SOLID WASTE EMISSIONS ESTIMATION TOOL (SWEET)

Version 2
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Developed by Abt Associates and SCS Engineers on behalf of the U.S. Environmental Protection Agency and the Climate and Clean Air Coalition Municipal Solid Waste Initiative (contract # EP-C-13-039, Work Assignment 4-53).

User Manual

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Solid Waste Emissions Estimation Tool (SWEET)
User Manual

Contents

1. Overview

This User Manual accompanies Version 2 of the Solid Waste Emissions Estimation Tool (SWEET). SWEET was developed by Abt Associates and SCS Engineers on behalf of the U.S. Environmental Protection Agency (EPA) and the Climate and Clean Air Coalition Municipal Solid Waste Initiative (Waste Initiative). The tool assists users in determining first-order city-level estimates of annual emissions of methane, black carbon, and other pollutants (e.g., carbon dioxide) from various sources in the waste sector. The tool was designed with a particular focus on methane and black carbon, which are short-lived climate pollutants (SLCPs).[1]

This manual contains:

- An overview of the tool and its design (Section 2),
- Detailed instructions on how to use the tool (Sections 3-9),
- Help with interpreting results (Section 10),
- A discussion of the tool's limitations and assumptions (Section 11),
- Answers to frequently asked questions (Section 12),
- Information on additional resources related to SWEET (Section 13).
- A consolidated list of data requirements (Appendix A),
- A sample SWEET analysis for a hypothetical city (Appendix B).

2. Getting Started

SWEET has 23 tabs, categorized in five basic sections (outline below). Brown tabs provide instructions, notes, assumptions, default values references, and additional information. Users are required to enter data in all five blue tabs. The three black tabs provide several tables and charts that summarize the tool's outputs. The five grey tabs provide more detailed emissions results from the baseline and alternative scenarios.

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[1] For more information on SLCPs in general, see the Climate and Clean Air Coalition's website.

2.1. Navigating the Tool

When you open the tool, you will be prompted to enable the tool's macros. You must do this in order for the tool to function correctly. You will either be prompted with a pop-up upon opening the tool, or a yellow warning bar will appear at the top of the program asking you to "Enable Content." If you did not choose to enable macros, close the tool and reopen it.

SWEET is an Excel-based tool. To move between the tabs, click on the tab you are interested in at the bottom of the screen. It is unlikely that all tabs will be visible across the bottom of your screen. Use the arrows in the bottom left-hand corner to view all tabs; the arrows on the right-hand side scroll across the tab currently open. You can also right-click in the lower left-hand corner to view a pop-up list of all tabs in the model. In addition, each tab contains a button linking back to the "General Information" data input tab to assist you in navigating between key tabs.

2.2. Entering Data

The tool requires data inputs for all stages of waste management, from collection to disposal and including diversion. Ensure you have all necessary data before proceeding with the tool. If your city is participating in the Coalition Waste Initiative, many of these data points have been recorded in your City Assessment. A list of necessary data points can be found in Appendix A.

In addition to assessing emissions from your current waste management scenario, SWEET allows you to explore alternative scenarios and their impacts on emissions. It is best to have these alternative scenarios defined before beginning to use the tool.

Enter data for your city's current waste management situation into all **blue** cells. You can also enter data in **green** cells, which are not required. Many of the blue and green cells contain helpful hints and definitions that will appear when you click on them.

Yellow cells are default values that are automatically provided. You can change these data points if you have local data available. You can reset any user-entered data to original default values by clicking on the "Reset Default Values" buttons provided on each data input page. The light **grey** cells, except for those in columns labeled "source" or "notes," contain calculated values and cannot be edited.

Specific instructions for entering data into each tab can be found in the sections below.

3. General Information

This tab collects general information about your city, its waste composition, and how waste flows from collection to disposal or beneficial use.

3.1. Waste Composition

Enter your city's waste composition in terms of percentage breakdown, ***not metric tons***, of waste collected (for example, 50% food waste, 10% plastic, 10% paper, and 10% other). Note that any decimal values entered will convert to percentages (i.e., if you enter 0.5, it will become 50%).

Double check that the sum of all values entered equals 100%. The total is automatically calculated in row 39, and an error message will appear in row 40 if the total does not equal 100%.

If you do not know the composition of the waste collected in your city, you can click the “Use Waste Defaults” button at the top of the table; this button will fill the table in with values typical for the global region (entered in cell C6) that your city is located. Some of these default waste compositions do not add up to 100%; you will need to adjust values as you see fit so the total equals 100%.

Note that “green waste” is another term for yard waste.

Waste composition is held constant in SWEET; the values you enter in this section of the tool will apply to all years during the period you analyze.

3.2. Waste Flow – Baseline

For each type of diversion facility (e.g., composting plant), enter the year the facility started operating in the “Diversion Scenario Start Year” row (row 53), and enter the average total tonnage of waste sent to the facility each year in row 54.

In the section of the table labeled “Composition of Waste Targeted for Diversion from Disposal,” enter the composition of the waste sent to the individual facility in terms of percentages. For example, if you are sending 1,000,000 tons to the composting facility, and 500,000 tons is food waste, enter 50% in the food waste cell. Make sure that for each waste category, the percentage multiplied by the total amount of waste diverted to the facility (row 54) does not result in a value greater than the amount you are collecting for that category (noted in cells D29-38). If the percentage results in a tonnage of waste greater than that being collected, you will see an error message in rows 106-109 in the “Review” box at the bottom of the tab (for more information on troubleshooting errors, see Section 3.5).

The sum of the waste composition must sum to 100% for each individual facility; totals are automatically calculated in row 69, and an error message will appear in row 70 if a given column does not add up to 100%.

3.3. Scenario Selection

For each dropdown in row 74, choose “Yes” or “No” depending on the number of scenarios you would like to evaluate, starting with Alternative Scenario 1. For example, if you would like to evaluate two alternative scenarios, choose “Yes” for Alternative Scenario 1 and Alternative Scenario 2 and “No” for Alternative Scenario 3 and Alternative Scenario 4. For every alternative scenario you wish to analyze, you will see additional cells highlighted in the Waste Flow – Alternative Scenarios section that need inputs in order for the model to generate emissions estimations.

3.4. Waste Flow – Alternative Scenarios

Here you will begin to create your alternative scenarios. Note there are other tabs in which you will alter the scenarios. If the only thing you will be changing in an alternative scenario occurs on another tab (for example, closing a landfill earlier than currently planned), you will need to copy and paste the information in the “Waste Flow – Baseline” table into the appropriate scenario(s).

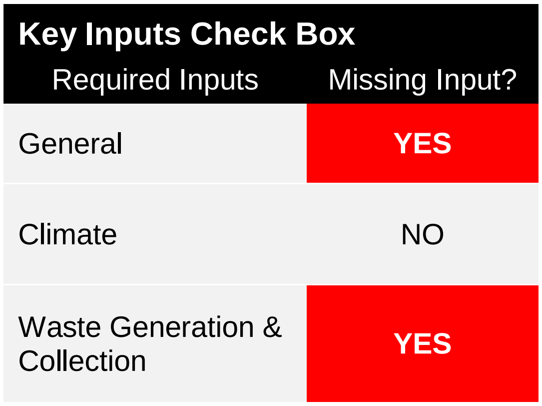
Name each scenario and provide a description if desired. We suggest labeling each scenario with a descriptive name (such as “Close Dump in 2020”) so that you can easily compare scenarios in the summary tabs.

If you would like to model a scenario in which you send more waste to a diversion facility than in the baseline scenario, enter this **additional, incremental waste quantity** in row 83. For example, consider a baseline scenario in which you are sending 1,000,000 tons of waste to a composting facility. If in one alternative scenario you would like to explore the impact of sending 1,500,000 tons to the compositing facility, enter 500,000 into row 83. Note, you can also consider the impact of sending less waste to a facility. To do so, enter a **negative** value into row 83. For example, if in your alternative scenario, you plan to develop a composting facility that will divert 500 tons from a waste combustion facility, enter 500 into row 83 for the composting facility and -500 into row 83 for the waste combustion facility.

In the section of the table labeled “Composition of Waste Targeted for Diversion from Disposal,” enter the composition of the waste sent to the individual facility, as you did in the “Waste Flow – Baseline” table. Make sure that for each waste category, the percentage multiplied by the total amount of waste does not result in a value greater than the amount you will be collecting in the start year. If you have set a start year greater than the current year, and you have a positive waste growth rate, the amounts collected will be slightly greater than those values currently listed in cells D29-38. If the percentage results in a tonnage of waste greater than that being collected for a given facility, you will see an error message in rows 106-109 in the “Review” box at the bottom of the tab (see Section 3.5). **The sum of the waste composition must sum to 100% for each individual facility**; totals are automatically calculated in row 99, and an error will appear in row 100 if the sum does not equal 100%.

3.5. Checking for Errors and Troubleshooting

There are two tables in this tab that will alert you to errors or missing data. The first is below the “Average Waste Composition” table. This error check box ensures that you have entered all necessary data points. Each row lists the individual tables on this sheet. If you have left out an input in a table, the cell next to the table’s name will be red, with the word “YES.” If all data points are filled in, the cell will be light grey and say “NO.” **Double check that all cells say “NO” before proceeding with data entry.**



Key Inputs Check Box

Required Inputs	Missing Input?
General	YES
Climate	NO
Waste Generation & Collection	YES

The second error check box is at the bottom of this sheet and points out values that are inaccurate or inappropriate. Errors are shown in the same format as described above.[2] Address errors in the order in which they are shown. **Ensure all cells say "NO" before proceeding to the next tab in the model.** The error checks ask the following questions:

- Are you diverting more waste than you are collecting overall?
    - If yes, the total tonnage you have entered in "Metric Tons Delivered to Diversion Facility Per Year" (row 54) or "Additional Metric Tons of Waste Delivered to Facility Per Year" (row 83), depending on which scenario has the error, is greater than the waste being collected in that year (cell D39 for baseline; dependent on waste growth rate for alternative scenarios).
    - To troubleshoot the baseline scenario, double check the values listed for the "Metric Tons Delivered to Diversion Facility Per Year" (row 54). You will have to make at least one value smaller.
    - To troubleshoot the alternative scenarios, reduce at least one of the values in "Metric Tons of Waste Diverted Per Year" (row 83) until the error message is gone.

- Are you recycling more than collecting?
    - If yes, this error means that for at least one waste category (e.g., plastic, metal, etc.), you are sending more to the recycling facility than you are collecting.
    - To troubleshoot, double check the percentages listed in rows 61-68 (baseline scenario) or rows 91-98 (alternative scenarios) for each waste category.
        - Multiply this percentage by the "Metric Tons Delivered to Diversion Facility Per Year" (row 54) or "Additional Metric Tons of Waste Delivered to Facility Per Year" (row 83).
        - If the resulting value is higher than the metric tons collected (cells D30-D39 for the baseline scenario), you will need to lower the inputted percentage until it results in a tonnage value lower than that collected.

- Are you sending more waste to Anaerobic Digestion or Composting than you are collecting?
    - If yes, this means that for at least one waste category (e.g., food, green, etc.), you are sending more to the composting or anaerobic digestion facility than you are collecting.
    - To troubleshoot, double check the percentage listed in rows 59-62 (baseline scenario) or rows 89-92 (alternative scenarios) for each waste category.
        - Multiply this percentage by the "Metric Tons Delivered to Diversion Facility Per Year" (row 54) or "Metric Tons of Waste Diverted Per Year" (row 83).
        - If the resulting value is higher than the metric tons collected (cells D29-D38 for the baseline scenario), you will need to lower the inputted percentage until it results in a tonnage value lower than that collected.

- Are you combusting more waste than collecting?

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[2] There is one error check (diversion start year) where an answer of "no" denotes an error, but the formatting (a red cell with white font) will be the same.

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  - If yes, this means that for at least one waste category (e.g., food, green, etc.), you are sending more to the waste combustion facility than you are collecting.
  - To troubleshoot, decrease the amount of waste sent to the waste combustion facility. This error can occur when too much waste is already diverted by other means such as Anaerobic Digestion, Recycling, or Composting.

- Are all your baseline waste diversion "start years" before your alternate scenario "start years"?
  - If no, then for at least one facility in the alternative scenario, you have entered a diversion start year (row 82) that is earlier than the start year listed for the baseline scenario (row 53). Double check the values in rows 53 and 82.

4. Collection – Transportation

On this tab, you will enter in information about your waste collection vehicle fleet (both primary and secondary collection).

In the appropriate row, enter the number of heavy-duty and light-duty trucks that are currently being used in your fleet. You will need to disaggregate your fleet vehicles by fuel type – diesel, gasoline, and natural gas. You can use SWEET to explore the impacts of changing this fleet mix in the alternative scenarios section. If you want to keep the same fleet in your alternative scenario, copy the values from the baseline scenario into the appropriate alternative scenario(s).

If you know the average number of miles traveled by heavy-duty or light-duty trucks each year, you can update the default value provided. Similarly, if you have more data on the number of hours trucks spend idling, you can update the default values. If you would like to reset the defaults to the original values provided by the model, press the “Reset Default Kilometers & Hours” button. This button will reset all default values for kilometers driven and hours idling.

You can also alter emissions factors if you have local data. Any values changed can also be reset to the defaults by clicking the “Reset Default Emissions Factors” button at the top of the page. This button will reset all default values for emission factors.

5. Waste Burning

This tab collects data about waste burning, both by residents and at the landfill, in your municipality.

Enter the percentage of waste that is burned in areas outside formal collection zones, inside formal collection zones, and at the landfill or dumpsite for the baseline scenario.

Enter the variables for the alternative scenarios. If there will be no change between the alternative and baseline scenarios, copy and paste the values from the baseline scenario into the appropriate alternative scenario(s).

Default values are provided for the emissions factors for each pollutant. If you have local data, you can alter these values; we recommend you provide sources and justification in the notes section. You can reset these values back to the default values by clicking the “Reset Emissions Factors” button at the top of the sheet, to the right of the legend.

6. Landfills and Dumpsites

This tab is where you will enter data about up to four landfills and/or dumpsites your city currently operates or plans to operate. Landfills/dumpsites are often the most significant source of methane emissions in the waste sector, so it is important that data entered into this tab be as accurate as possible.

At the top of the sheet, choose how many disposal sites you would like to analyze; do not forget to include any landfills you might wish to add in an alternative scenario. You can enter for up to four sites, either currently operating or closed.

Begin by entering data for the baseline scenario. The oldest year you can enter for a site’s opening year is 1960; if your landfill was opened prior to 1960, enter 1960. If a controlled dumpsite was formerly an open dumpsite, you should enter it as a controlled dumpsite. Similarly, if a landfill was formerly a controlled dumpsite, you should enter it as a landfill.

You can alter the default site-specific collection efficiency for gas utilization projects if desired; to reset the value back to the defaults, click the “Reset” button at the top of the page.

Table 1 provides a comparison of the characteristics of different disposal site types. This information will assist you in selecting the appropriate disposal site type (e.g., in row 17).

After entering baseline scenario data you can enter data for alternative scenarios. Remember that the alternative scenarios are in columns to the right of the baseline scenario. You will notice that the disposal site name, annual disposal, and waste depth carry over from the information you entered in the baseline scenario into the alternative scenarios. All other inputs will need to be entered for the alternative scenarios, even if the value is unchanged. For each disposal site, enter any changes you would like to analyze in each alternative scenario. Examples of scenarios you can analyze are:

- Converting a controlled dumpsite to a landfill, or a dumpsite to a controlled dumpsite.
- Closing a landfill earlier than initially planned.
- Installing gas extraction at a currently operating or closed landfill.

If there will be no change for a given landfill, copy and paste the baseline data into the appropriate alternative scenario.

Table 1. Characteristics of Solid Waste Disposal Site Types

Factor	Dumpsite	Controlled Dumpsite	Landfill
Environmental Factors			
Atmosphere			
Fires	Intentional burning common	Limited, can be present	Unlikely
Release of hazardous gases	Yes, if no collection exists	Yes, if no collection exists	Yes, if no collection exists
LFG collection and control	Possible, poor collection efficiency expected	Likely, collection efficiency will depend on site conditions	Likely
Unpleasant odors	Yes	Possible, depending on site conditions and whether LFG is uncontrolled	Minimal, if the right measures are taken to cover waste and control LFG
Ground/Soil			
Topographical Modification	Yes	Yes	Yes
Contamination (leachate)	Yes	Possible, depending on base or liner conditions	No
Gas Migration	Yes	Possible, depending on site conditions	No
Water (Surface and Ground Water)			
Channeling runoff	No	Possible, depending on site conditions	Yes
Contamination	Likely underground and surface water	Possible if low-permeability liners are not used	Minimal
Monitoring system present	No	No	Yes
Flora			
Vegetative cover alteration	Yes	Yes	Yes
Fauna			
Changes in diversity	Likely	Yes	No
Vector control	No	Potentially, depending on site conditions	No
Socioeconomic Factors			
Landscape			
Alteration of Condition	Yes	Yes, can be mitigated with visual buffer (for example, a forest buffer)	Yes, can be mitigated with visual buffer (for example, a forest buffer)
Humans			
Health hazards	Yes	Potentially, depending on site conditions	Potentially, depending on site conditions
Negative image	Yes	Yes	Yes, improved if there is post-closure utilization of land
Environmental education	No	Yes, in some cases	Yes, with careful planning
Economics			
Decline of land value	Yes	Yes	Yes
Formal employment	No	Yes	Yes
Changes in land use	Yes	Yes	Yes
Social			
Waste pickers	Yes	Yes, in some cases	No

7. Waste Handling Equipment

On this tab, you will enter information about your waste handling equipment, excluding equipment used during waste collection, which you entered in an earlier tab.

In the appropriate row, enter the number of pieces of each equipment type you have, categorized by fuel type (diesel or gasoline). You can analyze the impacts of changing this vehicle mix in the alternative scenarios section. If you want to keep the same fleet in your alternative scenarios, copy the values from the baseline scenario into the appropriate alternative scenario(s).

Default values are provided for the average number of hours each vehicle is used each year, the vehicle's average horsepower, and the gallons of fuel the vehicle uses on average each year. You can alter these values if you have the appropriate data. Note that if you click the "Reset" button at the top of the page, it will reset all of the default values.

8. Emissions Summaries

There are three tabs of summary data:

1) Summary – Emissions
2) Summary – Changes vs. Baseline
3) Summary – Graphics

8.1. Summary – Emissions

This tab shows emissions results in table format for eight pollutants:

- Carbon dioxide (CO_2)
- Nitrous oxides (NOx)
- Black carbon
- Organic carbon
- Methane (CH_4)
- Sulfur oxides (SOx)
- Two kinds of Particulate Matter (PM) – $PM_{2.5}$ and PM_{10}

Table 1 presents the total emissions of each scenario in a given year. Data is presented in terms of metric tons of carbon dioxide-equivalent (CO_2e). These estimates exclude SOx, $PM_{2.5}$, and PM_{10} (note: black carbon and organic carbon are components of $PM_{2.5}$).

Table 2 presents total emissions (in tons of CO_2e) for the baseline scenario broken down by sector. In addition, total emissions of SOx, $PM_{2.5}$, and PM_{10} are shown.

Tables 3-6 present total emissions (in tons of CO_2e) for each alternative scenario broken down by sector; each table is for an individual alternative scenario. In addition, total emissions of SOx, $PM_{2.5}$, and PM_{10} are shown. By default, only results for Alternative Scenario 1 are shown. If you have additional alternative scenarios, check the box next to the relevant scenario at the top of the page (rows 11-20).

8.2. Summary – Changes vs Baseline

This tab shows, in table format, the changes in emissions that result from each alternative scenario as compared to the baseline scenario.

Table 1 presents the emission changes for metric tons of CO_2e. As in the “Summary – Emissions” tab, the following pollutants are converted to CO_2e: CO_2, NOx, CH_4, black carbon, and organic carbon.

Table 2 presents the changes in SOx emissions, Table 3 presents the changes in $PM_{2.5}$ emissions, and Table 4 presents the changes in PM_{10} emissions.

8.3. Summary – Graphics

This tab presents the results as graphs. There are 20 figures on this tab:

- Figures 1 – 4 present overall emissions for different pollutants by scenario.
    - Note: Figure 3 (organic carbon) presents negative emissions. This is because organic carbon is an aerosol and has a net cooling effect on climate. Thus, when it is converted to metric tons of CO_2e, its value is negative.

- Figures 5 – 8 present emissions by pollutant and by source.
    - Note: Figure 6 shows SOx pollution from transportation combustion processes only.

- Figures 9 – 12 show the emissions profile for each individual landfill or dumpsite by scenario.
    - The emissions in Figures 9 – 12 account for emissions avoided through landfill gas collection systems.
    - Figures 9 – 12 correspond to landfills/dumpsites 1 – 4, respectively. If a user only enters data for one landfill or dumpsite, only Figure 9 will show data.

- Figures 13 – 16 present the transportation sector's emissions by pollutant and scenario.

- Figures 17 – 20 present emissions associated with waste burning, including open burning (e.g., in residential areas) and fires and landfills and dumpsites.

You can choose to show or hide any grouping of these figures (as they are grouped in the bulleted list above) by checking or unchecking the appropriate box at the top of the page.

9. Detailed Emissions Scenarios

These tabs (colored in grey) show resulting emissions of each pollutant in each sector for individual years from 1960 – 2120. The total amount of each GHG pollutant produced in a given year is visible in columns AD through AH.

See Table 2 below for a breakdown of pollutants by sector.

Table 2. Pollutants emitted in each sector of the waste management process.

	Pollutant							
Sector	CO_2	NOx	Black Carbon	Organic Carbon	CH_4	SOx	$PM_{2.5}$	PM_{10}
Waste Collection & Transport	X	X	X	X	X	X	X	X
Waste Burning	X	X	X	X	X	X	X	X
Landfills & LFG Combustion		X	X	X	X		X	X
Waste Handling	X	X	X	X	X	X	X	X
Organics Management					X			
Waste Combustion	X	X	X	X	X	X	X	X

10. Interpreting the Results

SWEET is designed to provide estimates of waste sector SLCP emissions for cities throughout the world, and to evaluate the effects of alternative waste management strategies on those emissions. Although SWEET uses state-of-the-industry assumptions and calculation methods, the emissions estimates should be considered as approximate and not a substitute for detailed technical analyses and feasibility assessments. Sources of potential model inaccuracies and uncertainties include the following:

- Uncertain emissions factors, particularly for waste burning and landfill methane.
- Uncertain estimates of waste decay rates and methane generation, collection, and oxidation rates at disposal sites.
- Limits to the complexity of user inputs, which were made to allow the model to be user-friendly and to limit model sensitivity to lack of data or data error.
- Limits to detailed accounting of site-specific factors influencing emissions.

Model uncertainties are discussed in more detail in Section 11. Despite these limitations, SWEET does provide estimates which are appropriate for evaluating net SLCP emissions under alternative scenarios and for guiding waste management decisions. Other potential uses for SWEET include the following:

- Monitoring progress and tracking performance in reducing emissions.
- Estimating the contribution of waste management improvements to a city's emissions reduction goals.
- Benchmarking against other cities.
- Using the results as inputs for other models to estimate air quality, health, and climate change impacts of waste management decisions.

11. Assumptions & Limitations

Given the complexity of the tool, assumptions were made for each step of the waste management process. The majority of these assumptions are outlined in the tool, in the orange tabs titled “Assumptions” and “Caveats and Notes”; these tabs can be found after the grey tabs of detailed emissions scenarios.

Because landfill and dumpsite emission calculations are more complex than for other sources in the waste sector, we provide the following detailed description of how SWEET calculates methane emissions from these sites and the limitations associated with these calculations.

Landfills and Dumpsites: Assumptions and Limitations

Methane emissions from disposal sites are estimated as the amount of methane generated, minus the amount either collected and destroyed in a combustion device, or oxidized in cover soils. Collected, measured methane flow rates represent the only real indication of the relative amounts of methane a disposal site is generating. Methane emissions rates and oxidation rates are not measured in the field except at a few research sites, so actual methane generation, oxidation, and emissions are always unknown and must be estimated.

Methane generation is calculated in SWEET using the following equation derived from the EPA’s Landfill Gas Emissions Model (LandGEM) version 3.02 (EPA, 2005).

Equation 1 – Landfill Methane Generation

$$Q_{CH4} = \sum_{t=1}^{n} kL_0\, Mi \; (e^{-kt_i})\ (MCF)$$

Where: Q_{CH4} = maximum expected methane generation flow rate (m^3/yr)
i = 1 year time increment
n = (year of the calculation) – (initial year of waste acceptance)
k = methane generation rate (1/yr)
L_0 = potential methane generation capacity (m^3/Mg)
M_i = mass of solid waste disposed in the i^{th} year (Mg)
t_i = age of the waste mass M_i disposed in the i^{th} year
MCF = methane correction factor

Equation 1 is used to estimate methane generation from each waste disposal site entered in the “Landfills and Dumpsites” tab (see Section 6). Methane is generated in a given year from the cumulative waste disposed up through the prior year, which has not already decayed and generated methane. The rate of waste decay and methane generation is defined by the model “k” value, which also defines the half-life of waste, the amount of time it takes for half of the waste to decompose (half-life = ln(2)/k). Model k varies significantly depending on organic waste type and climate, and is strongly influenced by waste moisture content. The total amount of methane produced by a tonne of waste is the potential methane generation capacity, or “L_0”, which varies by organic waste type.

SWEET applies the methane generation equation separately to each of the following five organic waste categories: food waste, green waste, paper (including cardboard), wood, and textiles. Each of the organic waste categories is assigned different pairs of values for the model k and L_0 that are based on the values used in the Colombia Landfill Gas Model, which was developed by the EPA's Landfill Methane Outreach Program (U.S. EPA, 2010). This multi-material approach was initially developed by the Intergovernmental Panel on Climate Change (IPCC) in their spreadsheet model (IPCC, 2006). Model k values used in SWEET for each waste category vary across five climates, which range from "very wet" sites experiencing greater than 2,000 mm/year precipitation to "dry" climates receiving less than 500 mm/year precipitation. Total methane generation from all wastes is calculated as the sum of the amounts of methane generated by each of the five organic waste categories.

Methane Correction Factor

SWEET also applies a "Methane Correction Factor" (MCF), which reduces estimated methane generation based on the degree to which aerobic conditions occur (IPCC, 2006). Landfills have no reduction in estimated methane (MCF=1). Dump sites greater than 5 m deep have a 20% reduction in methane (MCF=0.8). Dump sites less than or equal to 5 m deep have a 60% reduction in methane (MCF=0.4). The MCF adjustment is responsible for potential increases in estimated landfill methane emissions when a controlled dump site is remediated to a landfill.

The values assigned to the Equation 1 variables k, L_0, and MCF exert a strong influence on estimates of landfill methane emissions and overall SLCP emissions, since landfill methane tends to dominate waste sector SLCP emissions. Despite their importance, the effects of waste composition and site conditions on methane generation model parameters are poorly understood. Contributing to the uncertainty in assigning values to model parameters are the lack of measurements of methane emissions in the field, the fact that there are multiple variables which combine to affect estimated methane generation and collection rates, the limited availability and reliability of waste composition data (which can be highly variable), and the large range of potential impacts of site conditions on methane generation.

Gas Collection Efficiency

Generated methane is either collected and combusted, oxidized, or emitted. The percentage of generated methane that is collected is defined as the "collection efficiency". If you indicate that there is an existing or planned gas collection system for a landfill, a default collection efficiency value is assigned based on the disposal site management category (landfill, controlled dump site, or dump site). Default collection efficiencies are estimated based on the professional judgement of landfill gas modeling experts. These default values are relatively conservative (i.e., low) estimates, as they are applied to disposal sites worldwide across a wide range of conditions and are used to generate long-term emissions estimates. Because methane generation rates are calculated (modeled) estimates and not measured in the field, gas system collection efficiency estimates are uncertain and represent a large potential source of error in estimating methane collection and emissions rates, and overall SLCP emissions.

Default collection efficiency values are 60% for landfills, 50% for controlled dump sites that have been remediated to "landfill" status, 45% for controlled dump sites, 30% for dump sites that have been remediated to "controlled" status, and 0% (no gas collection possible) for unmanaged dumpsites. Note that EPA cites a “typical collection efficiency range of 50% to 95%...with a suggested average of 75%” (EPA, 2011) for sanitary landfills in the U.S.

Landfills that have or are planning a pipeline quality, high-Btu methane utilization project have their associated default collection efficiency reduced by 20% due to the project’s stringent gas quality requirements and associated reduction in collection efficiency and methane recovery.

Default collection efficiency estimates can be overridden only for landfills if you provide actual average methane recovery flow rates (in m^3/hour) for specified data years. The actual methane recovery rates will result in higher or lower site-specific collection efficiencies compared to the default values, when divided into model estimates of methane generation rates in the same year. Actual methane recovery data can be used to assign site-specific collection efficiencies for landfills up to a maximum of 85% (70% maximum for landfills with high-Btu projects).

Gas Flaring

If collected, methane will in most cases be combusted in an on-site landfill gas flare, which can achieve a methane destruction efficiency of 99% (EPA, 2011). If collected methane is combusted in a facility that uses the gas as an energy source, methane destruction efficiencies can be somewhat lower. A methane destruction efficiency of 98% is assumed in SWEET based on the average of values for various combustion devices (EPA, 2011, Table 1).

Oxidation

Rates of oxidation of uncollected methane in cover soils of disposal sites depend on cover soil type and thickness, climate, and the rate of methane flux to the cover soil per unit area. IPCC (2006) applies a 10% oxidation rate for all sites with a cover soil, but field research has found this value to significantly underestimate oxidation at landfills with active gas collection systems, particularly where high collection efficiencies (and low methane flux to the cover soils) are achieved. Oxidation rates reported by the Solid Waste Industries for Climate Solutions (SWICS) for sanitary landfills with gas collection systems ranged from 22% to 55% and averaged 35% (SCS, 2009).

SWEET has modified the IPCC default value of 10% to account for the effects of gas collection, and calculates oxidation rates according to the following equations, which vary by disposal site category:

- $Oxidation\ at\ landfills = 10\% + 15\% * (collection\ efficiency\ \%) * 15\%$,
  for a minimum of 10% and a maximum of 23%.
- $Oxidation\ at\ controlled\ dump\ sites\ remediated\ to\ landfills = 10\% + 10\% * (collection\ efficiency\ \%)$,
  for a minimum of 10% and a maximum of 15%.
- Oxidation at controlled dump sites is estimated to be 0% without gas collection and 5% with gas collection.
- Oxidation at (unmanaged) dump sites is estimated to be 0%.

12. Frequently Asked Questions

How do you define a Dumpsite, Controlled Dumpsite, and Landfill?
See Table 1 for complete list of explanations and definitions.

What type of waste is included in "green waste"?
Green waste includes all yard waste, wood, trees, shrubs, non-edible agricultural residues, and plant matter. This ***does not*** include manure, wastewater, or other organic wastes not derived from plants or trees.

My waste composition varies. Can I model different waste compositions in the same spreadsheet?
No. For simplicity, SWEET holds waste composition constant over time. To model changing waste compositions, we recommend creating two spreadsheets and modeling two separate baselines to determine the change in emissions.

What is the difference between residents inside and outside formal collection zones?
Formal collection zones are the geographic areas where waste is regularly collected from residents and businesses (including areas where informal sector workers regularly collect waste). Areas outside formal collection zones are those that do not receive regular waste collection services or cannot receive them on regular or periodic interval.

What pollutants are considered climate forcing pollutants in the model?
SWEET considers black carbon, organic carbon, nitrogen oxides (NO_x), methane (CH_4), and carbon dioxide (CO_2) as climate forcing pollutants. These pollutants' effects on climate are aggregated in the emissions summary tables and charts in terms of CO_2 equivalent (CO_2e).

Why are some CO_2e values negative, such as for organic carbon or nitrogen oxide?
NO_x and organic carbon are considered negative when expressed in units of CO_2e because these pollutants have a net cooling impact on climate. If you want to convert the values to metric tons, divide by their Global Warming Potential. If other results are negative, some input or assumption may have been entered incorrectly. Please check the error messages in the "General Information" tab.

Why do the graphs on the "Summary Graphics" tab present emissions for Alternative Scenarios I choose not to analyze?
Please troubleshoot your result by ensuring the cells on the "General Information" tab, row 78 select the correct values for "Yes" and "No." In addition, double check inputs entered in all possible blue and grey input cells. There can be inputs entered into alternative scenarios that you did not intend to analyze. Additional troubleshooting guidance is available in this manual.

13. Additional Resources

Additional resources related to SWEET are available on the Waste Initiative's Municipal Solid Waste Knowledge Platform: http://www.waste.ccacoalition.org/document/solid-waste-emissions-estimation-tool-sweet.

For any additional questions about the tool and its use, please contact the developers at SWEET@abtassoc.com.

Appendix A – Consolidated List of Data Required to Complete a Baseline Assessment

Click the icon below to view an embedded Excel workbook with the consolidated list of data required to complete a baseline assessment.

Appendix B – Sample SWEET Analysis

Click the icon to view an embedded Excel workbook with an example of how SWEET can be used to analyze alternative waste management scenarios.