Waste Reduction Model (WARM) Tool

User's Guide

WARM version: 14 (March 2016)
Software version: 1.5
Guide version: March 2018

Contents

1. Introduction 2
2. Installation 2
   2.1 Hardware and software requirements 3
3. First start and overview 3
4. Data entry 5
   4.1 Generate scenarios 5
   4.2 Further characteristics 6
   4.3 General Information 9
   4.4 Calculation 10
5. Results 10
   5.1 Summary 11
   5.2 Analysis 11
   5.3 Report export 12
6. Saving data 13
7. Other features 13
8. Contact 14
9. Acknowledgments 14

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United States Environmental Protection Agency

1. Introduction

The Waste Reduction Model (WARM) was created by the U.S. Environmental Protection Agency (EPA) to help solid waste planners and organizations estimate greenhouse gas (GHG) emission reductions from several different waste management practices. The purpose of this document is to provide guidance to WARM users in downloading, installing, and using the WARM Tool, including an overview of the tool's key functions and capabilities.

WARM calculates GHG emissions for baseline and alternative waste management practices, including source reduction, recycling, combustion, composting, anaerobic digestion, and landfilling. The model calculates emissions in metric tons of carbon dioxide equivalent ($MTCO_2E$) and metric tons of carbon equivalent (MTCE) across a wide range of material types commonly found in municipal solid waste (MSW). Moreover, results of energy consumption in million British thermal unit (million BTU) are also calculated. The user can construct various scenarios by simply entering data on the amount of waste handled by material type and by management practice. WARM then automatically applies material-specific emission factors for each management practice to calculate the GHG emissions and energy use of each scenario. Several key inputs, such as landfill gas recovery practices and transportation distances to MSW facilities, can be modified by the user.

The GHG emission factors used in WARM are based on a life cycle perspective. The model documentation describes this methodology in detail. The WARM model was implemented in the free, open source life-cycle assessment (LCA) software called openLCA. The resulting openLCA database is used for the calculation of impacts in the WARM Tool described in this guide. The WARM version implemented in this software is WARM v14 (March 2016).

2. Installation

There are versions of the WARM Tool available for Windows (64 bit and 32 bit upon request) and Mac (64 bit and 32 bit upon request). In all cases, the tool is provided in a compressed file (*.zip, *.gz), which should be first downloaded and then its content extracted (i.e., right click on the file → Extract…).

A folder "WARM" will be then generated. The file "WARM.exe" contained in it should be run to get the application started.

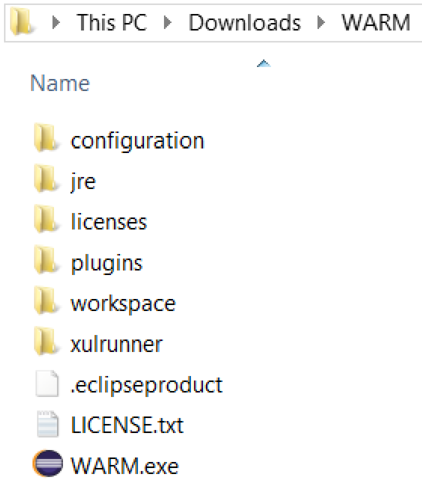

Figure 1. Content of WARM folder when extracted from the compressed file

2.1 Hardware and software requirements

Hardware:

- 1 GB RAM
- 140 MB (Windows), 64 MB (Mac) free hard disk space

Software:

- Microsoft Visual C++ Runtime v10 needs to be installed on Windows 64 bit because the WARM Tool contains a browser engine for the display of modern HTML pages that requires this runtime. If you have not installed it before running the tool, a message like in Figure 2 would be shown. You can download this runtime here.

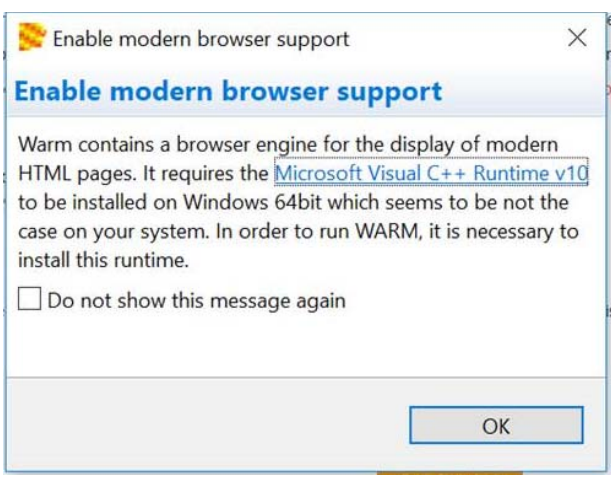

Figure 2. Message displayed if the MS Visual C++ Runtime v10 is missing

3. First start and overview

When first running WARM, the Home page is shown providing some information and tips about the tool.

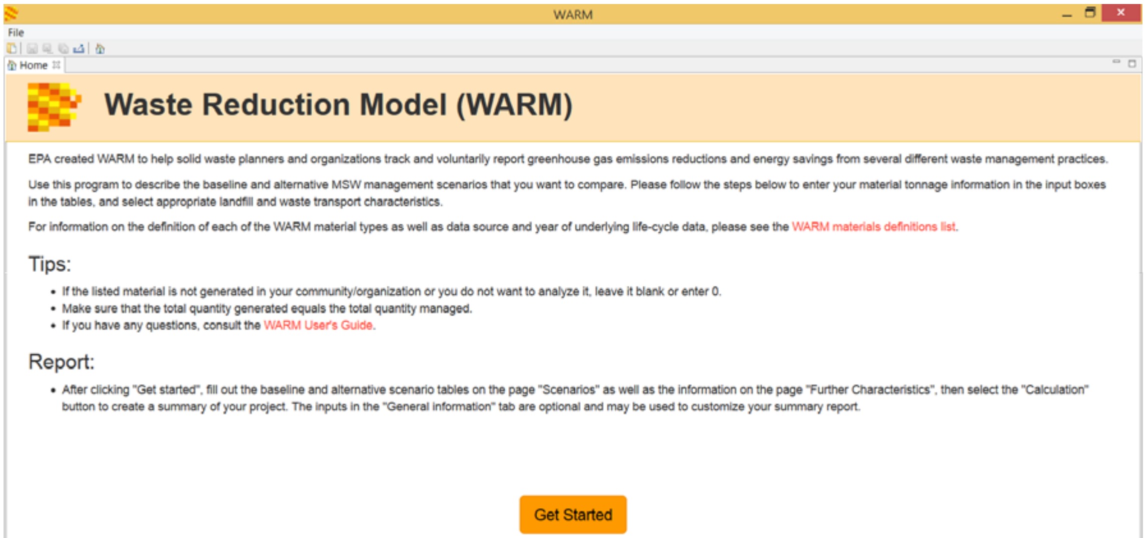

Figure 3. Home tab

If you click the button "Get Started", a new tab "Data Entry" appears, where the data for the analysis should be entered by the user. This tab consists of four steps: Scenarios, Further Characteristics, General Information and Calculation. You can navigate through them by clicking on the buttons on the top of the tab or on the "Back"/ "Next" buttons on the bottom of the page. You can also use the scrollbar in the right of the window to see the full content of each page. Detailed information about the "Data Entry" tab is provided in section 4 of this guide.

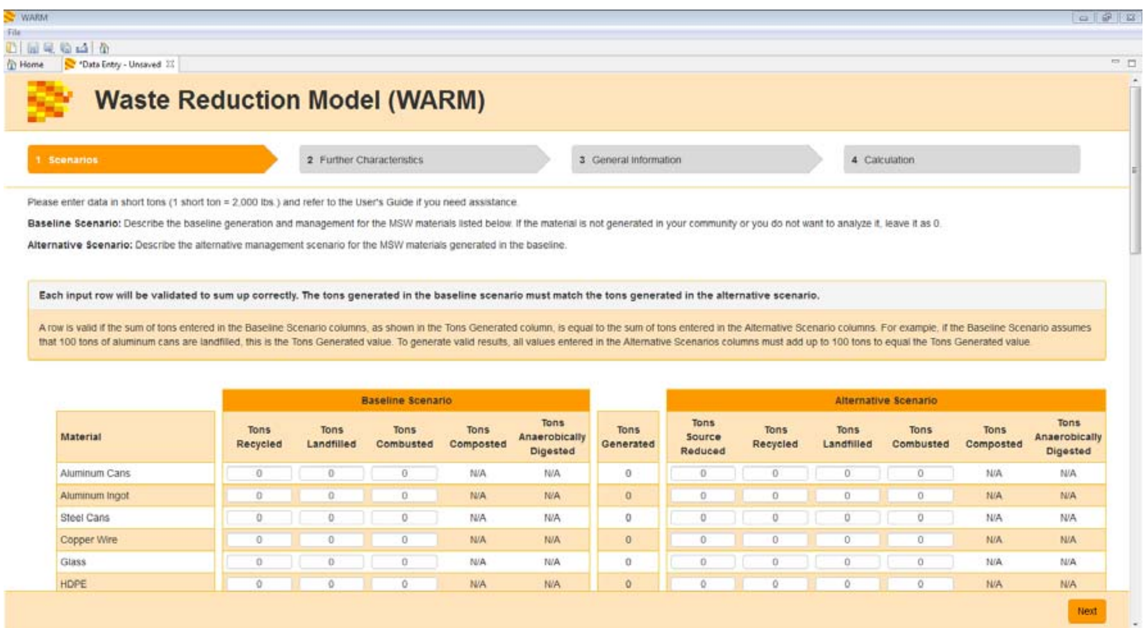

Figure 4. "Scenarios" step of the "Data Entry" tab

Several "Data Entry" tabs can exist at the same time in the software (i.e., various assessments); for creating new ones, just go to the Home tab and click "Get Started". If you had closed it, you can open it again by clicking on the icon on the toolbar.

After the calculation for the entered data is finalized, results will be shown in a new tab "Report". Detailed information about the results analysis is provided in section 5 of this guide.

It is also possible to save the data entered in the "Data Entry" tab for future assessments, as explained in section 6 of this guide.

4. Data entry

4.1. Generate scenarios

Baseline and alternative scenarios can be constructed by simply entering data on the amount of waste handled by material type and by management practice. There are fifty-four [material types](#) (rows) and six management practices available (columns): recycling, landfilling, combustion, composting, anaerobic digestion, and source reduction. This last practice is only included in the "Alternative Scenario", and refers to the decrease in waste generation compared to the waste handled in the baseline scenario.

There is an additional column "Tons generated" which is automatically updated by the tool and represents the total amount of waste handled in the baseline scenario, per material type. If data is introduced only for the alternative scenario, this field will remain as "0".

It is not necessary to enter data for all materials and management practices, only for those relevant for your assessment. When no data is added in a specific cell, the value remains as "0". In addition, not all management practices are available for all material types (e.g., food waste cannot be recycled). In those cases, "N/A" is written in the correspondent cell and no data can be entered by the user.

When scrolling down in the page view, the headers of the table columns will not be visible anymore. However, tooltips are available when typing in or hovering over each cell with information about the corresponding scenario and management practice.

	Baseline Scenario				
Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
Aluminum Cans	0	0	0	N/A	N/A
Aluminum Ingot	0	Base scenario - Tons landfilled	0	N/A	N/A
Steel Cans	0	0	0	N/A	N/A
Copper Wire	0	0	0	N/A	N/A
Glass	0	0	0	N/A	N/A
HDPE	0	0	0	N/A	N/A

Figure 5. Entering data on the "Scenarios" step of the "Data Entry" tab

The following requirements exist for entering the data:

- Amounts should be entered in short tons[1]
- Only numbers can be entered (i.e., no formulas supported)
- "." should be used as decimal separator
- The total amount of waste handled in the baseline scenario has to equal the total amount of waste entered for the alternative scenario, per material. A validation is done for each material, and if there were divergences between the quantities generated in each scenario, that row is highlighted and an exclamation mark added to the left of the material's name.

		Baseline Scenario						Alternative Scenario					
	Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested
!	Aluminum Cans	0	20	10	N/A	N/A	30	10	50	10	10	N/A	N/A
	Aluminum Ingot	0	0	0	N/A	N/A	0	0	0	0	0	N/A	N/A
!	Steel Cans	0	20	0	N/A	N/A	20	10	100	10	0	N/A	N/A
	Copper Wire	0	0	0	N/A	N/A	0	0	0	0	0	N/A	N/A
	Glass	75.5	15	0	N/A	N/A	90.5	10.5	75	5	0	N/A	N/A
!	HDPE	0	0	0	N/A	N/A	0	3	0	0	0	N/A	N/A

Figure 6. Error of validation for several materials in the "Scenarios" step (i.e., baseline total amount ≠ alternative total amount)

Once the data have been entered, you can continue to the next step clicking "2. Further Characteristics" (top of the page) or "Next" (bottom of the page). You can also navigate to other sections, like heading directly to the calculation if you want the keep all default options in the next sections. If the "Scenarios" step is left without having fixed possible invalid entries (i.e., total baseline ≠ total alternative), a warning message is displayed informing of the user that these amounts are not equal. The calculation can be run anyway, but the user should be aware of the existing differences in total quantities between scenarios.

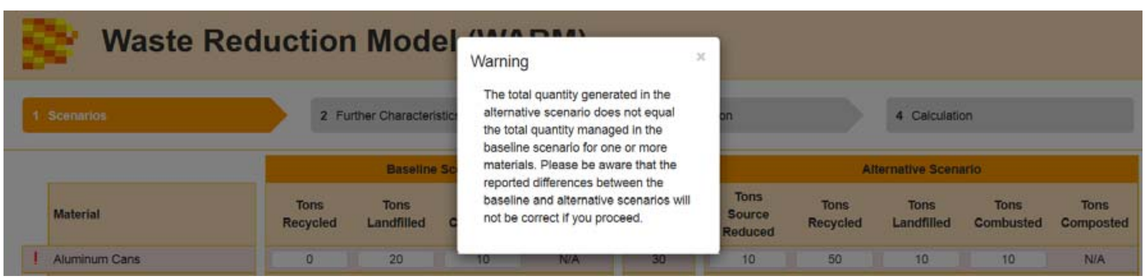

Figure 7. Warning message displayed if any material has invalid data entries

4.2. Further characteristics

Several key inputs affecting the GHGs and Energy results can be modified by the user. These are:

- Locations: they affect the emission factors for those management practices consuming/avoiding electricity. The specific regional grid mix is used depending on the state selected by the user in the drop-down menu. The value by default is "National Average".

[1] 1 short ton = 2,000 lbs = 907.18 kg

Figure 8. Locations options in "Further characteristics" section of the "Data Entry" tab

- Waste Transport Characteristics: the distances covered between the location where the waste was collected and the correspondent management facility can also be modified. The value by default is 20 miles. You can select the option "Define distance" to enter new values (also in miles).

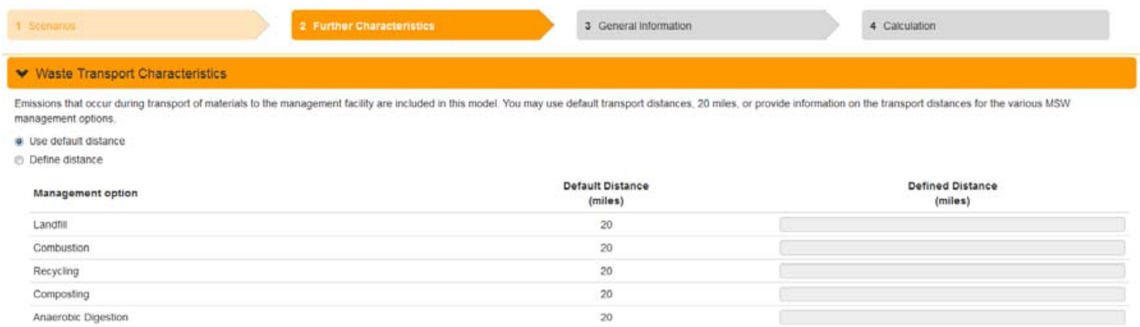

Figure 9. Waste transport options in "Further characteristics" section of the "Data Entry" tab

- Source reduction: you can decide whether the material that is source reduced would have been manufactured from the current mix of recycled and virgin materials or from 100% virgin materials. The option by default is "Current mix".

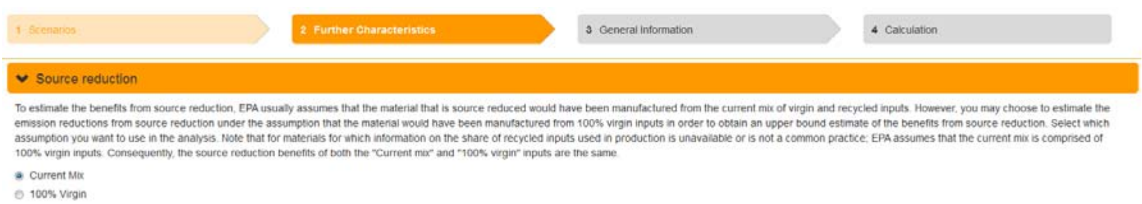

Figure 10. Source reduction options in "Further characteristics" section of the "Data Entry" tab

- Landfill characteristics: you can determine the:

  I) Type of landfill: there are four options available: No landfill gas (LFG) recovery, LFG recovery for energy, LFG recovery and flared, and a "National Average" type which calculates emissions based on the proportions of the other three types in 2012. Depending on the selection, the other two options for landfill characteristics will be modifiable or not. For instance, if "No LFG Recovery" is selected, there are no further options to be chosen. On the other hand, if "National Average" is selected, the option "III) Moisture Conditions and Decay Rates" is also modifiable.

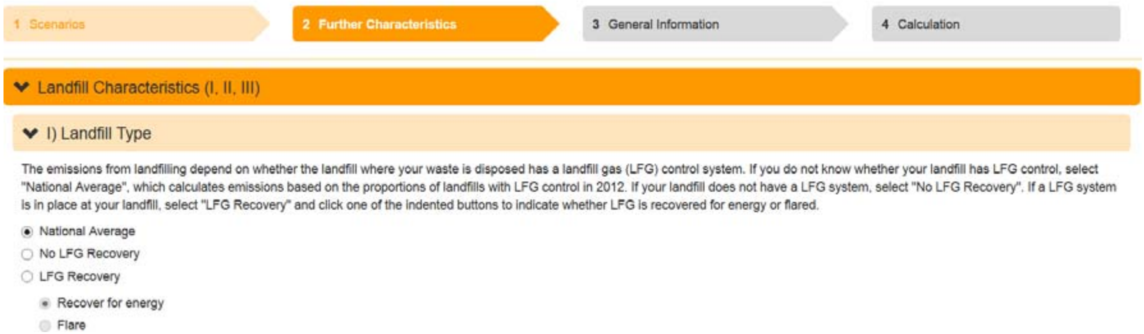

Figure 11. Landfill type options in "Further characteristics" section of the "Data Entry" tab

II) Landfill Gas Recovery: only relevant if any "LFG Recovery" option has been chosen previously. It represents four different gas collection efficiencies throughout the life of the landfill: typical, worst-case, aggressive, and California regulatory collections. Assumptions made for each option are explained in the tool.

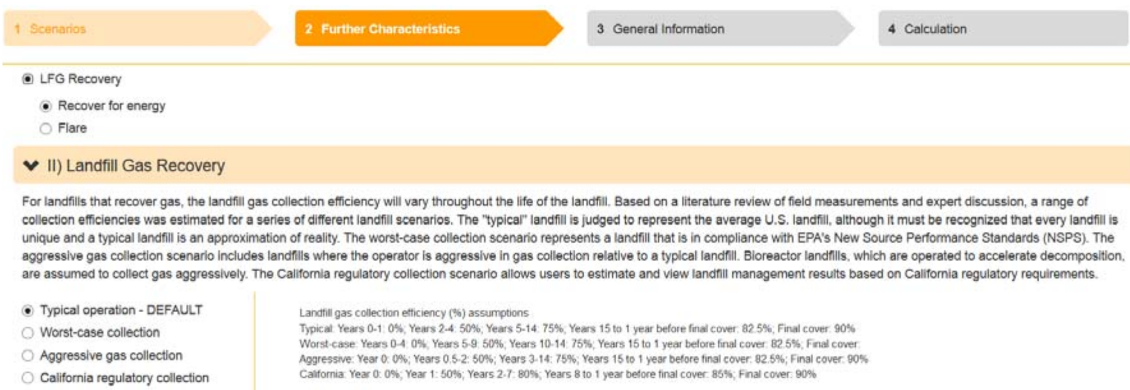

Figure 12. Landfill gas recovery options in "Further characteristics" section of the "Data Entry" tab

III) Moisture Conditions and Decay Rates: relevant if "National Average" or any "LFG Recovery" option has been selected as landfill type. You can select here between five moisture conditions and associated bulk MSW decay rates (k) the one which best represents the conditions in your assessed landfill. The options are: National Average, dry (k=0.02), moderate (k=0.04), wet (k=0.06) and bioreactor (k=0.12). A higher average decay rate means that waste decomposes faster in the landfill.

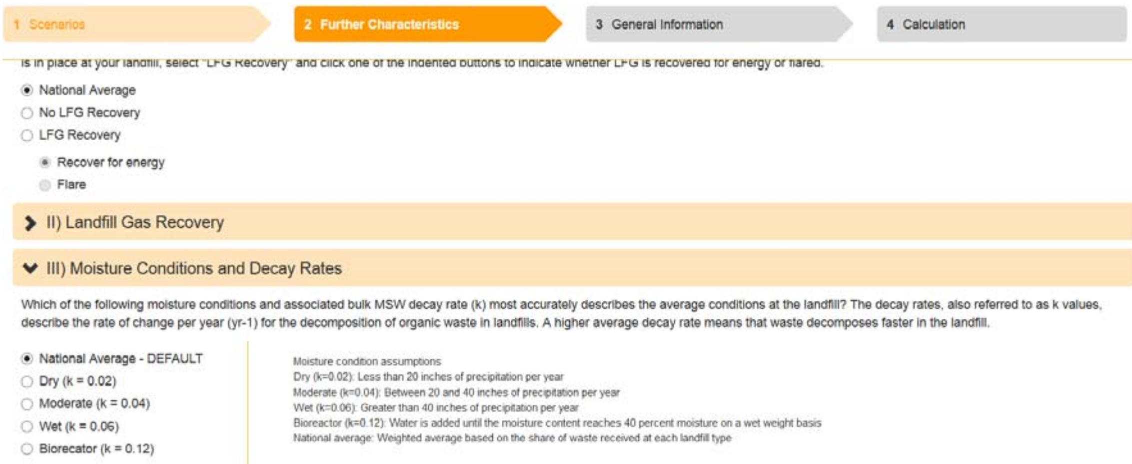

Figure 13. Moisture conditions and decay rates options in "Further characteristics" section of the "Data Entry" tab

- Anaerobic Digestion characteristics: you can determine the:
  - I) Digestion Type: You can select either wet or dry digestion based on your digester type. Note that for grass, leaves, branches, yard trimmings and mixed organics, wet digestion is not applicable based on current technology and practices in the United States. Therefore, dry digestion is the only digestion type modeled in WARM for these materials. Only one type of digestion process (wet or dry) can be modeled at a time in WARM.

Figure 14: Digestion Type options in "Further characteristics" section of the "Data Entry" tab

  - II) Digestate Curing: You can select that the digestate is cured before land application or not cured.

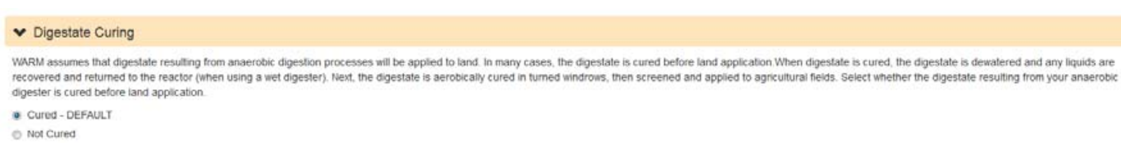

Figure 15: Digestate Curing in "Further characteristics" section of the "Data Entry" tab

You can collapse or expand each of these sections by clicking on the section's header area.

4.3. General Information

This page is included with documentation purposes. You can include your organization's name, your name, the reporting period and a description of the assessment in the existing text fields. The data typed in here will be shown in the report generated after the calculation.

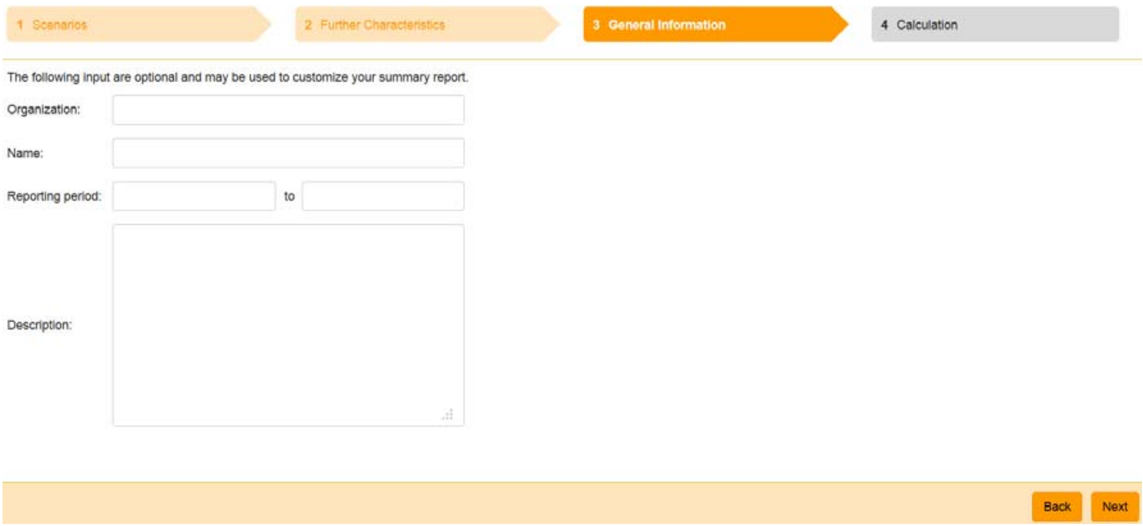

Figure 16. "General Information" section of the "Data Entry" tab

4.4. Calculation

Three types of calculations can be performed in the WARM tool:

- GHGs emissions in metric tons of carbon dioxide equivalent (MTCO2E)
- GHGs emissions in metric tons of carbon equivalent (MTCE)
- Energy consumed in million BTU

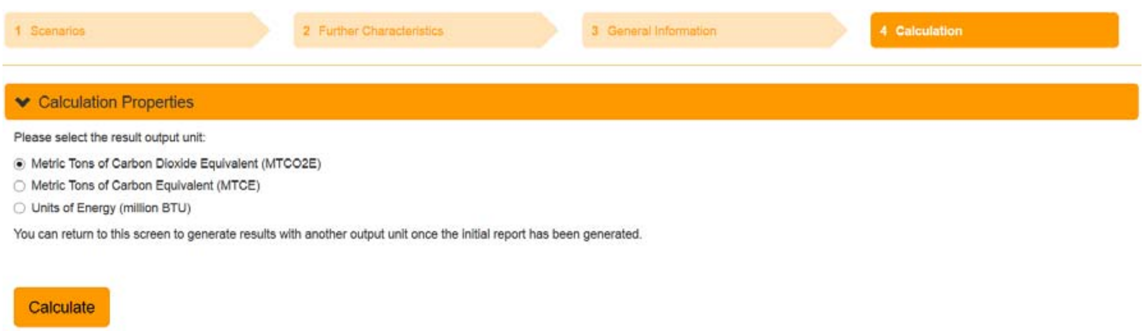

Figure 17. "Calculation" section of the "Data Entry" tab

After selecting the preferred calculation option, click on "Calculate" to get the results in a new tab "Report". You might need to wait a bit longer for the calculation to complete for the initial run.

5. Results

There are two sub-tabs within the "Report" tab created after the calculation: summary and analysis. They can be found in the bottom left corner of the "Report" tab.

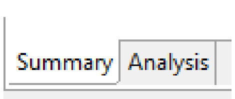

Figure 18. Detail of tabs found at the bottom of the "Report" screen

How to interpret the results presented in them? If a GHG emission value is negative, it means that those emissions have been avoided during the management of that specific material type and/or scenario. Likewise, if an energy consumption is negative, it means that the modelled scenario avoids the consumption of that amount of energy. If the total change between the alternative and baseline scenario is negative, then the alternative scenario will result in fewer GHG emissions or energy consumption than the baseline, and vice versa.

Only those materials for which data has been entered on the "Scenarios" step will be presented in the results.

As in the "Scenarios" step, there are also tooltips for each cell/bar of the different results' tables containing information about the data displayed in them.

5.1. Summary

This sub-tab contains a table similar to the one in the "Scenarios" step but also includes the GHG emissions/Energy consumption per material and scenario. In addition, there is a column on the right side with the change between the two scenarios (i.e., Alternative minus Baseline) for the metric selected in the calculation properties.

Moreover, there are equivalencies in the bottom right of the page for the resulting total change. For example, WARM includes the amount of passenger vehicles' annual emissions equivalent to the total change in GHG Emissions. Depending on the sign of the total change, this equivalency will be presented as removal of annual emissions (if the sign is negative) or adding of emissions (if the sign is positive).

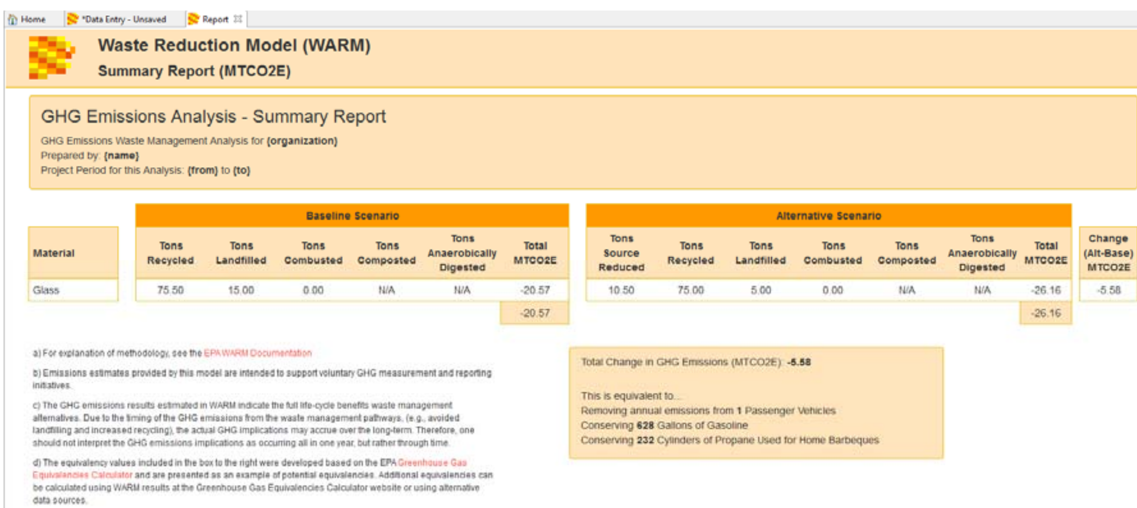

Figure 19. "Summary" sub-tab of the report

5.2. Analysis

This sub-tab contains four sections:

- Emission factors: this table contains the emission factors (in the selected metric) per relevant material type and management practice. The tons specified per material and management practice are multiplied by these factors to obtain the GHG emission/Energy consumption results.

Total GHG Emissions from Baseline MSW Generation and Management (MTCO2E): **-20.57**
Total GHG Emissions from Alternative MSW Generation and Management (MTCO2E): **-26.16**
Incremental GHG Emissions (MTCO2E): **-5.58**

MTCO2E = metric tons of carbon dioxide equivalent

Emission factors | Emissions from Baseline | Emissions from Alternative | Incremental Emissions from Alternative

Material	GHG Emissions per Ton of Material Source Reduced (MTCO2E)	GHG Emissions per Ton of Material Recycled (MTCO2E)	GHG Emissions per Ton of Material Landfilled (MTCO2E)	GHG Emissions per Ton of Material Combusted (MTCO2E)	GHG Emissions per Ton of Material Composted (MTCO2E)	GHG Emissions per Ton of Material Anaerobically Digested (MTCO2E)
Glass	-0.53	-0.28	0.02	0.03	N/A	N/A

a) For explanation of methodology, see the EPA WARM Documentation
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 20. "Emission factors" section in the "Analysis" sub-tab of the report

- Emissions from Baseline: this table contains the tons managed and the resulting GHG emission/Energy consumption per relevant material and management practice, as well as the totals per material, for the baseline scenario.

Emission factors | Emissions from Baseline | Emissions from Alternative | Incremental Emissions from Alternative

Material	Baseline Generation of Material (Tons)	Baseline Recycling (Tons)	GHG Emissions from Recycling (MTCO2E)	Baseline Landfilling (Tons)	GHG Emissions from Landfilling (MTCO2E)	Baseline Combustion (Tons)	GHG Emissions from Combustion (MTCO2E)	Baseline Composting (Tons)	GHG Emissions from Composting (MTCO2E)	Baseline Anaerobic Digestion (Tons)	GHG Emissions from Anaerobic Digestion (MTCO2E)	Total GHG Emissions (MTCO2E)
Glass	90.50	75.50	-20.88	15.00	0.30	0.00	0.00	N/A	N/A	N/A	N/A	-20.57

a) For explanation of methodology, see the EPA WARM Documentation
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 21. "Emissions from Baseline" section in the "Analysis" sub-tab of the report

- Emissions from Alternative: it contains the tons handled and the resulted GHG emission/Energy consumption per relevant material and management practice, as well as the totals per material, for the alternative scenario.

Emission factors | Emissions from Baseline | Emissions from Alternative | Incremental Emissions from Alternative

Material	Baseline Generation of Material (Tons)	Alternative Source Reduction (Tons)	GHG Emissions from Source Reduction (MTCO2E)	Alternative Recycling (Tons)	GHG Emissions from Recycling (MTCO2E)	Alternative Landfilling (Tons)	GHG Emissions from Landfilling (MTCO2E)	Alternative Combustion (Tons)	GHG Emissions from Combustion (MTCO2E)	Alternative Composting (Tons)	GHG Emissions from Composting (MTCO2E)	Alternative Anaerobic Digestion (Tons)	GHG Emissions from Anaerobic Digestion (MTCO2E)	Total GHG Emissions (MTCO2E)
Glass	90.50	10.50	-5.52	75.00	-20.74	5.00	0.10	0.00	0.00	N/A	N/A	N/A	N/A	-26.16

a) For explanation of methodology, see the EPA WARM Documentation
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 22. "Emissions from Alternative" section in the "Analysis" sub-tab of the report

- Incremental Emissions from Alternative: it contains the differences between the alternative and baseline scenario regarding tons handled and GHG emissions/Energy consumption per relevant material and management practice, as well as the total incremental results per material.

Emission factors | Emissions from Baseline | Emissions from Alternative | Incremental Emissions from Alternative

Material	Source Reduction (Tons)	Incremental GHG Emissions from Source Reduction (MTCO2E)	Incremental Recycling (Tons)	Incremental GHG Emissions from Recycling (MTCO2E)	Incremental Landfilling (Tons)	Incremental GHG Emissions from Landfilling (MTCO2E)	Incremental Combustion (Tons)	Incremental GHG Emissions from Combustion (MTCO2E)	Incremental Composting (Tons)	Incremental GHG Emissions from Composting (MTCO2E)	Incremental Anaerobic Digestion (Tons)	Incremental GHG Emissions from Anaerobic Digestion (MTCO2E)	Total Incremental GHG Emissions (MTCO2E)
Glass	10.50	-5.52	-0.50	0.14	-10.00	-0.20	0.00	0.00	N/A	N/A	N/A	N/A	-5.58

a) For explanation of methodology, see the EPA WARM Documentation
b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 23. "Incremental Emissions from Alternative" section in the "Analysis" sub-tab of the report

5.3. Report export

All the content of the "Report" tab can be exported as HTML by clicking on the icon of the toolbar. The exported file can then be opened in any modern web browser. The only difference with the view in the WARM Tool is that the report's sub-tabs, "Summary" and "Analysis", are included in the exported file as buttons in the top-right of the page.

Figure 24. WARM Report exported as HTML opened in a web browser

6. Saving data

All the entered data and selected options from the "Data Entry" tab can be saved in a file with the extension *.warm and be opened again in the tool for further assessments. To do this, select "File" in the menu bar and choose between any of the existing options (i.e., "Save", "Save as", "Save all"). For opening an existing file, select the option "Open…". The files with extension *.warm can only be opened from within this WARM Tool.

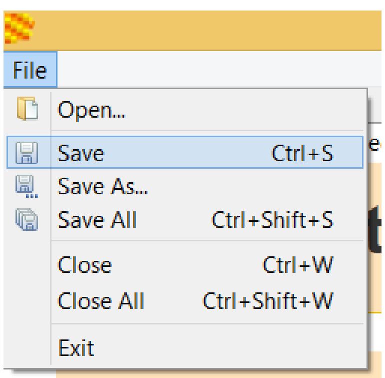

Figure 25. "File" menu options

The save/open functions are also available in the toolbar.

All the tabs that remain opened when closing the application will be displayed again the next time the tool is run. If you want to close permanently any tab, use the "Close" and "Close All" options of the "File" menu or click on the white cross in the right of the tab's header.

7. Other features

You can display several tabs at the same time in the tool by dragging and dropping the tabs into different positions in the window. Please, note that if the size of the window is too small, some elements might not be displayed properly (e.g., data entry tab).

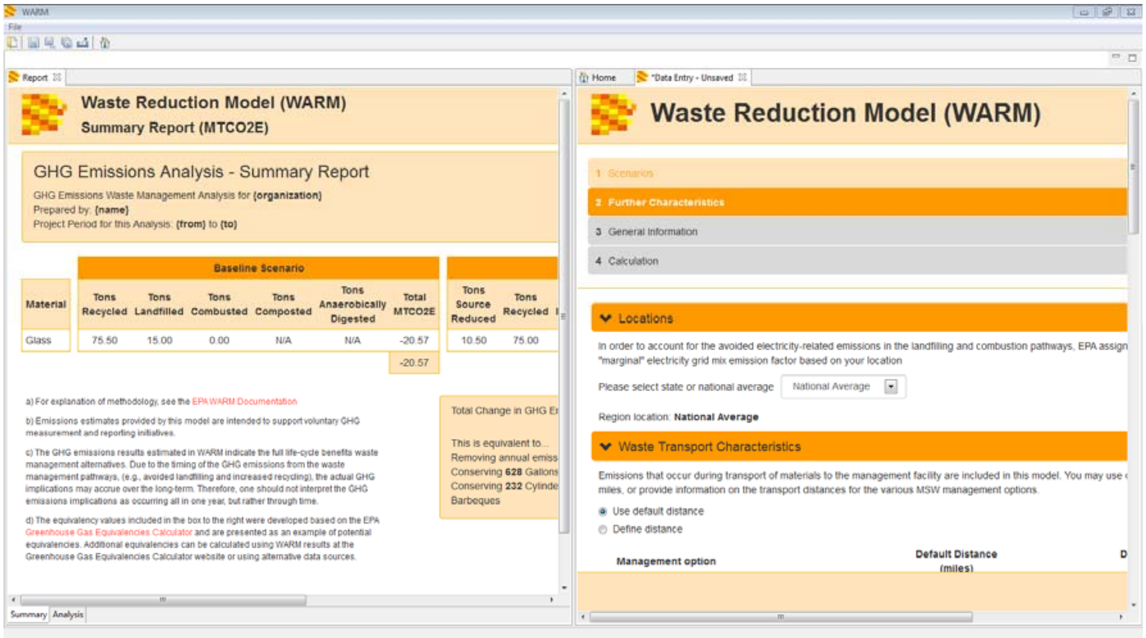

Figure 26. Display of two tabs simultaneously in WARM

8. Contact

If you have any feedback, comments or questions, please contact us.

9. Acknowledgments

WARM is developed by the U.S. EPA with support from GreenDelta, CSC, and ICF.

EPA United States Environmental Protection Agency