Waste Reduction Model (WARM) Tool

User's Guide

Software version: 1.0
Guide version: 1, July 2015

Contents

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.

WARM calculates GHG emissions for baseline and alternative waste management practices, including source reduction, recycling, combustion, composting, 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 BTUs 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 were developed following a life-cycle assessment (LCA) methodology using estimation techniques developed for national inventories of GHG emissions. The model documentation describes this methodology in detail. The WARM model was implemented in the free, open source LCA software openLCA. The resulting openLCA database is used for the calculation of impacts in the WARM Tool described in this guide. The model implemented in openLCA corresponds to the version of June 2015.

2. Installation

There are versions of the WARM Tool available for Windows (32 and 64 bit) and Mac (64 bit). 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.

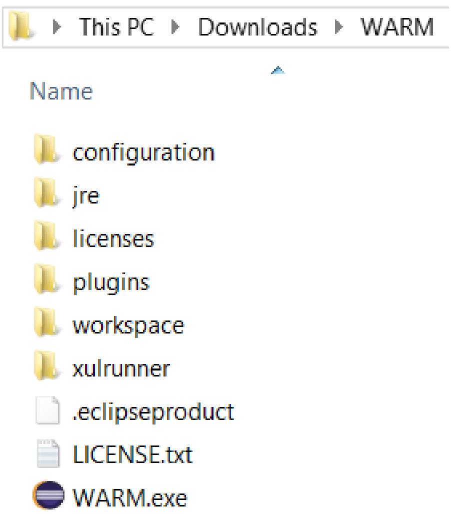


Figure 1. Content of WARM folder when extracted from the compressed file

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 had not installed it when running the tool, a message like in Figure 2 would be shown. You can download this runtime here.

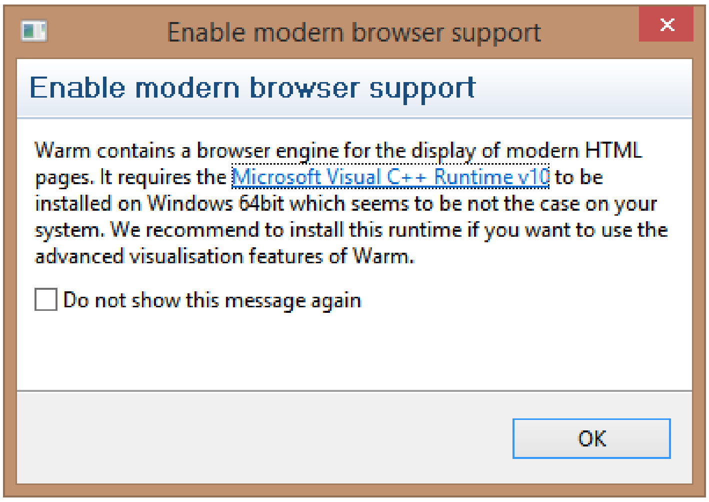


Figure 2. Message displayed if the MS Visual C++ Runtime v10 is missing

3. First start and overview

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

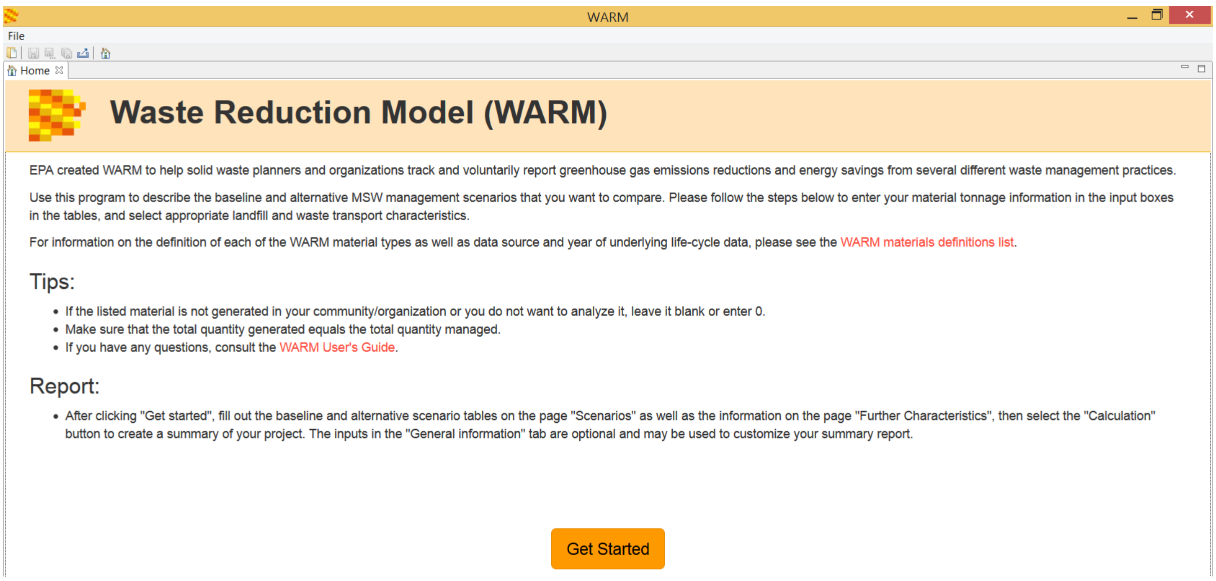


Figure 3. Home tab

If you click the button "Get Started", a new tab "Data Entry" appears, where the data for the analysis should be inputted 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 in the bottom. 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.

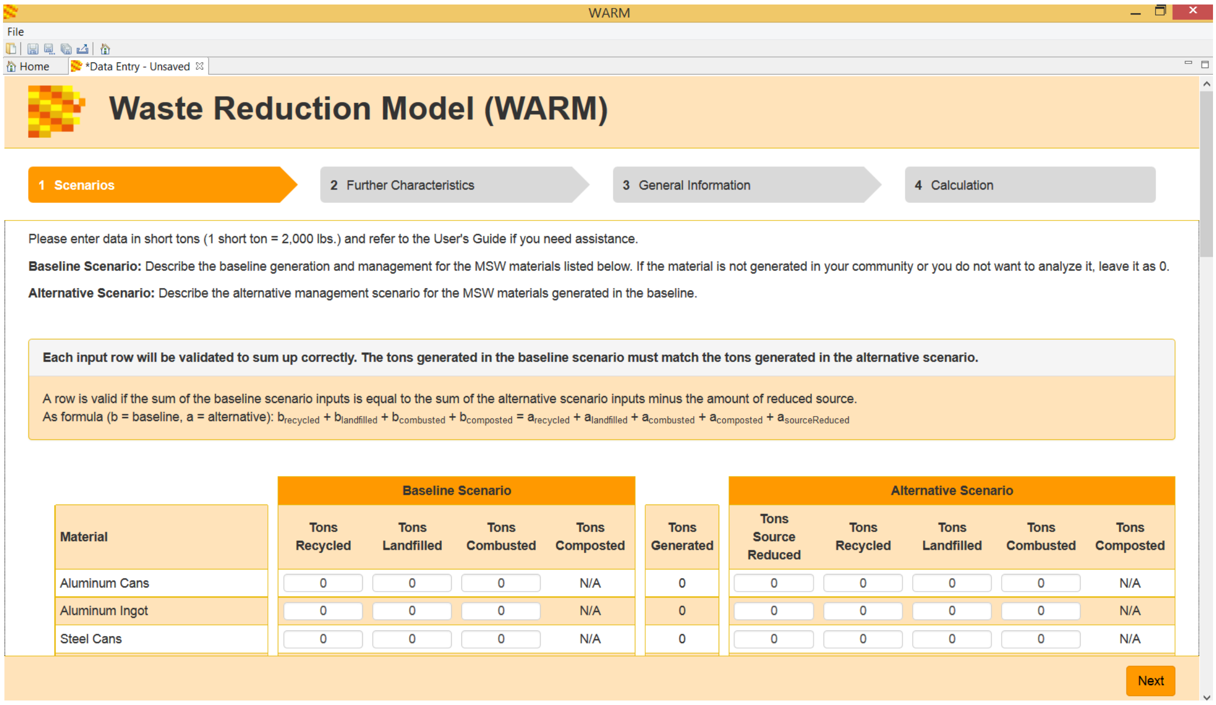


Figure 4. "Scenarios" section of the "Data Entry" tab

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's tab and click again "Get Started". If you had closed it, you could open it again by clicking on the icon of 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 inputted in the "Data Entry" tab for future assessments, as explained in section 6 of this guide.

4. Data entry

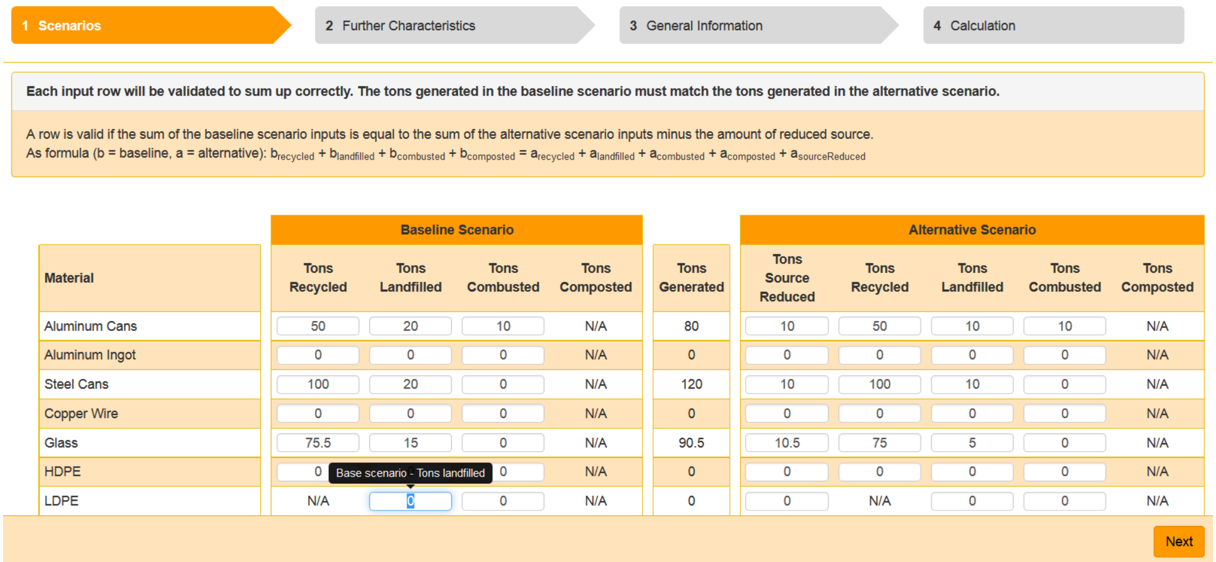
4.1. Generate scenarios

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 five management practices available (columns): recycling, landfilling, combustion, composting and source reduction. This last practice is of course 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 inputted 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.



Material	Baseline Scenario					Alternative Scenario				
	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Generated	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	50	20	10	N/A	80	10	50	10	10	N/A
Aluminum Ingot	0	0	0	N/A	0	0	0	0	0	N/A
Steel Cans	100	20	0	N/A	120	10	100	10	0	N/A
Copper Wire	0	0	0	N/A	0	0	0	0	0	N/A
Glass	75.5	15	0	N/A	90.5	10.5	75	5	0	N/A
HDPE	0		0	N/A	0	0	0	0	0	N/A
LDPE	N/A	0	0	N/A	0	0	N/A	0	0	N/A

Figure 5. Inputting of data in the "Scenarios" section 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 would be highlighted in red and an exclamation mark added in the left of the material's name.

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

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

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

Once the data has 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 step "1.Scenarios" is left without having fixed possible invalid entries (i.e. total baseline ≠ total alternative), a warning message is displayed informing of the existence of invalid data. The calculation can be run anyway, but the user should be aware of the existing differences in total quantities between scenarios.

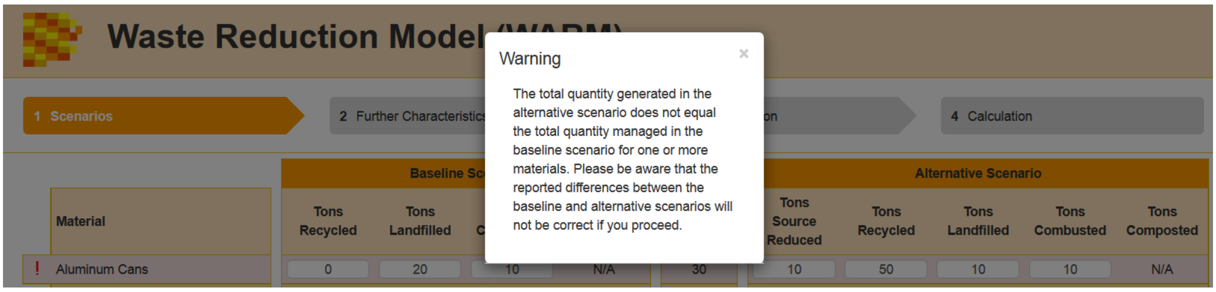


Figure 7. Warning message displayed if any material has invalid data entries

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".

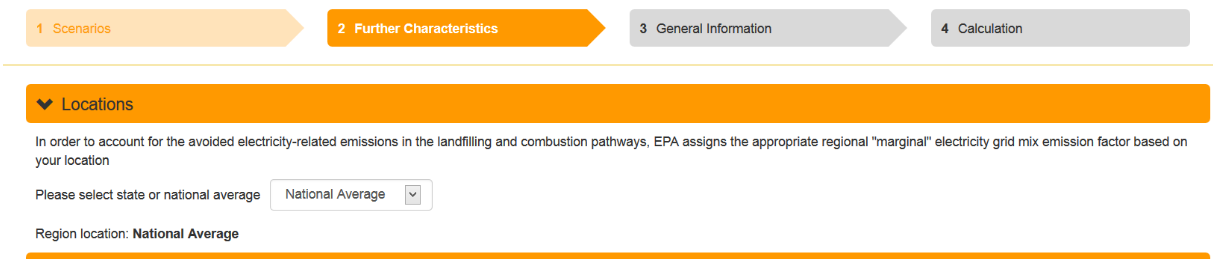


Figure 8. Locations options in "Further characteristics" section of the "Data Entry" tab

- 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).

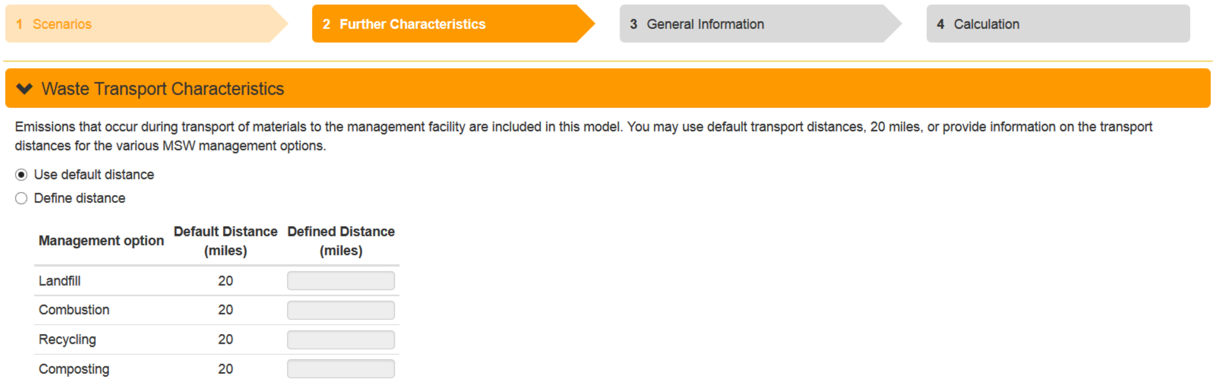


Figure 9. Waste transport options in "Further characteristics" section of the "Data Entry" tab

- 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 latter option would report a higher benefit from source reduction. The option by default is "Current mix".

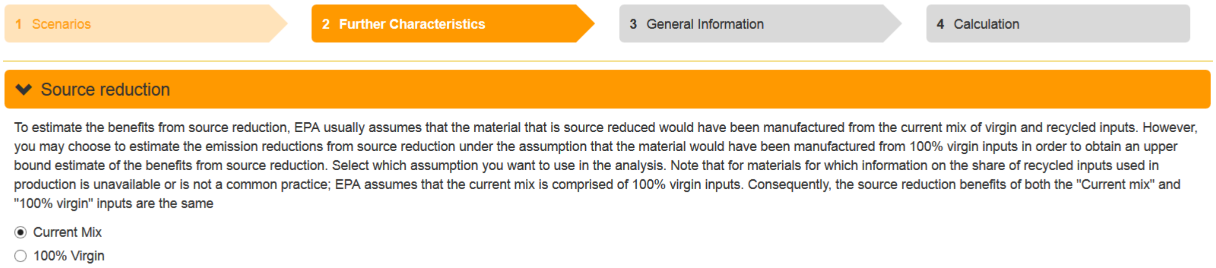


Figure 10. Source reduction options in "Further characteristics" section of the "Data Entry" tab

- 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.

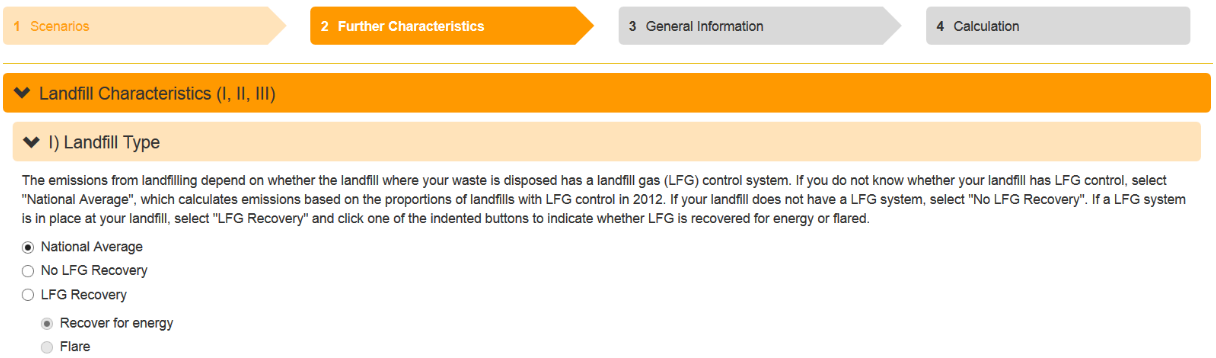


Figure 11. Landfill type options in "Further characteristics" section of the "Data Entry" tab

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.

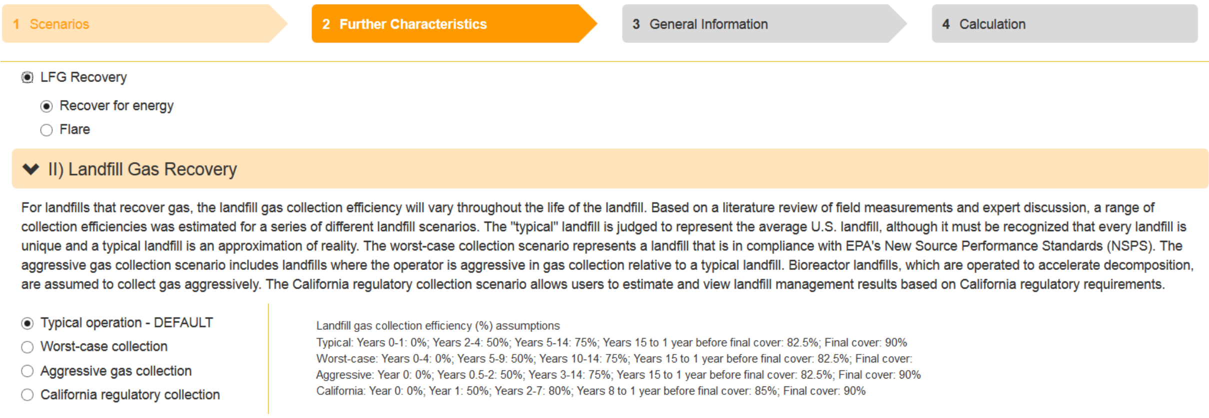


Figure 12. Landfill gas recovery options in "Further characteristics" section of the "Data Entry" tab

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.

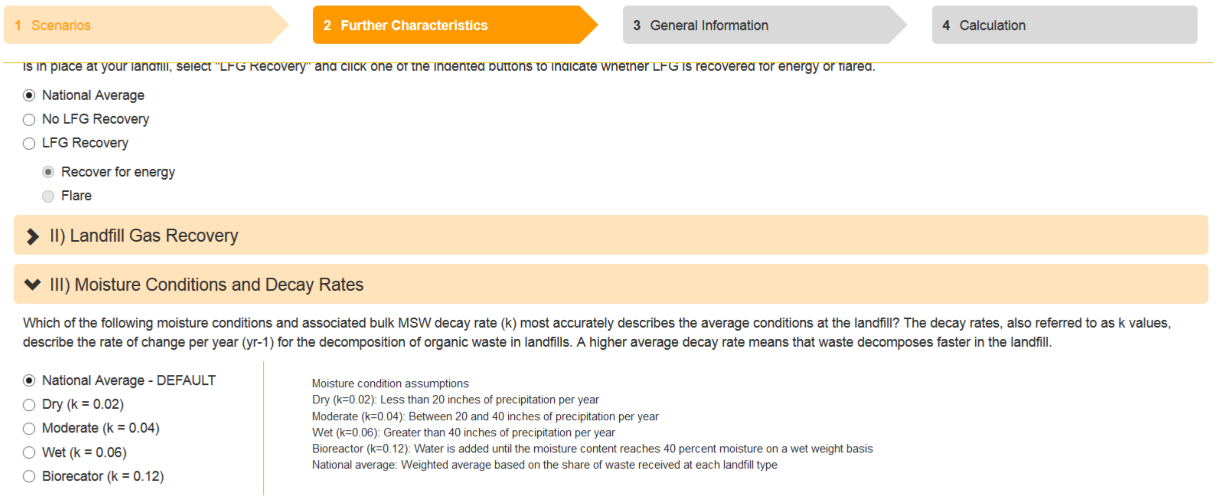


Figure 13. Moisture conditions and decay rates options in "Further characteristics" section of the "Data Entry" tab

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.

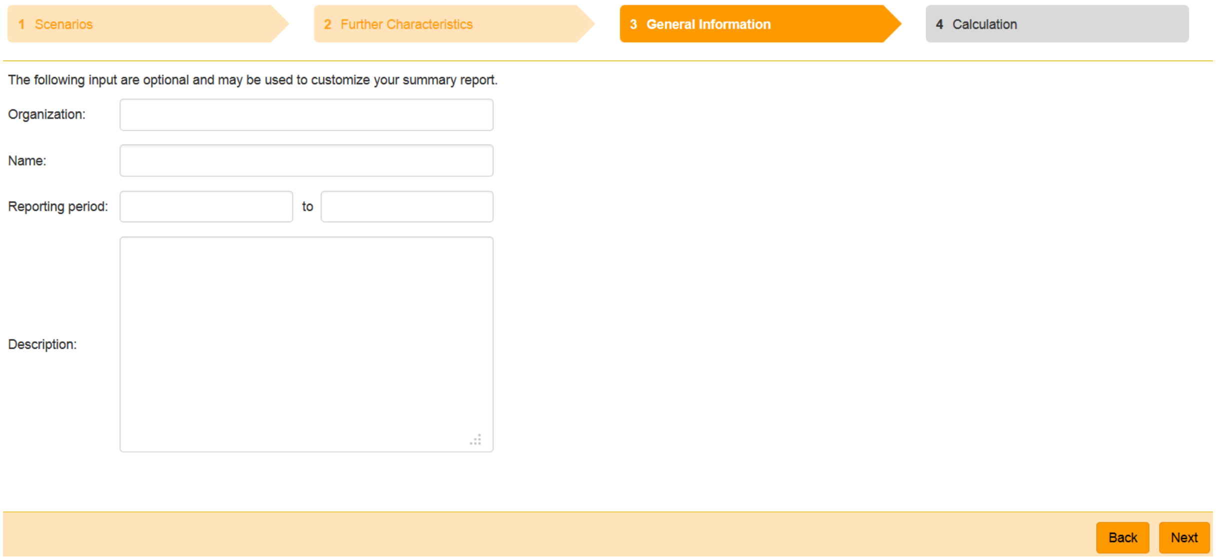


Figure 14. "General Information" section of the "Data Entry" tab

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

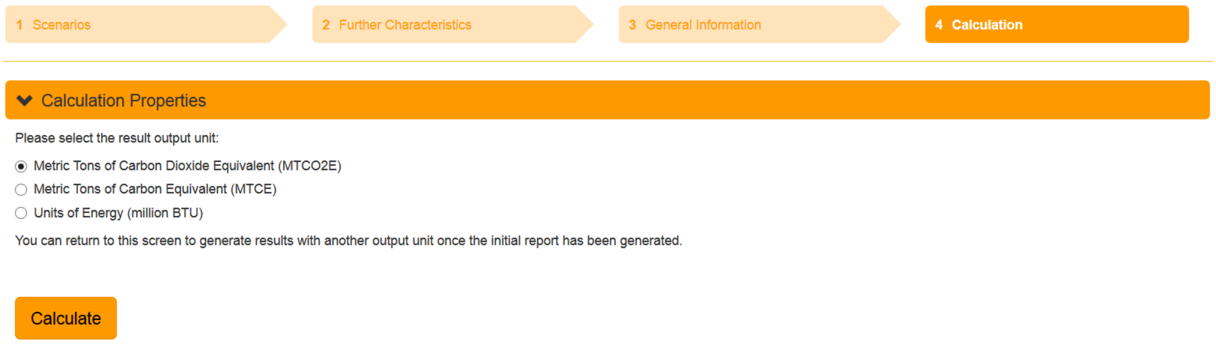


Figure 15. "Calculation" section of the "Data Entry" tab

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 three sub-tabs within the "Report" tab created after the calculation: summary, analysis and charts.

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 waste 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 imply less GHG emissions or energy consumption than the baseline, and vice versa.

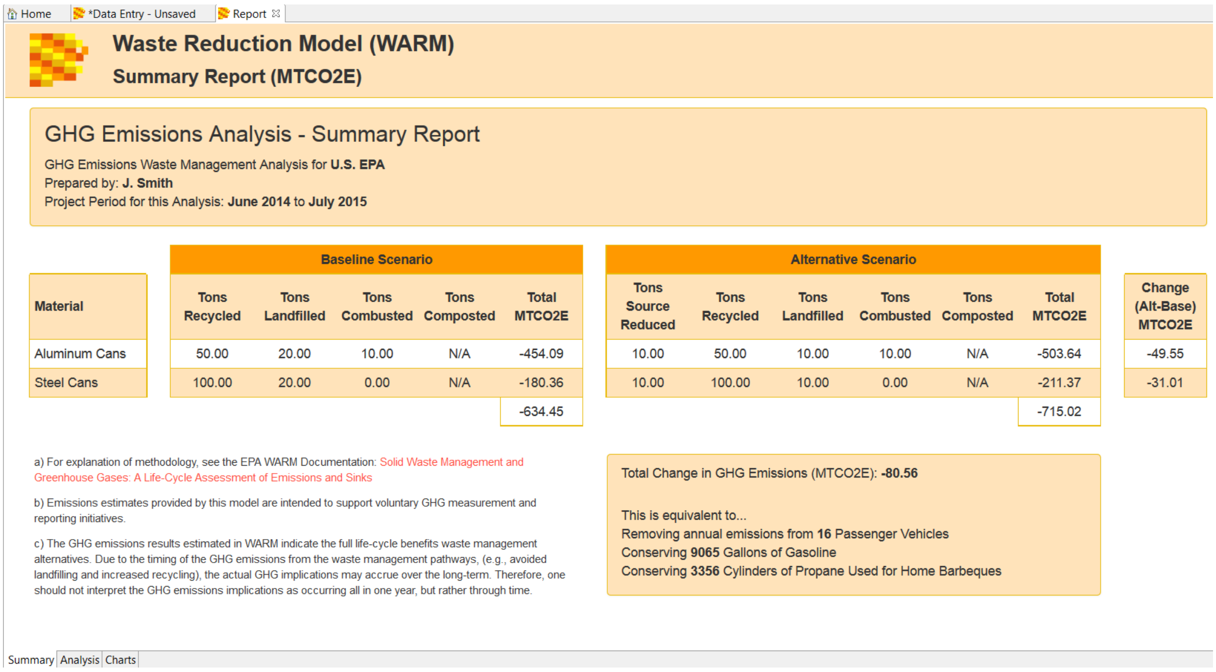
Only those materials for which data has been entered in the scenarios creation will be presented in the results.

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

5.1. Summary

It contains a table similar to the one in "1 Scenarios" but including also the GHG emissions/Energy consumption per material and scenario. In addition, there is an additional column in the right side with the change between the two scenarios (i.e. Alternative-Baseline) for the metric selected in the calculation properties.

Moreover, there are in the bottom right of the page some equivalencies to the resulting total change. For example, it is included 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).



Material	Baseline Scenario					Alternative Scenario						Change (Alt-Base) MTCO2E
	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	Tons Source Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E	
Aluminum Cans	50.00	20.00	10.00	N/A	-454.09	10.00	50.00	10.00	10.00	N/A	-503.64	-49.55
Steel Cans	100.00	20.00	0.00	N/A	-180.36	10.00	100.00	10.00	0.00	N/A	-211.37	-31.01
					-634.45						-715.02	

Figure 16. "Summary" tab of the report

5.2. Analysis

This tab contains four sections:

- Emission factors: it 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.

Home | *Data Entry - Unsaved | Report

Waste Reduction Model (WARM)

Analysis Report (MTCO2E)

Total GHG Emissions from Baseline MSW Generation and Management (MTCO2E): **-634.45**
Total GHG Emissions from Alternative MSW Generation and Management (MTCO2E): **-715.02**
Incremental GHG Emissions (MTCO2E): **-80.56**

MTCO2E = metric tons of carbon dioxide equivalent

Emission factors | Emissions from Baseline | Emissions from Projected Alternative | Incremental Emissions from Projected 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)
Aluminum Cans	-4.92	-9.11	0.04	0.05	N/A
Steel Cans	-3.06	-1.81	0.04	-1.55	N/A

a) For explanation of methodology, see the EPA WARM Documentation: Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 17. "Emission factors" section in the "Analysis" tab of the report

- Emissions from Baseline: 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 baseline scenario.

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

Material	Baseline Generation of Material (Tons)	Projected Recycling (Tons)	Annual Energy Use from Recycling (million BTU)	Projected Landfilling (Tons)	Annual Energy Use from Landfilling (million BTU)	Projected Combustion (Tons)	Annual Energy Use from Combustion (million BTU)	Projected Composting (Tons)	Annual Energy Use from Composting (million BTU)	Total Annual Energy Use (million BTU)
Aluminum Cans	80.00	50.00	-7638.22	20.00	10.55	10.00	6.32	N/A	N/A	-7621.35
Steel Cans	120.00	100.00	-1996.62	20.00	10.55	0.00	0.00	N/A	N/A	-1986.07

a) For explanation of methodology, see the EPA WARM Documentation: Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 18. "Emissions from Baseline" section in the "Analysis" tab of the report

- Emissions from Projected 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 Projected Alternative | Incremental Emissions from Projected Alternative

Material	Baseline Generation of Material (Tons)	Projected Source Reduction (Tons)	Annual GHG Emissions from Source Reduction (MTCE)	Projected Recycling (Tons)	Annual GHG Emissions from Recycling (MTCE)	Projected Landfilling (Tons)	Annual GHG Emissions from Landfilling (MTCE)	Projected Combustion (Tons)	Annual GHG Emissions from Combustion (MTCE)	Projected Composting (Tons)	Annual GHG Emissions from Composting (MTCE)	Total Annual GHG Emissions (MTCE)
Aluminum Cans	80.00	10.00	-13.41	50.00	-124.20	10.00	0.11	10.00	0.15	N/A	N/A	-137.36
Steel Cans	120.00	10.00	-8.35	100.00	-49.40	10.00	0.11	0.00	0.00	N/A	N/A	-57.65

a) For explanation of methodology, see the EPA WARM Documentation: Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 19. "Emissions from Projected Alternative" section in the "Analysis" tab of the report

- Incremental Emissions from Projected 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 Projected Alternative | Incremental Emissions from Projected Alternative

Material	Source Reduction (Tons)	Incremental Energy Use from Source Reduction (million BTU)	Incremental Recycling (Tons)	Incremental Energy Use from Recycling (million BTU)	Incremental Landfilling (Tons)	Incremental Energy Use from Landfilling (million BTU)	Incremental Combustion (Tons)	Incremental Energy Use from Combustion (million BTU)	Incremental Composting (Tons)	Incremental Energy Use from Composting (million BTU)	Total Incremental Energy Use (million BTU)
Aluminum Cans	10.00	-896.58	0.00	0.00	-10.00	-5.27	0.00	0.00	N/A	N/A	-901.85
Steel Cans	10.00	-298.47	0.00	0.00	-10.00	-5.27	0.00	0.00	N/A	N/A	-303.75

a) For explanation of methodology, see the EPA WARM Documentation: Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks

b) Emissions estimates provided by this model are intended to support voluntary GHG measurement and reporting initiatives.

Figure 20. "Incremental Emissions from Projected Alternative" section in the "Analysis" tab of the report

5.3. Charts

Contributions per flow, material type, management practice and pre-determined group of processes are presented as bar charts in four different sections:

- Flow contributions: in the GHG emissions calculation (i.e. MTCO2E, MTCE), the contribution per GHG flow assessed is presented for each scenario. The elementary flows displayed are:
  - Resources:
    - Carbon (forest storage)
    - Carbon (landfill storage)
    - Carbon (soil storage)
  - Air emissions:
    - Carbon dioxide
    - Dinitrogen monoxide
    - Ethane, hexafluoro, HFC-116
    - GHGs, unspecified
    - Methane
    - Methane, tetrafluoro, R-14

  In the Energy consumption calculation, a single flow is displayed "Energy, unspecified" (resource) for both scenarios.

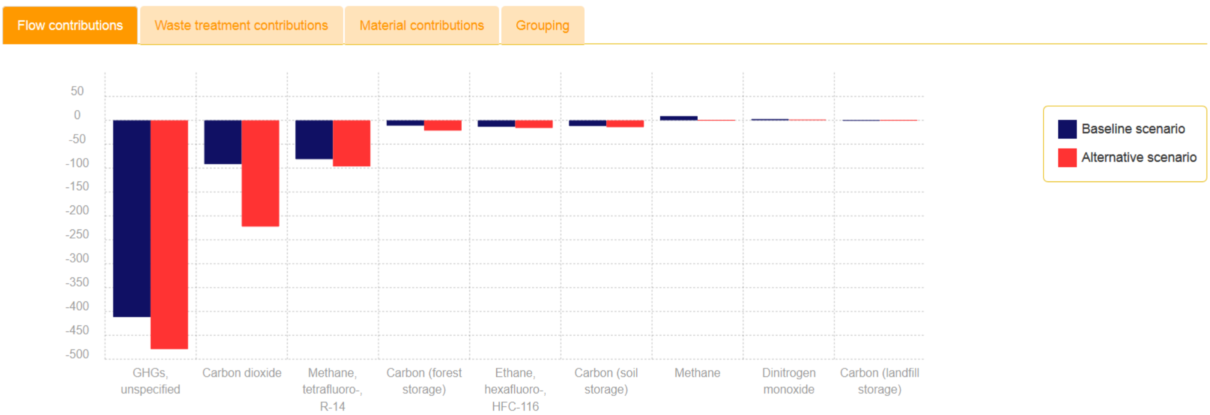


Figure 21. "Flow contributions" section in the "Charts" tab of the report

- Waste treatment contributions: the GHG emissions/Energy consumption per waste management option is presented here for each scenario and a maximum of six materials. The materials to be displayed can be selected clicking on the "Select material filter" button. A pop-up window with the relevant materials will be shown; once the materials have been chosen, click on "Apply selection".

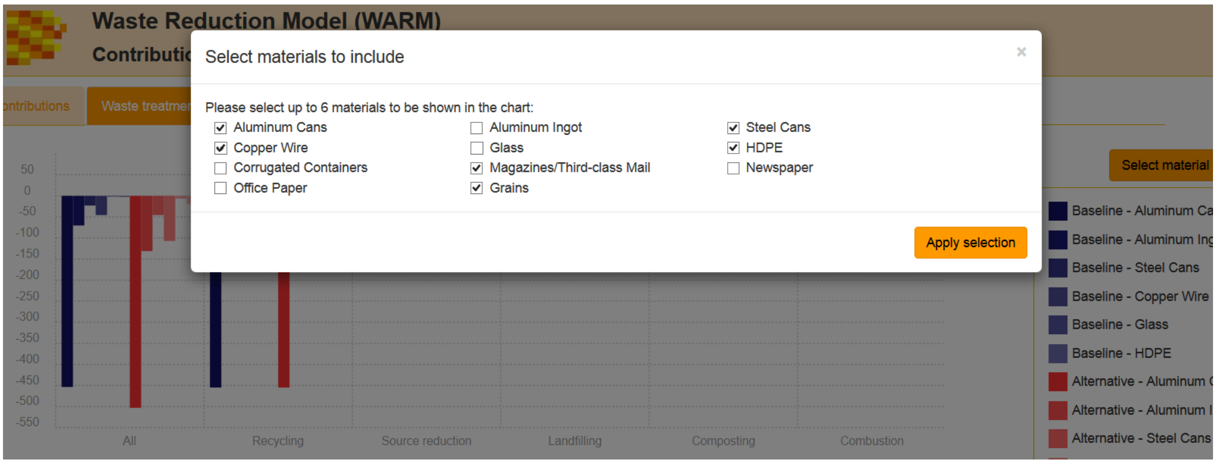


Figure 22. "Select materials filter" window in the "Waste treatment contributions" section of the "Charts" tab of the report

- Material contributions: the GHG emissions/Energy consumption per material type is presented here for each scenario and management practice. As in the previous chart, only up to six materials can be presented simultaneously. The materials to be displayed can be selected clicking on the "Select material filter" button.

Figure 23. "Material contributions" section in the "Charts" tab of the report

- Grouping: it contains GHG emissions/Energy consumption results per each pre-defined group of processes used in the WARM life cycle product system created in openLCA. The groups presented are:
  - landfilling
  - combustion
  - recycling
  - source reduction
  - composting
  - electricity
  - heavy equipment for composting
  - heavy equipment for landfilling
  - transport
  - forest carbon sequestration
  - other

For instance, "transport" will show the contribution to the total results of all processes related with transportation of waste to management facilities, transportation within the management facilities and transport to retailer. It should be noted that in the "source reduction" group all the manufacturing processes, including also energy and transport required during the manufacturing, are considered, and that these processes are used in the supply chain of both recycling and source reduction management practices.

5.4. 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 tabs "Summary", "Analysis" and "Charts" are included in the exported file as buttons in the top-right of the page.

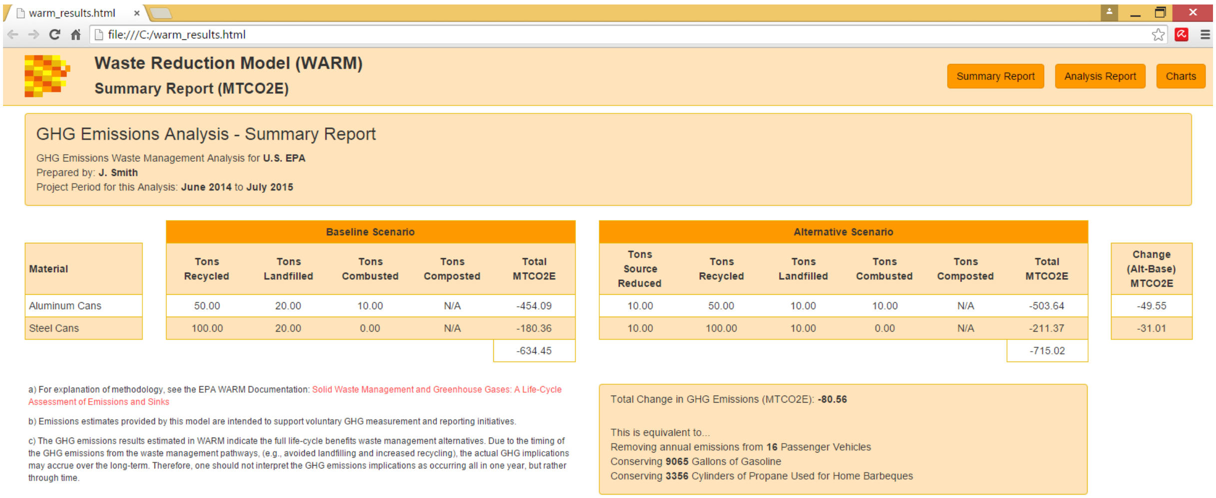


Figure 24. WARM Report exported as HTML opened in a web browser

6. Saving data

All the inputted 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 this end, 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.

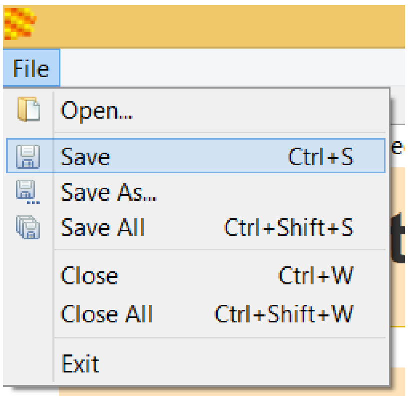


Figure 25. "File" menu options

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).

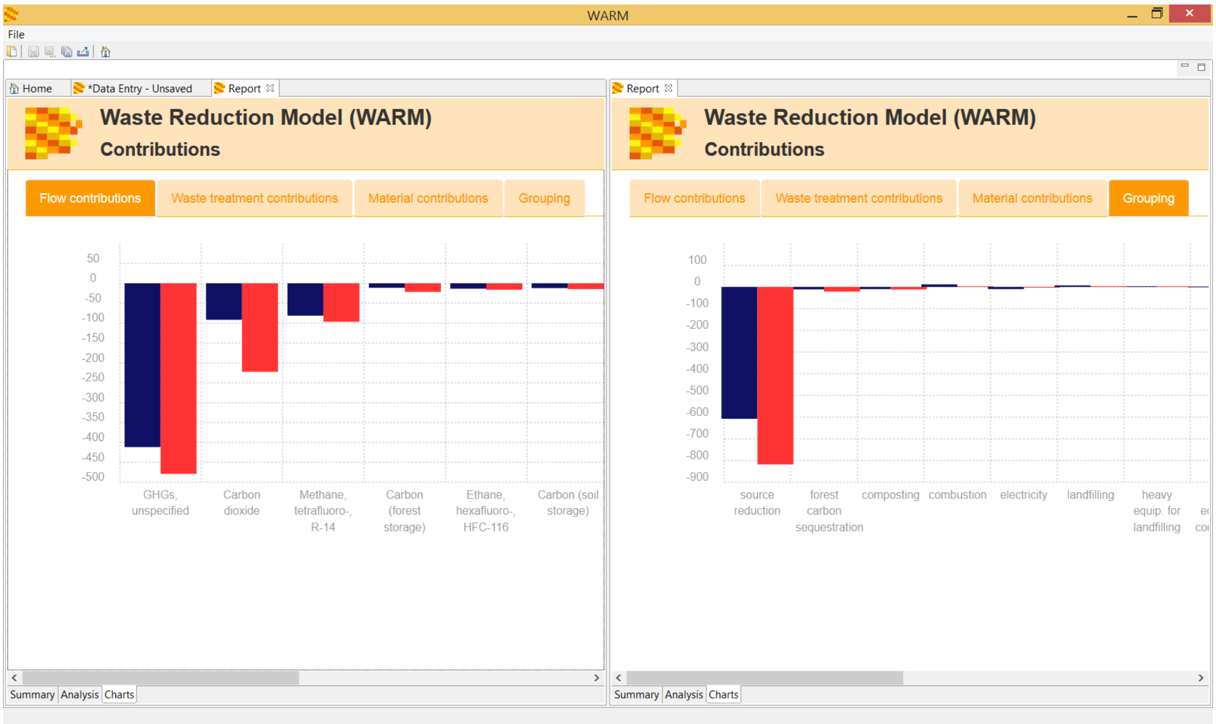


Figure 26. Display of two tabs simultaneously in WARM

8. Contact

The WARM model and tool are developed by U.S. EPA. If you have any feedback, comments or questions, please contact us.

EPA United States Environmental Protection Agency