

# 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 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-todate 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.

The Mobile Combustion module calculates methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions from highway vehicles, aviation, boats and vessels, locomotives, other non-highway sources, and alternative fuel vehicles. This module also includes optional

### 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.

calculations of carbon dioxide (CO<sub>2</sub>) from these sources, which are also calculated in the CO<sub>2</sub> from Fossil Fuel Combustion (CO<sub>2</sub>FFC) module. The Mobile Combustion module-based CO<sub>2</sub> calculations provide detail by transportation mode not available in the CO<sub>2</sub>FFC 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<sub>4</sub> in either gasoline or diesel fuel, CH<sub>4</sub> is emitted as a combustion product that is influenced by fuel composition, combustion conditions, and control technologies. Depending on the control technologies used, CH<sub>4</sub> 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

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converters. For highway vehicles, the emissions of unburned hydrocarbons, including CH<sub>4</sub>, 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<sub>4</sub> emissions include aggressive driving, low speed operation, and cold start operation. Poorly tuned highway vehicle engines may have a particularly high output of CH<sub>4</sub>.

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<sub>2</sub>O-forming process occurs during catalytic after-treatment of exhaust gases. The output of N<sub>2</sub>O from the catalyst is highly temperature dependent. Prigent and De Soete (1989) showed that as the catalyst warms up after a cold start, N<sub>2</sub>O 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<sub>2</sub>O exiting the catalyst than entering it. These results demonstrate that N<sub>2</sub>O is formed primarily during cold starts of catalyst-equipped vehicles. This explains why N<sub>2</sub>O 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<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> estimates, and compliment the CO<sub>2</sub> 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).

Module Worksheet	Input Data Required
4a Highway Vehicles - Emission Factors and	$CH_4$ and $N_2O$ emission factors (g/km traveled) for each type of control technology
VMT	State total VMT, 1990-present, for all vehicle types
4b Highway Vehicles -	Annual vehicle mileage accumulation (miles) for each model year in use
Allocating VMT by Model Year	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	Density factors (kg/gal or ton) for residual fuel, diesel fuel, and coal
and Fuel Consumption	$N_2O$ 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	Density factors (kg/gal) for diesel and gasoline
Consumption	N <sub>2</sub> O and CH <sub>4</sub> 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	CH <sub>4</sub> and N <sub>2</sub> O emission factors (g/km traveled) for each type of alternative fuel (methanol, ethanol, LPG, LNG, CNG)
VIVII	State total VMT, 1990-present, for alternative fuel vehicles

## Table 1. Required Data Inputs for the Mobile Combustion Module Ile Worksheet Input Data Required

### 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\*

\* 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<sub>4</sub>, N<sub>2</sub>O, and CO<sub>2</sub> 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

### **Emissions** = $\Sigma$ (EF<sub>abc</sub> x Activity<sub>abc</sub>)

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Where,
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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<sub>2</sub> 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<sub>2</sub> emissions worksheet; (11) review off-road CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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

- 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:

   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.





### 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<sub>4</sub> and N<sub>2</sub>O 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).

- 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.<sup>1</sup>
- 2. Enter CH<sub>4</sub> and N<sub>2</sub>O emission factors for each fuel type in g gas/kg fuel.<sup>2</sup>
- 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).<sup>3</sup>
- 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

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

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

<sup>3</sup> 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.

- Enter CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub> 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<sub>2</sub> emissions are calculated using unit conversion and default CO<sub>2</sub> emission factors.

### Figure 10. Example of the Highway CO<sub>2</sub> Worksheet in the Mobile Combustion Module

trane m	ventory Too	ol - CH4 and	N2O Emissio	ns from Mo	bile Combus	tion Module							
Eile E	dit <u>M</u> odule	Options									Type a	question for he	ip 💌 🗕
Highv	vay CO <sub>2</sub> Co	alculations											
	CO; emission	ns from highway vehicles	are calculated using the	following steps:									
us Continu	(1) utilize the (2) estimate ( (3) multiply fi	data on annual vehicle n galions of fuel consumed uel consumption by the ap	niles traveled for each ve for each vehicle type an ppropriate energy conter	chicle type and model ye d model year with defau tt and carbon coefficient	ear as determined in step It fuel efficiency data; ar Ito esimate CO <sub>2</sub> emissio	p 4 of the module; nd ons.							
	Gasoline fuel uncertainty o of varying da	I consumption is adjusted of the emission factors. The ta sources and methodol	I for ethanol. The uncerta te CO2 emission estimat logies. For further inform	inty of these emission e es in this module has gr ation, refer to the Mobile	estimates stems from as eater uncertainty than tr Combustion chapter of	sumptions associated w ansporation emission es the User's Guide.	th the vehicle miles tra- timates from the CO <sub>2</sub> Fi	veled data and *C module because					
w the total	vehicle miles trav	veled (¥MT, in millio	ns) by highway vehic	ole type. Values her	e are based on the	entries in Step 4 of	the module. A mor	e detailed breakdow	n is available on th	ne "VMT by MY" sh	eet."		
el type	Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	20/
soline	LDGV	17,602	17,131	18,576	19,352	19,850	20,566	21,140	21,899	22,944	23,552	24,146	24,86
soline	LUGI	7,018	8,005	9,360	10,257	10,544	1,036	11,460	12,088	12,521	13,166	13,544	14,02
Foline Filisto Fuel C	HUGY	382	403	921	424	431	437	160	997	461	467	402 ME	
tillate Fuel C		202	224	267	300	310	326	341	367	379	402	416	43
tillate Fuel C	HDDV	1642	1664	1846	2.022	2.180	2.333	2 4 4 4	2,586	2.694	2.774	2.829	2.85
oline	MC	110	112	125	132	136	142	145	149	154	159	158	14
oline	LDGV	1990 843,666,193	1991 800,558,289	1992 850,160,346	1993 869,568,554	1994 878,534,770	1995 898,574,102	1996 913,814,469	1997 938,187,386	1998 975,517,341	1999 996,876,875	2000 1,017,564,565	20
oline oline oline illate Fuel O illate Fuel O	LDGV LDGV HDGV HI LDOV HI LDOV HI LDOT HI LDOT	1930 843,666,193 397,081,866 60,634,750 6,075,947 9,141,260 276,896,4/9	1991 800,558,289 445,516,282 63,539,252 5,443,846 10,123,232 278,499,189	1992 850,160,346 514,465,889 65,761,657 5,687,544 12,061,623 306,700,862	1993 869,568,554 558,167,856 65,652,778 5,725,090 13,550,351 333,395,211	1994 878,534,770 569,827,218 66,071,472 5,486,167 14,041,321 356,334,863	1995 898,574,102 594,044,295 66,502,877 5,224,517 14,738,586 378,088,326	1996 913,814,469 614,461,807 66,766,530 5,014,981 15,401,481 392,465,367	1997 938,187,386 646,651,316 66,668,656 5,013,284 16,595,050 411760,526	1998 975,517,341 668,288,569 68,210,425 4,823,932 17,118,689 4,25,884,225	1999 996,876,875 698,973,106 68,364,497 4,635,846 18,153,101 4,06,123,555	2000 1,017,564,565 719,621,902 66,363,164 4,531,983 18,816,145 442,288,884	20 1,044,309,01 749,911,51 60,295,41 4,136,21 19,101,91 445,083,4
soline soline soline tillate Fuel C tillate Fuel O tillate Fuel O soline	IDGV LDGV HDGV HDGV HLDDV NI LDDV NI LDDV NI HDDV MC	1930 843,666,193 397,081,866 60,634,750 6,075,947 9,141,260 276,696,429 2,198,071	1991 800,558,289 445,518,282 63,539,252 5,443,846 10,123,232 278,499,189 2,243,847	1992 850,160,346 514,465,889 65,781,657 5,687,544 12,061,623 306,700,862 2,491,654	1993 869,568,554 558,167,856 65,652,776 5,725,090 13,550,351 333,395,211 2,645,788	1994 878,534,770 569,827,218 66,071,472 5,486,167 14,041,321 356,334,863 2,723,244	1995 898,574,102 594,044,295 66,502,877 5,224,517 14,738,586 378,088,326 2,839,147	1996 913,814,469 614,461,807 66,766,530 5,014,981 15,401,481 392,455,357 2,891,941	1997 938,187,386 646,651,316 66,668,656 5,013,284 16,556,050 411,750,536 2,971,489	1998 975,517,341 668,288,589 68,210,425 4,823,992 17,118,689 425,894,225 3,075,172	1939 936,876,875 638,973,106 68,364,497 4,695,846 18,153,101 436,123,565 3,163,212	2000 1,017,564,565 719,621,902 66,363,164 4,531,983 18,816,145 442,266,894 3,160,802	20 1,044,309,06 749,911,50 60,295,43 4,136,21 19,101,93 445,083,4 2,943,18
soline soline tillate Fuel C tillate Fuel C tillate Fuel C soline w the total	LDGY LDGY HDGV NI LDDY NI LDDY NI LDDY MC I emissions calcul	1390 943,666,813 397,081,866 60,634,750 6,075,947 9,141,260 276,898,429 2,188,071 lations. Physical unit	1991 800,558,289 445,516,282 63,539,252 5,443,846 10,123,232 279,499,189 2,243,847 ts are converted to aption (MMBTU)	1932 850,160,346 514,465,889 65,781,657 5,587,544 12,061,623 306,700,882 2,491,654 MMBTU, gasoline	1993 868,568,554 556,167,856 65,682,778 5,725,030 13,550,351 333,395,211 2,645,788 is adjusted to acco	1934 878,534,770 569,827,218 86,071,472 5,486,167 14,041,321 356,334,883 2,723,244 unt for ethanol, and	1995 898,574,102 534,044,295 66,502,877 5,224,517 14,738,586 378,068,326 2,839,147 the resulting cons	1396 913,814,469 614,461,807 68,786,530 5,014,381 15,401,481 332,455,357 2,831,341 umption is convert	1997 938,187,386 646,651,316 66,658,556 5,013,284 16,595,050 411,750,536 2,371,489 ed to CO <sub>2</sub> .	1398 975,517,341 668,289,569 68,210,425 4,823,932 77,118,669 4,25,894,225 3,075,172	1939 996,876,875 698,973,106 68,964,497 4,695,846 18,153,101 436,123,565 3,183,212	2000 1,017,564,565 7718,621,902 68,363,164 4,531,983 18,816,145 442,288,884 3,160,802	20 1,044,309,08 749,911,50 60,295,42 4,136,21 19,101,93 445,083,4 2,943,18
oline oline oline Ilate Fuel C Ilate Fuel C Ilate Fuel C oline the total	LDGY LDGY HDGV HLDDY HLDDY HLDDY HLDDY MC I emissions calcul ons consumption Yehicle Type	1930 943,656,183 397,061,856 60,634,750 6,075,947 9,141,260 22,658,429 2,188,071 lations. Physical unit to MMBTUs consum 1930	1991 800,558,289 445,516,282 63,539,252 5,443,846 10,123,232 278,499,189 2,243,847 ts are converted to nption (MMBTU) 1991	1932 850,160,346 514,465,889 65,781,657 5,687,514 12,061,623 306,700,882 2,491,654 MMBTU, gasoline 1992	1993 868,568,554 556,167,856 65,682,778 5,725,090 13,550,351 333,395,211 2,645,788 is adjusted to acco	1934 878,534,770 569,827,218 66,071,472 5,496,167 14,041,321 356,334,863 2,723,244 unt for ethanol, and 1934	1995 898,574,102 594,044,295 66,502,877 5,224,517 14,738,586 376,088,326 2,839,147 I the resulting cons 1995	1396 913,814,469 614,461,807 66,756,530 5,014,381 15,401,481 392,455,357 2,891,941 umption is convert	1997 938,187,386 646,651,316 66,668,656 5,013,284 16,555,050 411,750,536 2,371,469 ed to CO <sub>2</sub> .	1998 975,517,341 668,268,569 68,210,425 4,823,932 17,118,869 425,834,225 3,075,172 1998	1999 996,876,875 688,973,106 68,964,497 4,895,846 18,153,101 436,123,565 3,163,212 1999	2000 1,017,564,565 713,621,902 66,363,164 4,531,883 18,816,145 442,286,884 3,160,802 2000	20 1,044,309,01 749,911,51 60,295,43 4,136,22 19,101,93 445,083,4 2,943,11 2,943,11
ioline oline oline illate Fuel C illate Fuel C oline illate Fuel C oline ithe total <u>wert galli</u> <u>type</u> oline	LDGY LDGT HDGV NI LDDV NI LDDV NI LDDV MC I emissions calcul ons consumption Vehicle Type LDGY	1930 943,656,193 397,081,866 60,634,750 6,075,947 9,141,280 276,696,429 2,169,071 10,000 105,459,274 105,459,274 105,459,274	1991 800,558,289 445,516,282 63,539,252 5,443,846 10,123,232 277,493,189 2,243,847 ts are converted to nption (MMETU) 1991 100,058,786	1932 850,160,346 514,465,889 85,781,657 5,887,554 12,061,623 306,700,862 2,491,654 MMBTU, gasoline 1992 106,270,043 106,270,043	1993 8%558554 558,167,856 855,682,778 5,725,030 13,550,351 2,645,788 is adjusted to acco	1934 878,534,770 568,827,218 86,071,472 5,488,167 14,041,321 3365,334,863 2,723,244 unt for ethanol, and 1934	1995 898,674,102 594,044,295 66,502,877 5,224,517 14,738,586 378,088,326 378,088,326 378,088,326 14,738,586 378,088,326 14,738,58614,738,586 14,738,58614,758,586 14,758,58614,758,58614,758,58614,758,58614,758,58614,758,5861	1396 313,814,469 614,461,807 66,766,530 5,014,981 15,401,481 382,455,357 2,891,941 umption is convert 1996 114,226,809	1997 938,187,386 646,651,316 66,668,656 66,668,656 411,750,536 2,971,489 ed to CO <sub>2</sub> . 1997 117,273,423	1998 975,517,341 688,288,559 68,210,425 4,823,932 17,118,869 425,834,225 3,075,172 1998 121,939,668	1939 996,876,875 638,973,106 683,964,497 4,695,846 18,153,101 436,123,565 3,183,212 1939 124,603,609	2000 1,017,564,565 718,621,902 66,363,164 4,531,883 18,816,145 442,266,884 3,160,802 2000 127,185,571	20 1.044,308,01 749,3115,5 60,295,42 4,136,21 19,101,97 445,083,4 2,943,18 2,943,18 2,943,18 200 130,538,63
ofine     oline     oline     oline     illate Fuel C     illate Fuel C     illate Fuel C     illate Fuel C     oline     the total     avert gall     type     oline     oline     oline     oline	UDGV LDGT LDGT HDGV N LDDV N LDDV N LDDV MC I emissions calcul ons consumption Yehiole Type LDGY LDGT LDGT	1990 #3,66,133 397,061,666 60,624,750 6,075,947 9,141,280 27,6,598,429 2,198,071 Lations. Physical unit to MMBTUs consum 1930 106,466,274 49,555,233 7,875,945	1931           800,558,289           445,516,282           63,539,252           5,443,846           10,123,232           278,499,189           2,243,847           ts are converted to           nption (MMBTU)           1931           100,058,766           55,689,535           56,689,535	1992 650,160,346 654,465,869 657,751,657 5,687,754 5,687,754 12,061,623 306,700,662 2,431,654 MMBTU, gasoline 1992 106,270,043 64,306,208 0,020,209 200,209 200,209 200,209 200,209 200,209 200,209 200,209 200,209 200,209 200,209 200,200,209 200,200	1933 683,558,854 558,167,955 68,552,778 5,725,580 13,550,351 2,845,788 is adjusted to accoo 1933 006,858,669 88,770,982 006,858,669	1994 878,554,770 668,827,219 668,077,472 5,448,167 14,041,321 355,334,863 2,723,244 109,816,846 71,228,402 2,929,94	1995 98,574,902 584,044,265 68,502,877 5,224,517 14,728,865 28,39,147 14,728,865 28,39,147 14,728,585 112,321,783 142,321,783 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,83 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 123,27,85 124,27,97 124,57	1996 913,814,463 614,461,007 68,768,530 5,014,361 15,401,481 332,465,357 2,891,941 umption is convert. 1996 114,228,809 76,807,728	1997 935,187,386 64,6,651,316 66,668,656 5,013,284 16,555,050 411,750,536 2,371,489 ed to CO <sub>2</sub> . 1997 117,273,423 80,831,445 9,02550	1998 975,517,341 668,288,869 663,201,425 4,823,392 17,718,869 425,884,225 3,075,172 1998 123,939,668 83,558,074	1993 966,776,675 68,964,497 4,935,846 19,152,101 436,122,565 3,163,212 1999 124,603,609 87,371,558 0,009,603	2000 10/15/84.565 7/18.521/802 66,363,164 4,531,863 18,161,M5 442.266,884 3,160,802 2000 127,185,571 88,3652,738 9,055,571	20 1,044,309,06 749,91156 60,295,43 4,136,21 19,101,93 445,083,4 2,943,16 2,943,16 2,943,16 130,538,65 93,738,85 3,738,85 2,500,000
oline oline oline oline Fuel C illate Fuel C illate Fuel C illate Fuel C oline oline oline oline oline oline	Venicle Type LDGV LDGV LDGT HDGV N LDDT N LDDT N LDDT MC I emissions calcul ons consumption Yehicle Type LDGV LDGY HDGV HDGV N LDGY	1930 943,656,153 397,081,866 60,654,750 6,075,947 9,141,250 276,896,429 2,159,071 10,456,274 105,456,274 105,456,274 105,456,273 105,457,273,454 105,457,273,344 105,457,273,344 105,457,273,344 105,457,345 105,457,275,273,344 105,457,275,344 105,457,345 105,457,275,273,344 105,457,275,344 105,457,345 105,457,345 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457,457 105,457	1931 900,558,289 445,518,282 83,5183,852 5,443,346 10,123,232 278,498,189 2,243,947 15 are converted to 100,083,785 55,683,535 7,7942,405 751,299	1992 850,060,346 554,465,989 85,781,657 5,887,764 12,061,623 306,700,982 2,491,054 MMBTU, gasoline 1992 106,270,043 84,308,238 84,208,238	1933 965,566,854 556,157,356 66,652,776 5,725,090 13,550,351 333,395,211 2,645,788 1933 106,656,069 1933 106,656,069 83,770,882 82,206,597 70,000	1934 678,554,770 568,827,219 568,827,219 568,827,219 56,848,167 14,041,321 356,304,663 2,723,324 109,816,846 109,816,846 171,228,402 9,258,934 77,229,102	1995 898,574,102 594,044,255 594,044,255 522,4577 14,738,586 2,839,047 14,738,586 2,839,047 1995 112,321,763 1995 112,321,763 74,225,537 8,312,560 714,491 14,415 1995 112,321,763 14,415 1995 112,321,763 14,415 1995 112,321,763 14,415 1995 112,321,763 14,415 1995 112,321,763 112,322,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324,863 112,324 112,324,863 112,324 112,324,863 112,324 112	1996 912,814,463 614,461,007 65,766,530 5,5014,361 15,401,461 15,401,461 13,92,455,357 2,8361,341 umption is convert. 1996 114,226,809 76,807,726 8,345,518 40,245,515	1997 \$30,167,366 \$46,651,316 \$66,680,656 \$5,013,284 16,595,050 411,750,536 2,371,489 ed to CO <sub>2</sub> . 1997 117,273,423 80,831,415 8,333,882 \$89,211	1996 975,517,341 668,268,689 668,2014,25 4,823,392 17,118,689 4/225,684,225 3,075,172 1998 12(3/3),668 23,558,074 8,558,074	1995 966,878,875 689,873,105 689,874,975 4,855,846 18,153,101 436,22,565 3,183,212 1999 124,605,605 87,371,638 8,8,20,582 44,474	2000 1017;564,565 719;621,502 63,333,364 4,531,383 18,016,445 442,288,884 442,288,884 442,288,884 2000 127,185,571 83,982,738 82,285,295 5,575,445	20 1,044,309,08 749,31150 60,235,43 4,136,27 19,10137 445,083,41 2,943,18 20 130,538,83 93,738,93 7,558,83 93,738,93 7,558,83 93,738,93 7,558,83 93,738,93 7,558,83 5,72,20 5
coline     coline     coline     coline     coline     coline     coline     coline     coline     the total     coline     col	Venice Type LDGV LDGV HDGT HDGV NLDDV NLDDV NC I emissions calcul Ons consumption: Vehicle Type LDGV LDGV LDGT HDGV NLDDV NLDV NLDDV NLDV NLDV NLDV N	1990 943,656,133 337,051,866 60,834,750 60,075,947 9,141,260 9,141,260 9,141,260 9,141,260 9,142,060 1,266,964,429 1,266,964,429 1990 1990 1990 1990 1997 1990 1997 1997	1931 900,558,289 445,558,282 51,559,282 51,443,045 101,123,22 278,498,199 2,243,847 15 are converted to 1931 100,065,786 55,583,555 7,542,406 7,51,769 7,51,759 7,510	1932 950,160,346 54,465,885 65,701657 5,887,544 12,061,683 306,700,062 2,491,654 MMBTU, gasoline 1992 106,270,043 64,308,236 8,222,707 765,423 166,653	1933 683,568,554 558,167,856 65,852,778 5,725,560 13,550,351 2,645,788 133,395,211 2,645,788 1933 106,856,669 83,770,582 1933 106,856,669 1937 106,856,669 1937 106,856,669 1937 106,856,669 1937 106,856,669 1937 106,856,669 107,7582 106,857 107,7582 106,857 106,856,659 107,7582 106,857 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 106,856 107,7582 107,7582 106,856 107,7582 107,7582 107,7582 106,856 107,7582 107	1934 978,554,770 569,827,218 56,071,472 5,456,167 14,041,321 355,334,863 2,723,244 unt for ethanol, and 1934 109,816,846 77,228,402 9,256,934 757,613 1539,160	1995 688,574,102 584,044,255 66,502,877 5,224,817 14,738,585 2,839,147 146 resulting cons 1995 112,321,763 74,265,537 6,312,860 721,461 2,035,529	1396 913,814,463 614,463,607 65,766,530 5,5014,361 15,401,461 392,465,567 2,891,941 umption is convert 1996 114,226,809 76,807,726 6,345,508 63,45,508 63,2445,508	1997 338,167,386 64,6,681,216 66,688,656 5,013,264 16,585,050 411,760,536 2,371,489 ed to CO <sub>2</sub> . 1997 17,273,423 88,331,465 8,323,462 82,231 2,281,687	1998 375,517,241 668,248,659 668,240,455 4,823,382 17,718,869 425,894,425 3,075,172 1998 12(33),668 83,538,074 8,558,303 668,170 2,364,009	1999 966,876,975 688,877,316 683,874,316 88,964,497 4,855,846 98,853,046 436,823,865 3,183,212 1999 194,605,605 87,371,638 8,820,662 48,474 2,506,667	2000 10/7.564.565 778.521.402 68.353.064 4.531.863 8.0163.M5 44.2286.864 44.2286.864 3.160.902 2000 127.185.571 88.952.735 6.255.945 6.255.945 2.558.450	200 1,044,309,006 749,311,50 560,235,43 4,136,27 19,101,97 14,150,03,44 2,943,18 200 130,538,63 93,738,93 7,536,92 571,20 2,637,81 2
soline     soline     soline     soline     soline     soline     soline     soline     w the tota     mvert gall     soline	Venice Type LDGV LDGT HDGV NLDOT NLDOV NLDOV MC I emissions calcul ons consumption. Venice Type LDGT LDGY HDGV NLDOT NLDOV NLDOT NLDOV	1990 943,656,193 337,061,86 60,634,750 6,075,947 9,141,220 276,696,429 276,696,424 2,198,071 10,0000 10,000 10,0000 10,0000 10,0	1931 400,556,269 445,556,262 5,553,352 5,543,245 10,232,32 278,493,189 2,243,247 15 are coverted to nption (MMBTU) 1931 100,063,766 55,583,505 7,7,942,406 1337,370 38,459,412	1932 650,060,346 654,060,346 657,061,657 5,687,654 12,061,652 306,700,982 2,491,054 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,043 106,270,045 106,	1933 063,568,554 050,668,554 050,667,356 050,677,356 050,257 033,356,211 2,645,768 1953 106,858,065 058,770,882 0,858,065 058,770,882 0,206,597 700,008 1871,239 45,040,231 100	1334 678,534,770 568,827,238 568,071,472 56,85,167 16,041,321 356,324,063 2,723,244 uut for ethanol, and 1934 103,818,846 71,228,402 8,258,334 777,513 1353,040 43,200,148	1995 838,574,192 534,044,235 66,502,877 5,224,517 14,738,586 2,833,447 14,738,586 2,833,447 10,221,783 112,221,783 74,225,537 8,312,860 721,481 2,035,329 52,212,897	1996 918,814,463 614,463 65,768,633 5,014,981 15,401,481 15,401,481 352,455,357 2,891,941 umption is convert 1996 114,228,809 76,807,728 8,345,98 6,945,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 6,9245,98 7,926,99 7,926,99 7,926 7,927 7,926 7,927 7,927 7,927 7,926 7,927 7,926 7,927 7,9	1997 \$30,167,365 \$44,651,316 \$6,688,656 \$5,013,264 \$6,555,050 \$411,700,556 \$2,971,489 <b>2417,00,556</b> <b>2,971,489</b> <b>2417,073,423</b> \$0,831,455 \$3,32,882 \$6,823,145 \$3,32,882 \$6,823,145 \$2,321,857 \$5,869,788	1998 975,517,241 668,268,589 8,820,125 4,823,592 77,118,888 425,894,225 3,075,172 1998 12(3)39,668 83,558,674 8,8558,674 8,9558,674 8,9558,674 8,9558,7558,755 8,9558,7558,7558,755 8,9558,7558,7558,7558,7558,7558,7558,755	1995 966,875,875 689,877,875 689,874,975 4,885,846 18,153,010 436,123,865 3,183,212 1995 124,609,800 87,371,533 8,820,182 44,64,74 2,506,857 90,226,858	2006 1.017554.8565 715.621.902 65.933,164 4.531.833 8.045,145 44.2286,894 3.160,802 2000 127.185,571 83.982,738 8.235,735 8.235,735 8.255,455 2.5584,520 6.0177,713	200 1,044,309,08 749,311,50 62,254,34 4,158,27 19,101,37 44,59,82,41 2,243,18 2,243,18 2,243,18 2,243,18 2,243,18 2,253,85 5,71,20 2,253,78 5,453,20 5,71,20 2,253,78 5,453,20 2,453,18 5,453,20 2,253,18 5,453,20 2,253,18 5,453,20 2,253,18 5,453,20 2,253,18 5,453,20 2,253,18 5,453,20 2,253,18 5,453,20 2,254,18 2,
soline     soline     soline     soline     soline     soline     soline     with tota     wethe tota     wethe tota     soline	Unit fige LDGV LDGV HDGT HDGV N LDOV N LDOV MC emissions calcul ons consumption Wehiel Type LDGV UDGY HDGV N LDOV N LDOV	1390 943,668,163 397,061,666 60,634,760 60,75347 9,141,260 226,656,429 2,1590,071 1410065, <b>Physical unit</b> 106,468,274 46,855,223 4536,6274 45,855,223 433,22,844 34,22,844 34,244,245434,2454 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,2444 34,244434,2444 34,2444 34,2444 34,2444 34,244434,2444 34,2444 34,2444434,2444 34,2444434,2444 34,2444434,2444 34,2444434,24444 34,2444434,24444 34,244443444 34,24444443444444 34,24444444444444444444444444444	1931 800,5%2,89 445,5%2,82 445,5%2,82 5,443,846 10,132,32 278,498,189 2,243,847 2,243,847 10,0058,786 10,0058,786 55,688,505 7,942,406 155,688,505 7,1542,405 153,770 38,458,412 20,0461	1932 650,060,346 654,060,346 657,060,87 5,887,564 12,061,823 306,700,082 2,440,854 12,440,854 1992 1992 1992 1992 1992 1992 1992 1992 1992 1992 1992 1995	1933 963,563,554 956,167,956 65,652,778 5,725,190 11,550,251 303,395,211 2,645,788 108,589,069 1933 108,589,069 63,770,982 8,206,597 700,000 1871,239 46,040,239 300,723	1334 676,534,770 568,827,238 56,877,472 5,468,167 14,041,021 356,234,463 2,723,244 103,816,346 11,223,463 2,723,244 103,816,346 11,223,462 9,228,833 1533,040 1533,040,455	1995 698,574,902 594,044,265 594,044,265 75,224,517 14,738,586 2,839,147 14,255,537 8,322,560 112,321,783 114,225,537 8,322,560 721,461 2,035,529 52,212,187 3,34,633	1996 918,814,463 614,463 614,463,007 5,014,361 15,401,481 15,401,481 15,401,481 15,401,481 15,28,505 2,891,941 1995 114,228,805 114,228,805 114,228,805 114,228,805 114,228,805 114,228,805 12,245,55 2,268,571 5,4,96,218 5,405,218 5,405,218	1997 \$318,167,786 \$46,651,316 \$5,013,284 \$5,013,284 \$10,556 2,371,489 ed to CO_r. 1997 117,273,423 \$8,833,1415 \$3,03,582 \$8,833,1415 \$3,03,582 \$8,833,1415 \$3,03,582 \$8,833,1415 \$3,03,582 \$8,833,1415 \$3,03,582 \$8,833,1415 \$3,03,582 \$8,80,788 \$3,04,885 \$1,045 \$1,045	1998 975,517,241 668,268,568 8,82,04,25 4,82,3392 77,718,889 428,844,225 3,075,172 1998 12(3,39),668 83,558,074 8,558,075 8,558,0758,0758,0758,0758,0758,0758,0758	1995 968,876,075 683,973,166 83,973,166 4,853,644,97 4,853,646 1436,123,085 3,163,212 1999 124,605,605 8,7371,638 8,8520,562 464,474 2,506,657 60,226,589 337,901	2008 1,017,564,585 1718,021,564,585 1718,021,502 65,533,184 4,531,883 18,958,M5 442,2286,584 3,160,602 2009 127,195,571 83,952,738 10,072,715 10,072,	20 1044,309,06 749,31156,27 19,10137 44,5,083,44 2,943,18 200 130,538,63 93,738,93 7,558,92 5,72(2,2,837,8) 5,64,823,00 5,64,823,00 5,64,823,00 5,64,823,00 5,64,823,00 5,64,823,00 5,64,833,00 5,74,93
torine     torine     torine     torine     torine     torine     thate Fuel C     thate Fuel C     thate Fuel C     torine     the tota     nevert gall     torine     thate Fuel C	Ventor Type LDGV HDGV HDGV HDGV HDGV HDGV HDGV HDGV H	1930 943,665,153 337,051,66 60,634,760 6,075,947 9,141,260 276,656,429 1,142,200 1,142	1931 800,558,289 445,558,282 5,453,842 5,453,842 1,43,246 1,12,222 27,449,189 2,243,447 15 are converted to nption (MMB TU) 1931 100,063,766 55,638,555 7,542,406 7,517,89 1,337,770 34,459,412 U)	1992 650,160,346 654,465,885 65,761,657 5,827,544 12,061,623 308,700,862 2,451,654 MMBTU, gasoline 1992 196,270,043 64,308,236 8,222,107 765,423 1,665,653 42,353,329 311,457	1933 693,564,67,554 693,564,87,556 65,652,778 57,725,090 13,550,051 333,345,211 2,845,788 1933 1908,586,689 8,3770,582 8,266,597 790,608 8,270,582 4,640,231 4,640,231	1994 678,534,770 668,872,728 68,871,472 5,468,167 14,041,221 196,324,863 2,723,244 190,816,846 77,228,402 190,816,846 77,228,402 193,816,846 77,258,934 757,653 1,933,040	1995 698,574,902 698,574,902 654,044,235 65,502,877 5,224,517 14,738,586 2,239,147 14,738,586 2,239,147 14,232,17,85 112,321,785 74,225,537 4,232,580 73,24,85 52,212,187 354,883	1996 913,814,463 614,461307 66,766,830 50,143,861 75,401,461 932,465,557 2,2891,941 1995 114,228,805 75,807,728 93,745,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 93,245,518 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,218 94,149,149,149 94,149,14994,149 94,149,149 94,149,149 94,149,149,149 94,149,149 94,149,149 94,149,149 94,149,149 94,149,149 94,149,149,149,149 94,149,149,149,149,14994,149,149,149,149,149,149,149,149,149,1	1997 308 (87.788 64.6,851,35 65.688,656 50.13,284 15.555,550 41.770,556 271,489 ed to CO <sub>2</sub> . 1997 117,273,423 88,831,45 83,231,862 632,318 2,291,687 56,880,788 3,71,435	1996 975,177,241 662,208,089 68,270,425 4,823,982 77,18,869 4,225,684,225 3,075,172 12(35)3,666 83,558,074 8,558,203 6,582,303 6,582,303 6,583,384 3,284,095 5,883,384 3,284,397	1935 956,776,675 696,872,105 83,864,497 4,535,546 19,153,301 436,123,565 3,163,212 124,503,605 87,371,538 8,520,562 648,474 2,506,857 60,226,588 337,301	2000 10/17/54/565 7018/61/502 68,533,384 45,531383 38,958,445 44,2,286,884 3,160,802 2000 127,195,571 83,952,735 6,255,545 6,255,545 6,255,545 6,255,545 6,255,545 6,255,545 6,255,545	20 1044,303,06 744,3115,62 19,100,37 445,082,4 2,343,17 2,043,17 2,043,17 2,043,17 2,053,65 3,7,758,37 7,558,55 5,7122 2,237,8 5,7122 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,237,8 5,7125 2,12555 2,12555 2,12555 2,12555 2,125555 2,1255555 2,1255555
v soline soline soline soline tillate Fuel C tillate Fuel C	Unit Type LDGY LDGY HDGY N LDOY N LDOY N LDOY N LDOY N LDOY NC LDGY LDGY LDGY LDGY LDGY LDGY HDGY NC TUS consumption MC TUS consumption MC	1990 943,666,193 397,081,666 60,834,760 60,753,4760 60,753,4760 2,869,877 2,869,877 14tions. Physical unit to MMDTUs, consum 1990 106,448,274 49,855,223 7,7573,244 633,059 1,252,384 633,059 1,252,384 1,322,284 1,324,284 1,324 1,324 1,324 1,324 1,324 1,324 1,324 1,324 1	1991 445,558,289 445,558,282 54,559,522 54,3245 10,222 274,43,459,169 2,243,347 10,0069,765 10,0006	1932 950,060,346 554,465,889 65,704,657,84 12,061642 306,700,882 2,491654 1992 1992 1992 1992 1992 2,491654 1992 1995 1995 1995 1995 1995 1995 1995	1933 683,564,554 556,867,556 68,662,776 57,255,980 13,550,351 333,345,211 13,550,351 333,345,211 1933 1945,245,708 1933 1945,245,708 1933 1945,245,708 1947,245	1934 978,554,770 568,827,288 568,071,472 5,488,167 14,041,321 255,324,863 2,723,244 108,816,946 71,2528,402 1,553,040 3,452,054 777,613 1,553,040 3,40,455 1,553,040 3,40,455 1,555	1995 698,574,902 594,044,235 66,502,877 5,224,577 14,738,586 376,089,326 2,839,147 112,221,583 112,221,583 74,255,537 8,322,560 741,265,537 8,322,567 742,255,537 8,322,567 742,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 8,322,567 744,255,537 745,255,537 745,255,557,557 745,25	1396 918,844,463 64,4451007 86,766,8530 50,14,981 75,0014,981 332,455,557 2,891,941 1995 194,255,650 75,807,725 8,945,585 8,925,457 2,026,571 2,026,571 2,026,575 2,027,575 2,027,575 2,027,575 2,027,575 2,026,575 2,026,575 2,027,575 2,025,575 2,02	1997 1997 938 897 396 64,655 336 85,858 8556 80,8284 185,556 500 411,750,558 2,371,489 1927	1998 1975,17,241 662,208,163 482,208,163 482,208,163 482,2392 17,168,659 425,844,225 3,075,172 1999 123,535,667 425,554,073 48,555,073 48,555,073 48,555,073 48,4597 1999 1999 1999 1999 1999 1999 1999 1	1995 966,776,675 638,373,106 83,964,497 45,855,46 18,553,101 436,623,665 3,183,212 1999 124,605,660 87,371,638 8,623,565 3,37,70,635 4,64,77 2,256,857 4,64,77 2,256,857 3,37,801 1999	2006 1077544565 1077544565 1077544565 1075544565 1075544565 1075544565 10754545 1071853 107185571 2000 2000 2000 2000 2000 2000 2000 20	20 1044,309,06 749,31156 113,011,97 445,083,47 2,943,18 200 200 200 200 200 200 200 20
coline	Venice Type LDSV LDSV HDSV HDSV HDSV HDSV HDSV HDSV HDSV Venice Type LDSV HDSV HDSV HDSV HDSV HDSV HDSV HDSV H	1390 943,668,163 397,061,666 60,634,760 60,75347 9,141,260 226,656,429 2180,071 141006.5 Physical unit to MMBTUs consum 1990 106,468,274 435,55,223 106,468,274 435,55,223 106,458,274 108,058,274 104,368,274 104,368,274 104,368,274 104,368,274 104,368,274 104,368,274 104,368,274 104,368,275 104,375 104,375 104,375	1991 400,558,289 445,558,282 445,558,282 5,453,845 18,123,232 274,459,189 2,243,447 15 are converted to 100,063,768 55,683,555 7,542,406 751,769 7,517,69 7,517,69 7,517,69 7,517,69 7,517,69 1,337,470 33,455,412 20,461 40 99,611,952 99,611,952	1932 950,160,346 544,465,885 65,754,657 5,867,544 12,061,623 306,700,862 2,451,654 1952 1956 1957 1952 1957 1952 1957 1952 1957 1952 1957 1952 1952 1957 1952 1957 1952 1957 1952 1957 1952 1957 1957 1952 1957	1933 693,563,673,65 693,563,673,56 63,562,778 57,725,990 13,550,305 13,33,395,21 2,445,789 1933 1953 1953 1953 1953 1953 1953 195	1994 678,554,770 668,872,728 68,871,472 5,468,167 14,041,221 255,324,862 2,723,244 1994 1994 1994 1994 1994 1994 1994 1994 1994 1995	1995 698,574,902 698,574,902 698,574,902 68,502,677 5,224,597 14,738,868 2,2393,147 14,738,868 2,2393,147 112,321,783 74,205,537 74,205,537 74,205,537 74,205,537 74,205,537 74,205,537 74,205,537 74,4893 1995 110,857,589 110,857,585 110,857,585 110,857,585 110,957,585 110,957,597 110,957,597	1996 913,814,463 913,814,463 914,814,461807 96,766,530 96,704,961 97,804,941 9392,465,367 728,093 939,941 9392 941 9392 943,945,955 932,545 932,545 932,545 932,545 932,545 932,545 932,545 932,545 934,549 9354,549 9354,549 93556,549,549 935566,549 935566,549 935566,549 935566,549 935566,549 935566,549 935566,549 9355666,549 9355666,549 93556666666666666666666666666666666666	1997 1997 (38) 646,651,356 65,658,656 5,013,264 16,555,050 41,750,556 41,750,556 41,750,556 41,750,556 97,1469 ed to CO <sub>2</sub> . 1997 19,273,423 80,831,455 82,311 2,291,687 56,860,788 3,71,455 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997 114,455,625 1997	1998 975,517,241 662,200,265 68,200,425 4,823,592 17,718,869 422,684,225 3,075,172 1998 12(393,868 8,3,558,074 8,552,50,074 8,552,50,074 8,552,50,07 8,84,309 2,344,009 5,9,81,384 8,34,397 1998 113,145,675	1935 956,776,675 696,875,655 69,864,497 4,555,646 19,853,301 436,523,665 3,183,212 1939 124,605,605 8,520,562 6,867 4,874 2,556,687 40,255,588 3,37,501 1939	2009 2007,554,555 705,854,555 705,854,555 705,854,555 705,854,55 44,2285,884 3,160,892 2009 2009 2009 2009 2009 2009 2009 2	200 1044,309,08 749,31150 60,225,43 44,508,44 2,943,18 2,945,18 2,945
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## **Step (11)** Review the CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions in metric tonnes were calculated using unit conversion and default CO<sub>2</sub> 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<sub>2</sub> emissions calculations for off-road vehicles.

### Figure 11. Example of the Off-road CO<sub>2</sub> Worksheet in the Mobile Combustion Module

17 - Cu - 1	-			CH4 and N2O E	missions from Mo	bile Combustion M	lodule - State Inver	story Tool	Statement in the statement			1
Home	Insert Page Layout	Formulas Data	Review View	w Developer	Add-Ins Ad	robat						c
Non-h	highway CO <sub>2</sub> C	alculations							29			
Contin	CO <sub>2</sub> emissions from	off-road vehicles are calcul	ated using the follows	ng steps					1			
Continu	(1) Utilize consumption	ion data for each mode and	fuel type from steps f	through 8 of the mor	dule, and				1			1
	(2) Monphy Incidents	multion by the appropriate	energy content and o	arbon coernaent is e	Smale CO; envision	a						1
	For further information	on, refer to the Mobile Comb	ustion chapter of the	User's Guide.					k.			
w the emissi	ions calculations for each	off-road mode.										
Aviation	Verify the activity data (	(fuel consumption, in ga	illions) used to cale	ulate CO, emissio	ns from aviation.	1001	100/	1005	1007	1000	1000	
	Fuel Type	23.052.510	26 164 513	70 701 600	48 096 103	1204	40.082.764	43 703 068	40.661.068	20 545 554	44 226 767	12 992
	Jet Fuel, Nerosene	1 408 487	30,154,513	1.865.967	4 213 264	4.581.285	1 010 376	43,703,055	90,001,000	30,040,064	44,620,754	AC, PPE,
	Jet Firet, reprinte	840.462	785 884	885 534	824 648	843 395	624 178	624 673	716 741	735 618	983 601	789
						- Contract						
	Convert consumption s	o carbon content (ibs C)	4004	4002	4993	4004	1006	1006	1997	4608	4000	
	Jai Fool Kermane <sup>14</sup>	1 413 887 227	1 546 521 615	1 701 287 848	2 092 199 239	1 848 998 331	1 709 317 425	1 895 103 710	1 785 984 098	1 874 151 895	1 920 848 489	1 887 281
	Jet Fuel, Nachthatt	65.019.359	29,461,572	80 282 664	74 338 089	68.611.941	83,281,736	13,287,460	1 356 108	1,01.0,10.,000	1,464,0-0,000	1,000-200-2
	Aviation Gasoline	34,904,378	32,430,507	28,469,820	25,953,988	26,720,344	25,922,017	25,942,687	29.090.057	30,147,309	40,848,962	32,778;
	Convert carbon to emir	ssions (Ibs CO.)										
	Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2
	Jet Fuel, Kerosene**	5,184,253,164.52	5,670,799,255	6,238,055,438	7,671,397,210	6,772,327,213	6,267,497,225	6,959,713,603	6,475,275,018	6,138,556,215	7,043,111,052	6,846,587,
	Jet Foel, Naphtha**	238,404,317	108,025,763.23	294,369,769	272,572,994	251,577,115	305,366,365	48,720,686	4,972,294			
	Aviation Gasoline	127,982,720	118,911,860	104,389,338	95,164,622	97,974,595	95,647,397	95,123,184	109,599,809	110,540,132	149,779,526	120,189,
	Convert pounds to met	tric tons (MTCO.)	4004	4003	4003	1001	4005	1001	1007	4003	4000	
	Fuel Type	2.261.626	2 622 248	2 820 626	3 470 000	3.071.000	2 842 874	1999	2 027 120	2 704 200	3 104 005	3 105
	Jet Fuel, Kerosene	2,391,920	2,572,219	2,029,540	2,472,000	3,071,000	2,042,074	2,130,050	2,907,120	2,104,200	3,134,002	2,162,
	Jet Fuel, Naprina	100,130	40,000	100,000	123,030	114,113	130,011	42,000	40 745	60.140	47 634	
	Total	2,517,715	2,675,154	3,010,393	3,646,471	3,230,413	3,024,498	3,222,103	2,989,089	2,834,528	3,262,623	3,160,
Boats												
	Verify the activity data (	(fuel consumption, in gr	flons) used to calc	ulate CO2 emissio	ins from boats							
	Fuel Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2
	Residual Fuel Oi**					42,000						
	Distilate Fuel Oi**					15,596						

### Step (12) Review Summary Information

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

### Step (12a) Review CH<sub>4</sub> and N<sub>2</sub>O Summary Information

The Steps 4-9 above provide estimates of total CH<sub>4</sub> and N<sub>2</sub>O emissions from mobile combustion. This summary worksheet displays results in MTCO<sub>2</sub>E, Gg CH<sub>4</sub>, and Gg N<sub>2</sub>O. Figure 12 shows the summary worksheet that sums the CH<sub>4</sub> and N<sub>2</sub>O 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

	1001 - CF	14 and N2	O Emissio	ns from M	obile Com	bustion Me	odule								
🕙 Eile Edit Mo	dule Option	s											Type a que	stion for help	6
12a. Mobile S	ource E	mission	s Summo	iry, CH4	and N <sub>2</sub>	0	Ret Co	urn to ntrol	Review discus associated w	sion of uncerta ith these resul	inty ts	Continue to CO;	Summary	>	
Total CH4 and N2O Em	lissions from	Mobile Sou	rces (MTCO <sub>2</sub>	E)						Graphs	$\overline{}$		1		
Fuel Type/Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	200.	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	1,210,20	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	624 42	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	557 285	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	1,589	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	Г	he starting and the		111100040	70	74
Light-Duty Trucks	159	175	208	232	240	251	262	282	291	3	Click to	o reviev		336	352
Heavy-Duty Vehicles	4,253	4,310	4,782	5,240	5,647	6,045	6,332	6,699	6,980	7,1				7,432	8,057
Non-Highway	109,650	114,844	122,226	120,824	112,522	108,210	106,307	100,347	107,113	102,5	emissi	ons sur	nmary	11,759	148,547
Boats	477	607	469	395	409	497	436	449	456	500	523	550	5/3	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
													200		

### Step (12b) Review CO<sub>2</sub> 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<sub>2</sub>E 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<sub>2</sub> calculations rely on the same disaggregation of total vehicle miles traveled by vehicle type and model year that is used for the non-CO<sub>2</sub> 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<sub>2</sub>FFC 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<sub>2</sub> 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<sub>2</sub> emissions.

### **Non-highway vehicles**

- 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<sub>2</sub> 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<sub>2</sub> emission factor. The only major source of uncertainty is with the data sources used for disaggregating fuel consumption by type.

By contrast, the CO<sub>2</sub> 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<sub>2</sub> calculations rely on the same disaggregation of total vehicle miles traveled by vehicle type and model year that is used for the non- CO<sub>2</sub> 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.

### **1.6 REFERENCES**

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