
USER'S GUIDE FOR ESTIMATING EMISSIONS FROM MUNICIPAL SOLID WASTE USING THE STATE INVENTORY TOOL

JANUARY 2017



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This section of the User's Guide provides instruction on using the Municipal Solid Waste module of the State Inventory Tool (SIT), and describes the methodology used for estimating greenhouse gas (GHG) emissions from municipal solid waste management at the state level.

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1.1 GETTING STARTED

The Municipal Solid Waste 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 Municipal Solid Waste module, make sure your computer meets the system requirements. In order to install and run the Municipal Solid Waste 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 Municipal Solid Waste 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 Municipal Solid Waste 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 Municipal Solid Waste 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 Municipal Solid Waste 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 Municipal Solid Waste module and re-launch Microsoft Excel before opening the Municipal Solid Waste 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 Municipal Solid Waste 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 Municipal Solid Waste 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

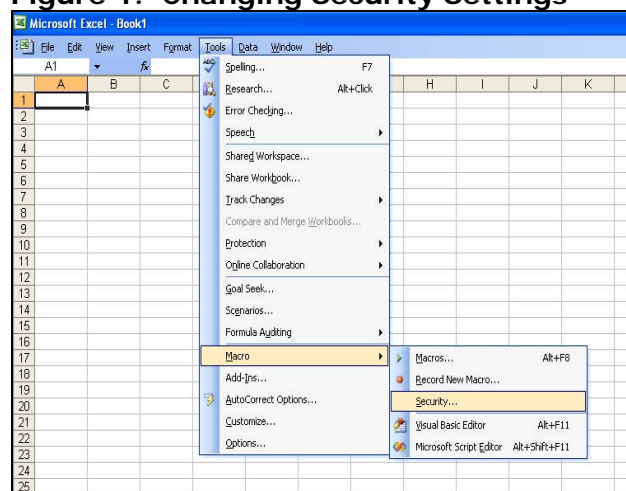


Figure 2. Adjusting Print Margins



1.2 MODULE OVERVIEW

This User's Guide accompanies and explains the Municipal Solid Waste 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.

The Municipal Solid Waste module calculates methane (CH_4) emissions from landfilling of municipal solid waste (MSW) and carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions from the combustion of MSW. 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 Methodology section for data requirements and methodology.

Box 1: State Solid Waste Data Sources

In-state sources, such as state departments of environmental protection, should be consulted first. Otherwise, default data provided by the Municipal Solid Waste module may be used.

In landfills, CH_4 and CO_2 are produced from anaerobic decomposition of organic matter by methanogenic bacteria. Organic waste first decomposes aerobically (in the presence of oxygen) and is then decomposed by anaerobic non-methanogenic bacteria, which convert organic material to simpler forms like cellulose, amino acids, sugars, and fats. These simple substances are further broken down to gases and short-chain organic compounds (H_2 , CO_2 , CH_3COOH , HCOOH , and CH_3OH), which support the growth of methanogenic bacteria. The bacteria further metabolize these fermentation products into stabilized organic materials and "biogas," which consists of approximately 50 percent CO_2 and 50 percent CH_4 by volume. Additionally, some landfills flare recovered landfill gas, which converts the CH_4 portion of the gas to CO_2 . There are also some landfills that collect and burn landfill gas for electricity production or other energy uses (known as landfill-gas-to-energy projects, or LFGTE), which are treated similarly to landfills that flare their gas.

Neither the CO₂ emitted directly as biogas nor the CO₂ emitted from combusting CH₄ at flares is counted as an anthropogenic greenhouse gas (GHG) emission. The source of the CO₂ is primarily the decomposition of organic materials derived from biomass sources (e.g., crops, forests), and in the United States these sources are grown and harvested on a sustainable basis. Sustainable harvesting implies that photosynthesis (which removes CO₂ from the atmosphere) is equal to decomposition (which adds CO₂ to the atmosphere).

Waste combustion emits both CO₂ and N₂O. CO₂ is produced from the oxidation of organic materials in waste, such as paper, food scraps, yard trimmings, and plastic. As with CO₂ from biogas and oxidation of CH₄, CO₂ emissions from biogenic sources (e.g., paper and food scraps) are not counted in GHG inventories because they simply return CO₂ that plants previously absorbed through photosynthesis to the atmosphere. However, some CO₂ is from nonbiogenic sources (e.g., plastic and rubber made from petroleum), and is thus counted in GHG emission inventories. N₂O is produced at the high temperature found in waste combustors by the combination of nitrogen (both nitrogen contained in the waste and nitrogen gas in the air) and oxygen gas in the air.

Users should also note that an additional waste-related greenhouse gas sink, carbon storage from landfilled yard trimmings and food scraps, is accounted for in the Land-Use Change and Forestry module of the SIT.

1.2.1 Data Requirements

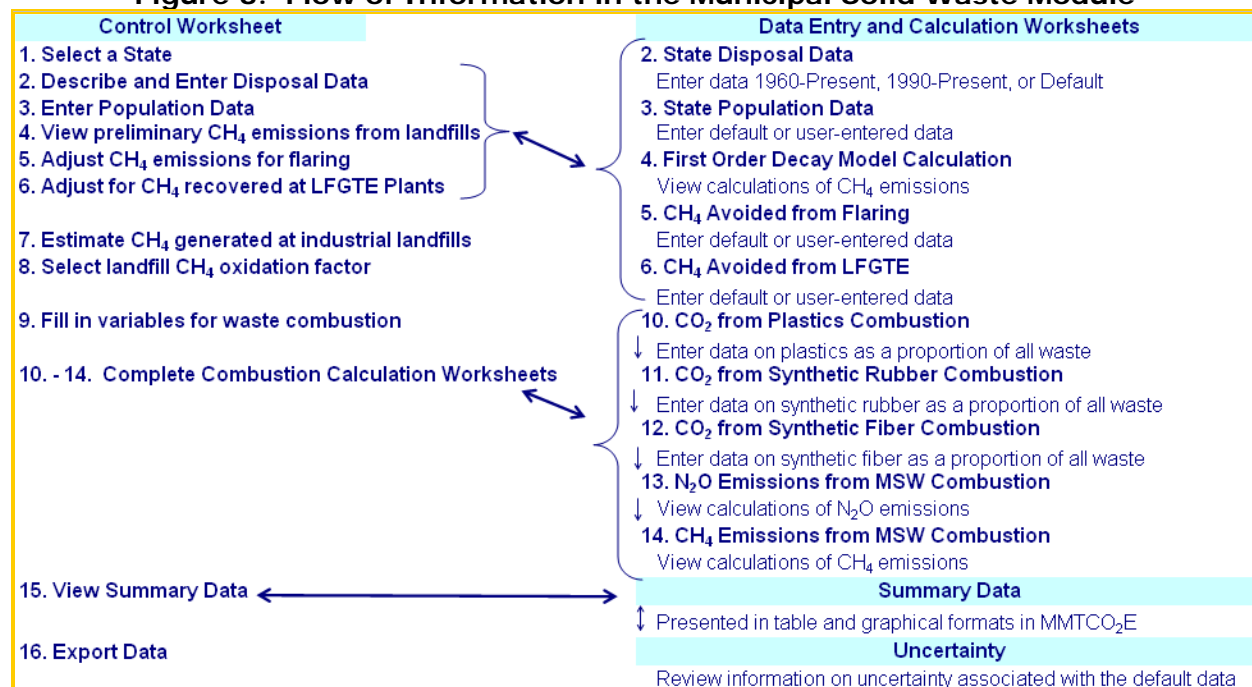
To calculate GHG emissions from municipal solid waste management, the data listed in Table 1 are required inputs (again, note that defaults are available for most of these data).

Table 1. Required Data Inputs for the Municipal Solid Waste Module

Solid Waste Sectors	Input Data
Landfills	<p>Amount of MSW landfilled in state from 1960 through the present OR from 1990 through the present (short tons)</p> <p>State population data, 1960 through the present</p> <p>Amount of CH₄ flared/recovered at landfills (short tons)</p> <p>Industrial landfill CH₄ emissions, as a percent of MSW landfill emissions</p> <p>Percent of landfill CH₄ oxidized at the landfill surface (oxidation factor)</p>
Waste Combustion	<p>Fraction of plastics, synthetic rubber, and synthetic fiber that is oxidized in a combustion facility</p> <p>Amount of MSW combusted for 1990 through the present (short tons)</p>
Plastic Combustion	<p>Polyethylene terephthalate (PET) as a proportion of all MSW discards</p> <p>High-density polyethylene (HDPE) as a proportion of all MSW discards</p> <p>Polyvinyl chloride (PVC) as a proportion of all MSW discards</p> <p>Low-density/linear low-density polyethylene (LDPE/LLDPE) as a proportion of all MSW discards</p> <p>Polypropylene (PP) as a proportion of all MSW discards</p> <p>Polystyrene (PS) as a proportion of all MSW discards</p> <p>Other plastic as a proportion of all MSW discards</p>
Synthetic Rubber Combustion	<p>Synthetic rubber durables as a proportion of all MSW discards</p> <p>Synthetic rubber clothing and footwear as a proportion of all MSW discards</p> <p>Other synthetic rubber non-durables as a proportion of all MSW discards</p> <p>Synthetic rubber containers and packaging as a proportion of all MSW discards</p>
Synthetic Fiber Combustion	<p>Synthetic fiber as a proportion of all MSW discards</p>

1.2.2 Tool Layout

Since the methodology of the Municipal Solid Waste module is complex, it is important to have an understanding of the module's overall design. The layout of the Municipal Solid Waste module and the purpose of its worksheets are presented in Figure 3.

Figure 3. Flow of Information in the Municipal Solid Waste Module

1.3 METHODOLOGY

This section provides a guide to using the Municipal Solid Waste module of the SIT to estimate GHG emissions from municipal solid waste management. The two sectors within the Municipal Solid Waste module, landfills and combustion, are treated separately. Steps 4 through 8 address the estimation of landfill CH₄, while Step 9 deals with combustion.

The following steps are involved in estimating emissions using the Municipal Solid Waste module: (1) select a state; (2) describe and enter state disposal information; (3) enter population data; (4) view preliminary CH₄ emissions from landfills; (5) adjust CH₄ emissions for the amount that is flared; (6) adjust for the amount of CH₄ recovered at landfill-gas-to-energy plants; (7) estimate CH₄ generated at industrial landfills; (8) select landfill CH₄ oxidation factor; (9) fill in the variables used for waste combustion; (10) complete the CO₂ from synthetic rubber combustion worksheet; (11) complete the CO₂ from synthetic fiber combustion worksheet; (12) complete the CO₂ from the combustion of synthetic fibers worksheet; (13) review estimates on the N₂O from MSW combustion worksheet; (14) review estimates on the CH₄ from MSW combustion worksheet; (15) review summary information; and (16) export data. Most of these steps take place on the control worksheet. The Municipal Solid Waste module will automatically calculate emissions after you make choices on the control worksheet and enter the required data on the individual sector worksheets. The tool provides default sector data for most sectors.

Step (1) Select a State

To begin, 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.

Step (2) Describe and Enter State Disposal Information

On the control worksheet, select the radio button that corresponds to the data you would like to use as shown in Figure 4. There are three data options for entering waste disposal data:

Option 1: If you have state-specific information on waste disposal from 1960 to the present, then no further disposal or population (see Step (3)) data are needed.

Option 2: If you have state data on waste disposal for 1990 through the present, but not dating back to 1960, the module will estimate waste disposal using historical population data and national per capita landfilling rates.

Option 3: If do not have state-specific disposal data, you may use the default disposal data already loaded into the module. Default disposal data were estimated by allocating national waste disposal data (U.S. EPA 2016) to the state level on the basis of a state's historical population (U.S. Census 2016).

Clicking either of the first two user-entered data options will take you directly to a disposal data entry worksheet where you will enter annual state disposal into the yellow input cells. If you choose to use the available default disposal data provided in the module, you may navigate to the data-entry worksheet using the gray "View / Enter Data" arrow to the right of the selection buttons.

The uncertainty associated with the three state disposal options varies. The range of uncertainty represented by these three options is highly variable. Option 1 is preferable, if the state-specific data entered into the module is well-documented and comprehensive. Option 2 attempts to leverage near-term historical data and to scale national information on per capita disposal, state population, and national population information to back cast waste disposal estimates. This approach draws on several assumptions, namely that per capita generation in the state is the same as per capita generation at the national level. Option 3 has the least reliance on state information, making it the easiest, but potentially the least certain of the three options.

The module uses a statistical model, known as a first order decay (FOD) model, to calculate landfill emissions. In the FOD model, the CH₄ emission rate is a function of the quantity of waste deposited in landfills (in short tons) over the previous 30 years.

Figure 4. Example of Steps 1 through 4 on the Control Worksheet

The screenshot shows the 'State Inventory Tool - Municipal Solid Waste Module' interface. It includes a title bar, menu bar (File, Edit, Module Options), and a search bar. The main content area contains five numbered steps with various input fields and buttons. Red arrows and text boxes provide guidance for each step:

- Step 1: Choose a State** - Points to the 'Select a State...' dropdown menu. A red box says 'Choose a state'.
- Step 2: Describe and enter the type of state disposal data that you have (if any):**
 - For 'annual disposal data', a red box says 'Select button corresponding to the type of disposal data you have...' pointing to the radio buttons.
 - For 'no disposal data', a red box says '...or choose the default data' pointing to the 'View / Enter Data' button.
 - A red box says 'Go to data entry sheets' pointing to the 'View / Enter Data' button.
- Step 3: Enter population data (if state disposal data from 1961-2005 is incomplete)**
 - For 'Use my population data', a red box says 'Choose default or other population data' pointing to the 'View / Enter / Edit Data' button.
 - A red box says 'Go to the Calculations Sheet' pointing to the 'View / Enter / Edit Data' button.
- Step 4: View the preliminary calculations of methane emissions from MSW landfills in Select a State...** - A red box says 'View preliminary CH₄ emission calculations' pointing to the 'Go to the Calculations Sheet' button.

Step (3) Enter Population Data

Unless you have entered disposal data for 1960 through the present, state population data will be required to calculate emissions. The module automatically uses the default population data (from U.S. Census). If you want to use population data from another source, click on the radio button indicating you would like to use your own data. This action will automatically take you to the population data entry worksheet; you may also navigate to this worksheet using the gray arrow ("View / Enter Data") to the right of the selection buttons, as shown in Figure 4.

Landfills

Step (4) View Preliminary CH₄ Emissions from Landfills

Once you have made your selections and entered data for the previous three steps, you may view preliminary calculations of CH₄ emissions from MSW landfills in your state by clicking on the gray arrow that says "Go to the Calculations Sheet." This worksheet shows the preliminary results of the FOD model calculations for MSW. These calculations are considered preliminary because CH₄ emissions for the amount collected and burned and the amount oxidized at the surface of the landfill is taken into account in later steps. The FOD model estimates the potential CH₄ emissions that occur during the inventory year, but which are associated with the waste landfilled over the past thirty years, using Equation 1.

Equation 1. First Order Decay Model Equation

$$Q_{Tx} = A \times k \times R_x \times L_o \times e^{-k(T-x)}$$

Where, Q_{Tx} = Amount of CH₄ generated in year T by the waste R_x ,
 T = Current year
 x = Year of waste input
 A = Normalization factor $(1-e^{-k})/k$
 k = CH₄ generation rate (yr⁻¹)
 R_x = Amount of waste landfilled in year x
 L_o = CH₄ generation potential

As the equation shows, emissions vary not only by the amount of waste present in the landfill, but also by the CH₄ generation rate (k). The CH₄ generation rate varies according to several factors pertaining to the climate in which the landfill is located and is automatically chosen based on the selected state from Step (1). Figure 5 shows the worksheet where the FOD model is applied. It is not necessary to enter any information on this worksheet, as its purpose is to clarify how the FOD model is applied to the previously entered data.

Figure 5. Example of the First Order Decay Model Calculations Worksheet

State Inventory Tool - Municipal Solid Waste Module

File Edit Module Options Type a question for help

4. Methane Emissions from Landfills in Connecticut Using the First Order Decay Model.

This sheet performs calculations; no data are entered below.

The first order decay (FOD) model estimates the potential CH₄ emissions that occur during the inventory year, but are associated with the waste landfilled over the past thirty years. These emissions vary not only by the amount of waste present in the landfill, but also by the CH₄ generation rate (k). The CH₄ generation rate varies according to several factors pertaining to the climate in which the landfill is located. In the Solid Waste module, these factors are simplified into two values, one for arid and one for non-arid states. For arid states (i.e., those states for which the average annual rainfall is less than 25 inches), a "k" value of 0.02 is used, for non-arid states, a "k" value of 0.04 is used. The methane generation potential (L_o) is equal to 100 m³/metric ton (EPA 1995). The first order decay model is based on the following equation:

$$Q_{Tx} = A \times k \times R_x \times L_o \times e^{-k(T-x)}$$

Where, Q_{Tx} = Amount of CH₄ generated in year T by the waste R_x ,
 T = Current year
 x = Year of waste input,
 A = Normalization factor, $(1-e^{-k})/k$
 k = CH₄ generation rate (yr⁻¹)
 R_x = Amount of waste landfilled in year x
 L_o = CH₄ generation potential

Emissions by year of waste disposal (cubic meters of CH₄)

Year	Waste Disposed (metric tons)	Potential Emissions (MTCO ₂ E)	1960	1961	1962	1963	1964	1965	1966
1960	453,804	-							
1961	479,044	25,413	1,779,392						
1962	507,408	51,243	1,709,621	1,878,358					
1963	540,934	77,648	1,642,586	1,804,707	1,989,574				
1964	574,332	104,896	1,578,179	1,733,943	1,911,561	2,121,033			
1965	606,851	132,945	1,516,298	1,665,954	1,836,608	2,037,866	2,251,989		
1966	638,080	161,716	1,456,843	1,600,631	1,764,594	1,957,960	2,163,687	2,379,496	
1967	667,563	191,107	1,399,719	1,537,870	1,695,403	1,881,188	2,078,848	2,286,195	2,501,947
1968	697,620	220,997	1,344,835	1,477,569	1,628,925	1,807,425	1,997,335	2,196,552	2,403,844
1969	730,664	251,398	1,292,104	1,419,633	1,565,054	1,736,555	1,919,019	2,110,424	2,309,588
1970	764,211	282,457	1,241,440	1,363,968	1,503,688	1,668,464	1,843,773	2,027,673	2,219,028
1971	789,452	314,178	1,192,762	1,310,486	1,444,727	1,603,042	1,771,477	1,948,167	2,132,018
1972	809,924	346,068	1,145,993	1,259,101	1,388,079	1,540,186	1,702,017	1,871,778	2,048,421
1973	828,586	377,854	1,101,058	1,209,731	1,333,651	1,479,795	1,635,280	1,798,385	1,968,101
1974	849,645	409,438	1,057,885	1,162,297	1,281,358	1,421,771	1,571,160	1,727,869	1,890,931
1975	871,863	440,964	1,016,405	1,116,722	1,231,115	1,366,023	1,509,553	1,660,118	1,816,786
1976	892,451	472,497	976,551	1,072,935	1,182,843	1,312,460	1,450,363	1,595,024	1,745,549
1977	913,985	503,947	938,260	1,030,865	1,136,463	1,260,998	1,393,493	1,532,482	1,677,105

Step (5) Adjust CH₄ Emissions for Amount of CH₄ Flared

The control worksheet offers three options for adjusting the module to reflect the amount of CH₄ that is flared:

Option 1: If you have state-specific data on short tons of CH₄ flared, you may enter these data by clicking on the corresponding radio button, as shown in Figure 6, and then entering your data on the Flaring worksheet;

Option 2: If you would like to use available default data provided in the module, select to use the default amount of CH₄ flared, which is based on U.S. EPA (2016a) data; or

Option 3: If you do not want to account for flaring of landfill gas in your state, you may choose to omit this section.

Figure 6. Example of Steps 5 through 8 on the Control Worksheet

The screenshot shows the 'State Inventory Tool - Municipal Solid Waste Module' interface. The worksheet is titled 'Control Worksheet' and contains several sections for data entry. Red arrows and text boxes provide guidance for Steps 5 through 8:

- Step 5: Adjust CH₄ emissions for amount of CH₄ flared.** The 'Flaring Data' section has three radio buttons: 'I have data on tons of methane flared.', 'Use the default (based on information provided by flare vendors).', and 'Omit this section; do not account for flaring.' A red arrow points to the first option, labeled 'Choose type of CH₄ flaring data'. Another red arrow points to the 'View / Enter / Edit Data' button, labeled 'Go to data entry sheets'.
- Step 6: Adjust CH₄ emissions for amount of CH₄ recovered at landfill-gas-to-energy (LFGTE) projects.** The 'Recovery Data' section has three radio buttons: 'I have data on tons of methane recovered.', 'I do not have data; use the default (LMOP).', and 'Omit this section; do not account for LFGTE projects.' A red arrow points to the second option, labeled 'Choose type of LFGTE data'. Another red arrow points to the 'View / Enter / Edit Data' button.
- Step 7: Estimate CH₄ generated at industrial landfills.** The text states: 'Methane generation from industrial landfills in the U.S. is assumed to be approximately 7% of generation from MSW landfills. You can adjust this value, if you wish, below, or enter a value of zero to omit industrial landfills from this module.' A red arrow points to the '7%' value, labeled 'Enter emissions from industrial landfills %'.
- Step 8: Select landfill CH₄ oxidation factor.** The text states: 'The EPA estimates that 10% of landfill methane that is not flared or recovered is oxidized in the top layer of soil over the landfill. Methane emissions are then reduced by this "oxidation factor." This factor is affected by many factors, including latitude and soil characteristics. You may use the default or enter your own value below.' A red arrow points to the 'Default Oxidation Factor' section, labeled 'Enter CH₄ oxidation factor'. Another red arrow points to the 'Oxidation Factor Used' section, labeled 'Check box for default'. A third red arrow points to the 'Use the Default? (Check for Yes)' checkbox, labeled 'Check box for default'.

Gas collection systems have been put in place at many landfills. At some landfills the CH₄ collected by these systems is flared. As explained in the Module Overview, the CO₂ produced by flaring is not counted as anthropogenic GHG emissions under the accounting system used in the module, so the quantity of CH₄ collected and flared may be subtracted from the total amount of MSW landfill CH₄ produced, as shown in Equation 2. Likewise, CH₄ that is collected and used to create electricity may also be subtracted, as discussed in Step (6) below.

Equation 2. Net CH₄ Emissions from Landfills

$$\text{Preliminary Net CH}_4 \text{ Emissions} = \text{Total CH}_4 \text{ Generated} - \text{CH}_4 \text{ Flared or Recovered for Energy} - \text{CH}_4 \text{ Oxidized in Landfill}$$

Step (6) Adjust For Amount of CH₄ Recovered at Landfill-Gas-to-Energy Plants

As mentioned in Step (5), some landfills collect and burn landfill gas to produce energy. Such operations are known as landfill gas to energy (LFGTE) plants. The CH₄ collected and burned as part of that landfill gas should be subtracted from the total CH₄ generation, as shown in Equation 2.

The following three options for adjusting CH₄ emissions for the amount recovered at LFGTE plants are provided on the control worksheet:

Option 1: If you have state-specific data on short tons of CH₄ burned in LFGTE facilities, you may enter those data by clicking on the corresponding radio button, as shown in Figure 6, and then entering your data on the LFGTE worksheet;

Option 2: If you would like to use default data provided in the module, select to use the default amount of CH₄ recovered at LFGTE plants, which is based on U.S. EPA (2016b) data; or

Option 3: If you do not account for CH₄ recovered at LFGTE plants, you may choose to omit this section and not account for LFGTE operations.

Step (7) Estimate CH₄ Generated at Industrial Landfills

Up to this point, all information entered in the module refers to CH₄ generated from MSW landfills. However, CH₄ is also generated from waste deposited in non-hazardous industrial landfills. Although CH₄ generation from non-hazardous industrial landfills is believed to be small relative to that from MSW landfills, industrial landfill CH₄ generation is still a significant source of CH₄ emissions. CH₄ generation from industrial landfills does not include CH₄ generation from industrial waste disposed of into MSW landfills, as these emissions have already been accounted for in the module.

The quantity of waste in industrial landfills and the quantity of CH₄ that it generates must be estimated due to a lack of data. Based on estimates of the quantity of waste in place at industrial landfills and on the estimated organic content of industrial landfills compared to MSW landfills, U.S. EPA (1993) estimated that CH₄ generation from industrial landfills in the United States is approximately 7 percent of CH₄ generation from MSW landfills in the United States, prior to adjusting for flaring and recovery or oxidation. If you have outside information, you may adjust this percent in the yellow box, as shown in Figure 6.

Step (8) Select Landfill CH₄ Oxidation Factor

The default assumption in Step (8) of the control worksheet is that 10 percent of the CH₄ generated that is not flared or recovered is oxidized in the soil (this holds for industrial landfills also). To use the default percent, click on the check box. To use your own oxidation factor, enter it in the yellow box as shown in Figure 6. If the user-specific inputs do not match the default data in the control worksheet (i.e., the default value is overwritten), the text will appear red.

Regardless of whether a landfill gas recovery system is in place, uncollected CH₄ will pass upward through the landfill cover or surrounding soils, where it may be oxidized (Whalen, Reeburgh and Sandbeck 1990). The amount of oxidation that occurs is uncertain and depends on latitude (affecting surface soil temperature), soil characteristics, and other factors.

Waste Combustion**Step (9) Fill in the Variables Used for Waste Combustion**

As described in the Module Overview, combustion of fossil-fuel derived materials in MSW results in emissions of anthropogenic CO₂, N₂O, and CH₄. To develop an estimate of CO₂ emissions, the module calculates combustion of the fossil-derived carbon in MSW for three waste categories: plastics, synthetic fibers (e.g. textiles), and synthetic rubber (U.S. EPA 2016). The defaults in the Municipal Solid Waste module use information on the typical composition of discards in the U.S. solid waste stream to estimate the mass of each of these waste types that is combusted, and estimates the proportion of each material that comprises fossil carbon. The module defaults also assume that 98 percent of the fossil carbon is converted to CO₂ in the combustion process (with the balance remaining in the ash).

Some of the data inputs required to complete estimates of GHG emissions from waste combustion are entered on the control worksheet as shown in Figure 7, and the remaining data inputs are entered on individual calculation worksheets for each type of material, as well as for N₂O and CH₄ emissions.

Fraction of Waste Oxidized

Enter the fraction of carbon that is oxidized for each material type in the yellow boxes on the control worksheet as shown in Figure 7. To use the default percent oxidized (98 percent); use the check boxes to the right of the yellow cells. If the user-specific inputs do not match the default data in the control worksheet (i.e., the default value is overwritten), the text will appear red.

Figure 7. Example of Steps 9 through 11 on the Control Worksheet

Waste Combustion

9. Fill in the variables that are used to estimate emissions from waste combustion.
Either Type in the value/percentage or Click the Default Box

Fraction Oxidized	Default Fraction Oxidized	Fraction Oxidized Used	Use the Default, (check for Yes)
Plastics	98%	98%	<input type="checkbox"/>
Synthetic Rubber in MSW	98%	98%	<input type="checkbox"/>
Synthetic Fibers	98%	98%	<input type="checkbox"/>

Enter waste combustion data for your state or use the default values

Waste Combustion Data

☐ I have data on tons of municipal solid waste combusted, 1990-2008.

☐ Use the default data.

View / Enter / Edit Data

10. - 13. Proceed to the following combustion worksheets to calculate emissions:

10. CO₂ from Plastics Combustion

11. CO₂ from Combustion of Synthetic Rubber in MSW

12. CO₂ from Combustion of Synthetic Fibers

13. N₂O from MSW Combustion

14. CH₄ from MSW Combustion

15. After completing steps 1 through 14, click View Results to proceed to the emissions summary worksheet for California.

View Summary Sheet

16. Export the results for use in the Synthesis Tool.

Export Data

Default or User-Entered Data

The module allows you to enter your own data on short tons of waste combusted in-state for the years 1990 through the present, or to use the default data, which is based on BioCycle (1991-2008). Choose the appropriate radio button; if you choose to enter your own data, this action will take you to the data entry worksheet. You may also navigate to this sheet using the gray “View / Enter / Edit Data” arrow to the right of the buttons. After completing this section of the control worksheet, go on to the combustion sector calculation worksheets.

Step (10) Complete the CO₂ from Plastics Combustion Calculation Worksheet

There are separate worksheets for each of the three types of fossil-derived MSW (plastics, synthetic rubber, and synthetic fiber) and each of the worksheets is similar in layout. An example of the plastics combustion worksheet is shown in Figure 8. Emissions are calculated using the following equation:

Equation 3. CO₂ Emissions from Combustion

$$\text{CO}_2 \text{ Emissions (MTCO}_2\text{E)} = \text{Material as Proportion of all Discards (\%)} \times \text{Total MSW Combusted (short tons)} \times \text{Carbon Content (\%)} \times \text{Fraction Oxidized (\%)} \times 44/12 \text{ (CO}_2 \text{ to C ratio)} \times 0.9072 \text{ (short tons to metric tons conversion)}$$

On the plastics combustion worksheet, enter the proportion of each type of plastic (PET, HDPE, PVC, LDPE/LLDPE, PP, PS, and other) as a percent of total discards in the blue cells. The default data are from U.S. EPA (2016), and may be selected by clicking the check box for each year, as shown in Figure 8, or by clicking the box "Select All Defaults." Total tons of waste combusted are drawn from the data you entered in Step (9); default carbon contents are provided for each type of plastic. Once you have entered data for each year, you may proceed to the synthetic rubber combustion worksheet by clicking on the gray arrow at the top of the page.

Figure 8. Example of Plastics Combustion Calculation Worksheet

10. CO₂ from Plastics Combustion in Connecticut

In the calculation of CO₂ emissions from plastic combusted, Default values or user-supplied data are used. This value is then multiplied by the proportion of the waste, and the fraction oxidized to determine CO₂ emissions. These values are then converted to MTCE and MTCO₂E. The methodology and factors used for these calculations are discussed in detail in Solid Waste Chapter of the User's Guide.

Return to the Control Sheet | Go to the Synthetic Rubber Combustion Sheet

Select All Defaults | Clear All Data

CO₂ from Plastics Combustion 1990 ☒ Default Proportion of Discards?

Plastics	Proportion of Discards	State MSW Combusted (short tons)	Carbon Content	Fraction Oxidized	Emissions (MTCE)	Emissions (MTCO ₂ E)
PET	9.7%	1,711,000	79%	0.98	116,578	427,819
HDPE	0.7%	1,711,000	83%	0.98	6,850	
PVC	1.7%	1,711,000	86%	0.98	22,250	
LDPE/LLDPE	0.8%	1,711,000	38%	0.98	4,747	
PP	2.7%	1,711,000	86%	0.98	35,600	
PS	1.5%	1,711,000	86%	0.98	19,636	72,000
Other	1.2%	1,711,000	92%	0.98	16,963	62,198
	1.1%	1,711,000	66%	0.98	10,632	38,986

CO₂ from Plastics Combustion 1991 ☒ Default Proportion of Discards?

Plastics	Proportion of Discards	State MSW Combusted (short tons)	Carbon Content	Fraction Oxidized	Emissions (MTCE)	Emissions (MTCO ₂ E)
PET	10.8%	1,885,000	79%	0.98	143,006	524,355
HDPE	0.8%	1,885,000	83%	0.98	8,396	30,784
PVC		1,885,000	86%	0.98	27,270	99,991
LDPE/LLDPE		1,885,000	38%	0.98	5,818	21,331
PP	1.7%	1,885,000	86%	0.98	43,633	159,986
PS	1.3%	1,885,000	86%	0.98	24,067	88,246
Other	1.2%	1,885,000	92%	0.98	20,791	76,233
		1,885,000	66%	0.98	13,032	47,783

CO₂ from Plastics Combustion 1992 ☒ Default Proportion of Discards?

Plastics	Proportion of Discards	State MSW Combusted (short tons)	Carbon Content	Fraction Oxidized	Emissions (MTCE)	Emissions (MTCO ₂ E)
PET						
HDPE						
PVC						
LDPE/LLDPE						
PP						
PS						
Other						

Step (11) Complete the CO₂ from Synthetic Rubber Combustion Calculation Worksheet

The synthetic rubber combustion worksheet is identical to the plastic combustion worksheet, except that it calculates emissions for durable goods, non-durable goods (clothing and footwear, and other non-durables), and packaging and containers made of synthetic rubber. Enter the proportion of each type of rubber in the green cells as a percent of total discards, or select the default data (U.S. EPA 2016). Once you have entered data for each year, you may proceed to the synthetic fiber combustion worksheet by clicking on the gray arrow at the top of the page.

Step (12) Complete the CO₂ from Synthetic Fiber Combustion Calculation Worksheet

Again, this worksheet is identical to the worksheets for plastic and synthetic rubber combustion. Enter synthetic fiber as a proportion of all discards, in the orange cells, or

choose the default proportions. The carbon content provided is a weighted average of the carbon contents of the major synthetic fibers used in the United States. Once you have entered data for each year, you may proceed to the N₂O from MSW combustion worksheet by clicking on the gray arrow at the top of the page.

Step (13) Review Estimates on the N₂O from MSW Combustion Calculation Worksheet

This worksheet does not require any data inputs; it presents an example of how the emissions are calculated based on the following equation (the emission factor is from U.S. EPA 2016a):

Equation 4. N₂O Emissions from Combustion

$$\begin{aligned} \text{N}_2\text{O Emissions (MTCO}_2\text{E)} = \\ \text{MSW Combusted (short tons)} \times 0.00005 \text{ (emission factor in tons N}_2\text{O/ton MSW)} \times 298 \\ \text{(N}_2\text{O GWP)} \times 0.9072 \text{ (short tons to metric tons conversion)} \end{aligned}$$

Step (14) Review Estimates on the CH₄ from MSW Combustion Calculation Worksheet

This worksheet does not require any data inputs; it presents an example of how the emissions are calculated based on the following equation (the emission factor is from U.S. EPA 2016a):

Equation 5. CH₄ Emissions from Combustion

$$\begin{aligned} \text{CH}_4 \text{ Emissions (MTCO}_2\text{E)} = \\ \text{MSW Combusted (short tons)} \times 0.00002 \text{ (emission factor in tons N}_2\text{O/ton MSW)} \times 25 \\ \text{(CH}_4 \text{ GWP)} \times 0.9072 \text{ (short tons to metric tons conversion)} \end{aligned}$$

Step (15) Review Summary Information

The steps above provide estimates of total emissions and reductions from municipal solid waste management. The information from the control worksheet and data entry worksheets is collected on the summary worksheet, which displays results in million metric tons of carbon dioxide equivalent (MMTCO₂E). Figure 9 shows the summary worksheet that sums the emissions from all sectors in the Municipal Solid Waste module. In addition, the results are displayed in graphical format at the bottom of the summary worksheets.

Figure 9. Example of the Emissions Summary Worksheet in the Municipal Solid Waste Module

State Inventory Tool - Municipal Solid Waste Module

File Edit Module Options Type a question for help

1.4 Connecticut Emissions Summary

This Worksheet Provides a Summary of Emissions from Landfills and Waste Combustion Once All Control Steps Have Been Completed.

Return to the Control Sheet Review discussion of uncertainty associated with these results

Emissions were not calculated for the following sources: Waste Combustion- Synthetic Rubber.

Total Emissions from Landfills and Waste Combustion (MMTCO₂E)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
CH ₄	0.855	0.879	0.873	0.793	0.784	0.770	0.762	0.753	0.63
CO ₂	0.545	0.669	0.579	0.496	0.689	0.705	0.737	0.758	0.85
N ₂ O	0.021	0.023	0.020	0.016	0.023	0.023	0.022	0.022	0.02
Total	1.420	1.572	1.473	1.305	1.495	1.497	1.520	1.533	1.51

CH₄ Emissions from Landfills (MTCO₂E)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Potential CH ₄	949,517	976,917	970,140	969,933	959,418	943,906	934,997	925,605	916,57
MSW Generation	887,399	913,007	906,672	906,479	896,653	882,156	873,829	865,051	856,60
Industrial Generation	62,118	63,910	63,467	63,454	62,766	61,751	61,168	60,554	59,96
CH ₄ Avoided	-	-	-	(88,858)	(88,858)	(88,858)	(88,858)	(88,858)	(211,56
Flare	-	-	-	-	-	-	-	-	-
Landfill Gas-to-Energy	-	-	-	(88,858)	(88,858)	(88,858)	(88,858)	(88,858)	(211,56
Oxidation of MSW Landfills	88,740	91,301	90,667	81,762	80,779	79,330	78,497	77,619	64,50
Oxidation of Industrial Landfills	6,212	6,391	6,347	6,345	6,277	6,175	6,117	6,055	5,99
Total CH₄ Emissions	854,565	879,226	873,126	792,967	783,504	769,544	761,525	753,072	634,50

Step (16) 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 GHG inventory for the state.

To access the "Export Data" button, return to the control worksheet and scroll down to the bottom (15). 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 Municipal Solid Waste module later, you will then need to re-export the results.

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.

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 was 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 the entire module.

Following data export, the module may be reset and run for another 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.

1.5 REFERENCES

BioCycle. 2010. 1991-2008. "The State of Garbage in America: Annual Nationwide Survey." *BioCycle*.

U.S. Census. 2016. State Population Datasets. Available online at: <http://www.census.gov>.

U.S. EPA. 2016a. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2014*. Office of Atmospheric Programs, U.S. Environmental Protection Agency. EPA 430-R-16-002. Internet address: <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014>.

U.S. EPA. 2016b. Landfill Gas-to-Energy Project Database 2013, Landfill Methane and Outreach Program. Available online at: <http://www.epa.gov/lmop/index.html>.

U.S. EPA. 2016. *Municipal Solid Waste in the United States: 2014 Facts and Figures*. Available online at: <http://www.epa.gov/epawaste/nonhaz/municipal/msw99.htm>.

U.S. EPA. 1993. *Anthropogenic Methane Emissions in the United States: Report to Congress*. Global Change Division, Office of Air and Radiation, U.S. Environmental Protection Agency, EPA/430-R-93-003. Washington, DC.

Whalen, S.C., W.S. Reeburgh, and K.A. Sandbeck. 1990. "Rapid Methane Oxidation in a Landfill Cover Soil," *Applied and Environmental Microbiology*. November 1990.