



CCaLC[®] Manual (V3.1)

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List of contents

1	System requirements.....	1
1.1	Users of Excel 2003.....	1
1.2	Users of Excel 2007 and Excel 2010	1
2	Compatibility with CCaLC V1.1 and CCaLC V2.0.....	2
3	Tool development credits.....	2
4	Acknowledgements.....	2
5	Introduction.....	2
6	CCaLC tool overview.....	3
7	Carbon footprint estimation.....	4
7.1	Defining system details.....	4
7.2	Defining the production stage names.....	6
7.3	Defining raw materials	7
7.4	Defining transport	9
7.5	Defining the production stage.....	12
7.5.1	Defining energy use.....	12
7.5.2	Defining land use change	13
7.5.3	Defining direct emissions	14
7.5.4	Defining packaging use.....	16
7.5.5	Defining waste	17
7.5.6	Linking waste to raw materials.....	18
7.5.7	Defining production stage outputs.....	19
7.6	Defining the storage stage.....	21
7.7	Defining the use stage.....	21
7.7.1	Defining appliance use.....	21
7.7.2	Defining biogenic carbon storage/uptake in products	22
7.7.3	Defining carbon release from product disposal.....	23
7.7.4	Co-product systems: System expansion and allocation	25
8	Viewing carbon footprint data and results.....	27
8.1	Numerical display	27
8.2	Graphical display	27
9	Modifying user carbon footprint databases.....	28
9.1	Creating a new user database item.....	28
9.2	Modifying an existing user database item	30
9.3	Deleting a user database item.....	31
10	Carbon footprint data quality assessment.....	31
11	Loading, saving, deleting or starting a new carbon footprint study.....	33
11.1	Loading an analysis.....	33
11.2	Saving an analysis.....	34
11.3	Starting a new study.....	34
11.4	Deleting an analysis	34
12	Carbon footprint summary	34
13	Data comparison	36
14	Sharing user-created studies and results between users.....	37
14.1	Importing and exporting studies	37

14.2	Exporting comparisons.....	38
14.3	Exporting graphs	38
15	Importing data sets.....	38
15.1	Importing data using the CCaLC template.....	38
15.2	Importing ILCD data	39
16	Calculating water usage and water footprint.....	41
16.1	Switching between water footprint and value added.....	41
16.2	Populating the water footprint data	41
16.3	Missing water data.....	43
16.4	Water usage graphs	43
17	Calculating other environmental impacts	43
18	Calculating value added.....	45
19	Example case studies.....	46
19.1	Biofeedstocks: PLA from wheat.....	47
19.1.1	Introduction.....	47
19.1.2	Goal and scope of the study.....	47
19.1.3	Inventory analysis.....	49
19.1.4	Impact assessment.....	50
19.2	Food and Drink: Lunch at a sandwich bar	51
19.2.1	Introduction.....	51
19.2.2	Goal and scope of the study.....	52
19.2.3	Inventory analysis.....	52
19.2.4	Impact assessment	53
19.3	Packaging: Drinks Packaging	55
19.3.1	Introduction.....	55
19.3.2	Goal and scope of the study.....	55
19.3.3	Inventory analysis.....	59
19.3.4	Impact assessment	61
	Appendix 1 – Methodology for calculating the carbon footprint of transport	65
	Appendix 2 – Data quality criteria.....	67
	A2.1 General about LCA data quality	67
	A2.2 Data quality assessment in the CCaLC tool.....	67
	Appendix 3 – Water use and water footprint.....	71

1 System requirements

The CCaLC tool is an Excel-based application run by macros. It was designed and built using the English version of Microsoft Excel for Windows XP. The tool may not run properly on non-English operating systems as well as on older versions of Excel or Windows. CCaLC is designed for use on PCs and is not suitable for use on Mac computers.

If on opening the tool, a message appears “The file can be opened as read only”, then:

- click on ‘Read-only’ to open the file
- save the tool under a different name and
- continue using the tool.

Please note that, depending on the speed of your computer, some operations may take longer time to complete. Normally, the hour-glass will indicate that the system is busy. If it appears that there is no response after clicking on an option or action-button or the cursor does not turn into the hour-glass, please wait a few moment as the system is busy and may take some time to complete the action.

The tool will run faster in Excel 2003 than in Excel 2007.

1.1 Users of Excel 2003

In order for the CCaLC macros to work correctly, the Excel security settings should be set to either Medium or Low. In Excel 2003, on opening the tool, click on 'Enable macros' when prompted.

1.2 Users of Excel 2007 and Excel 2010

In order for the CCaLC macros to work correctly, the Excel security settings should be set to either Medium or Low. In Excel 2007, on opening the tool, click on 'Security Warning - Options' and select 'Enable this content'.

To see the CCaLC menus in Excel 2007, click on the Add-ins tab on the main menu-bar. The menu items will be displayed on the left hand side of the main menu-bar.

For Excel 2007 and Excel 2010 users, when the user saves the CCaLC tool, it is automatically saved in Excel 2007 format (i.e. .xlsm form).

The CCaLC tool can be converted back to Excel 2003 format (i.e. .xls) from Excel 2007 (i.e. .xlsm) as follow:

- Open the CCaLC tool in Excel 2007 without out running the macros (i.e. do not click on 'Security Warning - Options')
- Select Save as Excel 97-2003 Workbook and Click Save
- Close the CCaLC tool. Now the saved CCaLC tool can be opened in Excel 2003 as well.

2 Compatibility with CCaLC V1.1, CCaLC V2.0 and CCaLC V3.0

CCaLC V3.1 is fully compatible with the previous version V1.1, V2.0 and V3.0. To transfer the studies from V1.1, V2.0 and V3.0 to V3.1:

- Save the study in V1.1, V2.0 or V3.0 by choosing the menu option *CF Study/Save CF study*
- Type the name of the study in the pop-up window and click OK
- Click the menu option *Share data/Export study* and click in the pop-up window on the study to be exported; the study will be saved in the directory chosen by the user
- Open CCaLC V3.1 and click on the menu option *Share data/Import study*; from the dialogue box that pops-up, select the file to be imported
- To view the study imported, click on *CF Study/Load study* and then in the pop-up dialogue box click on the radio-button User-defined where the imported study should be listed. Click on the study name and then on the OK button to load the study.

3 Tool development credits

CCaLC was developed by a research group based at the University of Manchester and led by Professor Adisa Azapagic. The following researchers were involved in the project:

- David Amienyo (case studies);
- Haruna Gujba (case studies and databases);
- Harish Jeswani (case studies and databases);
- Anthony Morgan (software development);
- Yu Rong (software development);
- Namy Espinoza-Orias (case studies and databases); and
- Heinz Stichnothe (methodology and case studies).

For further information visit www.ccalc.org.uk or contact: adisa.azapagic@manchester.ac.uk

4 Acknowledgements

The CCaLC project was funded by Carbon Trust, EPSRC and NERC (grant. No. EP/F003501/1). Numerous industrial partners have contributed to the development of the tool and their help is gratefully acknowledged. For more information visit www.ccalc.org.uk.

5 Introduction

The CCaLC tool allows quick and easy estimations of environmental impacts and value added along the supply chains. It takes a life cycle approach and it enables estimation of the following environmental impacts:

- Carbon footprint (or Global warming potential);
- Water footprint;
- Acidification potential;
- Eutrophication potential;
- Ozone layer depletion potential;

- Photochemical smog; and
- Human toxicity potential.

The tool has been developed with the following objectives in mind:

- to enable non-expert users to calculate the carbon footprint and other environmental impacts quickly and easily while following internationally accepted LCA standards such as ISO 14044 and PAS2050;
- to reduce the data collection effort by providing comprehensive databases;
- to help identify environmental hot-spots and improvement opportunities; and
- to enable trade offs between environmental impacts and economic costs.

6 CCaLC tool overview

The tool has been developed in Microsoft Excel and is run by macros. The worksheets are locked and are not accessible to the user. This prevents accidental changes to the databases and other parts of the tool. Information can be entered into the tool via user forms that are activated by clicking buttons at the top of worksheets. The user can navigate around the tool using the links provided.

Figure 1 shows the top-level layout of the tool. This represents a map of a typical product life-cycle and includes the following stages:

- Raw materials;
- Production;
- Storage;
- Use;
- Transport; and
- Waste.

The user can access any of these stages by clicking on the relevant box. The subsequent levels allow the user to modify information contained at these levels; this is described in more detail later on.

The Excel menu bars and toolbars are largely disabled for the sake of clarity, although the user can still make use of the in-built excel *File/Save* functions to save the tool at any point during the analysis. There are several menus specific to the tool, the functions of which are described later in this manual. The carbon footprint for each stage is shown in red, the value added in blue and the water usage in light green.

CCaLC contains three databases: CCaLC, Ecoinvent and User database. The CCaLC database consists of publicly available data compiled as part of the CCaLC project and data generated during the course of the project. The Ecoinvent database is a proprietary database that is included in the CCaLC tool with a kind permission of Ecoinvent. Although the Ecoinvent database is comprehensive, it should be noted that only data relating to Global Warming Potential (i.e. the carbon footprint) are included with the database and there are no data pertaining to other environmental impacts. User database is created and populated by the user as explained in the subsequent sections.

System Details:

Name: Red wine

	Amount:	Unit:
Functional unit:	1	bottle
Mass units:	kg	Units <input checked="" type="radio"/> Change the units displayed and convert (default) <input type="radio"/> Change only the units displayed
Energy units:	MJ	
Distance units:	km	
Volume units:	m ³	
Monetary units:	Pound (£)	
Exchange rate (per £):	1	
Data collected (yr):	2010	
Data source:	Confidential	
System last updated (date):	07/01/2010	
Author:	CCaLC	
Comments:	<p>The functional unit is one 0.75 l bottle of wine. The system boundary is from cradle to grave. Impacts from waste management of post consumer glass packaging have been accounted for during production of packaging.</p>	

OK Cancel

Figure 2 System Details user form

The user can also define different mass (g, kg, tonne), energy (MJ, kWh, BTU), distance (km and miles), volume (m³, litres) and monetary units (£, \$, €). The default values are **tonne, kWh, km, m³** and **£**, respectively. The units can be changed at any point during the analysis. If using a currency other than £, an exchange rate should be supplied in the textbox. This enables the user to switch between different currency types during the analysis.

NB: The units are not linked to the unit of the Functional Unit defined by the user. The user should ensure that they are working in consistent units at all times.

There are two ways to convert units. This can be specified in the section Units, which lists two options (see Figure 2):

- Change the units displayed and convert (default); and
- Change only the units displayed.

The default setting on the form is to convert units. This means that, should the user change units during the analysis, all amounts already entered will be converted to the new specified unit(s). Should the user require that the amounts entered are left unchanged but only the units displayed are changed (e.g. in the event that data were entered in the wrong units), then the second options should be selected.

Other information on this form is related to the age and source of data, date of conducting the study and the author – however, these are not compulsory but may be useful for transparency and record keeping.

The system details can then be updated by clicking on the *OK* button, after which the whole system is updated. This takes a short while to complete.

7.2 Defining the production stage names

Once the system details have been defined, the next step is to define the production stage names. This will then enable to ‘send’ the raw materials to the specified stages, during the definition of Raw materials stage.

This is carried out by clicking on the *Production* box at the top level of the tool (see Figure 1) which takes the user to the individual production stages (Figure 3). In total, ten production stages can be defined.

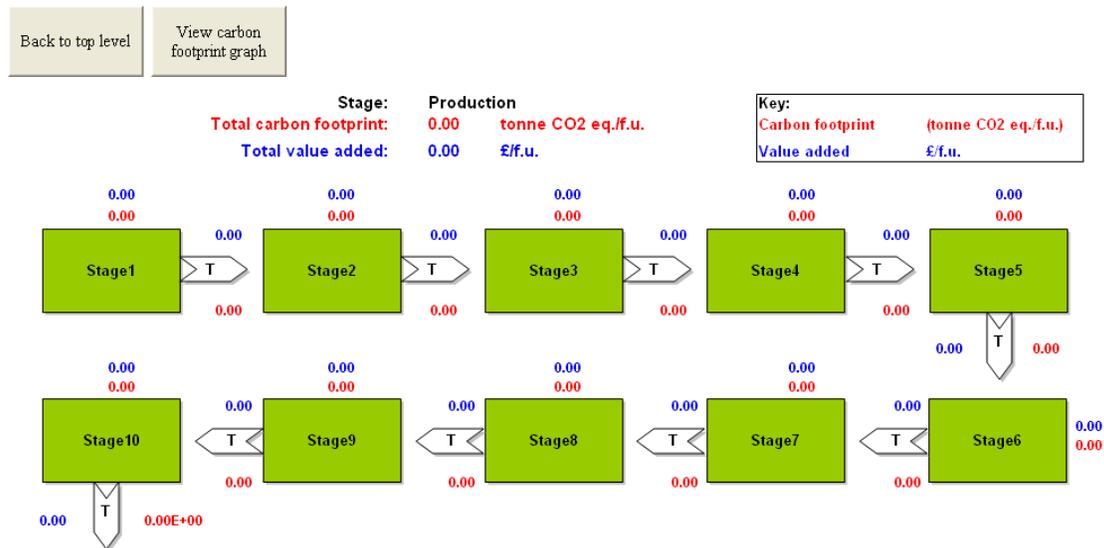


Figure 3 Overview of the Production stage

When the tool is first loaded with no study uploaded, the stage names are displayed as *Stage1*, *Stage2*...etc. (see Figure 3). The names of the stages can be defined or modified at any point during the analysis as follows:

1. Click on the stage to be modified (Figure 3); this takes the user to that stage with a number of navigation buttons at the top of the screen (as shown in Figure 4);
2. Click on the *Define Stage* button at the top of the screen;
3. Enter the name of the stage in the relevant text box
4. Enter any relevant comments in the *Comments* text box
5. Click *Update*.

Once this is done, the tool will update all instances of the stage name in the analysis. The same procedure should be carried out for the rest of the production steps, until they

have all been defined. The next step is then to define the raw materials being used the the different production stages.

It should be noted that the transport arrows do not connect different stages. Rather, they represent the transport of materials from an individual processing stage. Material flows may be transported between any of the processing stages – due to a large number of stages – due to a large number of transport flows and combinations, it is not practical to show all the transport connections graphically, but they are captured in the transport data sheets.

Back to production	Define stage	Define energy	Define waste	Define land use change	System expansion/ Allocation	View carbon footprint graph
--------------------	--------------	---------------	--------------	------------------------	------------------------------	-----------------------------

Functional unit: **Acrylic acid from wheat (allocation) 1 tonne**
 Stage: **Wheat cultivation**

Total carbon footprint for stage: 1.16 tonne CO₂ eq./f.u.
Total costs for stage: 378.45 £ /f.u.

Material/Packaging inputs	Amount (tonne)	Cost (£/tonne)	Cost (£/f.u.)
Farm yard manure/slurry	1.77	0.00	0.00
K Fertiliser	0.02	0.00	0.00
N Fertiliser	0.11	0.00	0.00
P Fertiliser	0.02	0.00	0.00
Pesticides	5.40E-04	0.00	0.00
Seeds - Wheat	0.10	0.00	0.00
Total:	2.02	Total: 0.00	

Energy type	Amount (MJ/f.u.)	CO2 eq. (tonne/MJ energy)	CO2 eq. (tonne/f.u.)	Cost (£/MJ)	Cost (£/f.u.)
Diesel (used in farm machinery)	4,540.70	7.80E-05	0.35	0.02	98.99
Total:	4,540.70	Total: 0.35	Total: 98.99		

Direct emissions	Amount (tonne/f.u.)	CO2 eq. (tonne/tonne GHG)	CO2 eq. (tonne/f.u.)
Nitrous Oxide to air	2.72E-03	298.00	0.81
Total:	2.72E-03	Total: 0.81	

Packaging type	Amount (tonne/f.u.)	CO2 eq. (tonne/tonne packaging)	CO2 eq. (tonne/f.u.)	Cost (£/tonne)	Cost (£/f.u.)
Total:	0.00	Total: 0.00	Total: 0.00		

Waste	Amount (tonne/f.u.)	CO2 eq. (tonne/tonne waste)	CO2 eq. (tonne/f.u.)	Cost (£/tonne)	Cost (£/f.u.)
Total:	0.00	Total: 0.00	Total: 0.00		

Define stage: Wheat cultivation

Details | Output | GHG emissions | All emissions

Stage name:

If agricultural stage, hectares used per f. u.

Comments:

Update

Exit

Figure 4 Stage details and Define Stage user form

7.3 Defining raw materials

Raw materials are defined by clicking on the *Raw Materials* box on the top level of the tool (Figure 1). The user is then taken to the next level down, showing the tables related to raw materials (Figure 5).

There are four tables which will be populated as the user enters data through the user forms. The data in these four tables are related to:

- raw materials – amounts used and their carbon footprints,

- energy - any additional energy used for raw materials that is not already accounted for within the carbon footprints of the raw materials (e.g. storage and refrigeration of raw materials);
- packaging – amounts used for both raw materials and product(s), together with the carbon footprints of packaging; and
- waste from raw materials and the carbon footprints related to waste management (e.g. due to spillage or perishable nature of raw materials).

The amount of each of these can be modified by clicking on the appropriate button at the top of the screen. The carbon footprint data are also specified here, either via the databases available or by entering user carbon footprint data.

To add a raw material to the analysis:

1. Click on the *Define Materials* button (Figure 5)
2. Select the appropriate database to use (CCaLC, Ecoinvent, User-defined)
3. From the first drop-down list, select type of raw material (e.g. agricultural inputs, construction materials etc.)
4. Select the required material from the next drop-down list
5. Select the required production stage from the second drop-down list where the raw material will be sent
6. Add the amount of material per functional unit in the textbox (Note: agricultural materials are defined in mass per hectare of land)
7. Select the data quality for the amount used (*high, medium, low*) to indicate how confident you are in the figure used [see Appendix 2 for a description of how the data quality is calculated for the system]
8. Add any comments that are appropriate to this instance of material use (this is optional but is recommended as a reminder for future uses)
9. Add the cost of the raw material, per unit mass, if needed
10. Click the *Update* button.

The Raw material table on the screen will be updated to show the material name, the amount used, the carbon footprint associated with it and its destination. The database section from which the data have been selected is also shown in the tables.

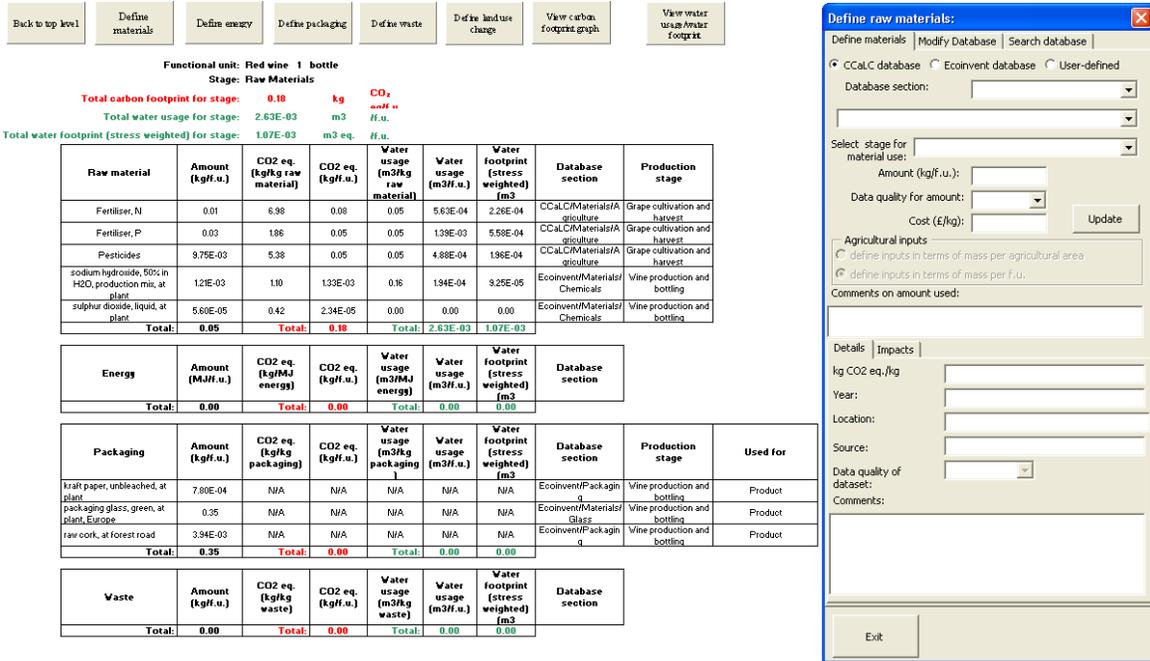


Figure 5 Raw materials stage with the *Define raw materials* user form

Other materials can be added in the same way. If a new material needs to be added to the database, then this can be done through the *Modify Database* tab. This is discussed in more detail in section 9.

The total carbon footprint for the Raw materials stage can be seen at the top of the screen in red. The costs incurred during the stage are shown in blue and if in the Water usage view, the water footprint will be shown in green.

The amount of material being used can be updated at any time or can be removed completely from the analysis by selecting that raw material in the *Define materials* user form and setting its amount to zero.

7.4 Defining transport

Transport links can be defined when there is a material to be transported between stages.

To define transport (Figure 6):

1. Click on the relevant transport box either at the top level or in the Production stage; this takes the user to the transport stage screen
2. Click the *Define Transport* button
3. A user form appears asking the user to *select* materials to be transported
4. Select the required material from the list box
5. Click on *Define Transport*. The *Define Transport* user form will then be shown (see Figure 7)
6. Choose the desired database (CCaLC or Ecoinvent)

7. Select the type of transport from the drop-down menu (e.g. *40 t – truck*)
8. Enter the distance travelled into the text box (*note the units required*)
9. Enter the estimated packing density of the material into the text box (if not known – leave as the default value of 1). The packing density is only important for low density products (approx. 300 kg/m³ or less)
10. If a truck has been selected, specify whether it returns back empty and if so, select the check box. Selecting empty return will increase the carbon footprint for a transport option by about 60%
11. Enter the cost of the transport per functional unit (if desired)
12. Select the data quality for the distance specified (*high, medium, low*) to indicate how confident you are in the figure used
13. Click the *Update* button.

The transport table will then be updated with information related to the journey that has just been specified. Information pertaining to transport type, distance, mass transported, carbon footprint for journey and total carbon footprint for the stage as well as any costs are all shown. The database section from where the carbon footprint data were sourced is also displayed.

A journey can be modified through the user form by selecting that journey again and changing the details. The journey can be removed in a similar way by setting the distance travelled to zero.

The methodology for calculating the carbon footprint of transport is given in Appendix 1.

NB Note that the transport within the Production stage is not shown on the top level view. The top level only shows the transport of raw materials into the production stage and then out of the production stage. Therefore, the carbon footprint for the transport within the Production stage is not displayed; however, it is shown in the relevant graphs and can also be viewed via the CF Summary menu option. Transport steps within the Production stage can also be only modified from the relevant production stage rather than from the top-level view.

CCaLC Manual (V3.1)

Back to top level
Define transport
View graph

Functional unit: Red wine 1 bottle
Transport stage: Raw Materials-->Processing

Total carbon footprint for stage: 0.00 kg CO₂ eq./f.u.
Total costs for stage: 0.00 £ /f.u.

Material transported	Transport Type	Distance (km)	Mass transported (kg)	Carbon footprint (kg CO ₂ eq./f.u.)	Empty return trip?	Cost (£)	Database section
			Total:	0.00		Total:	0.00

Transport data currently missing for: Fertiliser, N--> Grape cultivation and harvest Fertiliser, P--> Grape cultivation and harvest Pesticides--> Grape cultivation and harvest sodium hydroxide, 50% in H ₂ O, production mix, at plant--> Wine production and bottling sulphur dioxide, liquid, at plant--> Wine production and bottling kraft paper, unbleached, at plant--> Wine production and bottling packaging glass, green, at plant, Europe--> Wine production and bottling raw cork, at forest road--> Wine production and bottling	<div style="border: 1px solid blue; padding: 5px;"> <p style="margin: 0;">Select material to define transport for:</p> <div style="border: 1px solid gray; padding: 2px; min-height: 100px;"> Fertiliser, N-->Production - Grape cultivation and harvest Fertiliser, P-->Production - Grape cultivation and harvest Pesticides-->Production - Grape cultivation and harvest sodium hydroxide, 50% in H₂O, production mix, at plant-->Production - Wine production and bottling sulphur dioxide, liquid, at plant-->Production - Wine production and bottling kraft paper, unbleached, at plant-->Wine production and bottling packaging glass, green, at plant, Europe-->Wine production and bottling raw cork, at forest road-->Wine production and bottling </div> <div style="text-align: right; margin-top: 5px;"> <input type="button" value="Define Transport"/> </div> <div style="text-align: left; margin-top: 5px;"> <input type="button" value="Exit"/> </div> </div>
--	---

Figure 6 View of the Transport stage and a user form for defining transport

Define transport:

Transport details | Modify transport database | Search database

CCaLC database
 Ecoinvent database
 User database

Transport Type: Distance(km):

Packing density kg/litre:

Empty return trip?

Data quality for amount:

Cost of transport £/f.u.:

Comments on amount used:

Details | Impacts

kg CO₂ eq./kg-km:

Year:

Location:

Source:

Data Quality:

Comments:

Lorry transport; Euro 0, 1, 2, 3, 4 mix ; 22 t total weight, 17.3 t max payload. 85% utilisation ratio. Data from: European Reference Life Cycle Database (ILCD), European Commission - Joint Research Centre, <http://lca.jrc.ec.europa.eu/lcaifohub/datasetArea.vm>

Figure 7 Define Transport user form

7.5 Defining the production stage

The details of the production stages can be defined by specifying each individual production stage in turn (see section 6 for how to navigate in this stage). Once the raw materials have been defined, they will be showing as inputs into the production stages where they are being used. This can be viewed by clicking on Production box from the top level of the tool and then clicking on the individual stage of interest. This takes the user to the tables which show the raw materials input to that stage (see Figure 4).

7.5.1 Defining energy use

Energy use for the production (as well as other life cycle stages) can be defined by clicking the *Define Energy* button. The associated user form is shown in Figure 8.

The energy is defined as follows:

1. Select the required database (CCaLC or Ecoinvent)
2. Select the required energy type from the drop-down menu
3. Enter the amount used in the text box (NB: make sure the correct units are being used)
4. Select the data quality for the amount being specified to indicate how confident you are in the figure used (*high, medium, low*)
5. Enter the cost per unit of energy being used (if needed)
6. Include any relevant comments in the comments box (this is optional but is recommended as a reminder for future uses)
7. Click on the *Update* button.

Figure 8 Define Energy user form

The energy table on the screen will be updated with the relevant information and the carbon footprint and associated cost shown. The database from where the data were selected is also displayed.

7.5.2 Defining land use change

If following the PAS2050 guidelines, land use change relevant to the functional unit that has occurred during the last 20 years must be accounted for in the analysis. Land use change can be defined in any of the production stages as well as in the raw materials stage. The procedure is as follows (see Figure 9):

1. Click the *Define land use change* button in any Production or Raw material stage
2. From the drop-down list, select the country where the land use change has taken place

3. From the drop-down list, select the current land use (*annual cropland, perennial cropland*)
4. From the drop-down list, select the previous land use (*forest land, grassland*)
5. Enter the area of land changed per functional unit (*hectares*)
6. Enter the time the land is used for per functional unit (*years or pro-rata months expressed in years*)
7. Select the data quality for steps 5 and 6 above (*high, medium, low*) to indicate how confident you are in the figures used
8. Click *Update*.

Figure 9 Land use change form

7.5.3 Defining direct emissions

Direct emissions arising from the production as well as storage and use stages can be defined using the *Define stage* button in any of the production stages or the *Define storage/Define use* buttons in the storage and use stages, respectively. The user can define either direct greenhouse gas emissions and/or emissions of other substances that are relevant to other impact categories. Figure 10 and Figure 11 show the appropriate user forms. Direct greenhouse gas emissions can be defined as follows:

1. Select the gas emitted from the list of greenhouse gases
2. Enter the amount
3. Click *Update*.

Define stage: Wheat cultivation

Details | Output | GHG emissions | All emissions

Define greenhouse gas emissions directly emitted from stage:

Greenhouse Gas: CFC-11 Amount (tonne/f.u.): 1e-4

Data quality for amount: Medium Update

Details:

Chemical formula: CCl3F

tonne CO2 eq./tonne GHG: 4750

Figure 10 Defining direct GHG emissions

Other emissions can be defined as follows:

1. Select the medium in which the emissions occur (*air, fresh water, marine water, industrial soil, agricultural soil*)
2. Select the substance emitted
3. Enter the amount emitted
4. Select the data quality (*high, medium, low*) to indicate how confident you are in the amount specified
5. Click *Update*.

Define stage: Wheat cultivation

Details | Output | GHG emissions | All emissions

Emissions to: marine water

Substance: 1,1,1-trichloroethane Amount (tonne/f.u.): 12

Medium Data quality

Update

Details:

Acidification potential (kg SO2 eq./kg)

Eutrophication potential (kg phosphate eq./kg)

Ozone depletion potential (kg R11 eq./kg)

Photochemical (summer) smog (kg ethene eq./kg)

Human Toxicity Potential (kg DCB eq./kg) 9.65E+00

Global warming potential (kg CO2 eq./kg)

Figure 11 Defining other direct emissions

7.5.4 Defining packaging use

Packaging use for the production stage as well as any other stage can be defined by clicking the *Define Packaging* button in raw material stage. The associated user form is shown in Figure 12. Four databases exist for packaging: CCaLC food/drink, CCaLC other, Ecoinvent and User-defined.

Packaging can be defined as follows (Figure 12):

1. Select the required database (CCaLC food/drink; CCaLC other; Ecoinvent; User-defined)
2. Select the required packaging type from the drop-down menu
3. Select the processing stage for packaging from the drop-down menu
4. Select whether the packaging is required for raw material or for products Enter the amount used in the text box
5. Select the data quality of the amount being specified (*high, medium, low*) to indicate how confident you are in the figure used
6. Enter the cost per unit of packaging (if needed)
7. Include any relevant comments in the comments box (as a reminder for any future uses)
8. Click on the *Update* button.

The packaging table for the stage is then populated. Packaging types can be modified or removed from the analysis by selecting the packaging type and changing the details or setting the mass to zero, respectively.

Figure 12 Define Packaging user form

7.5.5 Defining waste

Waste use for the production as well as the other stages can be defined using the same procedure as for defining materials, energy or packaging. The user form is similar to those used for other life cycle stages and is shown in Figure 13.

The procedure for defining waste is as follows:

1. Select the required database (CCaLC, Ecoinvent or User-defined)
2. Select the required waste type from the drop-down menu
3. Enter the amount of waste in the text box
4. Select the data quality of the amount being used (*high, medium, low*) to indicate how confident you are in the figure used
5. Enter the cost of the waste per unit mass (if needed)
6. Include any relevant comments in the comments box (as a reminder for future uses)
7. Click on the *Update* button.

Figure 13 Define waste user form

7.5.6 Linking waste to raw materials

Waste can be linked to raw materials to allow the user to update automatically the amount of raw materials used when the amount of waste at a particular stage is changed (e.g. due to efficiency improvements). This feature is useful if a large number of raw materials are being used as it saves having to go back and update them manually if the waste amount changes.

To use this feature:

- click on the *Link waste* tab on the Waste user form (see Figure 14a). Two text boxes are shown on the form. The top box shows the list of waste streams used at this stage of the analysis that can be linked to materials used at that stage. The bottom box shows the list of materials that are currently linked.
- click on the *Modify material links* button to link a raw material to waste. This brings up a separate user-form that allows the user to create and remove links using the appropriate buttons (Figure 14b). The top box in this user form shows raw materials used at this stage and the bottom box shows the existing material links for the waste stream selected. In this case *Wheat – UK* is the only material available to link.

a) Link waste tab

b) Create/delete links form

Figure 14 Link waste forms

The user will not initially see any effects of material linking. However, if the amount of waste being used is changed, then the raw materials linked to it will be updated to reflect

that change. For instance, if the amount of waste at this stage was 0.1 kg when the material was linked, and it was increased to 0.2 kg, the amount of raw material, in this case *Wheat UK*, would be increased by 0.1 kg.

If multiple materials are linked to a waste stream, then the amounts are adjusted in proportion to the ratio of their use. For instance:

If three materials are linked to one waste stream:

Landfill Municipal = 1 kg

Material 1 = 4 kg

Material 2 = 4 kg

Material 3 = 2 kg

Then, increasing the amount of waste would have the following effect:

Landfill Municipal = 2 kg

Material 1 = 4 kg + 0.4 kg = 4.4 kg

Material 2 = 4 kg + 0.4 kg = 4.4 kg

Material 3 = 2 kg + 0.2 kg = 2.2 kg

7.5.7 Defining production stage outputs

Outputs from the production stages as well as storage can be defined in terms of mass or energy flows.

To define outputs from a stage:

1. Click on the *Define stage* button to bring up the user form (Figure 15)
2. Select the *Output* tab
3. Decide whether to define a product or a co-product (note that a product must be defined; defining co-products is optional, depending on the system being studied)
4. Type the name of the output flow into the drop down box provided (the material can be selected later on as well as its mass changed). **NB: Each output flow or co-product must have a different name even if they go through stages unchanged – this is to allow the system to distinguish between the flows in different stages**
5. If appropriate, select the destination stage for product mass flow. **NB: The product can be treated as either an intermediate product and sent on to another production stage (or storage or use) or a final product if sent to the use stage. Co-products do not have a destination as they are assumed to leave the system at that point, but they may be used for the purposes of allocation (see section 7.7.4). Energy outputs do not have a destination either and co-products defined as energy outputs may be used for the purposes of economic or energy allocation (see section 7.7.4).**
6. Add the amount of output to the text box
7. Add the value of the output (in desired)

8. If you wish to perform energy allocation at a later point, define the Lower Heating Value of any mass outputs; similarly, if you wish to perform economic allocation, the costs/values of all products and co-products must be defined
9. Click the *Update* button.

Once a mass output has been created, it will show up in the relevant transport stage as well as in the material inputs table of the appropriate stage (production, storage or use).

Define stage: Wheat cultivation

Details | **Output** | GHG emissions | All emissions

Modify existing output streams or create new streams:

Product

Output:

Define product in terms of mass or energy:

Mass Energy

Destination:

Amount (tonne/f.u.)

Value (£/tonne)

Co-product

Output:

Define co-product in terms of mass or energy:

Mass Energy

Amount (tonne/f.u.)

Value (£/tonne)

Energy allocation

If it is intended to perform energy allocation, then enter the lower heating value of the product or co-product here.

Lower heating value (MJ/kg)

Figure 15 Output tab on the Define stage user form

Note that it may be necessary to create a mass output from a stage for two reasons:

1. Transport can only be defined if there is a material flow between stages
2. Each stage is mass-balanced. Material outputs show up as a mass input at its destination stage. However, mass-balances are shown for information only and will not stop the tool from working.

7.6 Defining the storage stage

The storage stage is defined in a similar way to the production stage – see section Defining the production stage

7.7 Defining the use stage

Several features of the use stage make it a unique stage within the analysis. These are described below.

7.7.1 Defining appliance use

Often during the use phase of a product, it is necessary to use an appliance (e.g. for food preparation or laundry washing). To aid these analyses, the CCaLC tool contains databases for refrigeration, washing machines and ovens.

Appliance use can be defined as follows (Figure 16):

1. Click the *Define use* button
2. Select the appropriate database (*Fridges/Freezers, Washing machines/Dryers, Electric Ovens/Others*)
3. Select the appropriate appliance
4. Enter the appropriate data regarding *storage time, volume, cooking time* etc.
5. Select the data quality (*high, medium, low*) to indicate the level of confidence in the amount specified
6. Enter the carbon footprint per unit energy (*The default value is for the UK grid. Other values can be found in the energy database if needed*).
7. Enter the cost of the energy (if needed)
8. Click Update.

Figure 16 Appliances user form

7.7.2 Defining biogenic carbon storage/uptake in products

The impact on the carbon footprint of biogenic carbon storage or carbon uptake in products can be accounted for in CCaLC. The impact of this reflects the weighted average time of storage during a 100-year assessment period. Two carbon storage cases may be defined:

- a specific case of biogenic carbon storage following product formation; and
- a general case of biogenic carbon storage or carbon uptake.

For a specific case where the carbon storage benefit of a product exists between 2 and 25 years after product formation (and no carbon storage benefit exists after that time), the weighting factor applied is as follows:

$$\text{Weighting factor} = (0.76 \times t_0)/100$$

where t_0 is the number of years the full carbon storage benefit of the product exists following its formation.

For a general case, the weighting factor to be applied to the CO₂ storage benefit over the 100-year assessment period is calculated as follows:

$$\text{Weighting factor} = \sum_{i=1}^{i=100} x_i \div 100$$

where i is each year in which storage occurs and x is the proportion of total storage remaining in any year i .

For further descriptions of these calculation methods, see PAS2050, Annex C.

Carbon storage can be defined in CCaLC as follows (Figure 17):

1. Choose either a specific or a general case
2. If a specific case, select a storage time from the drop down list
3. If a general case, calculate a weighting factor using the methodology in the PAS2050
4. Enter the amount of carbon stored
5. Select the data quality (*high, medium, low*) to indicate the confidence level in the amount specified
6. Click *Update*.

The amount of carbon stored will be shown on the use stage worksheet and the total deducted from the carbon footprint at that stage.

Figure 17 Carbon storage

7.7.3 Defining carbon release from product disposal

In cases where the disposal of a product is not immediate, it may be appropriate to apply a weighting factor to the carbon footprint of the waste stream in order to account for carbon stored up to that point. Two end-of-life scenarios can be defined:

- a specific case for a delayed single release and
- a general case for a delayed release.

For a specific case where the disposal of a product occurs between 2 and 25 years after product formation, the weighting factor applied is as follows:

$$\text{Weighting factor} = (100 - (0.76 \times t_0)) / 100$$

where t_0 is the number of years between product formation and the single release of emissions.

For a general case where releases may not occur singularly, the methodology used is as follows:

$$\text{Weighting factor} = \sum_{i=1}^{i=100} x_i (100-i) \div 100$$

where i is each year in which emissions occur and x is the proportion of total emissions occurring in any one year i . The methodology for this calculation is given in PAS2050 Annex B.

The product's end of life can be defined as follows (Figure 18):

1. Choose whether a specific or general case is being modelled
2. If a specific case, select the time to disposal from the drop down list
3. If a general case, calculate a weighting factor as described in PAS2050 and enter it in the text box
4. Select the required database (CCaLC, Ecoinvent or User-defined)
5. Select the appropriate disposal waste stream from the drop down list
6. Enter the product mass
7. Enter the cost of disposal per unit mass (if needed)
8. Select the data quality (*high, medium, low*) to indicate the confidence level for the amount specified
9. Click *Update*.

Define carbon release from product disposal:

Emissions due to final disposal of a product can be calculated for specific cases (single release) or general cases (prolonged releases). See PAS2050, Annex B.1 for details. For specific cases, the user must specify the number of years between the formation of the product and the release date. For general cases, the user must calculate a weighting factor using the methodology in the PAS.

Specific case (single release)
 General case (delayed release)

Time to emission (years): Weighting factor:

Select waste stream for disposal method:
 CCaLC database Ecoinvent database User database

Data quality: Product mass (tonne): Cost per unit mass (£):

Details

CO2 eq. (kg/kg):

Year:

Location:

Source:

Data Quality:

Comments:

Waste incineration of paper fraction in municipal solid waste (MSW); average European waste-to-energy plant, without collection, transport and pre-treatment; at plant; Data from: European Reference Life Cycle Database (ILCD), European Commission - Joint Research Centre, <http://lca.jrc.ec.europa.eu/lcaifohub/datasetArea.vm>

Figure 18 End of product's life user form

7.7.4 Co-product systems: System expansion and allocation

In co-product systems it is often necessary to calculate the carbon footprint of each co-product. Within CCaLC, this can be carried out in two ways:

- by system expansion and
- by allocation (mass, energy and economic basis).

NB: The results of either system expansion or allocation are shown at the top level and not at individual stages.

To perform system expansion or allocation, click the *System expansion/allocation* button at a Production stage where co-products are produced. It is then possible to choose between system expansion and allocation by clicking on the appropriate buttons at the top of the tool. Note that, to be able to perform either operation, the co-products must first be defined (by clicking on *Define stage* and specifying co-product details; see section 7.5.7).

- System expansion

System expansion is performed by selecting a product/service that the co-product can substitute. The CCaLC tool then subtracts the carbon footprint of this substitute product/service from the carbon footprint of the whole system.

System expansion is carried out in CCaLC as follows:

1. Click on the *Perform system expansion* button
2. Select the required database (CCaLC, Ecoinvent or User-defined)
3. Select a co-product from the dialogue box that pops up; this brings up the *System Expansion* user form shown in Figure 19
4. Select a material or energy from one of the available databases
5. Enter the amount of product
6. Select the data quality (*high, medium, low*) to indicate the confidence level for the amount specified
7. Click *Update*.

The data tables are then updated and the amount to be subtracted from the carbon footprint of the whole system is shown.

- Allocation

Allocation can be carried out using mass, energy or economic basis. Allocation can be carried out in CCaLC as follows:

1. Click on the *Perform allocation* button; this brings up the user form shown in Figure 20
2. Select either *Mass, Energy or Economic* radio button (NB: PAS2050 requires economic allocation)
3. Click *Update* (NB: allocation can be deleted by setting the value in the Allocation text box to zero)

The allocation tables are then updated to show the allocation results. Note that to perform economic or energy allocation, all cost and energy data should be specified for all the products and co-products.

System expansion:

System expansion may be performed by selecting a product (material or energy type), the function of which the Co-product displaces. See PAS2050 section 8.1.1 for further details.
The displaced product may be selected from the current database:

Select database: CCaLC Ecoinvent User-defined

Metals

Select displaced product:
Aluminium extrusion

Amount of product displaced (tonne/f.u.)
1

Data quality for amount:
Medium

Details

CO2 eq.(tonne/tonne) 2.45E+00

Year: 2005

Location: Europe

Source: ILCD

Data Quality: High

Comments on data set:

Aluminium extrusion profile; primary production; production mix, at plant; aluminium semi-finished extrusion product, including primary production, transformation and recycling. The used average recycling rate is 88% for aluminium extruded products. Data from: European Reference Life Cycle Database (ILCD), European Commission - Joint Research Centre,

Update Exit

Figure 19 System expansion user form

Co-product allocation:

Select co-product:
Straw

Allocation method:
 Mass Economic Energy

Allocation (tonne CO2 eq./unit of co-product)
1.86E-01

Update

Exit

Figure 20 Allocation user form

8 Viewing carbon footprint data and results

8.1 Numerical display

Numerical carbon footprint results are displayed in red font throughout the tool. The units are expressed as *mass* per functional unit (f.u.) where *mass* is the unit specified by the user (e.g. kg, tonne, g).

Note the following:

- The total carbon footprint for the whole system is shown at the bottom of the screen on the top level of the tool
- The carbon footprint for the Raw materials, Production, Storage and Use stages is shown above the relevant box on the top level of the tool
- The breakdown of the carbon footprint for each stage can be seen in the tables by clicking on the relevant stage
- The carbon footprint of a particular material, energy, packaging, waste or transport type can be viewed in the relevant user form by clicking on Define material, energy etc.

8.2 Graphical display

Graphs showing carbon footprint results can be viewed by clicking the button *View graph of carbon footprint* at the top level of the tool. An example is shown in Figure 21.

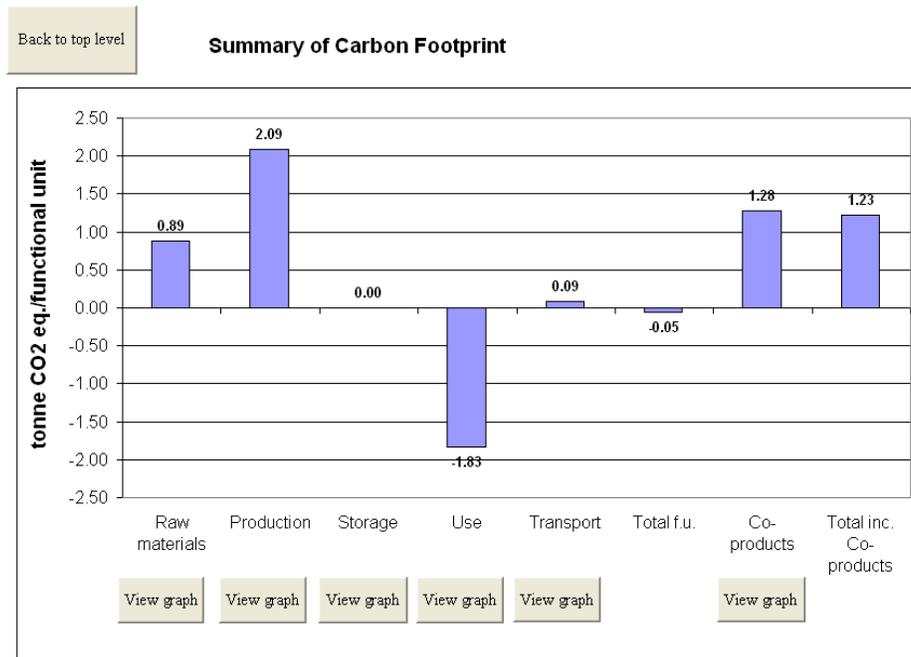


Figure 21 Graphical view of carbon footprint results at the top level of the tool

In addition, carbon footprint graphs can be viewed at each life cycle stage by clicking on the *View carbon footprint graph* button. This brings up a graph which allows drilling down

to see the breakdown of each material, production stage, etc. (see the example for the Production stage in Figure 22).

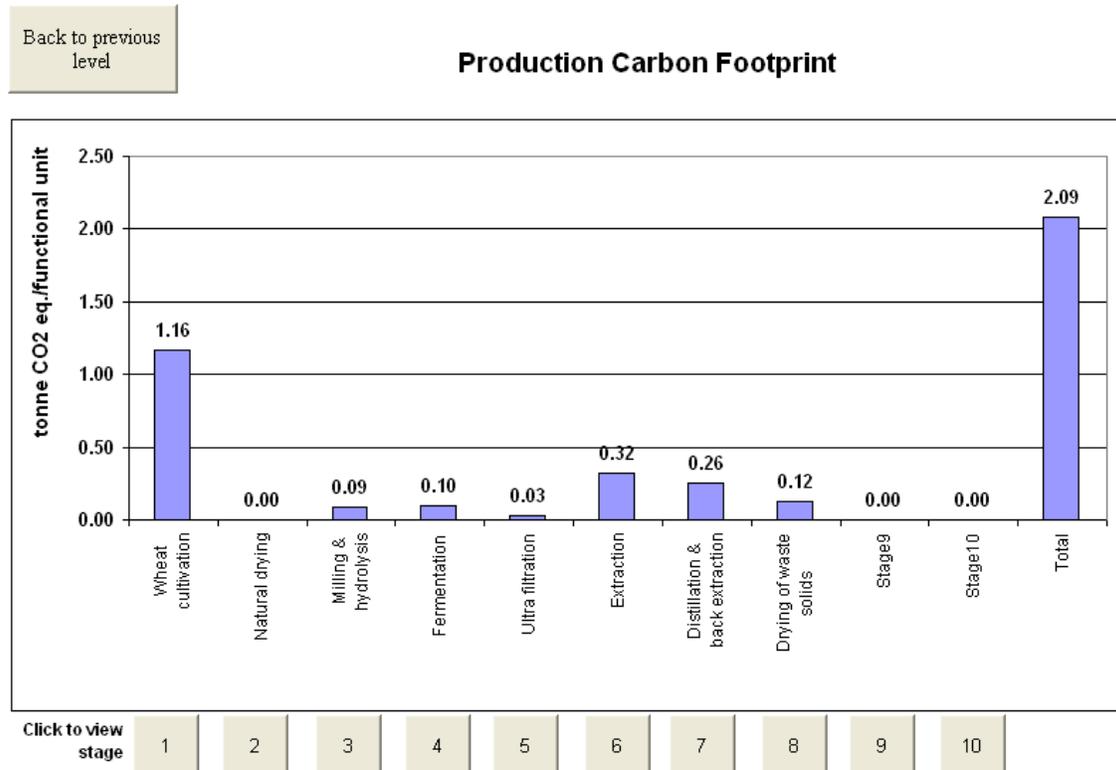


Figure 22 Carbon footprint for production stages

9 Modifying user carbon footprint databases

User-defined data can be added, modified and deleted, as explained below. The databases that come with the tool cannot be deleted or changed in any way.

9.1 Creating a new user database item

User data can be added in the CCaLC tool. This can be done for any of the following: materials, energy, packaging, waste and transport.

New data item can be created by:

- Selecting the *Modify Database* tab on the appropriate user form (see Figure 23 for a Raw materials example – to get there, click on the *Raw Materials* box from the top level view, then on the *Define Materials* button at the top of the screen and then on the *Modify Database* tab; the same applies for all other databases, i.e. energy, waste, packaging and transport)
- Clicking the *Create new item* button
- Filling in the appropriate fields in the resulting user form (see Figure 24).

Once created, the item will be shown in the relevant database.

NB:

- It is not possible to create a data item with a name that already exists in the database. Similarly, once created, the name of the user data item cannot be changed. If a name change is required, the user is advised to delete the item and then recreate it.
- The user-defined data can be found under the *User defined* database (see Figure 25).

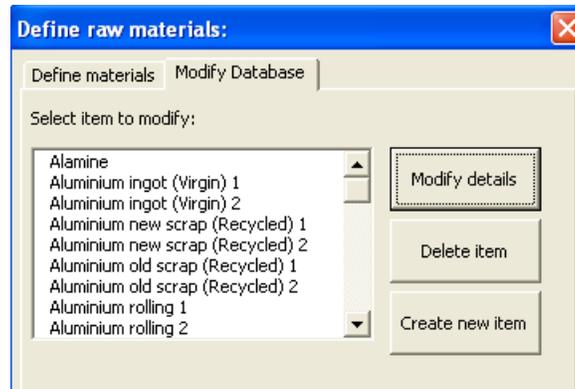


Figure 23 Modify database tab (for the Raw materials stage)

The screenshot shows a window titled "Create new database record:" with a close button in the top right. It has a "Details" section. The fields are: Name (text box), Carbon footprint (kg carbon dioxide eq./kg) (text box with value 0), Acidification potential (kg sulphur dioxide eq./kg) (text box), Eutrophication potential (kg phosphate eq./kg) (text box), Ozone layer depletion potential (kg R11 eq./kg) (text box), Photochemical smog potential (kg ethene eq./kg) (text box), Human toxicity potential (kg dichlorobenzene eq./kg) (text box), Year (text box), Location (text box), Source (text box), Data Quality (dropdown menu with "High" selected), and Comments (text area). At the bottom are two buttons: "Update database" and "Cancel".

Figure 24 Create new item form

Figure 25 Materials database: user-defined data items are placed in the *User defined* database

9.2 Modifying an existing user database item

To modify a user-created data item:

- Click on the button *Define ...* (e.g. *Modify Materials*)
- Click on the *Modify Database* button; this will show a list of the existing user-created items
- Select the item to be modified and then click on the *Modify Details* button; this brings up the form with the details for that item (see Figure 26)
- Change the details as desired and then press the *Update database* button.

Figure 26 Modify details for an existing user data item

9.3 Deleting a user database item

To delete a user-created data item:

- Click on the button *Define ...* (e.g. *Modify Materials*)
- Click on the *Delete Database* button
- Select the item to be modified; this brings up a warning on whether the user wants to delete the item
- Click Yes to update the database.

NB: Database items that are in use in the study active at the time of the attempted deletion cannot be deleted. The databases that come with the tool cannot be deleted either.

10 Carbon footprint data quality assessment

Throughout the tool, the user is required to specify the data quality for the information they are inputting. Data quality is expressed as either high, medium or low quality. Data

quality is specified at two instances: for the whole data set and for the amount being specified by the user.

The data quality for a data set is specified when the data set is created and is not subject to alteration during the analysis. Data quality of the data sets supplied within the tool will largely be high, as they are from trusted sources. For user defined data sets, the user can specify the data quality when they create it.

The data quality for the amount of material, energy, travel distance etc. specified by the user has to be specified each time the user adds a new datum to the analysis. The user is required to make a judgment as to how reliable they believe their data are. For instance, if a transport distance is known then the user might choose *high* quality of data; however, if the distance is only guessed at or generic, then the data quality for this datum will be low.

The overall data quality assessment is made by weighting each data point by its contribution to the total carbon footprint. A full description of the data quality model is given in Appendix 2.

To examine the data quality for the analysis, click on the *View data quality assessment* button the top level of the tool. This brings up the data quality assessment sheet (Figure 27) which shows the overall data quality for the analysis as well as the data quality for each individual stage.

Back to top level

Overall data quality: **Medium**

Data quality by stage:

Stage	Data quality
Raw materials	High
Co-products	High
Processing stages	
Wheat cultivation	Low
Natural drying	
Milling & hydrolysis	High
Drying of animal feed	
Fermentation	High
Ultra filtration	High
Extraction	High
Distillation & back extraction	High
Drying of waste solids	High
Stage10	
Average Processing	Medium
Storage	
Use	High
Transport stages	
Raw Materials-->Processing	
Wheat cultivation-->Natural	
Natural drying-->Milling & hydrolysis	High
Milling & hydrolysis-->Drying of	

Figure 27 (Partial) View of data quality assessment screen

11 Loading, saving, deleting or starting a new carbon footprint study

An existing carbon footprinting study can be loaded, saved or deleted by using the *CF study* menu option from the CCaLC menu at the top of the screen (see Figure 28). A new study can also be started by using the same menu option.

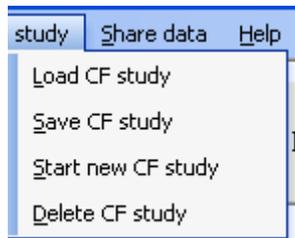


Figure 28 CF study menu options

11.1 Loading an analysis

An existing analysis can be loaded by selecting *Load CF Study* from the *CF Study* menu option. The user can then select from a range of either CCaLC or user-defined studies (see Figure 29). Note that user-defined studies can be found under the User-defined section.

NB: Loading a a CF study will overwrite any data currently being used. Therefore, users are advised to save their analysis before loading another one.

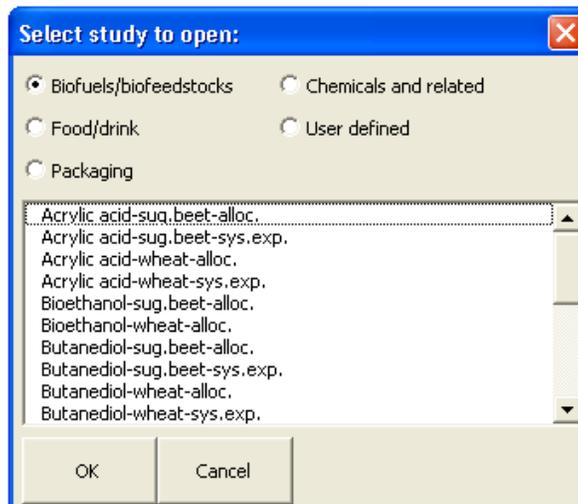


Figure 29 Load CF study user form

11.2 Saving an analysis

To save a study, select *Save CF Study* from the *CF Study* menu option and type a (unique) name into the drop down box. Alternatively, select a previously saved study to overwrite it with new results.

Note: Saving a study saves the specific analysis but it does not save the CCaLC tool. To do the latter, use the Excel File/Save menu. It is recommended that the user saves the CCaLC tool on a regular basis under a different name/names to avoid losing data.

11.3 Starting a new study

A new study can be started by selecting the *Start new CF study* item from the *CF Study* menu. The user will be asked if they are sure they want to start a new study and will then be given the option of saving the existing study first.

11.4 Deleting an analysis

To delete an existing analysis, select the *Delete CF study* option from the *CF Study* menu. This brings up the list of the user-defined studies that can be deleted. Select the appropriate study and click the *Delete* button to delete the study. If no studies are listed, that means that there are no user-defined studies and therefore the deletion is not possible.

12 Carbon footprint summary

A summary of the results of a carbon footprint study can be obtained via the *CF Summary/View CF Summary* menu option. This takes the user to a page with tables and graphs that summarise the analysis (Figure 30). The summary can be printed out by selecting *Print summary* from the *CF Summary* menu option.

An inventory of the materials, energy and packaging used in the analysis can be viewed by selecting the *CF Summary/View Inventory menu*. A partial view of the tables is shown in Figure 31.

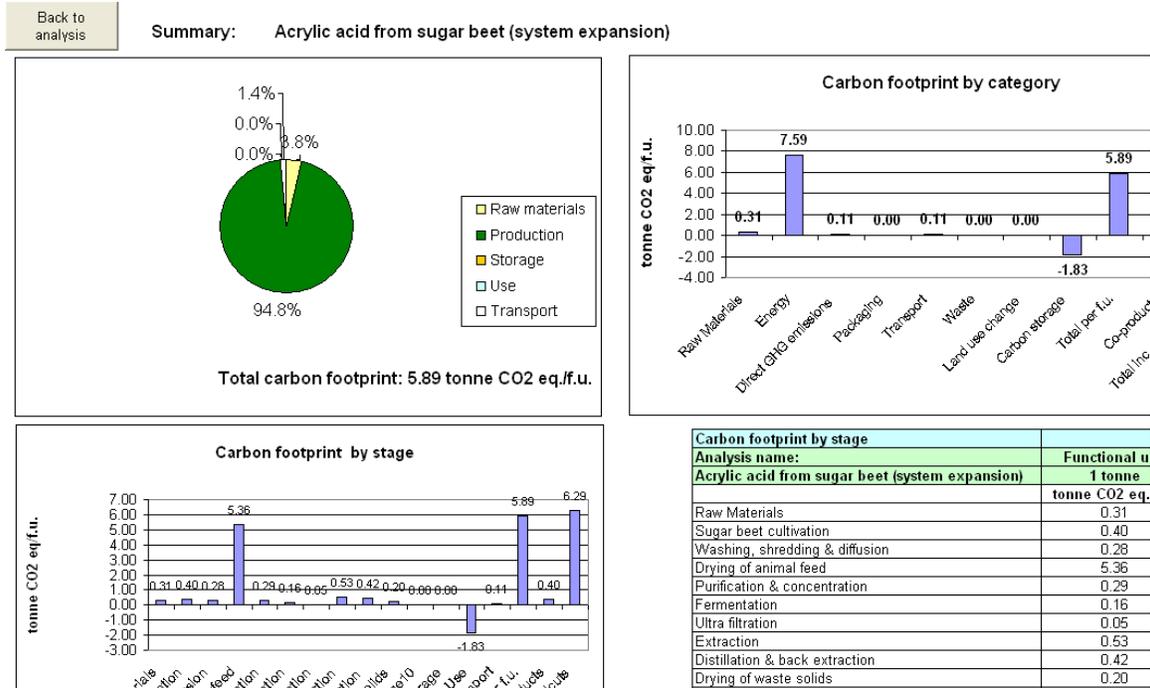


Figure 30 (Partial) View of the summary screen

Back to top level

Print inventory

Inventory analysis:

Acrylic acid

1 tonne

Raw materials:	Amount (tonne)	Stage:	Database section
Farm yard manure/slurry	1.77	Wheat cultivation	CCaLC/Materials/Biofuels/agriculture
K Fertiliser	0.02	Wheat cultivation	CCaLC/Materials/Biofuels/agriculture
N Fertiliser	0.11	Wheat cultivation	CCaLC/Materials/Biofuels/agriculture
P Fertiliser	0.02	Wheat cultivation	CCaLC/Materials/Biofuels/agriculture
Pesticides	5.40E-04	Wheat cultivation	CCaLC/Materials/Biofuels/agriculture
Seeds - Wheat	0.10	Wheat cultivation	CCaLC/Materials/Biofuels/agriculture
Diammonium phosphate (21% conc.)	0.04	Fermentation	CCaLC/Materials/Chemicals
Alamine	0.01	Extraction	CCaLC/Materials/Chemicals
Octanol	0.01	Extraction	CCaLC/Materials/Chemicals

Energy:	Amount (MJ)	Stage:	Database section
Diesel (used in farm machinery)	4,540.70	Wheat cultivation	CCaLC/Energy
Electricity-CHP-5	510.93	Milling & hydrolysis	CCaLC/Energy
Heat-CHP-5	1,626.06	Milling & hydrolysis	CCaLC/Energy
Electricity-CHP-5	1,410.48	Fermentation	CCaLC/Energy

Figure 31 (Partial) View of the inventory screen

13 Data comparison

Up to four analyses can be compared for either carbon footprint, water footprint, other environmental impacts or value added. This can be carried out via the *Comparison* menu and choosing the appropriate option (carbon footprint, water footprint, all impacts or value added).

To compare the alternative/different systems:

- Click the *Comparison/Appropriate option* from the CCaLC menu option; this takes the user to the appropriate tables (see Figure 32 showing an example for the carbon footprint)
- If any data are shown in the tables that are not part of the desired comparison analysis, click the *Clear data* button; this will delete any previous data that the user does not wish to consider
- Click the *Add current analysis* button, to add the data from the current analysis; if there were no other data in the tables, the data will be added to the first table; otherwise, the data will be added to the next empty table
- If all four tables are populated by data, the user will be given a choice as to where they would like new comparison added.

A graphical comparison of the data in the tables can be viewed by clicking on the *View graphs* button at the top of the sheet.

Back to top level		Add current analysis		View graphs	
-------------------	--	----------------------	--	-------------	--

1	Functional unit	Clear data	2	Functional unit	Clear data
Acrylic acid from sugar beet (system expansion)	1 tonne				
	tonne CO2 eq./f.u.				
Raw Materials	0.31				
Sugar beet cultivation	0.40				
Washing, shredding & diffusion	0.28				
Drying of animal feed	5.36				
Purification & concentration	0.29				
Fermentation	0.16				
Ultra filtration	0.05				
Extraction	0.53				
Distillation & back extraction	0.42				
Drying of waste solids	0.20				
Stage 10	0.00				
Storage	0.00				
Use	-1.83				
Transport	0.11				
Total inc. Co-products	6.29		Total inc. Co-products		
Co-products	0.40		Co-products		
Total per f.u.	5.89		Total per f.u.		

Raw Materials	0.31
Energy	7.59
Direct GHG emissions	0.11
Packaging	0.00
Transport	0.11
Waste	0.00
Land use change	0.00
Stored carbon	-1.83
Total inc. Co-products	6.29
Co-products	0.40
Total per f.u.	5.89

Raw Materials	
Energy	
Direct GHG emissions	
Packaging	
Transport	
Waste	
Land use change	
Stored carbon	
Total inc. Co-products	
Co-products	
Total per f.u.	

Figure 32 (Partial) View of the carbon footprint comparison sheet

14 Sharing user-created studies and results between users

14.1 Importing and exporting studies

User-created studies can be shared between users via the CCaLC menu option *Share data*.

To export studies, choose the *Export study* option. This brings up a form shown (Figure 33) that allows the user to select an analysis that has already been saved and then export it. This action will create a new excel file entitled *CCaLC_xxxx.xls* which the user can then re-name as required and then save. This file contains all of the analyses exported, along with any additions made to the database.

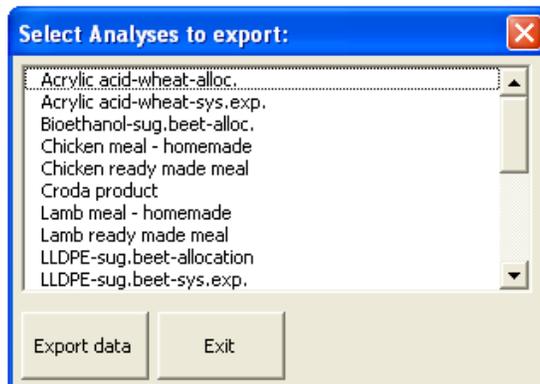


Figure 33 Study export form

To import a previously created analysis, the user should select the *Share data/Import* menu item. This then prompts the user to locate the previously created *CCaLC_xxxx.xls* (or user renamed) file in the desired directory. Once this is done, the user will be offered a choice of saved analyses to import (Figure 34). Multiple analyses can be selected at the same time.

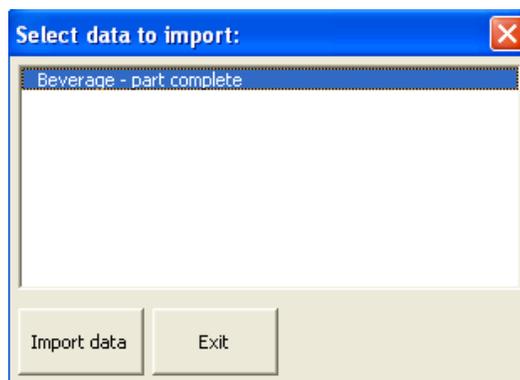


Figure 34 Data import form

Selecting one or more analyses from the list and clicking *Import data* will import the selected analyses to the tool and update the database accordingly. Imported analyses can then be examined using the *Load CF Study* menu item (section 11.1).

Note: In order for any of the import/export functions to work, the CCaLC tool must be the first and only excel workbook open. If this is not the case, the user will be prompted to close any other open excel files.

14.2 Exporting comparisons

Data from any comparisons made using the *Compare* menus can be exported using the *Share data/Export comparisons* menu. This creates a new workbook *Comparison export.xls*. This workbook contains all the comparison data as well as the appropriate graphs and can be modified by the user as any other Excel file.

14.3 Exporting graphs

Graphs from the analysis can be exported using the *Share data/Export graphs* menu. This creates a new workbook *Graph_export.xls* (which can be renamed) which contains all the graphs from the analysis. This function enables the user to change the graphs and the related data as they wish.

15 Importing data sets

15.1 Importing data using the CCaLC template

The CCaLC data template can be used to import large amounts of data into the tool. It is more efficient than entering data individually through the user-forms.

To import data via the CCaLC import template, click on the *Data Import/CCaLC Template* menu option at the top of the screen. This brings up the CCaLC template shown in Figure 35. The user has to enter into the template the relevant data for the data sets in question, including which section of the database it is destined for (e.g. material, energy etc.). Instructions for filling out the form correctly are shown at the top of the screen. Note that an entry must be completed (i.e. the cursor must be outside a cell) for the function buttons to work.

Once the fields have been filled out correctly, the user should click the *Import data* button at the top of the screen. If any of the requisite fields are not filled out correctly, the user will receive a warning and the data will not be imported.

Once imported, the data are then available for use in the tool. Data can be cleared from the table by clicking on the *Clear data* button.

Type Of Flow	Classification	Flow	Resulting amount	Mean amount	Data source type	Data derivation
Waste flow	Wastes / Radioactive waste	calcium fluoride, reactor fuel assembly supply, production mix, at plant, low radioactive	2.20106226324413E-5 kg (Mass)	2.20106226324413E-5	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Construction waste	demolition waste (unspecified)	0.0679308498842009 kg (Mass)	0.0679308498842009	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Radioactive waste	highly radioactive waste, reactor fuel assembly supply, production mix, at plant	6.52730098528985E-5 kg (Mass)	6.52730098528985E-5	Mixed primary / secondary	Calculated
Waste flow	Wastes / Radioactive waste	medium and low radioactive wastes, reactor fuel assembly supply, production mix, at plant	7.74979105662954E-5 kg (Mass)	7.74979105662954E-5	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Mining waste	mineral treatment residue (unspecified)	0.769837538922118 kg (Mass)	0.769837538922118	Mixed primary / secondary	Calculated
Waste flow	Wastes / Mining waste	overburden (unspecified)	60.9814258978428 kg (Mass)	60.9814258978428	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Radioactive waste	plutonium as residual product, reactor fuel assembly, reprocessing, production mix, at plant	1.3065730972222E-7 kg (Mass)	1.3065730972222E-7	Mixed primary / secondary	Calculated
Waste flow	Wastes / Radioactive waste	radioactive tailings, reactor fuel assembly supply, production mix, at plant	0.0385777813826348 kg (Mass)	0.0385777813826348	Mixed primary / secondary	Calculated
Waste flow	Wastes / Production residues	slag (unspecified)	60.8516210488477 kg (Mass)	60.8516210488477	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Radioactive waste	slag (uranium conversion), reactor fuel assembly supply, production mix, at plant	0.000130461961486889 kg (Mass)	0.000130461961486889	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Mining waste	tailings (unspecified)	-0.523239899438182 kg (Mass)	-0.523239899438182	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Radioactive waste	unspecified radioactive waste, reactor fuel assembly supply, production mix, at plant	0.000129955472531183 kg (Mass)	0.000129955472531183	Mixed primary / secondary	Unknown der
Waste flow	Wastes / Radioactive waste	uranium depleted, reactor fuel assembly supply, production mix, at plant	0.000150894745392729 kg (Mass)	0.000150894745392729	Mixed primary / secondary	Unknown der
Elementary flow	Emissions / Emissions to water / Emissions to fresh water	1,2-dibromoethane	-4.03992098145005E-13 kg (Mass)	-4.03992098145005E-13	Mixed primary / secondary	Unknown der
Elementary flow	Emissions / Emissions to water / Emissions to fresh water	1,2-dichloropropane	9.04230969261067E-15 kg (Mass)	9.04230969261067E-15	Mixed primary / secondary	Unknown der

Figure 36 (Partial) View of ILCD HTML file with data to be imported highlighted

Name of dataset:	Amount (either kg/MJ/kg.km):
	1

Type Of Flow:	Classification:	Flow:	Resulting amount:	Mean amount:		
Waste flow	Exchange of matter / Wastes / Radioactive waste	calcium fluoride; reactor fuel assembly supply, production mix, at plant, low radioactive	2.20106226324413E-5 kg (Mass)	2.20E-05	Mixed pr	
Waste flow	Exchange of matter / Wastes / Construction waste	demolition waste (unspecified)	0.0679308498842009 kg (Mass)	0.06793085	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	highly radioactive waste; reactor fuel assembly supply, production mix, at plant	6.52730098528985E-5 kg (Mass)	6.53E-05	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	medium and low radioactive wastes; reactor fuel assembly supply, production mix, at plant	7.74979105662954E-5 kg (Mass)	7.75E-05	Mixed pr	
Waste flow	Exchange of matter / Wastes / Mining waste	mineral treatment residue (unspecified)	0.769837538922118 kg (Mass)	0.769837539	Mixed pr	
Waste flow	Exchange of matter / Wastes / Mining waste	overburden (unspecified)	60.9814258978428 kg (Mass)	60.9814259	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	plutonium as residual product, reactor fuel assembly, reprocessing, production mix, at plant	1.3065730972222E-7 kg (Mass)	1.31E-07	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	radioactive tailings; reactor fuel assembly supply, production mix, at plant	0.0385777813826348 kg (Mass)	0.038577781	Mixed pr	
Waste flow	Exchange of matter / Wastes / Production residues	slag (unspecified)	60.8516210488477 kg (Mass)	60.85162105	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	slag (uranium conversion); reactor fuel assembly supply, production mix, at plant	0.000130461961486889 kg (Mass)	0.000130462	Mixed pr	
Waste flow	Exchange of matter / Wastes / Mining waste	tailings (unspecified)	-0.523239899438182 kg (Mass)	-0.523239899	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	unspecified radioactive waste; reactor fuel assembly supply, production mix, at plant	0.000129955472531183 kg (Mass)	0.000129955	Mixed pr	
Waste flow	Exchange of matter / Wastes / Radioactive waste	uranium depleted; reactor fuel assembly supply, production mix, at plant	0.000150894745392729 kg (Mass)	0.000150894	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to water / Emissions to fresh water	1,2-dibromoethane	-4.03992098145005E-13 kg (Mass)	-4.03992098145005E-13	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to water / Emissions to fresh water	1,2-dichloropropane	9.04230969261067E-15 kg (Mass)	9.04230969261067E-15	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to air / Emissions to air, unspecified	1,3,5-trimethylbenzene	2.73237164934572E-12 kg (Mass)	2.73237164934572E-12	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to air / Emissions to air, unspecified	2,3,7,8-tetrachlorodibenzo-p-dioxin	9.22153158223463E-11 kg (Mass)	9.22153158223463E-11	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to water / Emissions to fresh water	2,3,7,8-tetrachlorodibenzo-p-dioxin	4.51832871582608E-20 kg (Mass)	4.51832871582608E-20	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to water / Emissions to fresh water	acenaphthene	1.0833504699448E-9 kg (Mass)	1.0833504699448E-9	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to water / Emissions to sea water	acenaphthene	3.65233381550003E-8 kg (Mass)	3.65233381550003E-8	Mixed pr	
Elementary flow	Exchange of matter / Emissions / Emissions to water / Emissions to sea water	acenaphthylene	1.38803926557046E-8 kg (Mass)	1.38803926557046E-8	Mixed pr	

Figure 37 ILCD import template page after pasting the data and removing hyperlinks

16 Calculating water usage and water footprint

In addition to the carbon footprint, it is possible to estimate the impacts from water usage. Two values are estimated:

- water usage; and
- water footprints.

The former represents a simple sum of the total water usage in the life cycle of the product and the latter follows the methodology proposed by Pfister et al. (2009). The methodology used for water-related estimations is explained in Appendix 3.

The database containing the water usage data is different to that containing the main environmental impact data and the water-footprint is calculated in a separate area of the tool.

16.1 Switching between water footprint and value added

The button labelled 'Switch: Value added/Water footprint' may be used to alternate between a display of value added data (in blue) and water usage data (in green). This data is displayed in addition to the carbon footprint data (shown in red throughout).

16.2 Populating the water footprint data

By clicking on the 'View water usage/water footprint' the user is taken to the water usage screen. This is shown in Figure 38. The total water usage for the stage is shown at the top of the screen along with the water footprint data. The difference between these is discussed below. If some water data are missing, a warning is shown at the top of the screen.

Data set	Stage	Amount f.u.	Blue water (m ³ /unit)	Green water (m ³ /unit)	Total water (m ³ /unit)	Blue water (m ³ /f.u.)	Green water (m ³ /f.u.)	Total water (m ³ /f.u.)	Country of impact	Water stress index	Water footprint (stress weighted) (m ² eq.f.u.)
Diesel	Raw materials -> Grapes cultivation and harvest	7.00E-03 kg	0.76	0.00	0.76	5.32E-03	0.00	5.32E-03	Australia	0.40	2.14E-03
Diesel	Raw materials -> Wine production and bottling	1.00E-03 kg	0.76	0.00	0.76	7.60E-04	0.00	7.60E-04	N/A	N/A	0.00
N Fertiliser	Raw materials -> Grape cultivation and harvest	1.13E-02 kg	0.05	0.00	0.05	5.88E-04	0.00	5.88E-04	Australia	0.40	2.36E-04
P Fertiliser	Raw materials -> Grape cultivation and harvest	2.80E-02 kg	0.05	0.00	0.05	1.46E-03	0.00	1.46E-03	Australia	0.40	5.85E-04
Pesticides	Raw materials -> Grape cultivation and harvest	9.80E-03 kg	0.05	0.00	0.05	5.10E-04	0.00	5.10E-04	Australia	0.40	2.05E-04
Petrol	Raw materials -> Grape cultivation and harvest	3.00E-03 kg	0.76	0.00	0.76	2.28E-03	0.00	2.28E-03	Australia	0.40	9.17E-04
Petrol	Raw materials -> Wine production and bottling	6.00E-03 kg	0.76	0.00	0.76	4.56E-03	0.00	4.56E-03	N/A	N/A	0.00
sodium hydroxide, 50% in H ₂ O, production mix, at plant	Raw materials -> Wine production and bottling	1.00E-03 kg	0.16	0.00	0.16	1.60E-04	0.00	1.60E-04	China	0.48	7.65E-05
electricity, medium voltage, production GB, at grid	Grape cultivation and harvest	0.13 MJ	4.00E-02	0.00	4.00E-02	5.28E-03	0.00	5.28E-03	Australia	0.40	2.12E-03
electricity, medium voltage, production GB, at grid	Wine production and bottling	0.41 MJ	4.00E-02	0.00	4.00E-02	1.64E-02	0.00	1.64E-02	Australia	0.40	6.59E-03
Wine (Green glass2, 0.75 l, 85%R, 15%L)	Wine production and bottling	0.47 kg	9.97E-04	1.27E-02	1.37E-02	4.72E-04	6.00E-03	6.47E-03	Australia	0.40	1.90E-04
			Total:		3.78E-02	6.00E-03	4.38E-02			Total:	1.31E-02

Figure 38 Water usage/footprint screen

Water usage data are defined using the *Define water data* button. This brings up the the user form as shown in Figure 39a. By using the drop down menu at the top of the form, the user can select different stages. When a stage is selected, the two list boxes on the form will be populated. The top box will show data sets at this stage that currently have no water footprint data associated with them. The bottom box shows data sets for which water usage has been defined (and may be modified). The user can define data by selecting an item from the relevant list box and clicking the *Define water usage* button. The *Define water usage for data set* form is then shown (Figure 39b).

This form allows the user to associate water usage with a particular data set. There are two options:

- to enter user water usage data or
- to select an item from the CCaLC water use database to associate with the data set.

Water is defined as blue and green water, the sum of which represents the total water usage. A brief discussion of the meanings of these terms is given in Appendix 3. The user may choose which method to use by clicking on the radio buttons near the top of the form:

- if the *Define data* button is selected, the first section of textboxes will become active and the user can simply enter water usage data in terms of m^3 per unit;
- if the *Select from CCaLC* is selected then the user can select an item from the drop-down menu that approximates the original. Water usage data and references are shown greyed out and cannot be modified.

a) Define water usage data:

Select analysis stage:
 Grape cultivation and harvest

The following data need defining for water usage at this stage:

Process water	Define water usage
Agricultural water	

The following data may be re-defined for water usage at this stage:

electricity, medium voltage, production GB, at grid	Define water usage

Exit

b) Define water usage for data set:

Name: electricity, medium voltage, production GB, at grid

Stage: Grape cultivation and harvest

Define country data
 The water stress index for a given country is used to obtain the water footprint from the water usage data.

Country: Australia Water stress index: 4.02E-01

Define your own data or select an approximation from the CCaLC database:

Define data

Select from CCaLC water use database

Define data

Blue water (m3/MJ) [] Update

Green water (m3/MJ) []

Total water (m3/MJ) []

Select from CCaLC water use database

Electricity from Sugar cane

Blue water (m3/MJ) 0.027 Update

Green water (m3/MJ) 0.023

Total water (m3/MJ) 0.05

Location: Global

Comments:
 Wighted-global average; Source: Gerbens-Leenes, P. W., Hoekstra, A. Y., & van der Meer, T. 2009. The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply. Ecological Economics, 68(4): 1052-1060.

Exit

a) b)
Figure 39 Define water usage form

The drop-down menu at the top of the form contains a list of countries that have water-stress index values associated with them. This may be left blank, or a country selected in order to calculate water footprint data from the existing water usage data. The water footprint is the product of the blue water usage for a specific data set and the water stress index. A further discussion of this is given in Appendix 3.

When the *Update* button is clicked, the water usage table is populated with data. The data is also shown in green at each of the stages in the analysis.

16.3 Missing water data

Missing water data can be viewed by clicking the *View missing data* button at the top of the screen (see Figure 40).

Back to water usage table	Define water data	The following do not have any water usage data defined:
Data	Data type	Stage
Alamine	Materials	Raw materials
Diammonium phosphate (21% conc.)	Materials	Raw materials
Farm yard manure/slurry	Materials	Raw materials
K Fertiliser	Materials	Raw materials
N Fertiliser	Materials	Raw materials
Octanol	Materials	Raw materials
P Fertiliser	Materials	Raw materials
Pesticides	Materials	Raw materials
Seeds - Wheat	Materials	Raw materials
Diesel (used in farm machinery)	Energy	Wheat cultivation
Electricity-CHP-5	Energy	Milling & hydrolysis
Electricity-CHP-5	Energy	Fermentation
Electricity-CHP-5	Energy	Ultra filtration
Electricity-CHP-5	Energy	Extraction
Electricity-CHP-5	Energy	Distillation & back extraction
Electricity-CHP-5	Energy	Drying of waste solids
Heat-CHP-5	Energy	Milling & hydrolysis
Heat-CHP-5	Energy	Extraction
Heat-CHP-5	Energy	Distillation & back extraction
Heat-CHP-5	Energy	Drying of waste solids
40t truck	Transport	Natural drying-->
40t truck	Transport	Processing--->Storage

Figure 40 Table showing missing water data

16.4 Water usage graphs

Water usage and water footprint summary graphs can be viewed by clicking the *View graph* button. Graphs showing contribution of different stages to water usage are further also available.

17 Calculating other environmental impacts

In addition to the carbon and water footprints, the following other environmental impacts can be calculated in CCaLC:

- Acidification potential
- Eutrophication potential

- Ozone depletion potential
- Photochemical ozone creation potential
- Human toxicity potential.

The results for these impacts can be seen by clicking on the *View other environmental impacts* button at the top top level of the tool.

If the data for these impacts are incomplete, a message is displayed in red font, stating **'Warning: LCA data for some impacts are missing. To complete the analysis, click the button "Define other environmental impacts"'**.

If the user wishes to define the above environmental impacts, it is necessary to supply the relevant data. To do this, click on the *Define other environmental impacts* button. This brings up the form as shown in Figure 41.

Figure 41 Modifying user data for other environmental impacts

The top text box Figure 41 shows the data sets for which other impact data are missing. To specify missing data, select a data item and then click on the *Define impact data* button.

The bottom text box shows the user defined data sets for which impact data can be modified. To modify data, select a data set and then click on the *Define impact* button. Both buttons bring up the same user form (Figure 42). The form allows the user to specify the impact data for a specific data set by filling in the text boxes and clicking the *Update data* button.

Impact data for Diammonium phosphat...

Enter LCA data for the impact categories listed below:

Acidification potential (kg sulphur dioxide eq./kg)	0.00E+00
Eutrophication potential (kg phosphate eq./kg)	0.00E+00
Ozone layer depletion potential (kg R11 eq./kg)	0.00E+00
Photochemical ozone creation potential (kg ethene eq./kg)	0.00E+00
Human toxicity potential (kg dichlorobenzene eq./kg)	0.00E+00

Update data Exit

Figure 42 Define impact data user form

18 Calculating value added

Value added can be calculated by adding cost data at various points in the analysis (e.g. while defining materials, waste, transport etc.) The value added are shown in blue font above each stage as well as in the value-added tables.

To view a summary of the value added data, click on the *View value added analysis* button at the top of the tool. This takes the user to a summary value-added table (see Figure 43). The table lists the costs in each stage and value of the outputs, along with the overall value added for the analysis. If some cost data are missing, a warning is shown in blue stating that “*Some value-added data are missing or are zero*”. The missing data can be seen by clicking the *View missing data* button (Figure 44).

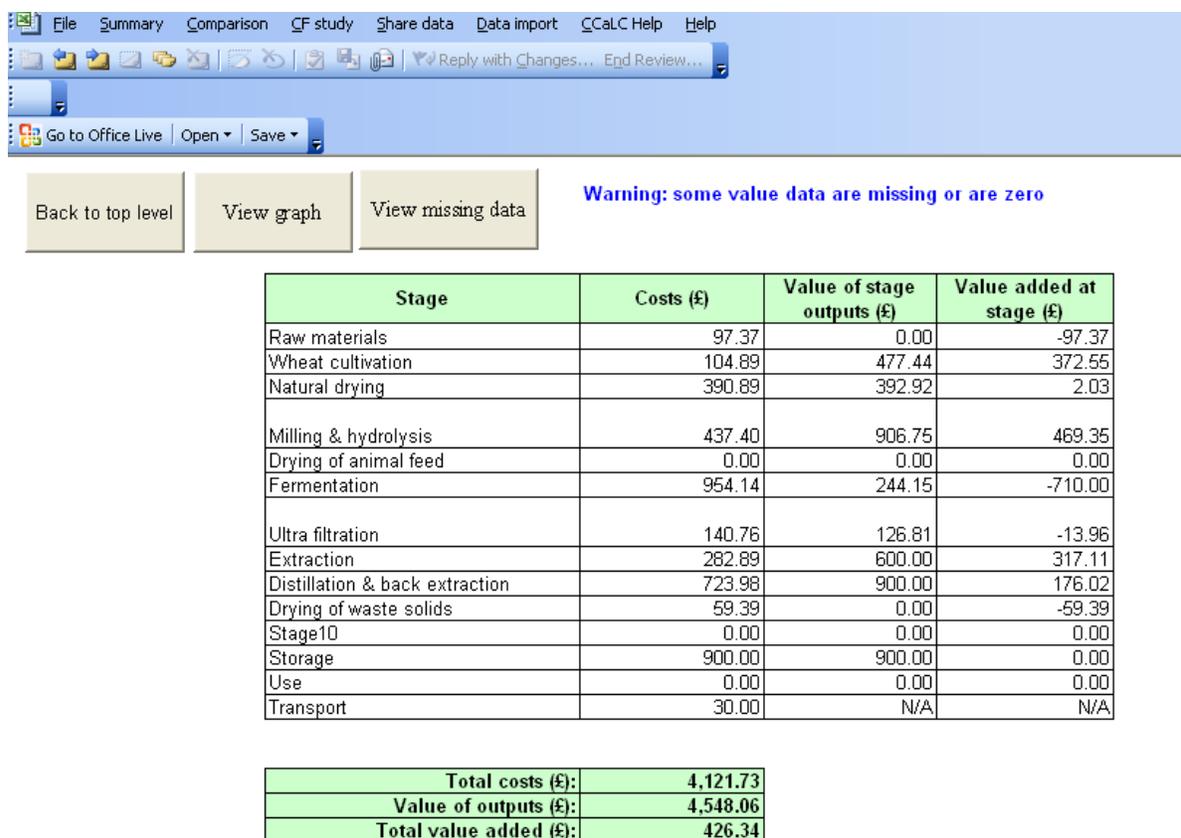


Figure 43 Value added summary

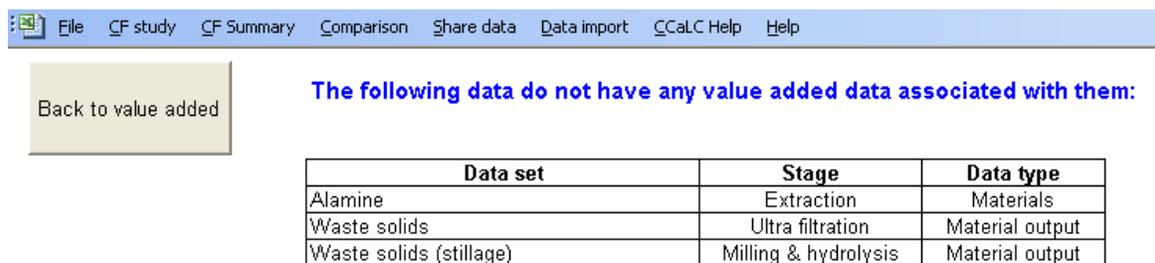


Figure 44 Summary of missing cost/value data

19 Example case studies

To aid the user in carrying out their own studies, the CCaLC tool has built in 54 example case studies in the following sectors:

- Biofeedstocks and biofuels;
- Packaging;
- Chemicals and related; and
- Food and drink.

Some of these are detailed below.

The case studies can be modified to suit the user and saved under a different name. The modified studies will be placed automatically within the User-defined case studies.

19.1 Biofeedstocks: PLA from wheat

19.1.1 Introduction

This section provides a brief description of the PLA case study based on Mortimer et al. (2009) and Mortimer et al. (2004).

The LCA study follows the ISO 14044: 2006 and PAS 2050: 2008 methodologies as far as possible. The following sections describe the goal, system boundaries and inventory data used for the case studies.

19.1.2 Goal and scope of the study

Goal of the study: The main goal of this study is to provide a carbon footprint analysis of PLA from wheat.

Functional unit: The functional unit of this study is defined as '1 tonne of PLA'.

Scope and system boundary: The system boundaries are from 'cradle-to-gate' for PLA. As shown in Figure 45, the life cycle stages include:

- raw materials extraction and production;
- wheat cultivation;
- PLA production processes (milling & hydrolysis, sterilisation and fermentation, filtration, purification & crystallisation, polymerisation & crystallisation and packaging); and
- production of co-products.

Some aspects of the life cycle supply chain are not considered due to limited data availability and they include:

- water used for agricultural and industrial processes; and
- wastewater discharged from agricultural and industrial processes; and
- transport of raw materials and waste.

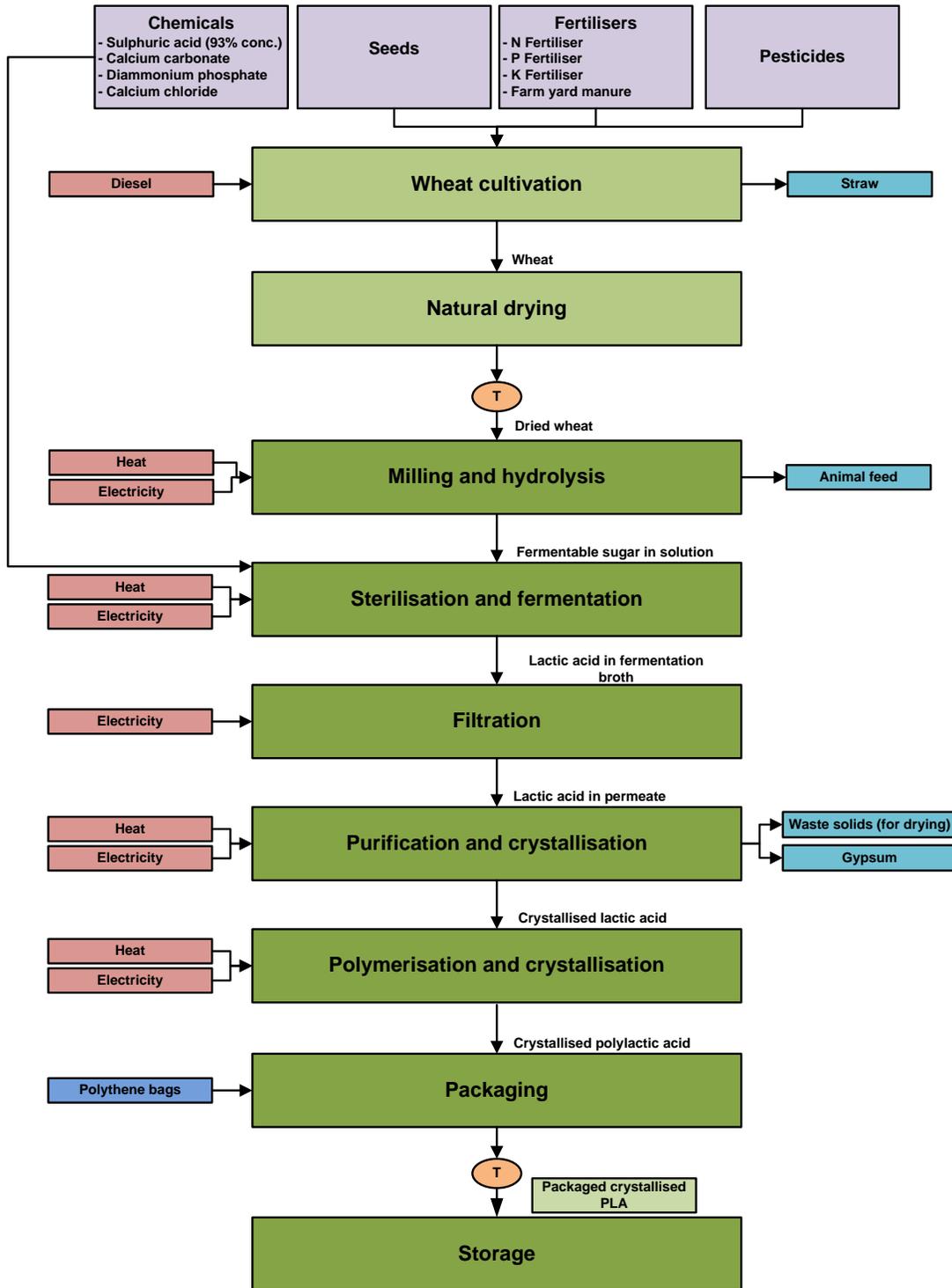


Figure 45 System boundary for PLA from wheat

19.1.3 Inventory analysis

Raw materials and energy: The inventories used for this study include the raw materials (fertilisers, pesticides and chemicals) and energy used for agricultural and industrial processes. These inventories are presented Table 1 and Table 2.

Table 1 Raw materials inventory

Raw materials	Quantity (tonne/functional unit)
Agricultural stage	
N Fertiliser	8.13E-02
Farm yard manure/slurry	1.35E+00
P Fertiliser	1.33E-02
K Fertiliser	1.67E-02
Pesticides	4.13E-04
Seeds – Wheat	7.49E-02
Production stage	
Sulphuric acid (93% conc.)	6.26E-01
Calcium Carbonate converted to CaO	4.22E-01
Diammonium phosphate (21% concentrated)	3.88E-02
Calcium chloride	1.25E-03
Packaging	
Polythene bags	0.004

Table 2 Energy inventory

Energy	Quantity (MJ/ functional unit)
Agricultural stage	
Diesel	3,457
Production stage	
Electricity	7,265
Heat	38,208

Transport: The transport distances in the life cycle stages are assumed to be as:

- Transport of wheat from farm to the PLA plant: 186 km using 40 t truck.
- Transport of PLA from farm to the storage: 450 km using 40 t truck.

Co-products: Co-products and their quantities, energy content and economic value are listed in Table 3.

Carbon storage in the product: 1.94 tonne CO₂ eq./ tonne of PLA.

Table 3 Co-products

Co-products	Quantity (tonnes)	Energy content (MJ/tonne)	Economic value (£/tonne)
Agricultural stage			
Straw	2.61	12,678	44
Production stage			
Animal feed	1.926	18,200	80
Gypsum	1.01	0	3

19.1.4 Impact assessment

The results of the carbon footprint analysis of PLA from wheat (economic allocation) as modelled in the CCaLC tool are shown in Figure 46. The carbon footprints are 2.22 tonne CO₂ eq., per tonne of PLA. The 'production' stage is the major 'hot spot' along the supply chains of PLA (Figure 47). This is mainly due to the use of energy in the production of PLA.

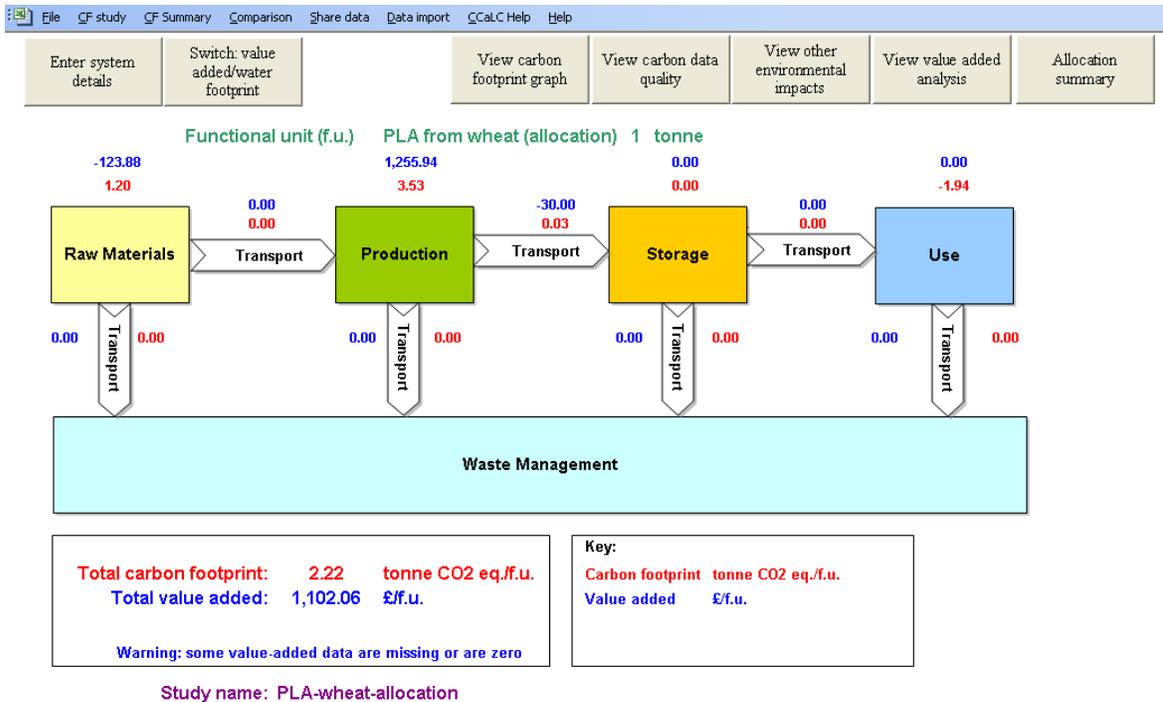


Figure 46 Carbon footprint of PLA from wheat

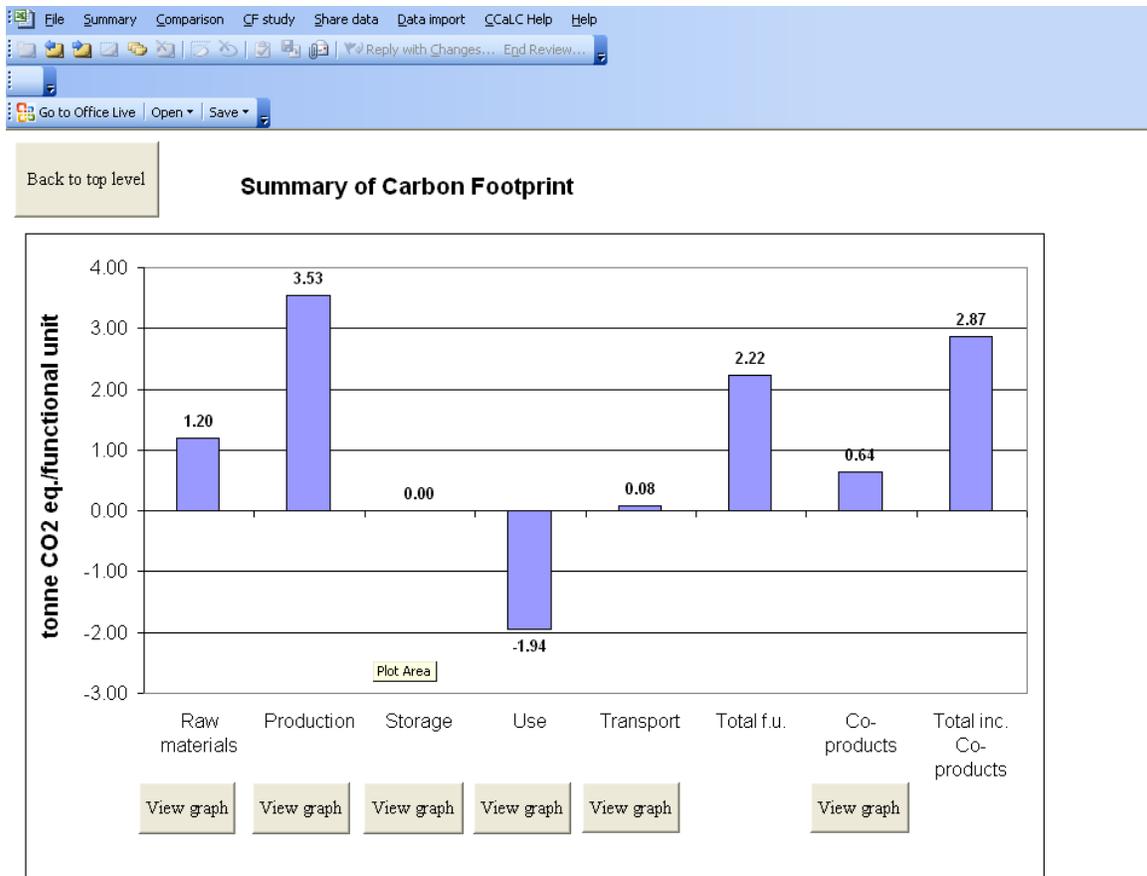


Figure 47 Contribution of life cycle stages to the total carbon footprint

References

- Mortimer, N., A. Evans, A. Ashley, C. Hatto, V. Shaw, C. Whittaker and A. Hunter (2009) Life cycle assessment workbooks for selection of major renewable chemicals, NNFFCC and North Energy.
- Mortimer, N., M. Elsayed, R. Horne (2004) Energy and greenhouse gas emissions for bioethanol production from sugar beet and wheat grain, Sheffield Hallam University.

19.2 Food and Drink: Lunch at a sandwich bar

19.2.1 Introduction

This report aims to provide a brief description of a food case study in the CCaLC tool. The study corresponds to the calculation of life cycle GHG emissions for a typical packed lunch consumed at a sandwich bar in the UK.

The LCA study follows the ISO 14044 and PAS 2050 methodology as far as possible. The following sections describe the goal, system boundaries and inventory data used for the case studies.

19.2.2 Goal and scope of the study

Goal of the study: The main goal of this study is to provide a carbon footprint analysis of a typical packed lunch consisting of a sandwich, potato crisps and a beverage.

Functional unit: The functional unit of this study is defined as ‘an individual serving of packed lunch consisting of a packed sandwich, a packet of potato crisps and a bottle of soft drink consumed at a sandwich bar’.

Scope and system boundary: The system boundaries of the study include ‘cradle-to-grave’ analysis for the lunch considered. As shown in Figure 48, the life cycle stages include:

- production of ingredients;
- manufacture of packaging;
- preparation of mayonnaise;
- preparation of ingredients;
- assembly of sandwich;
- consumption of lunch; and
- landfilling of waste food and packaging.

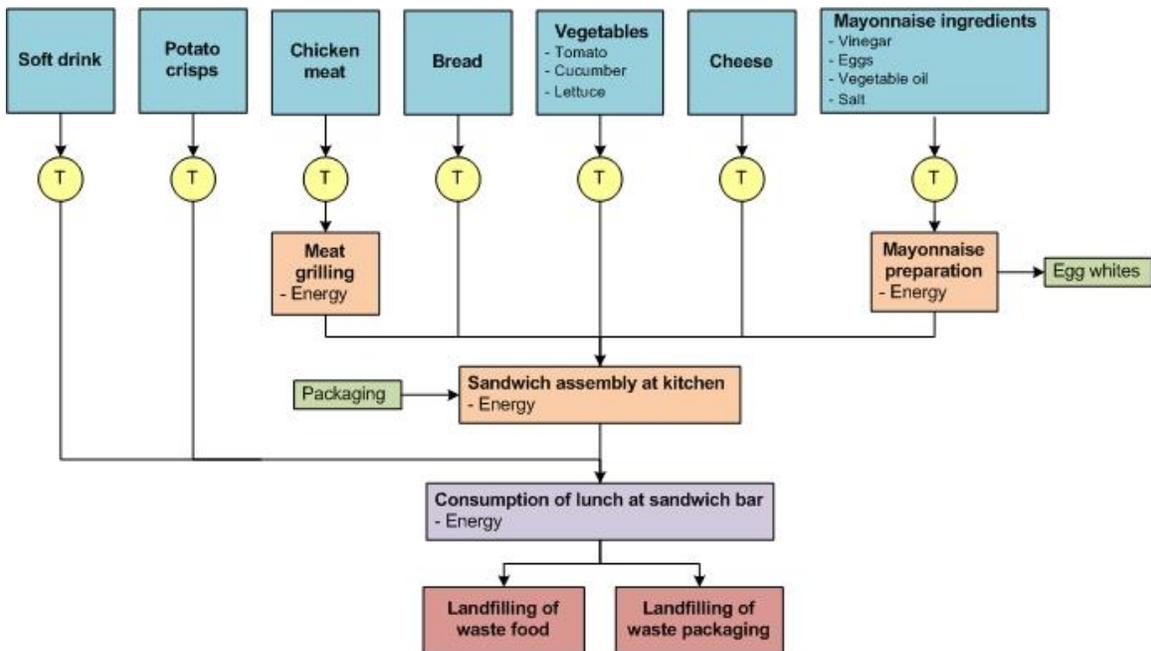


Figure 48 System boundaries for a packed lunch (T = Transport)

19.2.3 Inventory analysis

Raw materials and energy: These inventories are presented in Table 4 and Table 5.

Table 4 Materials inventory

Material	Life cycle stage	Quantity [g /functional unit]
Eggs	Mayonnaise preparation	6
Vinegar		2.20
Vegetable oil		15.2
Salt		0.3
Chicken meat	Meat grilling	60
Bread	Sandwich assembly	90
Cheese		40
Tomato		20
Lettuce		20
Cucumber		10
Potato crisps		35
Soft drink		500
Plastic packaging		12

Table 5 Energy inventory

Life cycle stage	Energy	Quantity [kWh /functional unit]
Mayonnaise preparation	Electricity	4.40 E-05
Meat grilling and kitchen operation	Electricity	1.10
Consumption at sandwich bar	Electricity	0.8

Transport: Transport of materials between life cycle stages is assumed to cover a distance of 50 km using a small van with a 7.5 tonne capacity.

Co-products and waste: In the mayonnaise preparation stage egg whites are produced as a co-product (3.8 g). At the consumption stage, 80 g of food waste are generated, corresponding to 30% of the sandwich (WRAP, 2008).

19.2.4 Impact assessment

The results of the carbon footprint analysis of the packed lunch as modelled in the CCaLC tool are shown in Figure 49 and Figure 50. The total carbon footprint is 2.49 kg CO₂ eq. per packed lunch consumed by one person at a sandwich bar.

The raw materials, production and use stages contribute 45.3%, 31% and 23.1% of the total life cycle GHG emissions respectively.

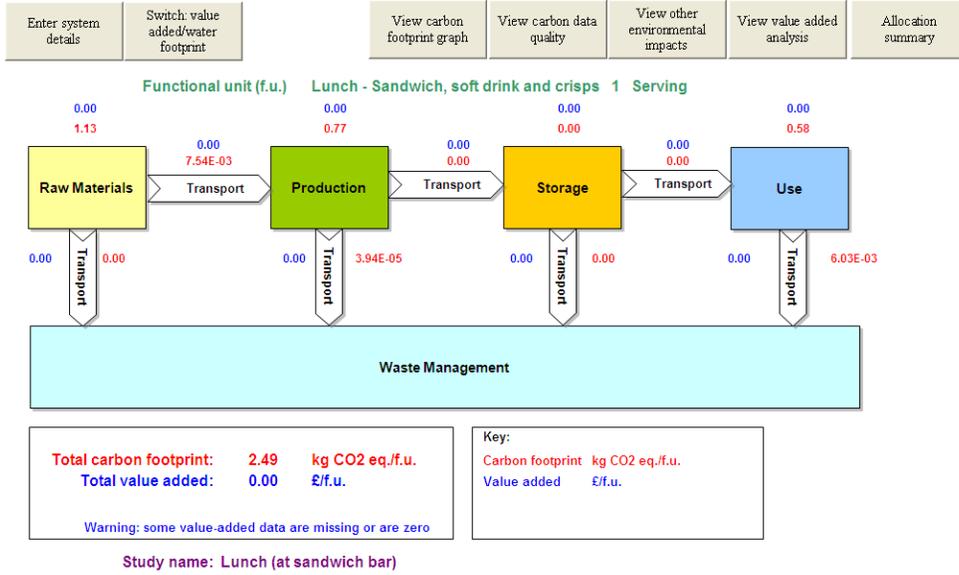


Figure 49 Carbon footprint of packed lunch

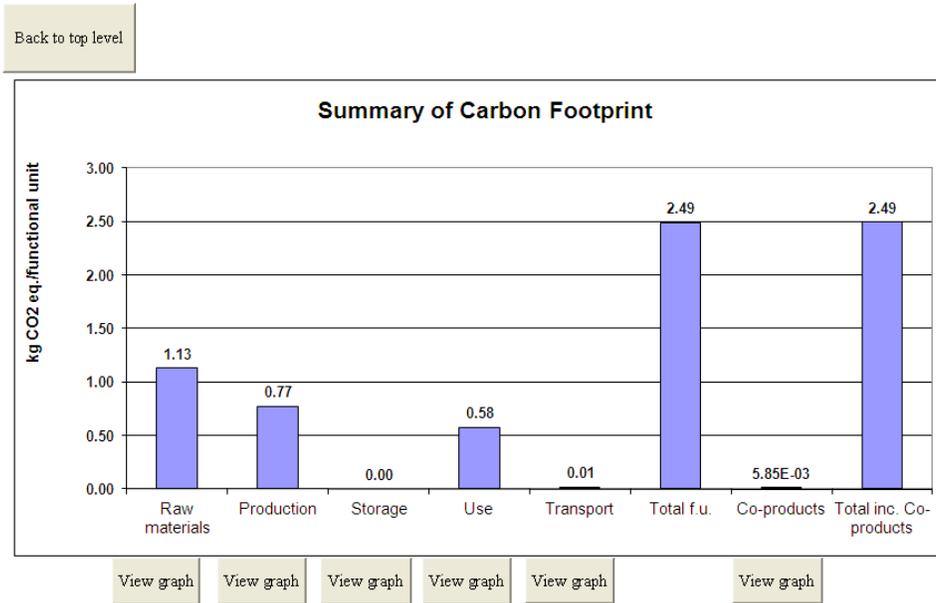


Figure 50 Life cycle stage contributions

References

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WRAP, 2008. *The food we waste.* Waste and Resources Action Programme, Banbury, Oxon.

19.3 Packaging: Drinks Packaging

19.3.1 Introduction

This section provides a brief description of the packaging case studies in the CCaLC tool. A generic study of three different types of beverage packaging (HDPE and PET bottles and aluminium cans) used in the UK was carried out to analyse and compare their carbon footprint while also identifying the hot spots along the supply chain.

The LCA study follows the ISO 14044: 2006 and PAS 2050: 2008 methodologies as far as possible. The following sections describe the goal, system boundaries and inventory data used for the case studies.

19.3.2 Goal and scope of the study

Goal of the study: The main goal of this study is to provide a carbon footprint analysis of three types of packaging used in the UK:

- HDPE milk bottle (2.272 litre)
- PET water bottle (0.5 litre) and
- aluminium can for fizzy drinks (0.33 litre).

Functional unit: The functional unit of this study is defined as 'the packaging system required to deliver 1000 litres of beverage.

Scope and system boundary: The system boundaries of the study include 'cradle-to-grave' analysis for the packaging systems considered. As shown in Figure 51-Figure 54, the following life cycle stages are considered:

- raw materials extraction and production;
- packaging production and transport to filling site;
- tops and labels production and transport to filling site;
- filling of the packaging;
- distribution of the filled packaging to consumers;
- transport of post-consumer waste to waste management; and
- landfill, incineration and recycling of the waste packaging.

The following is excluded from the system boundary:

- energy used for storage at the retail stage;
- energy use at the consumption stage;
- carbon footprint of the beverage; and
- secondary and tertiary packaging.

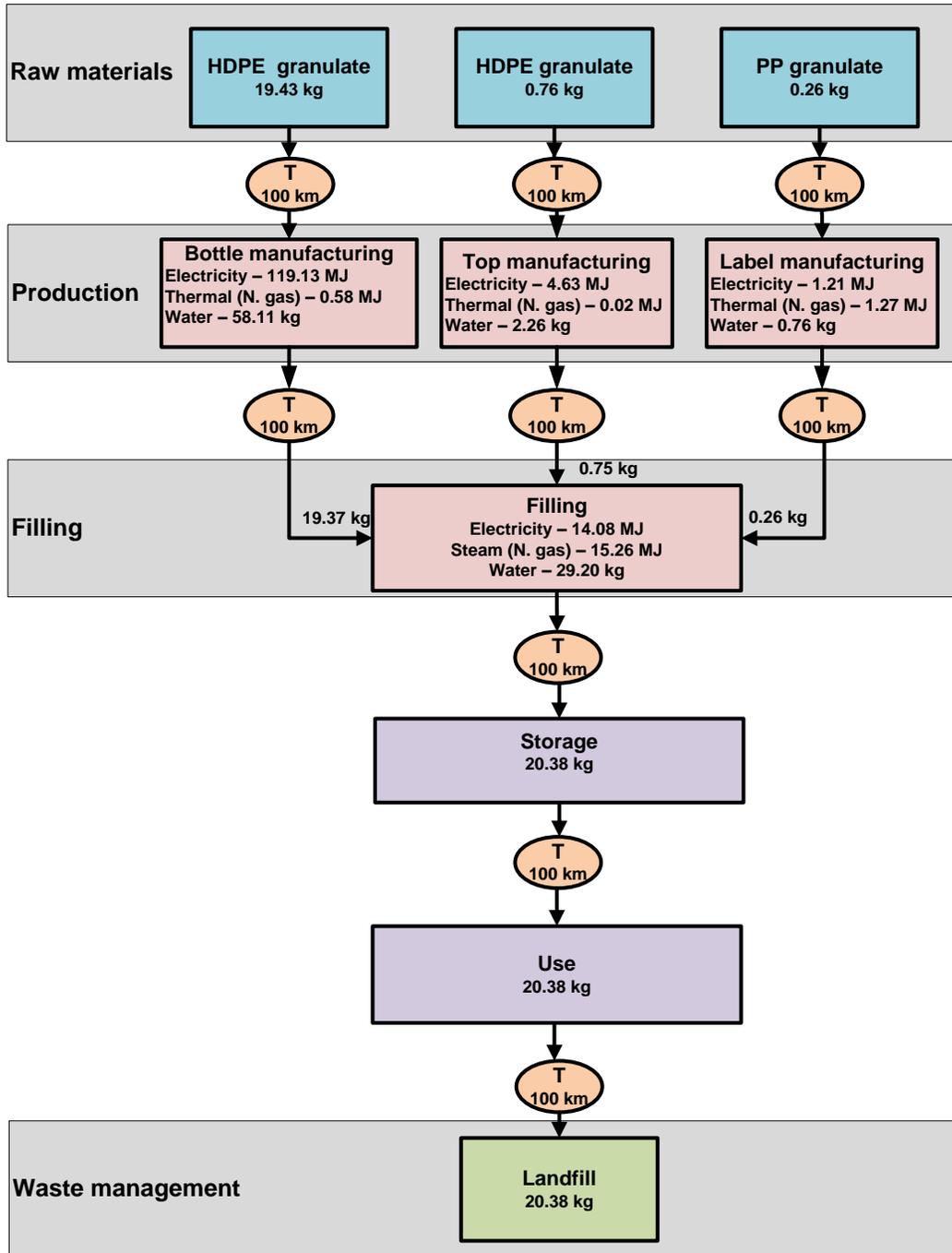


Figure 52 System boundary for the HDPE milk bottle (2.272 litre)

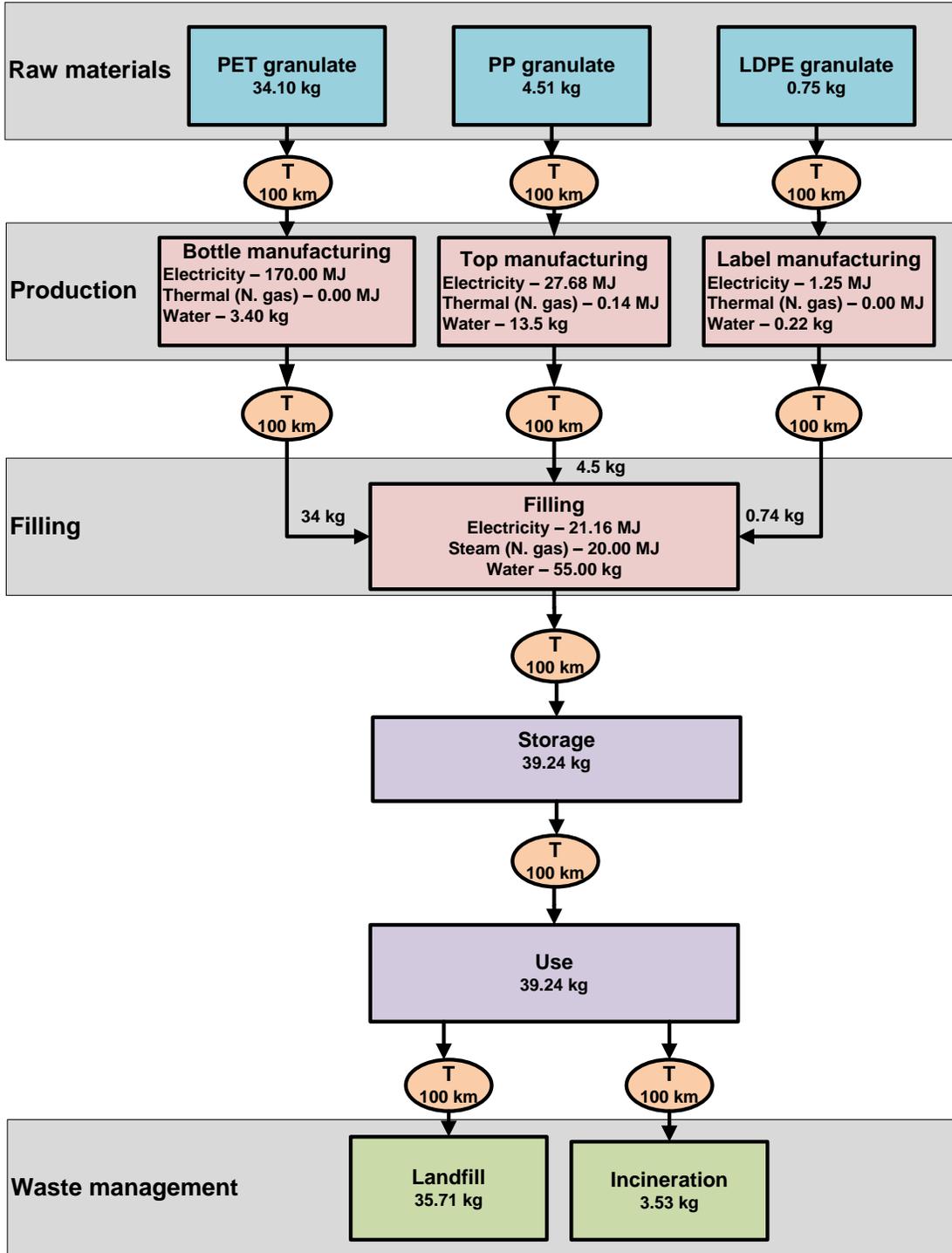


Figure 53 System boundary for the PET water bottle (0.5 litres)

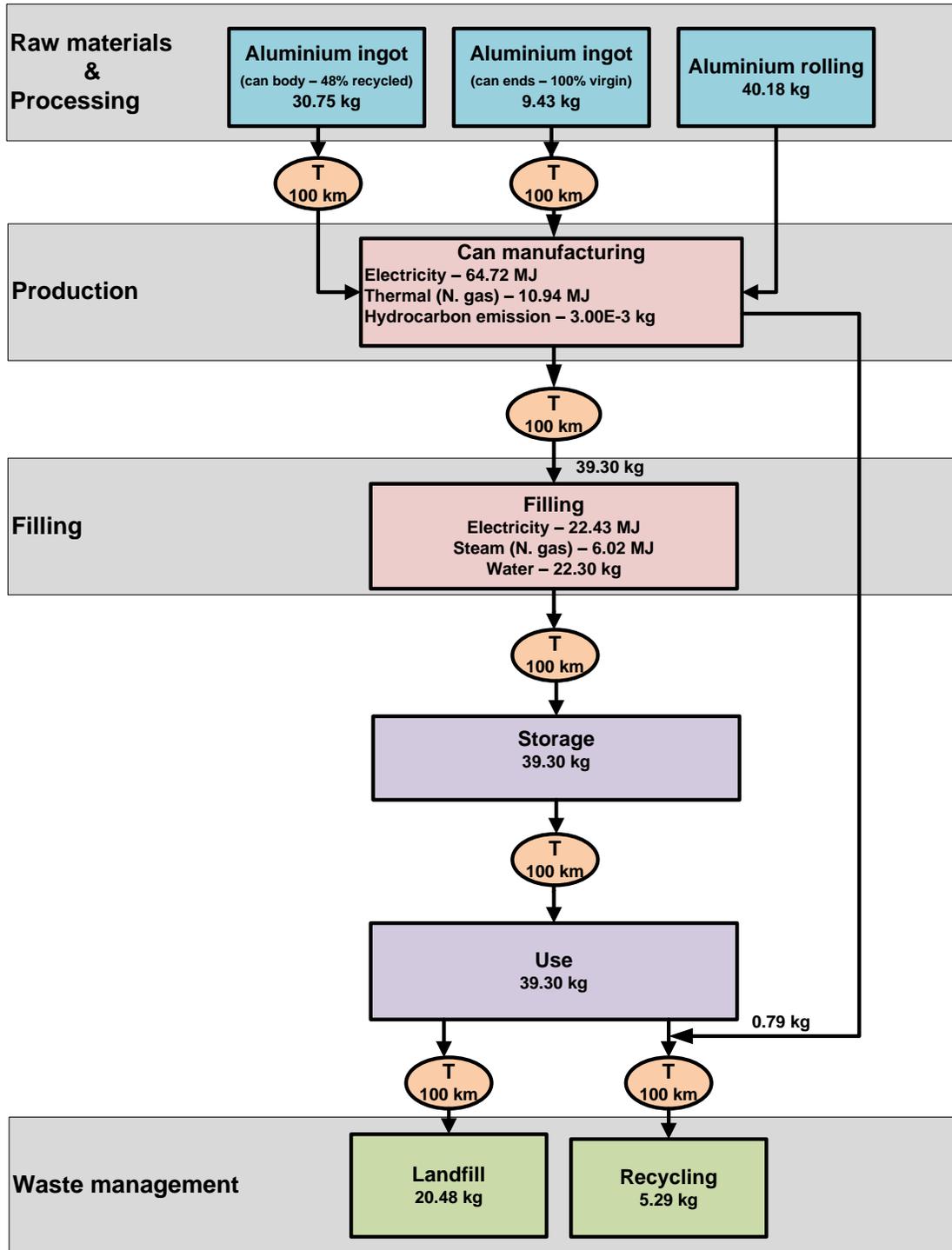


Figure 54 System boundary for the aluminium can (0.33 litre)

19.3.3 Inventory analysis

Description and weight of the packaging: The description and weight of the packaging types are shown in Table 6. The different packaging materials have been obtained from retail shops and weighted.

Table 6 Description and weight of the packaging materials

Description	HDPE bottle	PET bottle	Aluminium can
Type of beverage	Milk	Mineral water	Fizzy drink
Capacity (litres)	2.272	0.500	0.330
Number of bottles weighted	3	3	3
Average weight per bottle (g)	44	17	9.95 (can body) ¹
Material for top	HDPE	PP	AlMg3
Average weight of top (g)	1.71	2.25	3.05 (can end) ²
Material for label	PP film	LDPE film	N/A
Average weight of label (g)	0.58	0.37	N/A
Bottle weight per functional unit (kg per 1000 l)	19.37	34	30.15
Top weight per functional unit (kg per 1000 l)	0.75	4.5	9.24
Label weight per functional unit (kg per 1000 l)	0.26	0.74	N/A
TOTAL weight per functional unit (kg per 1000 l)	20.38	39.24	39.39

Manufacturing inventory: The manufacturing inventories for the packaging systems are shown in Table 7-Table 9. The manufacturing data for the HDPE and PET bottles have been estimated from Andrady (2003). The cans manufacturing data have been estimated from confidential sources.

Table 7 Manufacturing data for HDPE milk bottle (2.272 litres)

Inventory	Bottle manufacture	Tops manufacture	Label manufacture	Comments
Electricity (MJ per F.U.)	119.13	4.63	1.21	UK grid
Steam (MJ per F.U.)	0.58	0.02	1.27	Natural gas
Water (kg per F.U.)	58.11	2.26	0.77	

¹ The can body consists of 52% virgin and 48% recycled aluminium ingot (see Figure 54)

² The can end consists of 100% virgin aluminium ingot (see Figure 54)

Table 8 Manufacturing data for PET water bottle (0.5 litres)

Inventory	Bottle manufacture	Tops manufacture	Label manufacture	Comments
Electricity (MJ per F.U.)	170	27.68	1.25	UK grid
Steam (MJ per F.U.)	0.00	0.14	0.00	Natural gas
Water (kg per F.U.)	3.40	13.50	0.22	

Table 9 Manufacturing data for aluminium can (0.33 litres)

Inventory	Can manufacture	Comments
Electricity (MJ per F.U.)	10.94	UK grid
Thermal energy (MJ per F.U.)	64.72	Natural gas
Steel waste (kg per F.U.)	0.79	Sent to recycling
Hydrocarbon emission (kg per F.U.)	3.00E-03	

Filling stage: The energy (electricity and steam) and water requirement at the filling stage for the three packaging types were estimated from Schonert et al. (2002) and are presented in Table 10- Table 12.

Table 10 Energy and water data for filling the HDPE milk bottle

Inventory	Amount	Comments
Electricity (MJ per F.U.)	14.08	UK grid
Steam (MJ per F.U.)	15.26	Natural gas
Water (kg per F.U.)	29.20	

Table 11 Energy and water data for filling the PET water bottle

Inventory	Amount	Comments
Electricity (MJ per F.U.)	21.16	UK grid
Steam (MJ per F.U.)	20.00	Natural gas
Water (kg per F.U.)	55.00	

Table 12 Energy and water data for filling the aluminium can

Inventory	Amount	Comments
Electricity (MJ per F.U.)	22.43	UK grid
Steam (MJ per F.U.)	6.02	Natural gas
Water (kg per F.U.)	22.30	

Transport: All transport distances in the life cycle stages are assumed to be 100 km using 22 t trucks. The transport stages include:

- transport of raw materials to the manufacturing site;
- transport of packaging, tops/ends and labels from the manufacturing site to the filling stage;
- transport of the filled packaging from the filling site to storage at consumer, which includes transport to warehouse and retail centres;

- transport to landfill, incineration and recycling sites.

End of life scenarios: Different waste management scenarios have been considered for the different packaging materials in this study as shown in Table 13. Note that for the aluminium can closed loop recycling has been assumed for the can body so that allocation (through system expansion) is only carried out for the can ends.

Table 13 Waste management considered for the packaging systems

Type of waste management	HDPE bottle (%)	PET bottle (%)	Aluminium can (%)
Landfill	100	91	52
Incineration	n/a	9	n/a
Recycling	n/a	n/a	48
TOTAL	100	100	100

19.3.4 Impact assessment

The results of the carbon footprint analysis of the packaging as modelled in the CCaLC tool are shown in Figure 55-Figure 60. The carbon footprints of the three packaging are respectively 70, 186 and 295 kg CO₂ eq. per 1000 litres of beverage. The raw materials stage is the major hot spot for all three types of packaging, contributing 58%, 71% and 93% of the total carbon footprint for the HDPE, PET and Al containers, respectively.

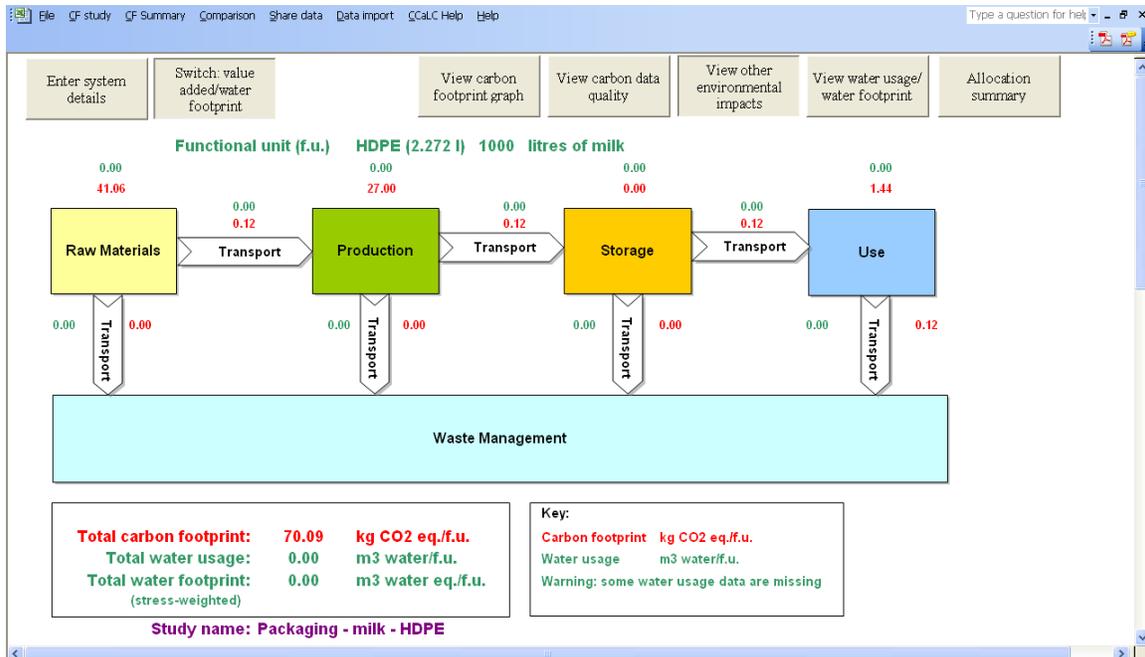


Figure 55 Carbon footprint of the HDPE milk bottle per 1000 l of milk packaged

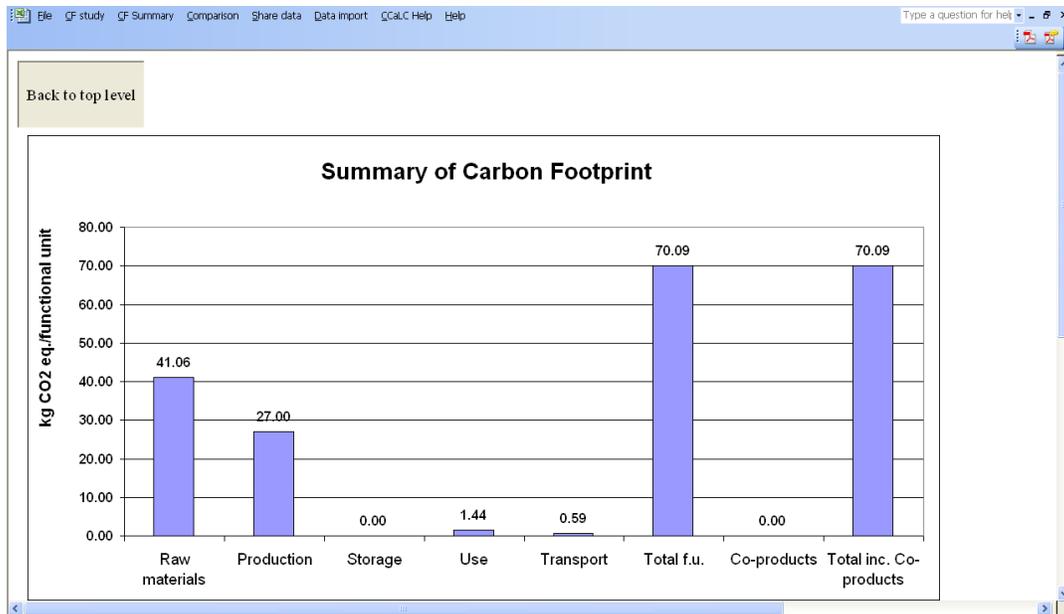


Figure 56 Carbon hotspots for the HDPE milk bottle (per 1000 l of milk)

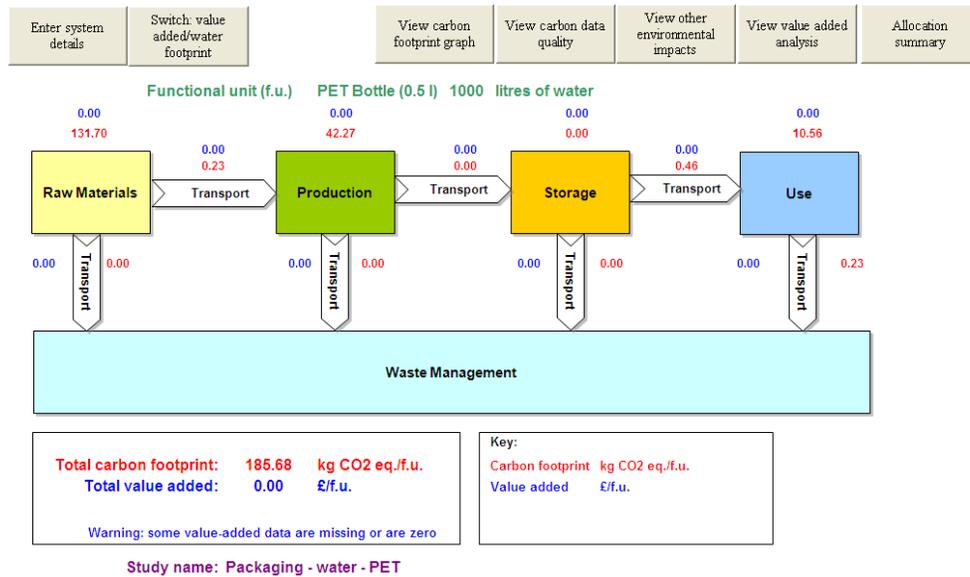


Figure 57 Carbon footprint of PET water bottle (per 1000 l of water)

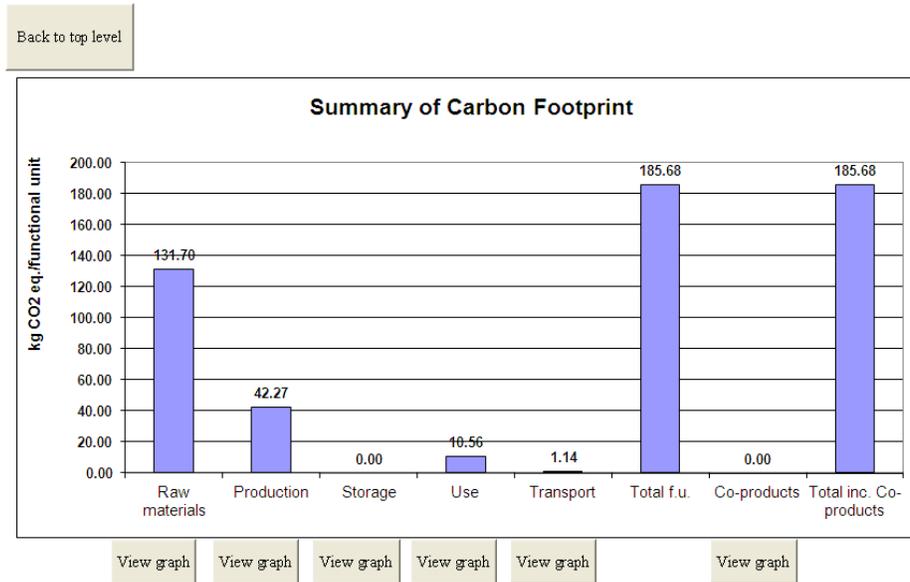


Figure 58 Carbon hotspots for the PET water bottle (per 1000 l of water)

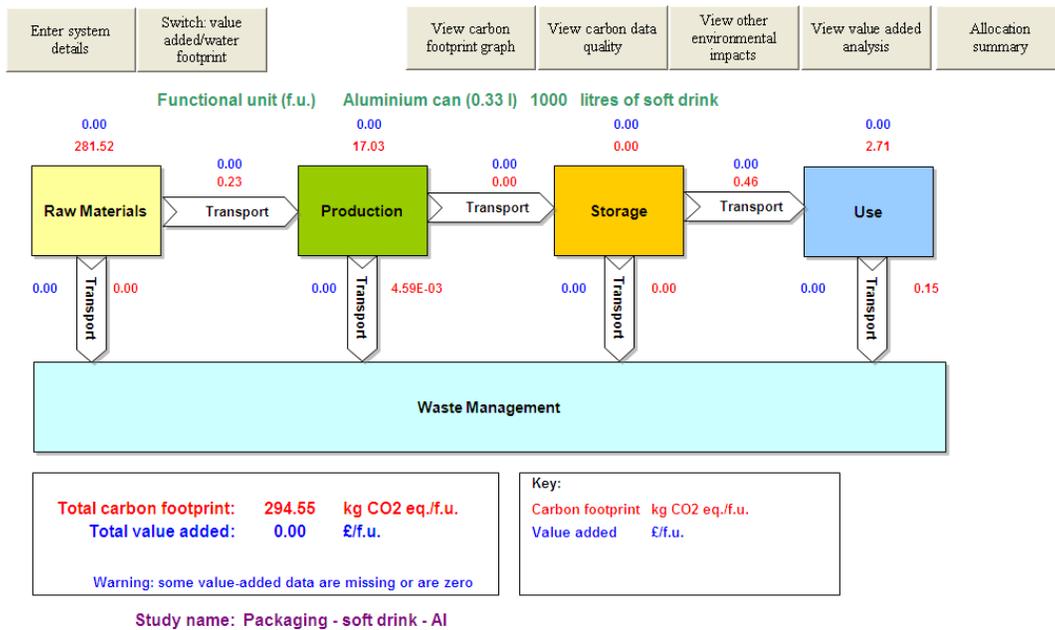


Figure 59 Carbon footprint of the aluminium can (per 1000 l of fizzy drink)

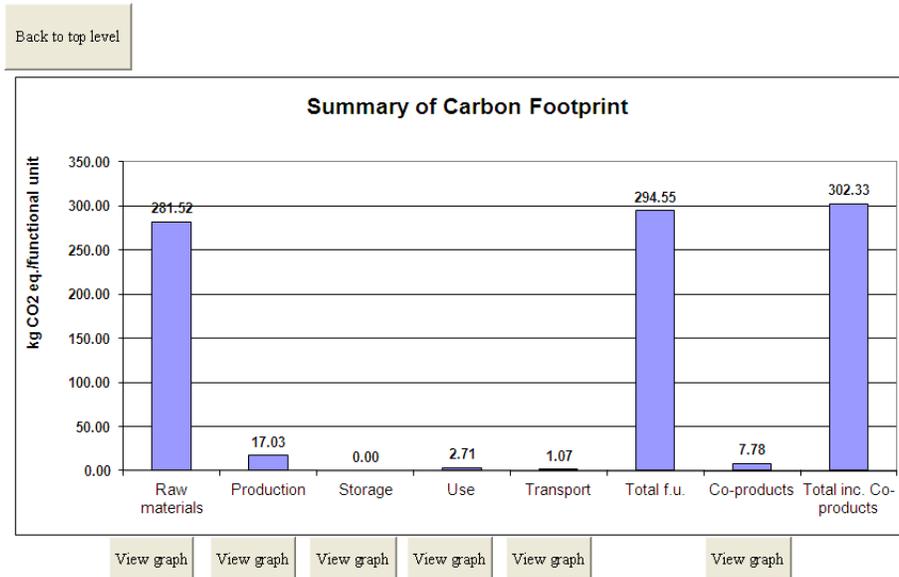


Figure 60 Carbon hotspots for the aluminium can (per 1000 l of fizzy drink)

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Appendix 1 – Methodology for calculating the carbon footprint of transport

Transport carbon footprint is calculated using the following equations:

NB. This applies to datasets within the CCaLC database and does not apply to Ecoinvent data for which limited amount of information is available. For Ecoinvent datasets, the transport density is not variable.

The density of the material transported is used to ascertain whether the transport is mass or volume limited:

If $\rho_{\text{pack}} < M_{\text{max}}/V_{\text{max}}$ **then** Volume limited

Else, if $\rho_{\text{pack}} > M_{\text{max}}/V_{\text{max}}$ **then** Mass limited

For Volume limited cases the total mass transported per load is:

$$M_{\text{trans}} = \rho_{\text{pack}} * V_{\text{max}} * f$$

For Mass limited cases the total mass transported per load is:

$$M_{\text{trans}} = M_{\text{max}} / \rho_{\text{pack}} * f$$

The number of functional units is then calculated per load:

$$f.u._{\text{load}} = M_{\text{trans}}/M_{\text{material}}$$

The carbon footprint per functional unit is then calculated:

$$c.f. = c.f._{\text{load}}/f.u._{\text{load}}$$

where:

ρ_{pack} is the packing density as defined by the user

M_{max} is the maximum transported mass

V_{max} is the maximum transported volume

M_{trans} is the total mass transported per load

f is the load factor (i.e. % loaded)

$f.u._{\text{load}}$ is the number of functional units per loaded vehicle

M_{material} is the mass of material transported per functional unit

$c.f._{\text{load}}$ is the carbon footprint of the vehicle at the current load

c.f. is the carbon footprint per functional unit

For trucks returning empty, the carbon footprint per functional unit is augmented by the ratio of the carbon footprint of the vehicle when it is loaded and when it is empty, i.e.:

$$c.f._{total} = c.f. + c.f. * [(c.f._{empty} / c.f._{load})]$$

where:

c.f._{total} is the total carbon footprint per functional unit

c.f. is the carbon footprint associated with transporting the material mass

c.f._{empty} is the carbon footprint of the vehicle when running unloaded

Appendix 2 – Data quality criteria

A2.1 General about LCA data quality

According to PAS2050, the following data quality requirements should be considered when performing an LCA:

- time related coverage;
- geographical coverage;
- technology coverage;
- precision and accuracy;
- completeness;
- consistency;
- reproducibility; and
- sources of data (primary or secondary).

Thus, data quality assessment is a complex task as multiple aspects need to be considered, including the context in which the data are used. Enough information on the data is therefore fundamental to avoid their misinterpretation or misuse.

A2.2 Data quality assessment in the CCaLC tool

The quality of data within the CCaLC tool can be defined by a user as:

- High
- Medium or
- Low.

To help the user determine whether their data are of High, Medium or Low quality, a methodology specific to the CCaLC tool has been developed using the data quality criteria mentioned in the previous section. The criteria used in the methodology are summarised in Table A2.1. Table A2.2 shows how these can be aggregated to arrive at an overall Data Quality Indicator (DQI) - High, Medium or Low. For these purposes, each data quality criterion is assigned a weight of importance on a scale of 1-10. For example, as shown in Table A2.1, “Age of data” has the weight of 2, being twice as important as the geographical origin of data. Each data quality indicator is assigned (an arbitrary) maximum score for each criterion: e.g. the High indicator has a score of 3, Medium has 2 and Low has a score of 1 (see Table A2.2). Applying the weights of importance for each criterion and its maximum score for the respective quality indicators, the maximum score for each quality indicator is:

- 30 for High;
- 20 for Medium; and
- 10 for Low.

For the purposes of the analysis in the CCaLC tool, the following score ranges have been adopted for the data quality assessment:

- Low data quality: score in the range of 1-10;
- Medium data quality: score in the range of 11-20; and
- High data quality: score range of 21-30.

An example shown in Table A2.2 shows an overall score of 19, indicating Medium data quality (noting that the overall score for Medium quality is between 11-20).

Table A2.1 Matrix of Data Quality Indicators (DQI) for the CCaLC tool

Data quality criteria	Data quality indicators		
	High	Medium	Low
Age of data	< 5 years	5 - 10 years	> 10
Geographical origin of data	Specific	Partly specific	Generic/average
Source of data	Measured and/or modelled based on specific data (e.g. the company data or from suppliers)	Modelled using generic data from LCA databases; <u>some</u> data derived using expert knowledge	<u>Mainly</u> sourced from literature and/or estimated and/or derived using expert knowledge
Completeness of data	All inputs and outputs considered	Majority of relevant inputs and outputs considered	Some relevant inputs and outputs considered or known
Reproducibility /reliability/ consistency of data	Completely reproducible/reliable/ consistent	Partly reproducible/reliable/ consistent	Not reproducible/ not known

Table A2.2 Aggregating individual Data Quality Indicators (DQI) to arrive at an overall DQI (High, Medium or Low)

Data quality criteria	Weighting for each criterion on a scale 1-10*	High quality Max. score for each criterion: 3	Medium quality Max. score for each criterion: 2	Low quality Max. score for each criterion: 1	Example data quality assessment
Age	2	3	2	1	1 (Low)
Geographical origin	1	3	2	1	3 (High)
Source	3	3	2	1	2 (Medium)
Completeness	2	3	2	1	3 (High)
Reproducibility /reliability/ consistency	2	3	2	1	1 (Low)
Maximum score		30 (max score) Overall score for High in the range: 21-30	20 (max score) Overall score for Medium in the range: 11-20	10 (max score) Overall score for Low in the range: 1-10	19 (overall score) Data quality indicator: Medium

*The sum of all weights is 10.

NB: The overall score of 19 has been calculated in the following way:
 Overall score = $2*1+1*3+3*2+2*3+2*1 = 19$
 Therefore the overall data quality indicator = Medium

It should be noted that the overall data quality will depend on both the quality of the particular datasets used by the user as well as on the confidence the user places on the quantity/amount of materials, energy etc. they are defining for each sub-system.

For example, the quality of the background dataset for UK electricity mix and the related carbon footprint may be High; however, the user may not be confident in the data related to the amount of electricity used in a particular sub-system so that the quality of this datum may be Medium or Low. In this case, since the data quality for the set is already defined (as high), the user will only need to specify the quality for the quantity/amount and the tool will calculate the overall data quality for that particular sub-system. The process is repeated for each sub-system.

The approach used for calculating DQI for a sub-system is shown in Table A2.3. Note that the quantity/amount is considered more important here than the quality of the dataset.

Table A2.3 Aggregating the Data Quality Indicators (DQI) to arrive at an overall DQI for each sub-system

DQI for user-defined dataset*	DQI for the amount/quantity entered in the CCaLC tool by the user	Data quality of each sub-system (DQS)
High	High	High (3)
Medium	High	High (3)
Low	High	Medium (2)
High	Medium	Medium (2)
Medium	Medium	Medium (2)
Low	Medium	Medium (2)
High	Low	Medium (2)
Medium	Low	Low (1)
Low	Low	Low (1)

*Note that the datasets already available in the tool have a predefined DQI so that the user only needs to define the quality of their own datasets.

Once the data quality indicators have been calculated for each sub-system, a weighted approach is then applied for assessing the overall data quality of the whole system based on the percentage contribution of each life cycle stage to the total carbon footprint. The overall data quality for the whole system is therefore calculated as:

$$DQ_{CF} = \sum_{n=1}^N I_n \left(\sum_{m=1}^M DQS_m \right)$$

where:

DQ_{CF} - overall data quality of the system

I_n – percentage contribution of each life cycle stage to the total carbon footprint (%)

DQS_m – data quality (1, 2 or 3) for sub-system m

For the purposes of the analysis in the CCaLC tool , the following ranges have been adopted for the overall data quality of the whole system:

- Low data quality: $DQ_{CF} = 100 - 166$;
- Medium data quality: $DQ_{CF} = 167 - 233$; and
- High overall data quality: $DQ_{CF} = 234 - 300$.

Appendix 3 – Water use and water footprint

A3.1 Water use

The water use represents the sum of all the water consumed in a supply chain, comprising blue and green water.

Blue water use refers to consumption of freshwater from rivers, lakes and aquifers. Water consumption indicates the freshwater withdrawals which are evaporated, discharged into different watersheds or the sea after use and embodied in products and waste.

Green water is the amount of rainwater (stored in the soil as soil moisture) used by plants is referred to as green water. Its relevance is significant in the case of agricultural systems.

A3.2 Water footprint (stress-weighted)

The water footprint (stress weighted) is calculated according to the midpoint impact assessment method proposed by Pfister et al. (2009)³. This method assesses the environmental impacts of freshwater consumption by incorporating Water Stress Index (WSI) as a mid-point characterisation factor. WSI indicates the water consumption impacts in relation to the water scarcity. This method considers only blue water consumption. Therefore, the water footprint is calculated as below:

$$\text{Water footprint (m}^3 \text{ eq./fu)} = \text{Blue water use (m}^3 \text{/fu)} \times \text{WSI}$$

The CCaLC tool contains WSI values for all countries at a national level. The WSI values, which range from 0.01 to 1, are derived using the following equation:

$$\text{WSI} = \frac{1}{1 + e^{-6.4\text{WTA}^* \left(\frac{1}{0.01} - 1 \right)}}$$

where WTA* is a modified WTA to account for monthly and annual variability of precipitation.

³ Pfister, S., Koehler, A., Hellweg, S., 2009. Assessing the environmental impacts of freshwater consumption in LCA. *Environmental Science & Technology*, 43 (11), 4098-4104.