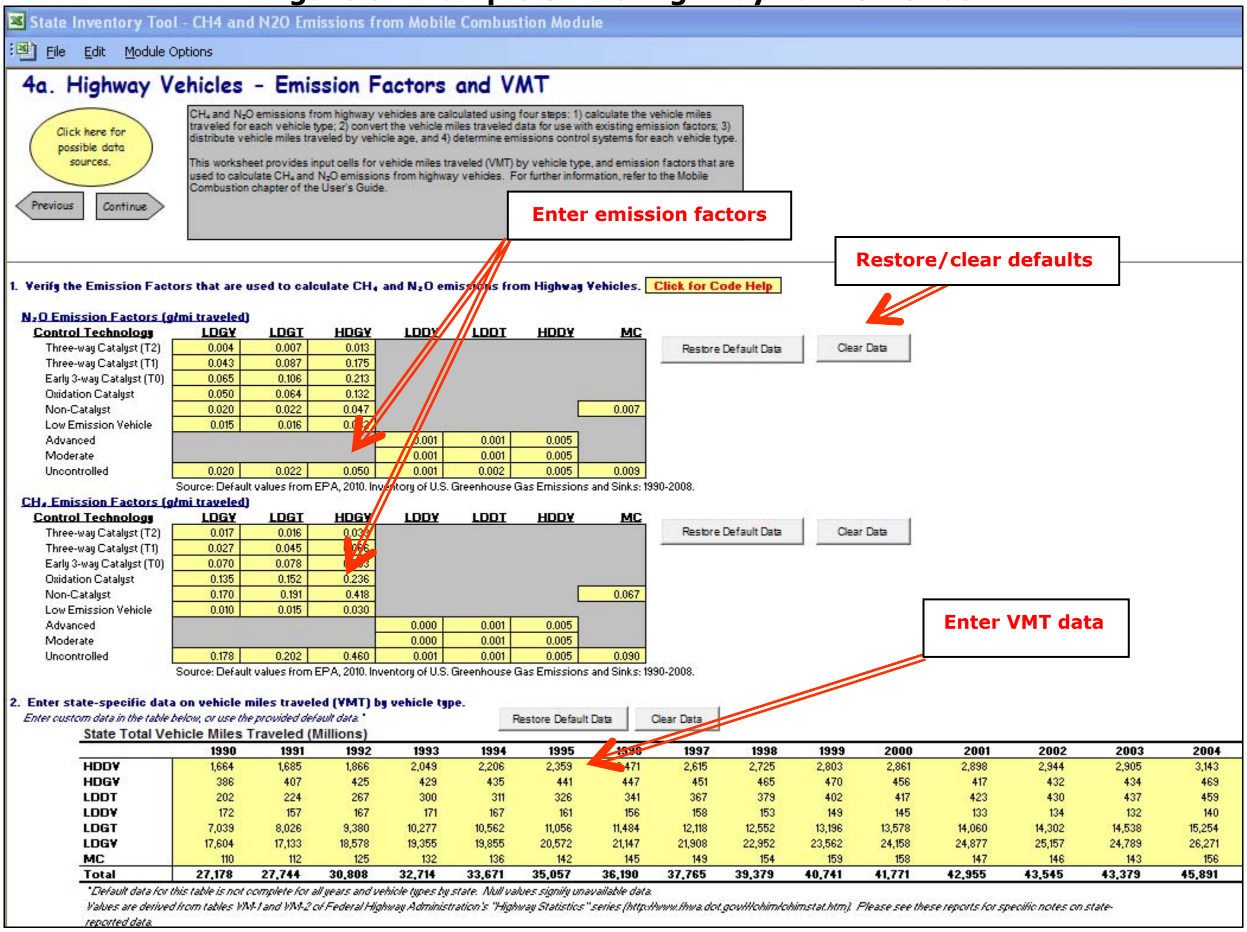
1. Enter emission factors for each control technology and vehicle class, for both CH_4 and N_2O on the Highway 4a worksheet.

    a. Default emission factors for each gas, control technology, and vehicle class are used to populate the tables and are from U.S. EPA (2016), as shown in Figure 5.

    b. To use your state-specific emission factors, either click the "Clear Data" button and enter your emission factors in the yellow cells, or overwrite the default emission factors in the yellow cells. To restore all default emission factors, click the "Restore Default Data" button.

2. Enter the vehicle miles traveled for each vehicle type, by year, from 1990 to the present year. These default data are from FHWA (2016).

Figure 5. Example of the Highway 4a Worksheet



Step (4b) Highway Vehicles - Allocating VMT by Model Year Worksheet

1. Distribute vehicle miles traveled by vehicle age on the Highway 4b worksheet. In order to account for changes over time in the control technologies used by vehicles, estimates of VMT by vehicle type must be distributed across vehicle model years. To make this apportionment, it is necessary to incorporate the following distributions: (1) vehicle age distribution, and (2) annual age-specific vehicle mileage accumulation. Vehicle age distribution simply refers to the age distribution of the vehicle fleet. This distribution may vary by state due to climate and road maintenance practices (e.g., whether roads are salted, which causes faster deterioration of cars), cultural reasons (e.g., higher demand for older “cruisers” in Los Angeles), and/or economic reasons.

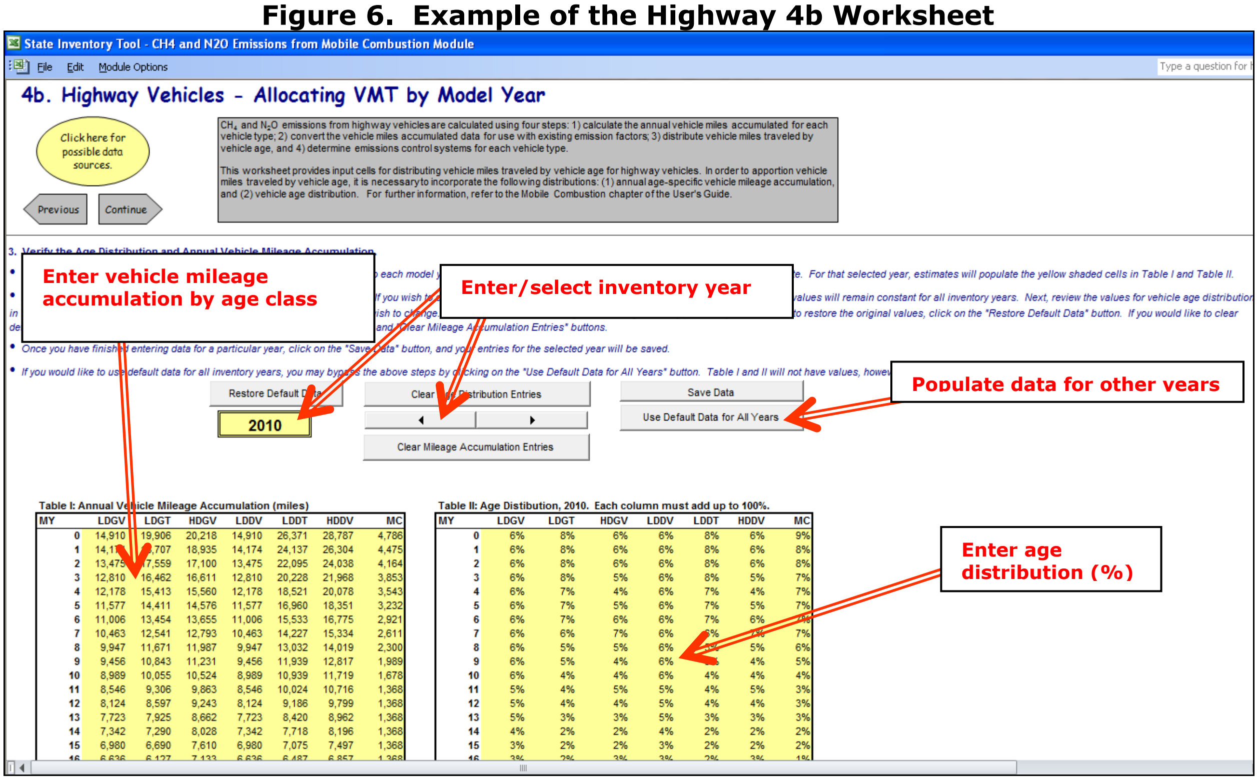
    a. First, choose the year of the inventory you are performing in the yellow box at the top of the sheet using the arrow buttons, as shown in Figure 6. Default data (U.S. EPA 2016) for the current year’s age distribution is automatically selected as you change the inventory year using the arrow buttons; you may overwrite it if you wish or clear it by clicking “Clear Age Distribution Entries”; to restore the default data, click “Restore Default Data.”

b. Next, enter the mileage accumulation for each vehicle age class/model year in the year of the inventory in Table I. This table refers to the relative distance vehicles are driven annually, by vehicle type. The vehicle ages are displayed as numbers in ascending order from the inventory year. That is, if the inventory year is 2005, cars built in 2005 are year “0” vehicles, cars built in 2004 are year “1” vehicles, and so forth.

c. Enter the percent age distribution for vehicles in the inventory year in Table II. This age distribution represents the percent of vehicles on the road in the inventory year, based on the year the vehicle was manufactured. This table is similar to Table I in that if the inventory year is 2005, cars built in 2005 are year “0” vehicles, cars built in 2004 are year “1” vehicles, and so forth.

d. Finally, populate similar tables for the entire time series by clicking the “Use Default Data for All Years” button at the top of the page. This will populate the historical time series based on default data from U.S. EPA (2016). This step creates an emissions estimate for each year from 1990 to the current inventory year.

Figure 6. Example of the Highway 4b Worksheet



Step (4c) Highway Vehicles - Allocating Control Technology by Model Year Worksheet

1. In the Highway 4c worksheet, you will enter percentage of vehicles with each control technology, by vehicle type.

a. Enter the distribution of emissions control equipment type by vehicle model year for motorcycles and diesel vehicles in Table I, as shown in Figure 7. The three types of control technology for motorcycles and diesel vehicles are Advanced (A), Moderate (M), and Uncontrolled (U). Default data from U.S. EPA (2016) are automatically entered in the yellow cells, but you may overwrite or delete them if you wish, using the “Restore Default Data” buttons above the Table I.

b. In Table II of this worksheet, enter the distribution of emissions control equipment type by vehicle model year for gasoline vehicles (LDGV, LDGT, and HDGV), as shown in Figure 7. The types of control technologies used are (in order of most recent employment): three-way catalyst (T2), low-emission vehicle (L), three-way catalyst (T1), early three-way catalyst (T0), oxidation catalyst (O), non-catalyst (N), and uncontrolled (U). Defaults are automatically entered in the yellow cells, but you may overwrite or delete them if you wish, using the buttons above the table.

Figure 7. Example of the Highway 4c Worksheet

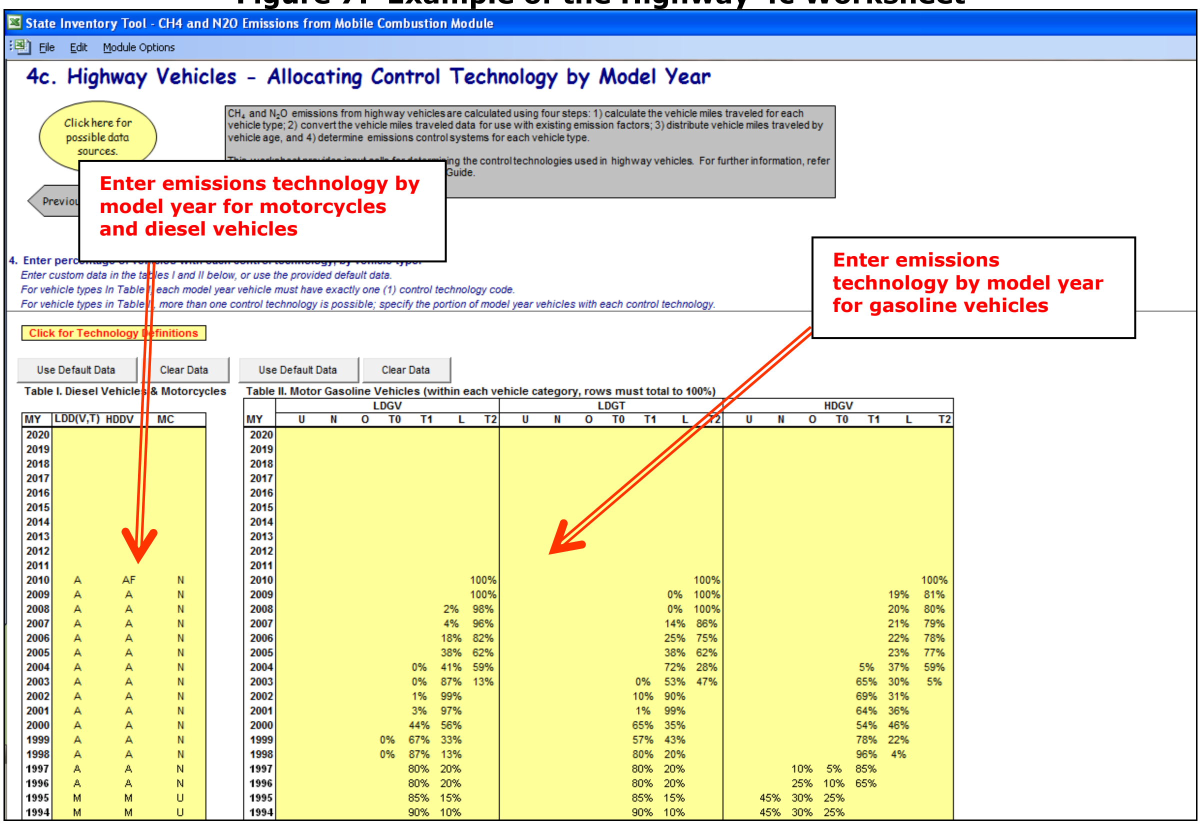


Table I. Diesel Vehicles & Motorcycles

MY	LDD(V,T)	HDDV	MC
2020			
2019			
2018			
2017			
2016			
2015			
2014			
2013			
2012			
2011			
2010	A	AF	N
2009	A	A	N
2008	A	A	N
2007	A	A	N
2006	A	A	N
2005	A	A	N
2004	A	A	N
2003	A	A	N
2002	A	A	N
2001	A	A	N
2000	A	A	N
1999	A	A	N
1998	A	A	N
1997	A	A	N
1996	A	A	N
1995	M	M	U
1994	M	M	U

Table II. Motor Gasoline Vehicles (within each vehicle category, rows must total to 100%)

	LDGV							LDGT							HDGV						
MY	U	N	O	T0	T1	L	T2	U	N	O	T0	T1	L	T2	U	N	O	T0	T1	L	T2
2020																					
2019																					
2018																					
2017																					
2016																					
2015																					
2014																					
2013																					
2012																					
2011																					
2010							100%							100%							100%
2009							100%						0%	100%						19%	81%
2008						2%	98%						0%	100%						20%	80%
2007						4%	96%						14%	86%						21%	79%
2006						18%	82%						25%	75%						22%	78%
2005						38%	62%						38%	62%						23%	77%
2004					0%	41%	59%						72%	28%					5%	37%	59%
2003					0%	87%	13%					0%	53%	47%					65%	30%	5%
2002					1%	99%						10%	90%						69%	31%	
2001					3%	97%						1%	99%						64%	36%	
2000					44%	56%						65%	35%						54%	46%	
1999				0%	67%	33%						57%	43%						78%	22%	
1998				0%	87%	13%						80%	20%						96%	4%	
1997					80%	20%						80%	20%				10%	5%	85%		
1996					80%	20%						80%	20%				25%	10%	65%		
1995					85%	15%						85%	15%			45%	30%	25%			
1994					90%	10%						90%	10%			45%	30%	25%			

Step (5) through Step (8) Complete the Non-Highway Worksheets

Although mobile sources other than road vehicles account for a significant fraction of total mobile CH_4 and N_2O emissions, they have received relatively little study compared to passenger cars and heavy-duty trucks. Major sources of pollutant emissions among non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, agricultural and construction equipment, railway locomotives, boats, and ships. Although each transportation mode has its own worksheet in the module, the method used for estimating emissions for these non-highway sources is almost identical, and will be described collectively. The steps below are illustrated in Figure 8 (the Marine worksheet is used as an example; the other worksheets are very similar).

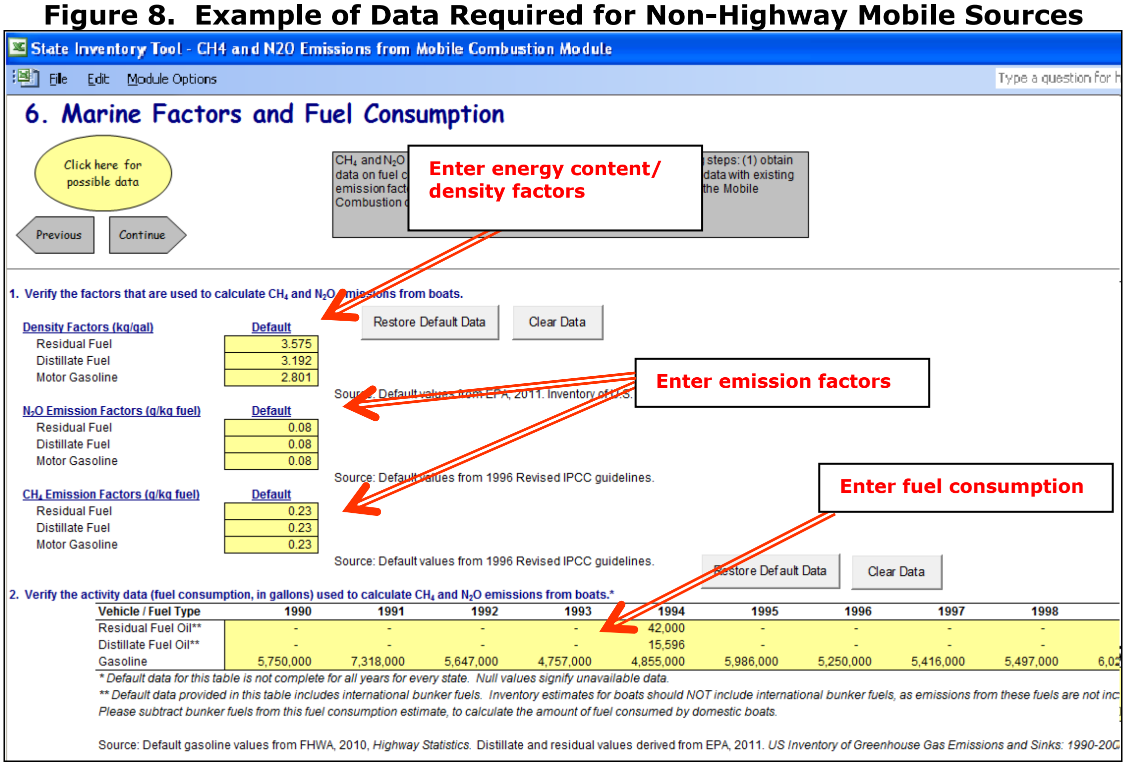
1. Enter energy contents (for aviation, in kg/million Btu) or density factors (for modes other than aviation, in kg/gallon of fuel or ton coal). Select the defaults by clicking the “Restore Default Data” button.[1]

2. Enter CH_4 and N_2O emission factors for each fuel type in g gas/kg fuel.[2]

3. Enter fuel consumption data from 1990 to present for each type of fuel in million Btu (aviation), gallons of liquid fuel (all modes except aviation), or tons of coal (locomotives).[3]

4. On the “Other non-highway” worksheet, you must complete the above steps three times: for farm equipment, for construction equipment, and for other non-highway equipment, such as snowmobiles.

Figure 8. Example of Data Required for Non-Highway Mobile Sources



Step (9) Complete the Sector Worksheet for Alternative Fuel Vehicles

[1] Default data are from EIA (2015a) (aviation, locomotives, other non-highway); U.S. EPA (2016) (marine).

[2] Default data are from U.S. EPA (2016) (alternative fuels, jet fuel); IPCC/UNEP/OECD/IEA (1997) (all other fuels).

[3] Default data are from EIA (2016) (aviation); FHWA (2016) (marine); U.S. EPA (2016) (marine, other non-highway); EIA (2015b) (locomotives).

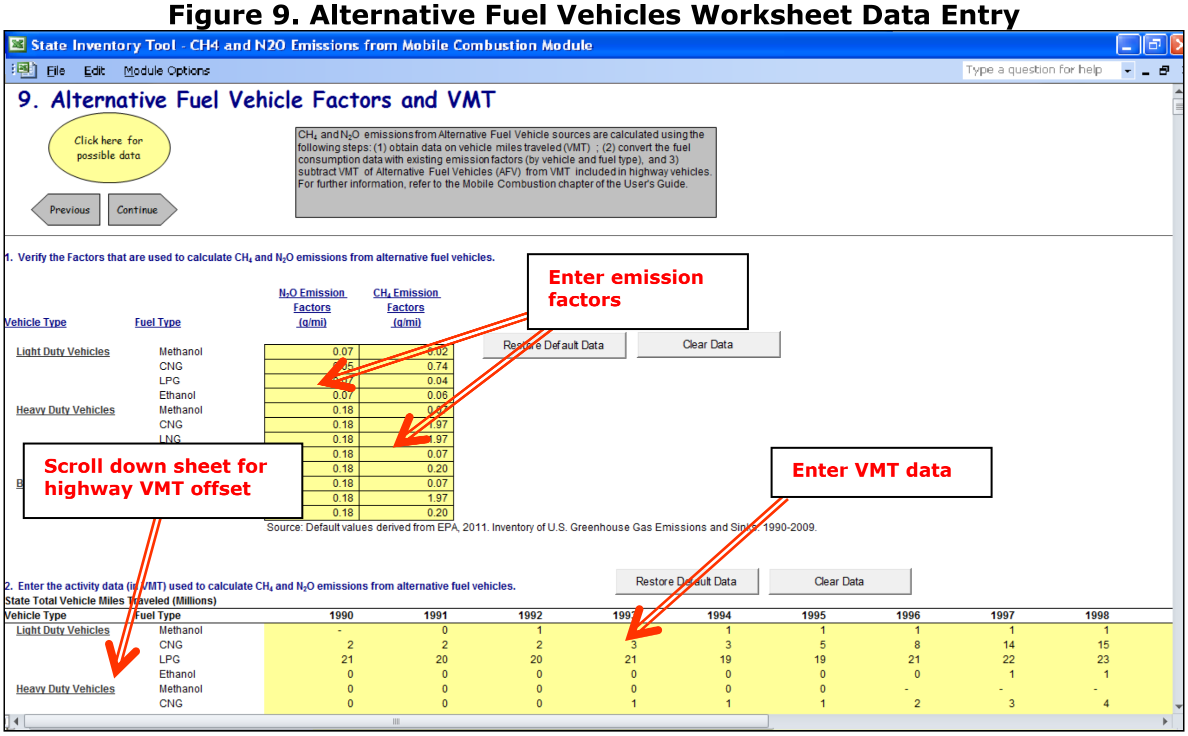
The methodology for alternative fuel vehicles is a simplified version of the methodology used for highway vehicles; an emission factor is multiplied by the VMT of each type of vehicle, based on the fuel used. The alternative fuels for which you can calculate emissions are methanol, ethanol, compressed natural gas (CNG), liquefied natural gas (LNG), and liquefied petroleum gas (LPG). The steps below are illustrated in Figure 9.

1. Enter CH_4 and N_2O emission factors for light-duty vehicles, heavy-duty vehicles, and buses for each relevant fuel type. The default data are from U.S. EPA (2016) and are populated by selecting the “Restore Default Data” buttons. If you would like to use different data, you may overwrite the yellow cells, or use the “Clear Data” button and enter your state-specific data.

2. Enter VMT for each vehicle by fuel type from 1990 to present.

3. Check the box to correct for alternative fuel vehicle VMT included in highway vehicle VMT. Default data for highway VMT are assumed to include alternative fuel vehicle miles traveled, therefore this box is checked in its default state and AFV VMT is automatically subtracted from highway VMT. Uncheck this box if the highway VMT data you entered do not include alternative fuel vehicles.

Figure 9. Alternative Fuel Vehicles Worksheet Data Entry



Step (10) Review the CO_2 Emissions Calculation Worksheet for Highway Vehicles

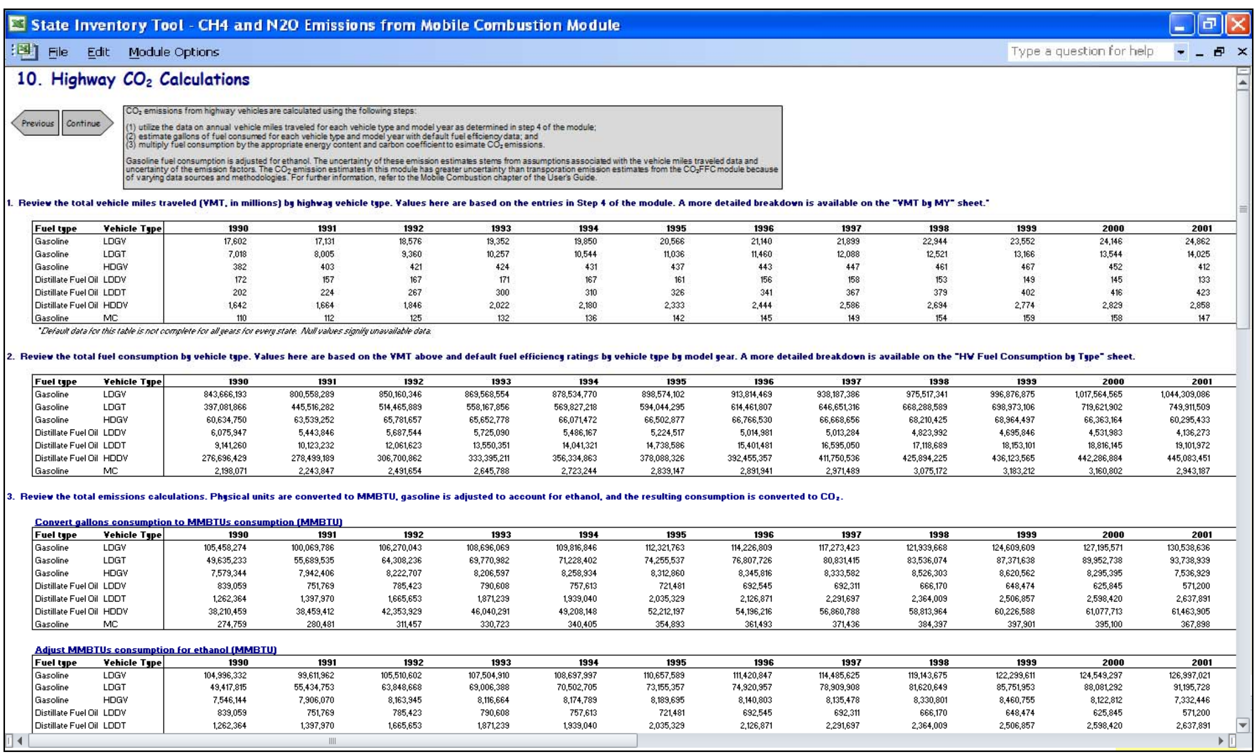
The gray arrows in the upper left of your screen will take you through Steps 10 and 11 if you chose to conduct optional CO_2 calculations in Step 3. The methodology to calculate CO_2 emissions from highway vehicles requires a conversion from the measured activity (vehicle miles traveled) to fuel consumption because CO_2 emission factors are based on gallons of fuel consumed instead of miles driven. Because vehicle miles traveled have already been entered in Step 4, this step only requires the review of established data. Figure 10 shows the automatic CO_2 emissions calculations for highway vehicles.

1. Review the total vehicle miles traveled by highway vehicle type for each calendar year. These total vehicle miles traveled values are automatically summed for each calendar year based on the values entered in Step 4 of this module.

2. Review the total fuel consumption by highway vehicle type for each calendar year. The fuel consumption is calculated based on the total vehicle miles traveled and average vehicle fuel efficiency by vehicle class and model year.

3. Review the total emissions calculations for each highway vehicle type. Fuel consumption is converted to MMBTU consumption using unit conversion factors and then gasoline consumption is adjusted to account for ethanol blending in gasoline. CO_2 emissions are calculated using unit conversion and default CO_2 emission factors.

Figure 10. Example of the Highway CO_2 Worksheet in the Mobile Combustion Module



State Inventory Tool - CH4 and N2O Emissions from Mobile Combustion Module

File Edit Module Options Type a question for help

10. Highway CO_2 Calculations

Previous Continue

CO_2 emissions from highway vehicles are calculated using the following steps:

(1) utilize the data on annual vehicle miles traveled for each vehicle type and model year as determined in step 4 of the module;
(2) estimate gallons of fuel consumed for each vehicle type and model year with default fuel efficiency data; and
(3) multiply fuel consumption by the appropriate energy content and carbon coefficient to esimate CO_2 emissions.

Gasoline fuel consumption is adjusted for ethanol. The uncertainty of these emission estimates stems from assumptions associated with the vehicle miles traveled data and uncertainty of the emission factors. The CO_2 emission estimates in this module has greater uncertainty than transporation emission estimates from the CO_2FFC module because of varying data sources and methodologies. For further information, refer to the Mobile Combustion chapter of the User's Guide.

1. Review the total vehicle miles traveled (VMT, in millions) by highway vehicle type. Values here are based on the entries in Step 4 of the module. A more detailed breakdown is available on the "VMT by MY" sheet."

Fuel type	Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline	LDGV	17,602	17,131	18,576	19,352	19,850	20,566	21,140	21,899	22,944	23,552	24,146	24,862
Gasoline	LDGT	7,018	8,005	9,360	10,257	10,544	11,036	11,460	12,088	12,521	13,166	13,544	14,025
Gasoline	HDGV	382	403	421	424	431	437	443	447	461	467	452	412
Distillate Fuel Oil	LDDV	172	157	167	171	167	161	156	158	153	149	145	133
Distillate Fuel Oil	LDDT	202	224	267	300	310	326	341	367	379	402	416	423
Distillate Fuel Oil	HDDV	1,642	1,664	1,846	2,022	2,180	2,333	2,444	2,586	2,694	2,774	2,829	2,858
Gasoline	MC	110	112	125	132	136	142	145	149	154	159	158	147

*Default data for this table is not complete for all years for every state. Null values signify unavailable data.

2. Review the total fuel consumption by vehicle type. Values here are based on the VMT above and default fuel efficiency ratings by vehicle type by model year. A more detailed breakdown is available on the "HV Fuel Consumption by Type" sheet.

Fuel type	Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline	LDGV	843,666,193	800,558,289	850,160,346	869,568,554	878,534,770	898,574,102	913,814,469	938,187,386	975,517,341	996,876,875	1,017,564,565	1,044,309,086
Gasoline	LDGT	397,081,866	445,516,282	514,465,889	558,167,856	569,827,218	594,044,295	614,461,807	646,651,316	668,288,589	698,973,106	719,621,902	749,911,509
Gasoline	HDGV	60,634,750	63,539,252	65,781,657	65,652,778	66,071,472	66,502,877	66,766,530	66,668,656	68,210,425	68,964,497	66,363,164	60,295,433
Distillate Fuel Oil	LDDV	6,075,947	5,443,846	5,687,544	5,725,090	5,486,167	5,224,517	5,014,981	5,013,284	4,823,992	4,695,846	4,531,983	4,136,273
Distillate Fuel Oil	LDDT	9,141,260	10,123,232	12,061,623	13,550,351	14,041,321	14,738,586	15,401,481	16,595,050	17,118,689	18,153,101	18,816,145	19,101,972
Distillate Fuel Oil	HDDV	276,696,429	278,499,189	306,700,862	333,395,211	356,334,863	378,088,326	392,455,357	411,750,536	425,894,225	436,123,565	442,286,884	445,083,451
Gasoline	MC	2,198,071	2,243,847	2,491,654	2,645,788	2,723,244	2,839,147	2,891,941	2,971,489	3,075,172	3,183,212	3,160,802	2,943,187

3. Review the total emissions calculations. Physical units are converted to MMBTU, gasoline is adjusted to account for ethanol, and the resulting consumption is converted to CO_2.

Convert gallons consumption to MMBTUs consumption (MMBTU)

Fuel type	Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline	LDGV	105,458,274	100,069,786	106,270,043	108,696,069	109,816,846	112,321,763	114,226,809	117,273,423	121,939,668	124,609,609	127,195,571	130,538,636
Gasoline	LDGT	49,635,233	55,689,535	64,308,236	69,770,982	71,228,402	74,255,537	76,807,726	80,831,415	83,536,074	87,371,638	89,952,738	93,738,939
Gasoline	HDGV	7,579,344	7,942,406	8,222,707	8,206,597	8,258,934	8,312,860	8,345,816	8,333,582	8,526,303	8,620,562	8,295,395	7,536,929
Distillate Fuel Oil	LDDV	839,059	751,769	785,423	790,608	757,613	721,481	692,545	692,311	666,170	648,474	625,845	571,200
Distillate Fuel Oil	LDDT	1,262,364	1,397,970	1,665,653	1,871,239	1,939,040	2,035,329	2,126,871	2,291,697	2,364,009	2,506,857	2,598,420	2,637,891
Distillate Fuel Oil	HDDV	38,210,459	38,459,412	42,353,929	46,040,291	49,208,148	52,212,197	54,196,216	56,860,788	58,813,964	60,226,588	61,077,713	61,463,905
Gasoline	MC	274,759	280,481	311,457	330,723	340,405	354,893	361,493	371,436	384,397	397,901	395,100	367,898

Adjust MMBTUs consumption for ethanol (MMBTU)

Fuel type	Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gasoline	LDGV	104,996,332	99,611,962	105,510,602	107,504,910	108,697,997	110,657,589	111,420,847	114,485,625	119,143,675	122,299,611	124,549,297	126,997,021
Gasoline	LDGT	49,417,815	55,434,753	63,848,668	69,006,388	70,502,705	73,155,357	74,920,957	78,909,908	81,620,649	85,751,953	88,081,292	91,195,728
Gasoline	HDGV	7,546,144	7,906,070	8,163,945	8,116,664	8,174,789	8,189,695	8,140,803	8,135,478	8,330,801	8,460,755	8,122,812	7,332,446
Distillate Fuel Oil	LDDV	839,059	751,769	785,423	790,608	757,613	721,481	692,545	692,311	666,170	648,474	625,845	571,200
Distillate Fuel Oil	LDDT	1,262,364	1,397,970	1,665,653	1,871,239	1,939,040	2,035,329	2,126,871	2,291,697	2,364,009	2,506,857	2,598,420	2,637,891

Step (11) Review the CO_2 Emissions Calculation Worksheet for Non-Highway Vehicles

Step 11 conducts similar calculations as those done in Step 10, but for non-highway vehicles, including planes, boats, locomotives, and other off-road vehicles. This step requires users to review established data and automatic calculations in the sheet. Figure 11 shows the automatic CO_2 emissions calculations for highway vehicles. Note that calculations for each separate class of non-highway vehicles (planes, boats, locomotives, and other) are separately listed on the page. Scroll down through each section when conducting the following steps.

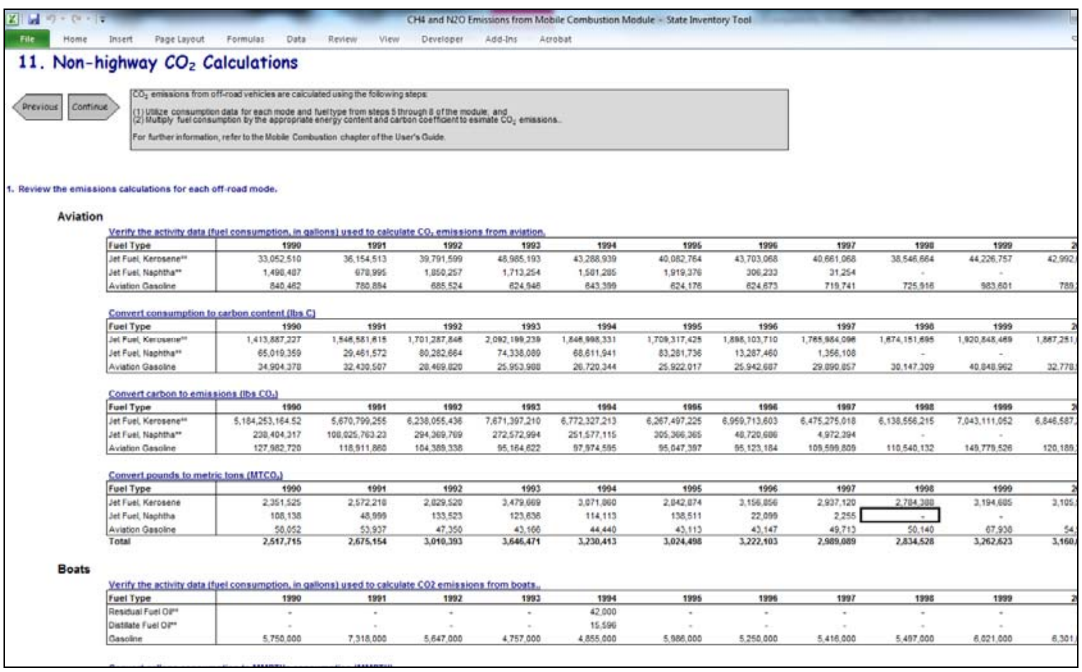
1. Review the total fuel consumption by non-highway vehicle type for each calendar year.

2. Review the total emissions calculations for each non-highway vehicle type. Fuel consumption was converted to carbon content consumed using unit conversion factors. CO_2 emissions in metric tonnes were calculated using unit conversion and default CO_2 emission factors.

3. Review the total emissions calculations at the bottom of the page, which sums up the emissions of each non-highway fuel type calculated in previous steps.

Figure 11 shows the automatic CO_2 emissions calculations for off-road vehicles.

Figure 11. Example of the Off-road CO_2 Worksheet in the Mobile Combustion Module



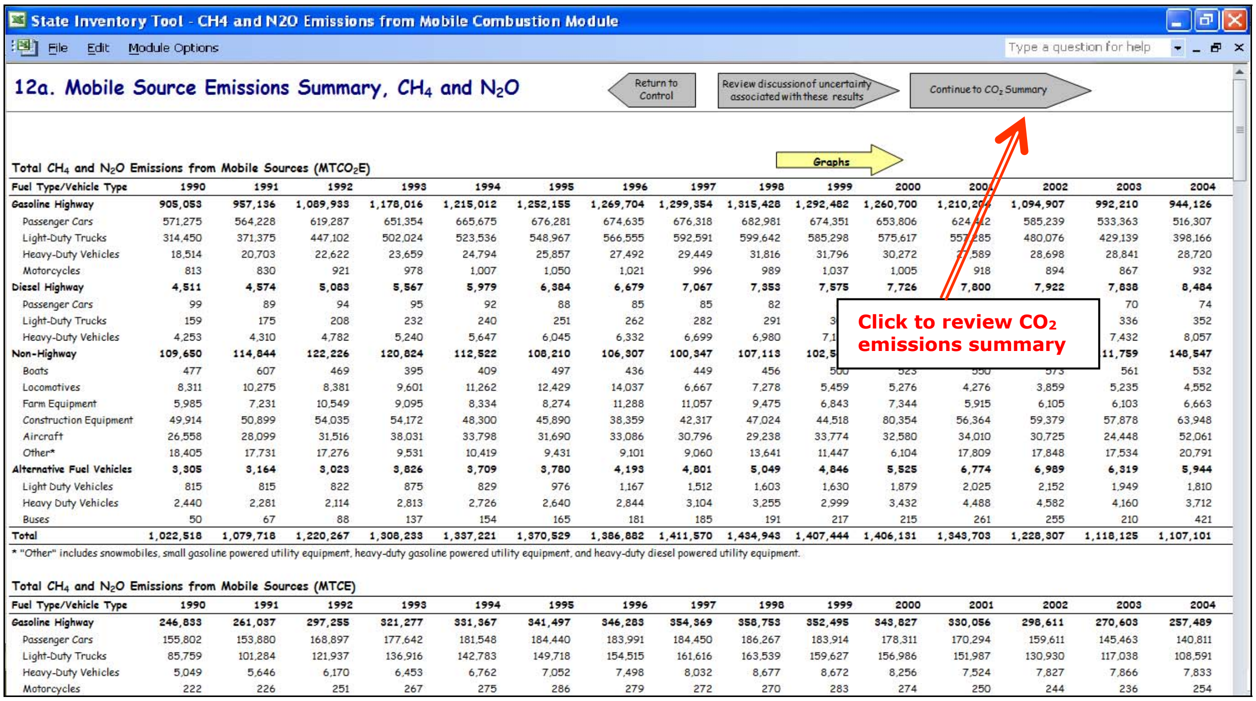
Step (12) Review Summary Information

The information from each sector worksheet is collected on the summary worksheets.

Step (12a) Review CH_4 and N_2O Summary Information

The Steps 4-9 above provide estimates of total CH_4 and N_2O emissions from mobile combustion. This summary worksheet displays results in $MTCO_2E$, Gg CH_4, and Gg N_2O. Figure 12 shows the summary worksheet that sums the CH_4 and N_2O emissions from all sectors in the Mobile Combustion module. In addition, the results are displayed in graphical format at the right of the summary worksheet.

Figure 12. Example of the Emissions Summary Worksheet in the Mobile Combustion Module



Total CH_4 and N_2O Emissions from Mobile Sources ($MTCO_2E$)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gasoline Highway	**905,053**	**957,136**	**1,089,933**	**1,178,016**	**1,215,012**	**1,252,155**	**1,269,704**	**1,299,354**	**1,315,428**	**1,292,482**	**1,260,700**	[illegible]	**1,094,907**	**992,210**	**944,126**
Passenger Cars	571,275	564,228	619,287	651,354	665,675	676,281	674,635	676,318	682,981	674,351	653,806	[illegible]	585,239	533,363	516,307
Light-Duty Trucks	314,450	371,375	447,102	502,024	523,536	548,967	566,555	592,591	599,642	585,298	575,617	[illegible]	480,076	429,139	398,166
Heavy-Duty Vehicles	18,514	20,703	22,622	23,659	24,794	25,857	27,492	29,449	31,816	31,796	30,272	[illegible]	28,698	28,841	28,720
Motorcycles	813	830	921	978	1,007	1,050	1,021	996	989	1,037	1,005	918	894	867	932
Diesel Highway	**4,511**	**4,574**	**5,083**	**5,567**	**5,979**	**6,384**	**6,679**	**7,067**	**7,353**	**7,575**	**7,726**	**7,800**	**7,922**	**7,838**	**8,484**
Passenger Cars	99	89	94	95	92	88	85	85	82	[illegible]	[illegible]	[illegible]	[illegible]	70	74
Light-Duty Trucks	159	175	208	232	240	251	262	282	291	[illegible]	[illegible]	[illegible]	[illegible]	336	352
Heavy-Duty Vehicles	4,253	4,310	4,782	5,240	5,647	6,045	6,332	6,699	6,980	[illegible]	[illegible]	[illegible]	[illegible]	7,432	8,057
Non-Highway	**109,650**	**114,844**	**122,226**	**120,824**	**112,522**	**108,210**	**106,307**	**100,347**	**107,113**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**148,547**
Boats	477	607	469	395	409	497	436	449	456	500	523	550	573	561	532
Locomotives	8,311	10,275	8,381	9,601	11,262	12,429	14,037	6,667	7,278	5,459	5,276	4,276	3,859	5,235	4,552
Farm Equipment	5,985	7,231	10,549	9,095	8,334	8,274	11,288	11,057	9,475	6,843	7,344	5,915	6,105	6,103	6,663
Construction Equipment	49,914	50,899	54,035	54,172	48,300	45,890	38,359	42,317	47,024	44,518	80,354	56,364	59,379	57,878	63,948
Aircraft	26,558	28,099	31,516	38,031	33,798	31,690	33,086	30,796	29,238	33,774	32,580	34,010	30,725	24,448	52,061
Other*	18,405	17,731	17,276	9,531	10,419	9,431	9,101	9,060	13,641	11,447	6,104	17,809	17,848	17,534	20,791
Alternative Fuel Vehicles	**3,305**	**3,164**	**3,023**	**3,826**	**3,709**	**3,780**	**4,193**	**4,801**	**5,049**	**4,846**	**5,525**	**6,774**	**6,989**	**6,319**	**5,944**
Light Duty Vehicles	815	815	822	875	829	976	1,167	1,512	1,603	1,630	1,879	2,025	2,152	1,949	1,810
Heavy Duty Vehicles	2,440	2,281	2,114	2,813	2,726	2,640	2,844	3,104	3,255	2,999	3,432	4,488	4,582	4,160	3,712
Buses	50	67	88	137	154	165	181	185	191	217	215	261	255	210	421
Total	**1,022,518**	**1,079,718**	**1,220,267**	**1,308,233**	**1,337,221**	**1,370,529**	**1,386,882**	**1,411,570**	**1,434,943**	**1,407,444**	**1,406,131**	**1,343,703**	**1,228,307**	**1,118,125**	**1,107,101**

* "Other" includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Total CH_4 and N_2O Emissions from Mobile Sources (MTCE)

Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gasoline Highway	**246,833**	**261,037**	**297,255**	**321,277**	**331,367**	**341,497**	**346,283**	**354,369**	**358,753**	**352,495**	**343,827**	**330,056**	**298,611**	**270,603**	**257,489**
Passenger Cars	155,802	153,880	168,897	177,642	181,548	184,440	183,991	184,450	186,267	183,914	178,311	170,294	159,611	145,463	140,811
Light-Duty Trucks	85,759	101,284	121,937	136,916	142,783	149,718	154,515	161,616	163,539	159,627	156,986	151,987	130,930	117,038	108,591
Heavy-Duty Vehicles	5,049	5,646	6,170	6,453	6,762	7,052	7,498	8,032	8,677	8,672	8,256	7,524	7,827	7,866	7,833
Motorcycles	222	226	251	267	275	286	279	272	270	283	274	250	244	236	254

Step (12b) Review CO_2 Summary Information

If you conducted optional CO_2 calculations in Steps 10-11 above, this summary worksheet collects the CO_2 emission results. The results are displayed in $MTCO_2E$ by mobile source and fuel type from all sectors in the Mobile Combustion module. In addition, the results are displayed in graphical format at the bottom of the summary worksheet.

Step (13) Export Data

The final step is to export the summary data. Exporting data allows the estimates from each module to be combined later by the Synthesis Module to produce a comprehensive greenhouse gas inventory for the state.

Note: the resulting export file should not be modified. The export file contains a summary worksheet that allows users to view the results, as well as a separate data worksheet with an unformatted version of the results. The second worksheet, the data worksheet, contains the information that is exported to the Synthesis Tool. Users may not modify that worksheet. Adding/removing rows, moving data, or making other modifications jeopardize the ability of the Synthesis Module to accurately analyze the data.

To access the “Export Data” button, return to the control worksheet and scroll down to the bottom (13). Click on the “Export Data” button and a message box will open that reminds the user to make sure all sections of the module have been completed. If you make any changes to the Mobile Combustion module later, you will then need to re-export the results.

Clicking “OK” prompts you to save the file. The file is already named, so you only need to choose a convenient place to save the file. After the file is saved, a message box will appear indicating that the data were successfully exported.

While completing the modules, you are encouraged to save each completed module; doing so will enable you to easily make changes without re-running it entirely.

Following data export, the module may be reset and run for an additional state. Alternatively, you may run the remaining modules of the State Inventory Tool to obtain a comprehensive profile of emissions for your state.

1.4 UNCERTAINTY

In the upper right-hand corner of the summary worksheet is a button: “Review discussion of uncertainty associated with these results.” By clicking on this button, you are taken to a worksheet that discusses the uncertainty surrounding the activity data and emission factors, and how the uncertainty estimates for this source category affect the uncertainty of the emission estimates for your state.

The uncertainty for the optional CO_2 calculations bears special consideration because these calculations are supplemental to those already contained in the CO_2FFC module. The Mobile module provides an additional level of detail by estimating CO_2 emissions by transportation mode and vehicle type. The CO_2FFC module calculates CO_2 emissions based on total fuel consumption across all modes, while the Mobile module calculates CO_2 emissions based on activity data (such as vehicle miles traveled). It is anticipated that the CO_2FFC module provides a more accurate estimate of total CO_2 emissions in the transportation sector due to less uncertainty in the estimates of total fuel consumption than in the detailed activity data. However, fuel consumption is not otherwise available on the detailed level needed for analysis by mode and vehicle type.

With highway vehicles, the CO_2 calculations rely on the same disaggregation of total vehicle miles traveled by vehicle type and model year that is used for the non-CO_2 calculations. The module then uses average fuel economy by vehicle type and model year to estimate fuel consumption. Error in the vehicle split, age distribution, or fuel efficiency factors will affect the estimates. The estimates may also differ from the CO_2FFC module because there may be differences between the state where fuel is sold and the state where that fuel is consumed. For example, if a state has lower fuel taxes than its neighbors, interstate travelers may purchase fuel in a low-tax state and consume that fuel in a state with higher fuel taxes, causing a disconnect between reported fuel consumption and VMT.

As a result of these issues, the uncertainty surrounding the CO_2 emissions estimates from gasoline and diesel is particularly high. Caution should be used when interpreting these results.

1.5 EXPLANATION OF MOBILE COMBUSTION MODULE UPDATES

In the upper right-hand corner of the summary worksheet is a button: "Review discussion of uncertainty associated with these results."

The bottom-up CO_2 calculations in the Mobile Combustion module provide estimates of CO_2 emissions from the transportation sector disaggregated by mode and vehicle type. Because the bottom-up calculations require more assumptions than the top-down calculations in the CO2FFC module, the overall totals in the CO2FFC module are assumed to be more accurate, and the new calculations are intended as a complement to the CO2FFC module. The following methodologies were used:

Highway vehicles

1. Utilize the data on annual vehicle miles traveled for each vehicle type and model year as determined in step 4 of the module;

2. Estimate gallons of fuel consumed for each vehicle type and model year with default fuel efficiency data;

3. Adjust gasoline fuel consumption based on the reported amount of ethanol consumed annually by the transportation sector in each state; and

4. Multiply fuel consumption by the appropriate energy content and carbon coefficient to estimate CO_2 emissions.

Non-highway vehicles

1. Utilize consumption data for each mode and fuel type from steps 5 through 8 of the module (aviation, boats & vessels, locomotives, and other non-highway vehicles); and

2. Multiply fuel consumption by the appropriate energy content and carbon coefficient to estimate CO_2 emissions.

The methods for non-highway vehicles are essentially the same those in the CO2FFC module, because they rely on a simple multiplication of fuel consumption times the CO_2 emission factor. The only major source of uncertainty is with the data sources used for disaggregating fuel consumption by type.

By contrast, the CO_2 calculations for highway vehicles require estimating fuel consumption based on vehicle miles traveled by vehicle type—which is itself the product of estimates—because fuel consumption is not otherwise available on the detailed level needed for analysis by mode and vehicle type.

With highway vehicles, the CO_2 calculations rely on the same disaggregation of total vehicle miles traveled by vehicle type and model year that is used for the non- CO_2 calculations. The module then uses average fuel economy by vehicle type and model year to estimate fuel consumption. Error in the vehicle split, age distribution, or fuel efficiency factors will affect the estimates. The estimates may also differ from the CO2FFC module because there may be differences between the state where fuel is sold and the state where that fuel is consumed. For example, if a state has lower fuel taxes than its neighbors, interstate travelers may purchase fuel in a low-tax state and consume that fuel in a state with higher fuel taxes, causing a disconnect between reported fuel consumption and VMT. As a result of these issues, the uncertainty surrounding the CO_2 emissions estimates from gasoline and diesel is particularly high.

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